CANADIAN AGRICULTURE

FOR HIGH SCHOOLS

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"When agriculture flourishes all other pursuits are in full vigour."

Xenophon.

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CANADIAN AGRICULTURE

PART 1

AGRICULTURAL BOTANY

CHAPTER I

Introductory

The Plant Kingdom consists of a great variety of forms, including Bacteria, Fungi (e.g. Molds, Wheat Rust, Mushrooms, etc.), Seaweeds, Mosses, Ferns, Conifers (e.g. Spruce, Tamarack, Pine, Fir, etc.) and the Flowering Plants. The latter constitute an enormous group of more than 125,000 kinds or species and are our most familiar plants.

Plants are living organisms which manufacture the food materials upon which all forms of animal life are either directly or indirectly dependent.

CHAPTER II

The Parts of a Flowering Plant

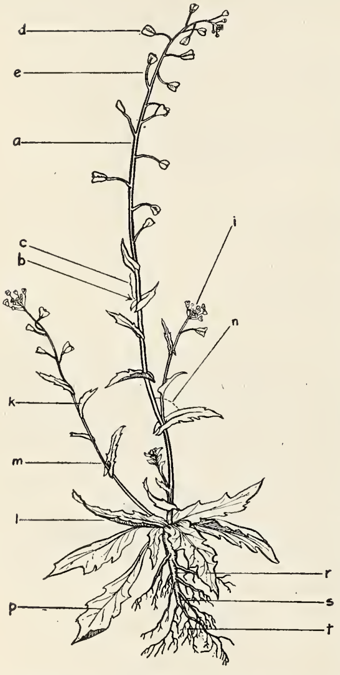


Fig. 1.
Shepherd's Purse. (a) axis; (b) node; (c) internode; (d) fruit; (e) pedicel; (i) inflorescence; (k) cauline leaf; (l) radical leaf; (m) axillary bud; (n) leafaxil; (p) midrib; (r) primary root; (s) secondary root; (t) tertiary rootlets.

Our first problem will be to learn something of the construction and function of the parts of a typical plant.

In order to obtain a general idea of the living organism called a Flowering Plant let us examine the Shepherd's-purse, which may be found on waste ground throughout the growing season.

The plant can be divided into two distinct parts differing in colour and form and which clearly live under very different conditions. One part, the *Root-System*, is whitish in colour and consists of a main portion and a number of side-branches. The other part, the *Shoot-System*, is green in colour and consists of a vertical axis or stem along which are borne, at intervals, lateral stems and flat outgrowths—the leaves.

The Root-System.—We have already noticed that the Root-System consisted of a main portion and branches from this main root. The main part of the root is called the *primary root.* The side branches which come off the primary root are called *secondary* or *lateral roots.* If we examine the secondary or lateral roots carefully we shall see that they vary in size: the largest and oldest are near the top and the smallest and youngest are near the tip of the primary root. Also we shall find other roots growing out in all directions from these secondary roots. These are called *tertiary rootlets.*

The Shoot-System.—Along the green axis or stem we have noticed lateral stems and leaves. That portion of the stem from which a leaf branches is called a *node:* the part of the stem between two nodes is called an *internode.* Each lateral stem or branch arises from the main axis or stem immediately above a leaf, that is, in the *axil* of the leaf. The lateral stems are therefore said to be *axillary.* In the axils of the upper leaves, very young, short branches may be observed. Such immature or embryonic branches are known as *buds.*

At the base of the stem there is usually a number of leaves so close to one another that it is impossible to distinguish the internodes. These leaves form a rosette on the surface of the ground. They are called *radical* leaves. The leaves borne on the upper part of the stem are called *cauline* leaves.

The leaves of the Shepherd's-purse are quite variable in form. The margin of some of them is quite regular; in others it is deeply indented. In most of the radical leaves two parts can be distinguished, the leaf-stalk, called the *petiole*, and the flat part, the *blade* or *lamina.* The cauline leaf as a rule has no petiole: two projections from the base of the lamina form a sheath about the stem attaching themselves directly to it. Such a leaf is said to be *sessile;* there is no leaf-stalk or petiole present.

If we examine the lamina very carefully we shall see that running from its base to the tip is a prominent strand, the main vein or *midrib*, as it is called. From the midrib we see branching out a number of finer strands, the *lateral veins*.

Terminating the main axis or stem of the plant and at the end of some of the larger branches we see clusters of flowers, *inflorescences*. Each individual flower is supported by a stalk or *pedicel*. It will be observed that the younger flowers near the tip are extremely close together on the axis of the inflorescence, while the older flowers are much further apart.

During the development of the flower, certain important events take place as a result of which the outer leaf-like parts wither and the central part, the *ovary*, becomes greatly enlarged to form the *fruit*. Thus in older plants it will be observed that many of the flowers have been replaced by fruits—flat, triangular structures. In fact these fruits resemble somewhat a shepherd's pouch—hence the common name of the plant, Shepherd's-purse. When the fruit is ripe it splits open and sheds the *seeds* contained within. These seeds have developed from very small structures, called *ovules*, in the ovary of the young flower.

Exercises.—(1) Make a drawing of a typical plant of Shepherd's-purse, labelling neatly all the parts described above.

(2) Split open a mature fruit and observe how the seeds are attached and arranged. Make sketches to illustrate your observations.

(3) Count the number of seeds in one of the fruits, and then estimate the number of seeds produced by a typical plant of Shepherd's-purse.

CHAPTER III

THE ROOT AND ITS FUNCTIONS

Kinds of Roots.—If we compare the roots of a carrot or turnip with those of wheat or corn we find some striking

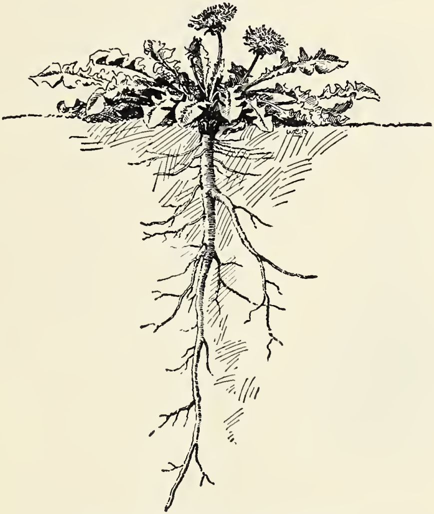


Fig. 2. Tap-root of the Dandelion

differences. The former have a very thick primary root, with a number of smaller secondary roots. Plants that have this type of root are said to be *tap-rooted*. Tap roots are common among biennial plants, which during the first year of growth store up a large supply of sugar or other foods to be used in the second year for the production of flowers and fruit. They are also found in many perennials (e.g. Dandelion) where they likewise serve as storage organs for the food material laid up for subsequent growth.

The roots of Corn or Wheat plants are composed of many slender branches with no dominant or main root. They are called *fibrous* roots. Trees often develop a tap root when young. Later the growth of the tap root is retarded and the secondary roots increase in size until finally the tree may be said to possess fibrous roots.

Fig. 3.
Root of Corn plant showing prop roots at (o).

Careful examination of a mature Corn plant will often reveal the presence of roots growing from the stem a little distance above the surface of the ground and apparently acting as a support for the tall plant. These roots are called *prop* roots. Roots sometimes grow from the stems or leaves of plants when the latter are pressed into the soil. They are *adventitious* (chance) roots. Use is made of this fact in propagating Geraniums, Raspberries and Willows by "slips" or stem-cuttings, and in developing new Begonia plants by leaf cutting.

The Root-System.—All the roots of a plant constitute its root-system. The root-system includes not only the primary and secondary roots which are large enough to be seen easily, but also a great mass of slender, delicate tertiary rootlets. The rootlets in turn have attached to them many *root hairs* which are of prime importance to the plant, as we shall learn later in the chapter. The extent of the root-system depends upon the species of plant, the nature of the soil, and the amount of moisture in the soil. The roots may be quite close to the surface, extending in all directions, or they may penetrate to great depths in the soil. An example of a deep-rooted plant is Alfalfa whose roots often grow to depths of five or six feet and in cases of severe drought in California have been known to work their way over twenty feet from the surface.

The Functions of the Parts of the Root-System.—The root system of a plant has two main functions: to provide anchorage for the plant, and to collect food for the plant and convey it to the stem. The root-systems of some plants also act as storehouses for food for later use. The first function is self-evident and needs no further elaboration. We shall confine our attention to the other function.

Cut a thin cross section of a Carrot and hold it up to the light. You should have no difficulty in distinguishing three clearly defined parts of the root. In the centre is a yellow area which is commonly called the *central cylinder*. Surrounding the central cylinder is a broad area known as the *cortex*. The outer layer of the root consists of cork-like material.

Taste a piece of the cortex of the carrot. What familiar substance can you detect? Taste the central cylinder and determine whether this substance is present to the same extent in this part of the root as in the cortex. Dilute a few crops of tincture of iodine with about five parts of water. Pour a few drops of this diluted solution on some starch. The blue colour imparted to the starch is known as the iodine test for starch. Pour some of the iodine solution over a slice of carrot, allow it to stand for a few minutes and, from the result, determine which part of the root contains starch. From these experiments it may be concluded that the cortex of the carrot is used as a storehouse for foods such as sugar and starch. The central cylinder contains many "canals" that convey upwards to the stem the water and mineral substances gathered by the root hairs and rootlets from the soil. The outer corky layer of the root prevents loss of moisture by evaporation and protects the cortex against injury.

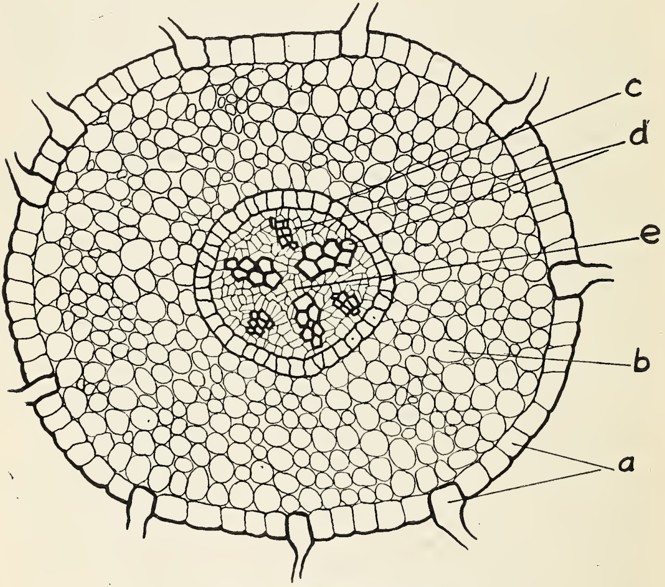


Fig. 4. Cross section of the Carrot.

The root hairs are very small and are so delicate that they are usually broken off when the plant is removed from the ground. They may be more readily observed by germinating radish seeds on dark blotting paper. Place a thick sheet of blotting paper in the bottom of a soup plate or pie tin. Moisten the paper with water and lay on it the seeds to be germinated. Then cover with a second plate inverted over the first one. The covering plate should also be lined with moist blotting paper. Examine frequently, keeping the blotting paper moistened throughout the experiment. If a radish seedling is examined closely it will be found that the root, with the exception of a portion at the tip, is covered with fine whitish hairs.

The root hairs which thus grow out in great numbers near the tips of rootlets are very slender tube-like structures, and it is through them that practically all the plant food is absorbed from the soil. Before mineral food in the soil can be absorbed it must be dissolved in water.

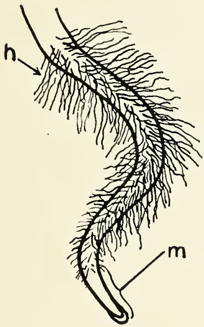


Fig. 5. Root hairs.

Water and dissolved mineral food pass from the soil through the thin membranes of the root hairs and from the root hairs into the cortex of the root. From the cortex these substances move into the transporting "canals" of the root and through these upwards into the stem.

The passage of water and dissolved mineral substances into the root hair is a process known as *diffusion*. A law of diffusion is that a substance will move to a point where there is less of that particular substance, as is well illustrated by the diffusion of ink in a glass of water. As water and dissolved materials pass up the root into the stem, more of these substances enter the root by way of the root hairs.

Conditions Necessary for Proper Functioning of Roots.— Essential to the health and good growth of a plant is the presence in the soil of plant food substances that will dissolve readily in water. There must also be sufficient water in the soil to dissolve the food materials and to supply moisture for various processes in the plant. Too much water in the soil prevents the roots from functioning properly as it drives the air from the soil and suffocates the roots. A low temperature chills the roots and may cause wilting or death of the plant.

Exercises.—(1) Examine the root-systems of the Beet, Tumbling Mustard, Ball Mustard, Dandelion, Potato, Onion, Sweet Clover, and Cabbage, and classify each as fibrous or tap-rooted.

(2) Make a list of plants the roots of which are used as food.

(3) Sow a number of grains of wheat at a depth of about half an inch in clean sawdust. Add water as required throughout the growth of the seedlings. Examine the roots of the plants at various stages. Show in a series of drawings the change from the temporary root-system of three roots to the permanent root-system of the plants.

(4) On what parts of a root-system do root hairs occur?

(5) What is the function of root hairs? Explain how water and mineral substances enter the root from the soil.

CHAPTER IV

The Stem and Its Functions

Forms of Stems.—Stems may be classified as *aerial* and *underground*, depending upon their position with respect to the earth.

Among aerial stems a number of types may be recognized, including:

(a) *Erect*, or upright stems.—This is the common type. They are wholly self-supporting and well adapted for presenting a maximum of leaf surface to the sun's rays.

(b) *Prostrate*, which lie upon the ground, e.g. Cucumber, Pumpkin, Strawberry (*runners*).

(c) *Climbing*, which raise themselves into the light by ascending a support such as a wall, fence or some erect plant.

Among climbing plants, there is (1) the *twining type*, e.g. Hop, Bean, Morning Glory, which ascend spirally about their support; and (2) the *tendril type*, e.g. Sweet Pea, Grape, which fasten to their support by means of tendrils, which are really modified leaves or stems. In some tendril climbers, e.g. Virginia Creeper, the tendrils have swollen ends, which act as adhesive discs, by means of which tenacious attachment is made. Some climbing plants, e.g. Poison Ivy, are attached by roots which grow into crevices of the support. Virginia Creeper attaches itself by both roots and adhesive tendrils.

Underground stems often bear a close resemblance to roots, from which they may be distinguished by having in mind the following stem-characters: presence of nodes, internodes and leaves. The leaves are usually scale-like on underground stems; for example, the so-called "eyes" of the Potato are buds and are located in the axils of small scale-like leaves, which mark the nodes of the underground stem.

Underground stems are well adapted for propagating new plants, for the following reasons:

(a) They are well protected from fires and drought, and to some extent from frost. Many of our native and introduced grasses have perennial underground stems which send up aerial stems each year.

(b) They usually serve as storage organs for food and hence can produce leafy shoots early in the growing season and often can mature fruit before the dry season commences or before competition with other plants is keen.

(c) Even small pieces may serve to produce new plants. Weeds, such as Canada Thistle, and Couch Grass which have underground stems, are difficult to eradicate because under some circumstances they may be multiplied rather than destroyed in working the land.

The following types of underground stems may be noted:

(a) *Rhizome* or *Root-stock*, a much elongated form resembling a root, and very common among Grasses, sedges, Ferns and many other plants.

(b) *Tuber*, a shortened, condensed form, really a portion of a rhizome which has become enlarged in connection with the storage of food. A familiar example is the Potato.

(c) *Bulb*, really a huge bud, only a small portion of it being stem. It consists of a short, vertical stem, upon which are arranged several thick, fleshy, over-lapping scale-like leaves. In the axils of some of the leaves are small rudimentary buds. Most of the food is stored in the leaves rather than in the stem. Examples include Onion, Tulip and Lily.

Buds.—A bud may be defined as an undeveloped or embryonic shoot. Buds may contain leaves only (*leaf buds*), or flowers only (*flower buds*) or both leaves and flowers (*mixed buds*). Buds are described as *terminal* when occurring at the tip of a stem, and as *lateral* when located on the side of a stem. Since lateral buds usually occur in leaf axils, they are further described as *axillary*. In the Manitoba Maple and various other plants, there is an accessory bud on either side of the axillary bud. Also, buds, termed *adventitious*, may arise without any definite order from stems, roots or leaves, their formation being due to the stimulus of a wound, in many instances. The development of shoots from adventitious buds on stumps and roots of willows may be seen everywhere.

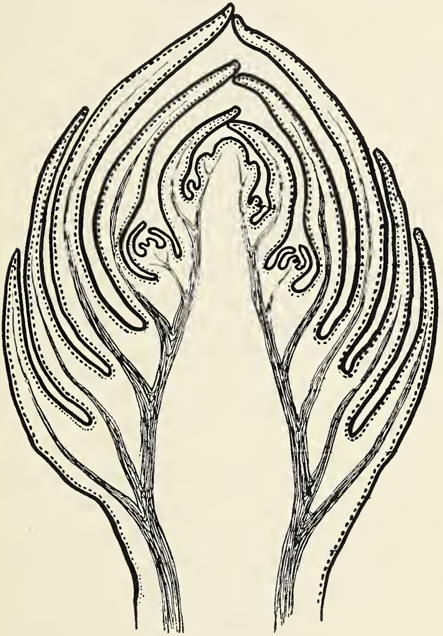


Fig. 6. A Bud.

Some forage plants (e.g. Alfalfa) may yield a number of crops of hay each year owing to the continuous development of adventitious buds on the lower part (*crown*) of the stem.

Towards the end of the growing season, resting or *winter buds* become conspicuous on trees and shrubs. (Figure 7.) These buds have closely overlapping *bud-scales*, often reinforced with waxy, mucilaginous, or hairy coverings, which serve to protect the delicate parts within against loss of water at a time when none can be obtained from the soil. Bud-scales, in most cases, are simply modified leaves. When the bud unfolds in the spring, the bud-scales fall off, leaving a cluster of ring-like scars on the stem. Thus at the beginning of each season's growth there occurs a group of *bud-scale scars*, and by counting the number of these groups on a shoot one can determine its age.

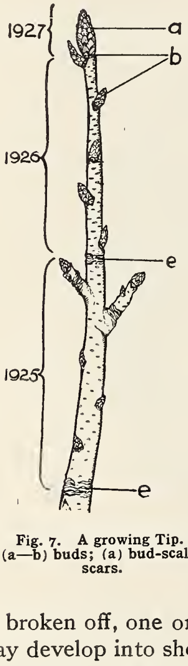


Fig. 7. A growing Tip. (a—b) buds; (a) bud-scale scars.

Winter buds are formed also by perennial herbs, whose aerial stems die down each autumn. These buds may occur on a short, basal stem, or on a horizontal underground stem or otherwise, depending upon the habit of the plant.

Not all buds grow into shoots. Many remain in the resting (*dormant*) condition indefinitely, while some that have been dormant for a period may grow out, owing to some change that has taken place in the plant or in its surroundings. For example, if a terminal bud or shoot of a plant be broken off, one or more lateral buds, heretofore dormant, may develop into shoots.

Structure of Stems.—The stems of flowering plants may be classified according to their structure into two groups, namely, *Monocotyledonous* and *Dicotyledonous*.

The first type is well illustrated by the Corn stem, which may be studied by cutting a piece of the stalk both lengthwise and crosswise. An outer, hard cortex which gives strength and rigidity to the stalk may be readily observed. Inside the cortex is a softer tissue, known as the pith. Scattered through the pith, and extending lengthwise in it, are numerous threadlike strands or bundles. These bundles consist of fibres, which strengthen the stem, and tubes or vessels, which convey sap upwards from the root and food downwards from the leaves to the stem and root. They are

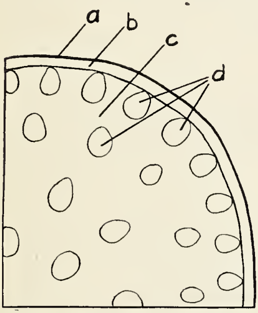


Fig. 8a. Cross section of a corn stem. (a—b) cortex; (c) pith; (d) fibro-vascular bundles.

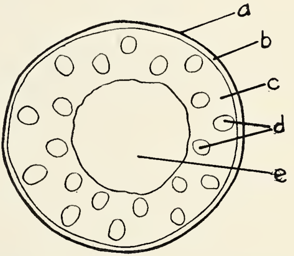


Fig. 8b. Cross section of a wheat stem. (a—b) cortex; (c) pith; (d) fibro-vascular bundles.

called *fibro-vascular bundles*. Other Monocotyledonous stems like Wheat and Grasses are hollow; the bundles are limited to a narrow zone within the tough cortex.

The Dicotyledonous type of stem is well illustrated by the Sunflower. A cross section of this stem shows that the fibro-vascular bundles are arranged in a definite ring, occupying a position between the cortex and the pith. In older stems of the sunflower the bundles coalesce to form a continuous ring of vascular tissue. An additional feature of Dicotyledonous stems may best be seen in a woody stem, e.g. Willow or Poplar, about one-quarter of an inch in thickness. In a cross section

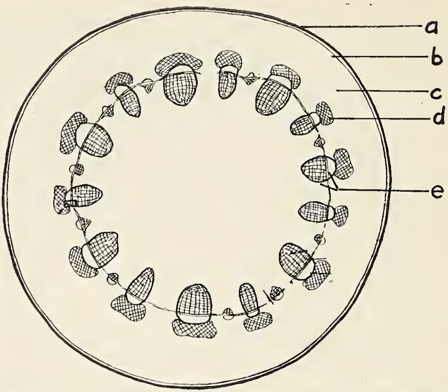


Fig. 9. Dicotyledonous stem showing circular arrangement of fibro-vascular bundles.

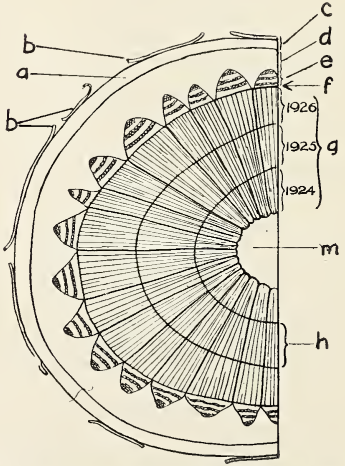


Fig. 10. Woody stem showing growth in annual "rings".

of such a stem there will be observed two, three or more rings of woody, vascular tissue. Each year a new ring of this tissue is added and thus the stem grows in diameter. By counting the number of these annual rings in the trunk of a tree, the age of the tree may be determined. On the outer surface of the outermost woody ring is a growing tissue, known as the *cambium*, and it is this tissue which produces a new ring of wood each year. Monocotyledonous stems, like Corn and Wheat, do not have a cambium. Outside of the cambium is the cortex or *bark*, the outer part of which becomes corky as the stem grows older. This outer, corky layer protects the stem against injury and prevents excessive loss of moisture.

Functions of Stems.—An important function of the stem is to support the leaves, buds, flowers, and fruit. A second function is to conduct the soil water from the roots to the leaves and to distribute the food manufactured in the leaves to other parts of the plant. Certain stems, like the tuber of the Potato, are used for the storage of food.

Exercises.—(1) Dig up some of the noxious weeds which have rhizomes. e.g. Canada Thistle, Perennial Sow Thistle, Couch Grass, and discover what you can about the underground parts.

(2) Cut sections across the woody stems of Poplar, Willow, Dogwood and other trees which are available. Examine them with a hand lens and make drawings to show the parts described in this chapter. In each case determine the age of your specimen by counting the annual rings.

CHAPTER V

The Leaf and Its Functions

The External Form of Leaves.—A typical leaf consists of two main parts: (a) a broad, thin, blade or *lamina*; (b) a narrow stalk or *petiole*. The base of the petiole is frequently enlarged to form a cushion by which the leaf is attached to the twig. In some leaves there is a pair of leaf-like appendages, *stipules*, at the base of the petiole. Leaves with stipules are *stipulate;* those without stipules are described as *exstipulate*. The petiole is absent in some leaves, which are therefore described as *sessile;* leaves with petioles are *petiolate*. Many leaves, particularly those which are sessile, have an expanded base, a sheath, which enwraps the stem more or less.

The lamina varies greatly in form and size in different plants; it may be narrow and cylindrical as in Pine and Spruce, or it may be thick and fleshy. Usually, it is a thin, flat, plate-like structure. That portion of the lamina attached to the petiole is known as the *base;* the opposite end is the *apex;* and the edge is the *margin*.

The slender and rather prominent strands which extend through the lamina are the *veins*. They are profusely branched to form a framework, the ultimate and finer branches of which form a close network. When the main veins are nearly the same size and run side by side from base to apex of the lamina, the leaf is described as *parallel-veined*. This is the case in Grasses, Lilies and other Monocotyledons. When the main vein or veins branch and re-branch to form a network, the leaf is said to be *net-veined*. This type of venation characterizes Dicotyledons. When there is one prominent vein or *mid-rib*, extending through the middle of the leaf with a number of lesser veins branching off laterally, in a regular manner, the leaf is described as *pinnately net-veined.* When a number of large veins radiate from the base towards the margin, the leaf is described as *palmately net-veined.*

The *margin* of a leaf may be so deeply indented at several points that the leaf may thus be divided into several parts or *lobes.* If these parts or lobes are in pairs opposite each other the leaf is said to be *pinnately-lobed;* if the lobes radiate as do the outstretched fingers from the palm of the hand, the leaf is described as *palmately-lobed.* Again, the lamina may be so divided that it consists of several entirely separated lobes united only at their bases to a common stalk, e.g. clover, rose. Each lobe is known as a *leaflet* in this case. A leaf consisting of several leaflets is said to be *compound;* those that are not divided into leaflets are said to be *simple.*

Arrangement of Leaves.—Leaves come off from the stem in a very regular, definite fashion. In all cases, the arrangement is such that the maximum of leaf surface is exposed to the light, the leaves being so placed as to shade one another as little as possible. Three common arrangements are as follows:

(a) *Opposite*, when the leaves are in pairs, two appearing at a node.

(b) *Whorled*, when several occur at each node.

(c) *Alternate*, when there is one leaf at a node.

The Internal Structure of the Leaf.—Plants are built up of innumerable box-like units known as *cells* which are so small that they can only be seen with a microscope. These cells differ widely in size and shape and in other structural features, as well as in the functions they perform in the plant. All cells at first contain a living substance, *protoplasm*, but many cells at maturity are no longer living since their protoplasm has disintegrated. Their cavities may become filled with a variety of substances. A group of cells of the same general type is known as a *tissue.*

Tissues.—The typical leaf (Figure 12), consists of tissues of three kinds:

(a) *Conducting tissue*, which conveys water and mineral substances from the stem, and, as we shall see later, returns complex foods to the stem. It also gives support and rigidity to the leaf, providing a framework for the more delicate, surrounding tissue. It is connected with and is similar to the fibro-vascular bundles of the stem. The veins, or a large proportion of them, are composed of this tissue.

Fig. 11. A plant cell.

(b) *Mesophyll*, which occupies the interior of the leaf and consists of thin-walled cells with numerous air-spaces among them. In this tissue the smaller of the conducting strands or veins extend and terminate. The cells of this

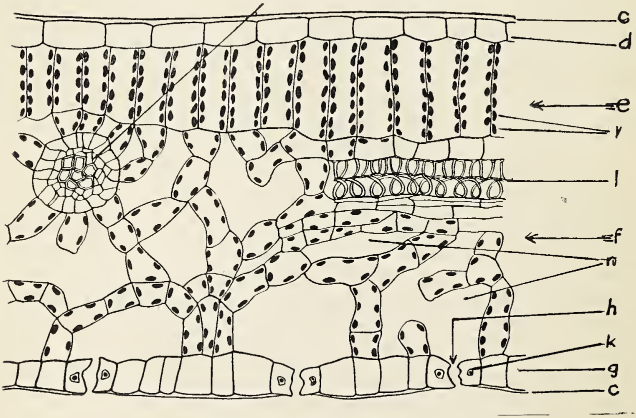


Fig. 12. Vertical section of a leaf.

tissue have in their protoplasm, numerous small, green bodies known as *chloroplasts*, which give the green colour to the leaf and which are of the greatest importance, as we shall see presently. The colour of the chloroplast is due to a green pigment known as *chlorophyll.* The mesophyll of most leaves consists of two regions: (1) the *palisade tissue*, towards the upper side of the leaf, and consisting of one or more tiers of elongated cells, vertically placed and compactly arranged; (2) the *spongy tissue* consisting of irregular cells with many air-spaces among them.

(c) *Epidermis*, which encloses and protects the other tissues. It is coated with a waxy layer, the *cuticle*, which sheds water from the leaf and protects the delicate tissues within from drying out. The epidermis forms a continuous covering over the leaf except where certain minute openings, known as *stomata* (singular, *stoma*) occur. These openings are indeed very small, and also very numerous; although they are spaced at distances which in proportion to their size are considerable, they frequently number as many as 50,000 per square inch of leaf surface. Indeed, in the Lilac leaf there are over 150,000 per square inch. Stomata are thirty times smaller than the hole made by the finest sewing needle.

The Part Water Plays in Plant-growth.—It is common knowledge that plants must be regularly supplied with water; obviously, water is essential to plant life. Water has at least three important functions in the plant:

(a) *Mechanical.* Water must be supplied to the softer tissues for the maintenance of rigidity; witness the wilting of potted plants that have not been watered for some time. The individual cells must be distended in order that a tissue may retain its proper form. Also, cells must be in a turgid condition, in order that certain vital functions, such as growth, may take place.

(b) *Transportation.* Mineral salts of the soil are dissolved in water, and in solution enter the root-hairs and are transported through the plant. These salts are essential in the manufacture of certain plant food. Also plant foods may be transported in a watery solution.

(c) *Plant Foods.* Water is itself used in the manufacture of complex plant foods.

The Functions of Leaves.—The main function of the leaf is to manufacture complex plant foods known as carbohydrates. These foods are made from carbon dioxide and water.

We have already learned something of the way in which water enters the plant, of its passage from the root-hairs

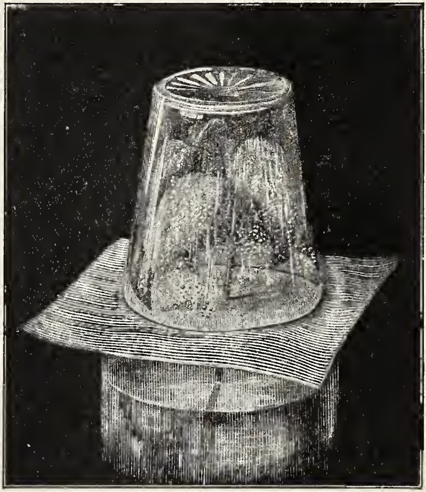


Fig. 13. An experiment to illustrate transpiration.

across the cortex of the root to the conducting tissue, through this fibro-vascular tissue to the stem and finally to the leaves. This water is distributed through the veins and then into the mesophyll cells. Here a certain amount of it is used in the manufacture of carbohydrates, but a large proportion of it escapes in the form of water vapour from the cells into the surrounding air-spaces of the mesophyll. This escape is another example of diffusion, that is, movement to a place where there is less water. The air-spaces of the mesophyll are in direct contact, through the stomata, with the air surrounding the leaf. From the air-spaces, therefore, this water vapour finds its way through the stomata and so into the atmosphere.

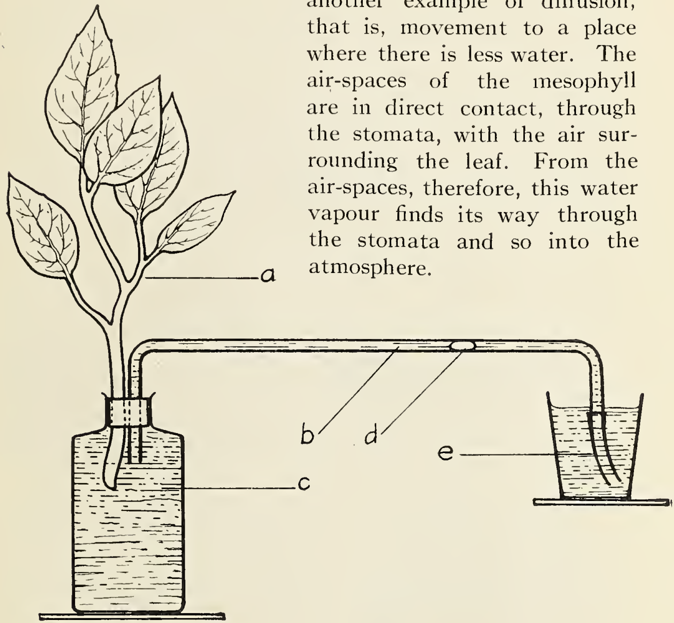


Fig. 14. An experiment to measure the rate of transpiration. The float (d) moves towards (b) as additional water is required in (c) by the plant cutting (a).

This giving-off or loss of water from the plant is known as *transpiration*. As indicated above, it is an unavoidable process, caused by the fact that the vapour pressure is lower in the atmosphere than it is in the air-spaces of the plant. The main exit of water-vapour is through stomata, but there is also some loss through the *lenticels*, or minute openings in the stem, and through the *cuticle* of stem and leaf. Enormous quantities of water are transpired by plants. For example, it has been estimated that a Sunflower plant transpires about one pint, and a large Birch tree over sixty gallons of water per day.

Among the conditions which influence the *rate of transpiration*, the following are obviously important:

(a) *Temperature*. The water-holding capacity of the atmosphere increases as the temperature rises, and there also takes place a more rapid movement of the water particles. More rapid transpiration results.

(b) *Humidity*. A lower humidity favours higher transpiration.

(c) *Air Currents*. Immediately surrounding the mouth of the stoma there is a "vapour density cap"—a region where the vapour density is higher than farther out in the atmosphere. When this "cap" is swept away by the wind, water particles will escape from the stoma more readily, and hence the rate of transpiration will be increased.

The Manufacture of Carbohydrates in the Plant.— Carbohydrates are organic compounds containing carbon, hydrogen and oxygen in various proportions. Among the more important carbohydrates are starch (abundant in the Potato tuber and in grains of cereals), cane-sugar (which we use on the table) and grape-sugar (abundant in fresh fruits). The sugars are soluble in water, but starch is insoluble and so it occurs in the plant only in the form of granules (*starch grains*). (Figure 15.)

The only place known to man, where these very important foods are manufactured on a large scale is in the green plant. The manufacturing goes on only in the green parts of the plant, that is in the mesophyll cells of the leaf and in some of the cells of the stem which contain chloroplasts. The pigment,

Fig. 15. Starch grain.

chlorophyll, which the chloroplasts contain, is essential to the process. Sunlight, or some other form of light, is also essential since this supplies the energy for the process. The raw materials are water and carbon dioxide. The water reaches the green cell by transportation from the soil. Carbon dioxide passes into the cell by diffusion from the atmosphere, by way of the stomata and the air-spaces of the plant. The amount of carbon dioxide contained in the air is exceedingly small, being only a small fraction of one per cent. Although large quantities of the gas are removed from the air by green plants, similar large quantities are constantly being added to the air as a result of:

(a) Burning of plant materials, including wood, oil, coal, and other fuels.

(b) Decay of plant and animal remains.

(c) Animal and plant respiration.

(d) Disintegration of rock carbonates.

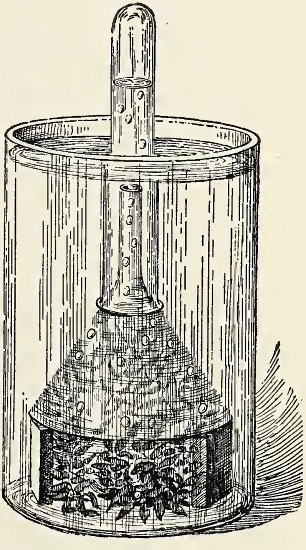


Fig. 16. An experiment to show the escape of oxygen.

The carbohydrate formed in the process, by the uniting of water and carbon dioxide, is probably grape-sugar. From this sugar, other carbohydrates, particularly starch, are formed in the cells. A by-product of the process is oxygen. Part of this oxygen may be used up in respiration (as will be explained later), while part of it escapes by diffusion into the atmosphere.

The process, which has been briefly described above, is known as *photosynthesis*. Water and carbon dioxide are united by the energy of the sun's rays to form carbohydrates. Carbohydrates are the starting points from which, by a complex series of processes other important substances, fats and proteins, are built up in plants and animals.

Since carbohydrates, fats and proteins are the three great foods of man and animals, as well as of plants, it follows that the food-supply of the world is dependent upon photosynthesis. Also, since the bodies of plants and animals are constructed of substances derived from carbohydrates, fats and proteins, it is apparent that many important features of our civilization —buildings, clothing, furniture, paper—are made possible largely by the property which the green plant cells possess to lay hold of the energy in the sun's rays. Also, it is the sun's energy which is released when fuel, wood, oil or coal is burned. Coal has been formed from green plants that flourished in past ages; therefore, the energy which, in many cases, heats our buildings and turns our wheels of industry is really solar energy that has been stored in the form of organic substances.

Respiration.—Plants, like animals, make use of the oxygen of the air in the process of *respiration* and, like animals, they set free carbon dioxide and water as waste products of respiration. The process of respiration must not be confused with photosynthesis. Unlike the latter, respiration takes place, not only in the leaves, but in all the living parts of the plant, and is carried on continuously. A more detailed account of the process of respiration is given in the next chapter.

Exercises.—(1) Make a drawing of a typical leaf and label its parts.

(2) What functions does water perform in the plant?

(3) Name the factors that affect the rate of transpiration from the plant.

(4) What are carbohydrates? From what are they manufactured? What conditions must prevail in order that these substances may be formed? What are the by-products produced?

(5) Cut shoots of vigorous young Corn, Bean, and Fuchsia plants, and twigs of Spruce or other trees. Stand the shoots with their cut ends in water, to which a little red ink has been added. After some hours, note the colouration in the veins of the leaves. Make incisions into the stem and cut sections in different parts, in order to follow the course of the liquid up the stem and into the leaf. What conclusions can be drawn from your observations?

(6) To show that starch is abundant in the leaves of plants that have been exposed to sunlight, remove a leaf from a Geranium, Clover, Garden Nasturtium or other plant that has been standing in strong sunlight for some time, and treat it as follows: Boil the leaf in water and then transfer it to a beaker containing a little commercial alcohol. The chlorophyll will be extracted by the alcohol, leaving the leaf almost colourless. Then place the leaf in an iodine solution. Starch is coloured blue by iodine, so if starch is present in any reasonable quantity in the leaf, the latter should turn bluish in colour.

(7) To show that sunlight is necessary for photosynthesis, place potted plants (e.g. Garden Nasturtium) in darkness for a day or two (or until starch is no longer present in the leaves), then place some of the plants in the strongest sunlight available, keeping the rest of the plants in darkness to serve as "controls". After a few hours test for starch in leaves from each set of plants.

CHAPTER VI

The Utilization of Foods in the Plant

Plant Foods.—Before considering the way in which a plant utilizes its food let us note certain additional facts about the nature of these substances. Organic plant foods may be divided into three main classes, namely, carbohydrates, fats and proteins. The carbohydrates include the starches, sugars and cellulose. Like carbohydrates, fats are composed entirely of carbon, hydrogen and oxygen, but differ in the proportions of these elements. In the plant, fats and sugars are seemingly convertible one into the other. Fats occur in the form of minute drops, known as oil droplets, in plant cells. Proteins are complex and very important substances, composed of carbon, hydrogen, oxygen, nitrogen and commonly a small amount of sulphur or phosphorus.

Elements Required for the Normal Growth of Plants.—Passing mention may be made of the elements, other than carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus that enter into the construction and activities of the plant. Besides these six elements, at least four others, namely, potassium, calcium, iron, and magnesium, are necessary to the normal growth of plants. Each of these elements plays an essential part in the activities of protoplasm; for example, magnesium enters into the composition of chlorophyll, and iron, although not a constituent of chlorophyll seems to be necessary in the production of chlorophyll by the cell.

With the exception of carbon, which comes from the air, the elements enter the plant mainly from the soil, being absorbed in solution. Most of the elements come from inorganic substances which are slowly dissolved by rain water. Nitrogen, however, originates chiefly from organic materials, remains of plants and animals that have been decomposed by soil micro-organisms. After a long series of transformations, in which fungi and bacteria play important parts, nitrogen may emerge as "nitrate", and in this form it can enter the plant from the soil solution. As will be explained in a subsequent chapter, there are still other ways in which nitrogen may be added to the soil and made available for plants.

As crops are removed from agricultural lands the available supply of some of these essential elements, notably nitrogen, potassium and phosphorus, becomes reduced to the point where fertilizers containing these elements must be added to the soil if permanent productiveness is to be maintained.

Translocation.—The sugar which is manufactured by photosynthesis, and the starch, fat and other foods which arise from this sugar, are used up by the living cells of the plant. Some of the food is used in the green parts of the plant, but most of it is moved to other parts—large amounts going to growing-points, storage organs, seeds, and fruits. The movement of food from the leaves is known as *translocation*. Since the substances being translocated must pass through cell-walls, they must be in solution and not in solid form. Therefore, starch which occurs in granules, cannot be translocated as such but is changed into sugar by a special substance an *enzyme* formed by the protoplasm. Translocation goes on day and night but cannot keep pace with the rate at which food is being produced in strong sunlight. Therefore, starch accumulates in the leaf during the day and disappears during the night.

Fig. 17. A granule.

The Storage of Foods in the Plant.—We may picture then, soluble foods being translocated to various parts of the plant, and at their destination being either used up or stored for further use. Storage of food commonly occurs in seeds and fruits, in the cortex and pith of stems and roots, and in special storage organs, such as bulbs, tubers, rhizomes, tap roots, etc.

Sugar is stored in many fruits, in some roots, e.g. sugar beet, and in stems, e.g. sugar cane. Starch may be stored in seeds, as in wheat and corn, in roots, as in the turnip, or in tubers, as in the potato. Fats are often stored in seeds, as in flax, corn and cotton. Proteins are particularly abundant in seeds of beans, peas, and other legumes.

Digestion of Stored Foods.—Foods that are stored must be *digested*, that is, put into soluble and utilizable form, before they can be used up by the plant. We have already referred to the change of starch to sugar in the leaf; this is a process of digestion, and is effected by an enzyme called *diastase*. It is this enzyme, or a similar one, that is secreted by our salivary glands and which changes our starchy foods, such as bread and potato, to sugar. The same enzyme is produced also in certain storage organs of the plant and digests the starch when carbohydrate food is required.

Similarly, other foods are digested, in each case a specific enzyme being immediately responsible for the process. For example, cane sugar is changed to two simple sugars by an enzyme *invertase*, fats are digested by *lipase*, and proteins in the plant are broken down into their "building-blocks" by enzymes very similar to those that effect like changes in the digestive tract of Man.

Assimilation of Digested Food.—The living substance of plant cells is called *protoplasm*. Since many of the manifestations of life depend upon the chemical nature and physical properties of protoplasm, the substance has been called "the physical basis of life". The process of building up protoplasm from substances produced by the digestion of foods in the plant is called *assimilation*. The products of protein digestion in particular are thus utilized. Of the details of the process of assimilation we are almost totally ignorant. During assimilation the food materials become endowed with those remarkable properties possessed by living substance. In other words, it is here that dead matter becomes alive. Of utmost importance, however, is the fact that this unique transformation never occurs in nature apart from living substance.

The great mass of protoplasm in each adult organism began its existence as a tiny droplet in a single cell (as we shall see later). On the other hand, as far as we know, a new individual never comes into existence apart from protoplasm already existing.

Respiration of Digested Food.—Some of the products of digestion are not assimilated, but are used to provide energy for the vital processes that go on in protoplasm. Grape-sugar is one of the most important substances used in this way. It will be recalled that energy of the sun's rays went into the uniting of carbon dioxide and water to form grape-sugar. The energy which is thus "tied up" in the sugar is known as *potential* energy. We are reminded that potential energy is likewise possessed by coal and other fuels, and that when coal is burned this energy is released in the form of *kinetic* energy—that is, capable of doing work. So, in the plant, when grape-sugar is "burned" or *oxidized*, its potential energy is changed to kinetic energy, which is utilized in doing work. In this process, as in the burning of coal, oxygen is used up, and carbon dioxide and water are given off. This process, by which substances are broken down in the plant, with the release of energy and with the ultimate production of carbon dioxide and water, is termed *respiration*. All organisms carry on respiration. It is a function of every living cell.

Let us note a few further features of this process. While the main respiratory substances are food reserves, particularly grape-sugar, energy is undoubtedly released also by the breaking down of protoplasm, but the steps are unknown. (It was once thought that respiration involved the breaking down of protoplasm only.) The substances respired are to the plant cell what coal is to a factory; but whereas in the factory, combustion of fuel takes place only at a high temperature, in the cell oxidation goes on at ordinary temperatures.

Since respiration is an oxidation process, oxygen must be supplied. Also, since respiration goes on in every living cell, oxygen must reach all parts of the plant that are alive. The cells do not fit closely together, the spaces among the cells permit oxygen to pass from one part to another and to reach the inner regions of the plant. Not only is oxygen permitted to reach the cells in this way but carbon dioxide formed during respiration can thereby escape. Oxygen enters and carbon dioxide leaves the plant by way of the stomata and lenticels (openings in the bark) and through the thin-walled cells of the root-hairs and growing points. This interchange of gases is readily effected in the shoot of the plant and also in the root-system if the plant is growing in a porous, well-drained soil. If, however, the air-spaces in the soil become filled with water, or if a compact crust develops over the surface of the soil, the normal activities of the roots are seriously impaired. Proper drainage and cultivation of soils is therefore of utmost importance.

Finally, let us compare these two very important processes, namely, photosynthesis and respiration—the former a "building-up" and the latter a "breaking-down" process. The contrasting features may be presented in tabular form as follows:

Photosynthesis	**Respiration**
Occurs only in *green* tissue	Occurs in *all* living tissues
Requires light energy	Irrespective of light
Uses carbon dioxide	Liberates carbon dioxide
Liberates oxygen	Uses oxygen
Stores energy	Releases energy
Constructs food	Destroys food
Increases weight	Decreases weight

Exercises.—(1) What are the three main classes of foods? To what extent do these resemble each other? How and where do fats occur in the plant? Of what are proteins composed?

(2) Name ten elements required for the normal growth of plants. What are the special uses of magnesium and iron? Which of the elements are obtained from the air? Which are obtained from the soil? What are nitrates? What elements are likely to become deficient in the soil as a result of continual cropping? How are these restored?

(3) What foods are manufactured in the green parts of the plant? By what process is this accomplished? Where are these foods used? Define translocation. Why does starch accumulate in the leaf during the day? In what form are plant foods stored? In what parts of the plant?

(4) What is digestion? How is each of the following digested: starch, cane sugar, fats, protein?

(5) Name two ways in which digested foods are used in the plant. Explain fully how respiration differs from photosynthesis.

(6) Place a drop of iodine solution on a shaving of Potato tuber, and on the whitish internal substance of a Bean. From results obtained what food constituent do you know is present in these materials?

(7) The simplest test for proteins is that they are turned yellow by nitric acid, and the colour is intensified by the addition of ammonia. Place a little flour in a glass tumbler or test tube, add nitric acid, mix thoroughly with a glass rod, and allow to stand for a few minutes. Note the change in colour. Then add ammonia and note any further change. Repeat the experiment with crushed Peas or Beans.

(8) Break a raisin into small pieces, place them in a test tube, cover with water, and boil for a few minutes. Then add about a teaspoonful of Fehling's Solution, and heat again. The formation of yellowish, brown, or reddish-brown solids indicates the presence of a reducing sugar. Repeat the experiment substituting some small pieces of carrot for the raisin.

Note.—Fehling's Solution:

(a) 35 grams coppersulphate in 500 cc. of water.

(b) 173 grams Rochelle salts and 50 grams sodium hydroxide in 500 c.c. of water.

Keep the solutions separately, and mix in equal quantities when required.

(9) Crush a small piece of cocoanut or some flaxseed upon a piece of white paper. Hold up the paper to the light, and note the grease spot produced by the fats in the plant. This is the simplest test for **fats.**

CHAPTER VII

The Flower and Its Functions

The primary function of a flower is to produce seed. The parts of the flower that are necessary for the production of seeds are called the *essential organs*, and those that serve as a covering or protection for the essential organs are called the accessory parts or *floral envelopes*.

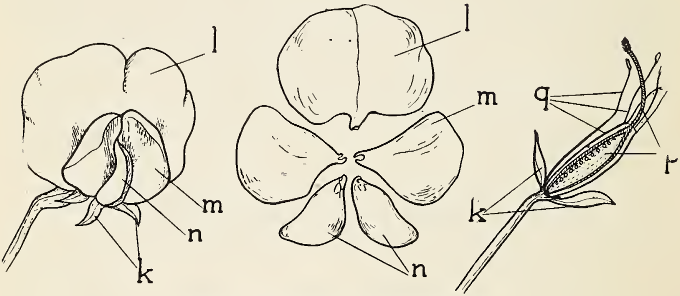


Fig. 18. The flower of the Sweet Pea.

Let us examine the Sweet Pea in order to identify the parts of a flower. On the outside of the flower is the green *calyx*. (Figure 18k.) Each division of the calyx is a *sepal*. In the Sweet Pea the sepals are joined but in many other flowers the sepals are entirely separate. The showy part of the flower is the *corolla*. (Figure 18l, m, n.) Each part of the corolla is called a *petal*. The calyx and the corolla are the accessory parts of the flower.

Carefully remove the petals and calyx from the flower. Just inside the two petals which form a hood are ten slender stalks, the *stamens* or male organs of the flower. (Figure 18q.) The enlarged part of the top of the stamen is the *anther*. In it you will find yellow powder which is *pollen*. The slender part of the stamen is the *filament*. In the centre of the flower and surrounded by the stamens is the *pistil* or female organ. (Figure 18p.) The pistil consists of three parts: (1) the *stigma*, knob-like tip of the pistil; (2) the *style*, a long slender stalk; (3) the *ovary*, the enlarged part at the base of the pistil. In the ovary are minute structures called *ovules* which develop into the seeds of the plant. The stamens and the pistil constitute the essential organs of the flower.

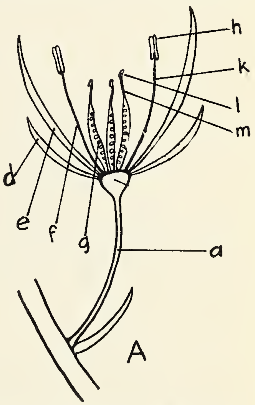


Fig. 19. Diagram of Flower Parts.

Most flowers resemble the Sweet Pea in having both pistils and stamens. They are said to be *perfect* flowers. In some plants the stamens are to be found in one flower and the pistils in another. Flowers which bear pistils and no stamens are known as *pistillate;* those which bear stamens but no pistils are *staminate* flowers. In the Corn plant the tassels are the staminate flowers, and the silks are the pistillate flowers. Cucumbers, Squash and Marrows resemble Corn in having staminate and pistillate flowers on the same plant. In the Willows, Poplars and Manitoba Maple the staminate and pistillate flowers are on different trees.

Pollination.—Before an ovule can develop into a seed, it must receive a droplet of protoplasm from a pollen grain. The way in which this is effected will now be explained. When the pollen grains are mature, the wall of the anther breaks open and the pollen emerges in the form of a powdery mass. If pollen grains are to function in the process of seed production they must then find their way to the stigmas of the pistils. The transference of pollen from the anther to the stigma is known as *pollination*.

The agents by which plants are pollinated in nature are mainly three, namely, gravity, wind and insects. Pollination may result by pollen falling from flowers on higher branches or from anther to stigma in the same flower. Flowers of Spruce, Corn and many others are largely wind-pollinated In flowers which are regularly pollinated in this way, a very large quantity of pollen is produced. For example, an individual corn plant, in the numerous flowers of its tassel, produces about 50,000,000 pollen grains. In insect-pollinated flowers, usually much less pollen is produced. Such flowers are generally dressed in attractive colours and have sugary secretions and often structural devices especially adapted to effect pollination. As the insect pushes into the flower to obtain honey, pollen from the opened anthers sticks to its body; this pollen may be brushed on to the stigma of the same flower or it may be carried to stigmas of other flowers visited by the insect.

Pollination may take place by the transfer of pollen from stamen to pistil of the same flower that is, *self-pollination* or, by transfer to another flower of the same species, *cross-pollination*. The latter term is sometimes used with a more restricted meaning. For example, in the case of the Apple, horticulturists consider that cross-pollination occurs only when the pollen transferred has come not only from a different flower, but from a different tree and moreover from a tree of a different variety. The reason for this is that some varieties of Apple will not bear much fruit or set seed unless pollinated by pollen from a different variety of Apple.

Self-pollination is the usual method in some plants, e.g. Wheat, Barley, Oats and Garden Pea, but among plants in general, cross-pollination is the more usual; indeed, many have flowers so constructed to prevent self-pollination.

Some plants, e.g. Red Clover, and several cultivated fruit trees, will develop little seed or fruit when self-pollinated.

Germination of the Pollen Grain and Fertilization.— The pollen grain, having reached the stigma of the pistil germinates in a sugary solution secreted by the stigma and pushes out a thread-like tube, a *pollen tube*, which grows into the stigma and down the style to the cavity of the ovary. (Figure 20n.) Attracted by a substance secreted by the ovule, the tip of the pollen tube grows across the cavity of the

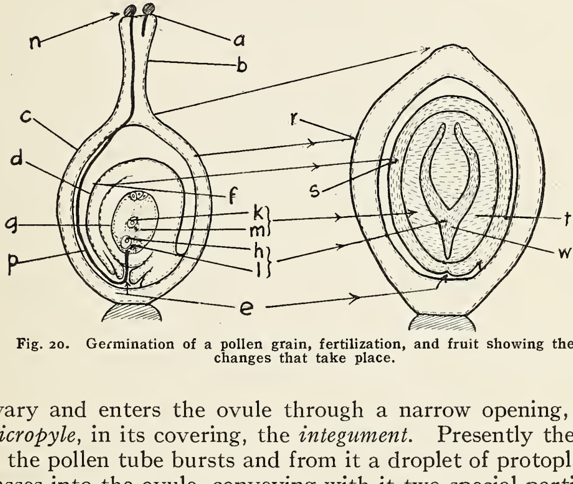


Fig. 20. Germination of a pollen grain, fertilization, and fruit showing the changes that take place.

ovary and enters the ovule through a narrow opening, the *micropyle*, in its covering, the *integument*. Presently the tip of the pollen tube bursts and from it a droplet of protoplasm passes into the ovule, conveying with it two special particles of protoplasm known as *male nuclei*. One male nucleus then unites with the *female nucleus* or *egg* in the ovule. This union of male and female nuclei is known as *fertilization*. The fertilized egg, the product of the union, is a cell which by subsequent division gives rise to a new plant. For a considerable period, however, this new individual remains in a resting, or dormant, state as an embryo within the seed.

Following fertilization, marked changes take place in the ovule as it develops into a seed. (Figure 20.) The ovule as a whole usually increases greatly in size. Its integument hardens to form a *seed-coat* or *testa*. The embryo which develops from the fertilized egg grows at the expense of the surrounding tissue of the ovule. It may eventually occupy all the space within the seed-coat, having digested and stored within itself all the food material available; or, at maturity it may occupy a comparatively small part, the remainder of the space within the testa being packed with food reserves and known as the *endosperm* of the seed. The endosperm is also a product of fertilization, having been initiated by the fusion of the second male nucleus with an endosperm nucleus in the ovule. In Flowering Plants, therefore, there occurs a *double fertilization*.

Fertilization results in the production of a seed, including the development of a new individual which resides in the seed. It leads also to the production of fruit. The stimulus provided by fertilization and by the development of the ovule extends to the pistil and in some cases to other regions of the flower, producing marked changes in these various parts. The *fruit* is essentially the ripened ovary, whose wall becomes hardened or otherwise modified to form the *pericarp*. It contains the seed or seeds, which are ripened ovules. However, the fruit is sometimes the product of more than one ovary and in some cases includes parts of the flower other than the ovaries.

It must be made clear that a pollen tube can fertilize only one ovule. Therefore, in an ovary such as that of the Tomato, which may contain over 100 ovules, a corresponding number of pollen tubes must enter the ovary to effect a maximum production of seed. Hence a like number of pollen grains must reach the stigma. In mature fruits of the Apple and Bean, undeveloped ovules frequently occur, probably because of insufficient pollination. On the other hand there is great wastage of pollen, much more being produced than ever functions in fertilization. There are great losses during transportation, especially among wind-pollinated plants. Frequently, also, more pollen grains reach the stigma than can possibly function because of the limited number of ovules in the pistil. In Corn, for example, there is only one ovule in the pistil, and hence only one pollen tube required, although many are usually present on the stigma.

In the absence of fertilization, the ovule shrivels and no fruit is produced. To this statement there are a few exceptions. In the Dandelion, for example, ovules develop into seeds without fertilization; and in the Banana and Seedless Orange, fruits develop although no fertilization occurs.

Exercises.—(1) Make a sketch of the flower of the Sweet Pea, and name all visible parts. Make drawings of the stamens and pistil, naming the parts of each.

(2) Define and state the purpose of pollination. By what agents are plants pollinated? Is there any relation between the method of pollination and the amount of pollen produced, the colour of the flower, or the structure of the flower? Explain fully. Name and give examples of the kinds of pollination.

(3) Trace the steps from pollination to the formation of the embryo. Explain what is meant by double fertilization. What are the results of fertilization? What is the difference between a fruit and a seed?

CHAPTER VIII

SEEDS

Botanically speaking, a seed is a ripened ovule containing an embryo. A *fruit* is defined as one or more ripened ovaries, either with or without adjacent flower parts. Many small one-seeded fruits such as Wheat, Oats, Barley, Corn, are popularly called seeds. The botanist regards them as fruits because the outer hard covering of the "seed" in each case is the ovary wall. There are two common types of seeds; the Bean is an example of the first type; the Corn is representative of the second type.

The Seed of a Dicotyledon.—Beans that have been soaked over night will serve for our study of the first type of seed. On the outside of the Bean is a covering called the *testa* or seed-coat. On the testa is a conspicuous scar, which occupies about one-quarter of the length of the seed.

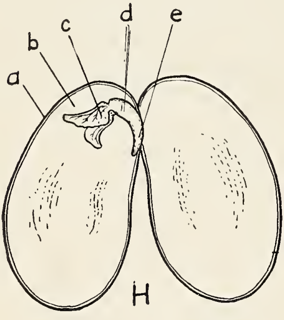


Fig. 21. Seed of a Dicotyledon.

This scar is the *hilum*, and marks the point where the seed was attached to the pod. Close to one end of the hilum is a minute opening, the *micropyle*. It was through this opening that the pollen tube entered the ovule, and through this the young root later emerges. If the seed-coat is carefully removed the parts of the *embryo* may be seen. The seed may easily be separated into two parts, the *cotyledons* or seed-leaves. Plants like the Bean, Apple, Pea, Pumpkin, Squash and Clover, which have seeds containing two cotyledons are called *Dicotyledons*. At one end of the cotyledons is the *plumule*, in which a pair of folded leaves, the first *true* leaves of the plant, may be readily observed. Here also is a stout, curved part, the *hypocotyl*, with which is merged a pointed *radicle* that produces the root as the seed germinates. (Figure 21.) The food for the use of the seedling plant is stored in the cotyledons. Prove that both starch and proteins are present in the cotyledons of the bean.

The Seed of a Monocotyledon.—Corn, Wheat, Barley, Rye, Timothy, Rye Grass, and other grasses differ from the Dicotyledons in having seeds with but one seed-leaf or cotyledon. They are therefore called *Monocotyledons*. Examination of a soaked corn kernel will reveal a tough jacket which is made up of the ovary wall and the testa. The two are so closely united that they cannot be distinguished without the aid of a microscope. The remainder of the seed consists of two main parts lying side by side, the *endosperm* and the *embryo*. The endosperm contains starch, protein, and fat for the use of the young plant. The hard endosperm, the outer part, is darker in colour and has a large proportion of protein. The inner part, the soft endosperm, is rich in starch. A special layer of cells, the *aleurone layer*, is found around the border of the hard endosperm; these cells are packed with aleurone grains rich in protein. The single cotyledon of the Corn, called the *scutellum*, digests the food and transfers it to the embryo. The plumule and radicle are each enclosed in a sheath.

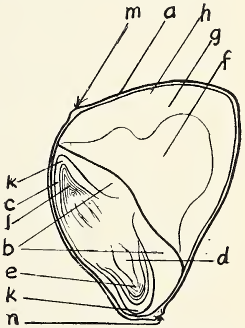


Fig. 22. **Seed of a Monocotyledon.**

The grain of Wheat is very similar in structure to that of Corn. At one end of the grain (the end which bore the stigmas) is a tuft of hairs, the *brush*, and at the opposite end is the embryo. Along one side is a furrow or *groove.* As in the endosperm of Corn, there is an outer aleurone layer packed with protein granules. Within this layer is the bulk of the endosperm, which, unlike Corn, is fairly uniform in appearance and constitution. It consists of starch grains, intermixed with many protein granules. The latter provide the "gluten" of white flour, and are largely responsible for the quality of the flour. In the milling of white flour, the ovary wall, the testa, aleurone layer, and some of the outermost starch grains are removed and constitute the *bran.*

The Germination of Seeds.—In the seed, the young plant or embryo is in a dormant state, but, under suitable conditions it will begin to grow rapidly. *Germination* refers to the awakening of the young plant and to its early growth as a seedling.

Seeds will germinate only when water, oxygen and a moderately high temperature are provided. Water is absorbed in large quantities and makes possible certain important transformations. Oxygen is required for respiration; if seeds are planted too deeply, they germinate poorly because of lack of oxygen. The best temperature for good germination varies with different seeds. Also minimum and maximum temperatures vary with seeds of different kinds.

When a seed germinates, *enzymes* secreted by certain of its cells change the reserve foods to soluble form; these are transferred to the growing cells of the embryo where they provide material and energy for growth. In Wheat, for example, enzymes are secreted by cells of the scutellum lying next to the endosperm and also by cells of the endosperm. These enzymes digest the starch grains and other food reserves in the endosperm, and the substances which thus arise are transferred by diffusion across the scutellum to the growing tips of the seedling.

The following types of germination are of common occurrence:

(a) *Common Bean Type.*

On germination of the seeds of the Common or Kidney Bean, the radicle is pushed out and grows into the soil, very soon producing a small root-system which anchors the seedling. The hypocotyl grows in length rapidly, becomes greatly arched and then straightens, thereby pulling the cotyledons out of the ground and carrying them and the plumule aloft. The plumule then commences rapid growth.

Other seeds which germinate in this way are Pumpkin, Squash, Turnip, Radish, Sunflower, Alfalfa, Castor Bean, and Buckwheat. In most of these, the cotyledons shrivel and fall off very soon after the seedling is well established, but in Buckwheat and Castor Bean the cotyledons become green and function as ordinary leaves for some time.

(b) *Pea Type.*

On germination of the seeds of the Pea, the radicle grows into a root-system, and the axis of the plumule elongates, the delicate bud being protected by reason of a small apical hook that bears the brunt of the movement upwards in the soil. When the plumule comes above the surface of the soil, this special curvature rapidly straightens out. In contrast with the first type of germination described, the cotyledons of the Pea are not pulled out of the seed-coat, but, with the testa, remain where the seed was planted. The cotyledons collapse as the food material is removed, being finally reduced to shrunken remnants. This type of germination occurs also in the Broad (or English) Bean and in the Scarlet Runner Bean.

(c) *Corn Type.*

This type of germination resembles the last in that the cotyledon (only *one* in the corn type) remains in the soil, but differs in the fact that the cotyledon functions as an absorbing organ. Also, the plumule, during its growth upwards, through the soil, is protected by a sheath-like covering, which is later ruptured by the expanding leaves. Another feature is that the seedlings produce roots from their nodes, these adventitious roots constituting the permanent root-system of the plant. This type of germination is characteristic of members of the Grass Family.

Dispersal of Seeds.—A large proportion of plants have special devices which secure the scattering of their seeds to greater or shorter distances. Some fruits are so constructed that the seeds are thrown out and projected to some little distance by the sudden rupture or swelling of certain tissues. In general, however, outside agents, notably wind, animals, Man, and water, are responsible for dispersing seeds.

(a) *Dispersal by Wind.*

Among seeds dispersed by wind are those that are minute and light, and those with special devices such as *wings* and *plumes*. The fruits of the Curled Dock, and of various Maples have wings by which they float away in the breeze. The small seeds or fruits of many of our most prevalent weeds, e.g. Thistles, Fireweed, Fleabane, Groundsel, and Dandelion, are regularly dispersed to great distances. They are provided with tufts of long fine hairs which function as parachutes. Seeds of this kind, when once caught up by the wind, may be carried for many miles before they drop to the ground. The stems of the various "tumble-weeds", e.g. Tumbling Mustard, Tumbling Pigweed and Russian Thistle, break off near the ground and are rolled along by the wind, dropping their seeds on the way. Fruits and seeds of some plants, e.g. Ragweed and Pigweed, are usually blown about over frozen ground or snow.

(b) *Dispersal by animals and by Man.*

Fleshy fruits and seeds are adapted for dispersal by animals. When fleshy fruits are eaten, the soft parts are digested, but the embryos, protected by hard seed-coats, pass through the digestive tract unharmed. Indeed, some seeds will germinate only after they have passed through the digestive tract of some animal. Even when the stones or seeds of fruits are not swallowed, the bird or other animal may carry them to a considerable distance from the parent plant.

Dry fruits and seeds are constantly being distributed by animals, carried in mud adhering to their feet, in wool or hair of their bodies, and so on. Seeds of the Mustards are sticky when wet and are dispersed by adhering to the feet of animals or the boots of Man. Many fruits bear spines or hooks by which they catch on the coats of passing animals and are later brushed off. Familiar examples include the burs of the Burdock and the hooked or spiny fruits of Cleavers, Beggar-ticks, Buttercups and Wild Carrot.

Many plants have been widely distributed by Man in connection with agriculture and other activities. He frequently sows Wheat, Oats, Clover Seed, etc., that contain seeds of other plants. The latter are usually troublesome weeds, not infrequently originating in a distant country, and transported with agricultural seed. Seeds are commonly dispersed by threshing machines and vehicles. It is only necessary to examine the vegetation in the vicinity of a railroad station to realize the extent to which plants are distributed by railways. Many plants found along the railways are "new-comers" which, in some case have been transported long distances. The seeds have been carried while attached to live stock, or in straw and hay used as feed, bedding or packing, or in manure. In this way, Canada Thistle, Couch Grass, Russian Thistle, Russian Pigweed, Ox-eye Daisy, etc., are carried to new localities.

(c) *Dispersal by Water.*

Many plants, especially those that grow in or near water, produce seeds that will float for short or long periods. Seeds of this kind are dispersed by streams, rivers, and ocean currents, and are sometimes carried long distances.

Exercises.—(1) Name two common seed types, and give examples of each. Draw diagrams of representatives of each type, and label all the parts.

(2) Define germination. What are the requirements for germination? Describe the work of enzymes during germination. What are the common types of germination?

(3) Germinate seeds of Common Bean, Pea or Runner Bean, and Corn or Wheat. In each case, make a series of drawings, illustrating various

stages in development of the seedling and labelling all parts neatly. These seeds may be germinated on sheets of moist blotting paper as described in an earlier chapter, or they may be germinated in moist sawdust or moist earth. In each case, note the total number and percentage of seeds germinated and also the time required for germination, taking as the criterion of germination the emergence of the radicle.

(4) What are the chief agents responsible for the dispersal of seeds? Name seeds that are dispersed by each agent. State the special adaptations for dispersal of the seeds in each class.

(5) Examine fruits of common weeds and try to discover how the seeds are dispersed in each.

CHAPTER IX

Classification of Plants

The Plant Kingdom consists of the following main groups or divisions:

(a) *Thallophyta* (Bacteria, Algae, Fungi, Molds, Yeasts, Smuts, Rusts, Mushrooms, etc.)

The Thallophyta include a number of groups differing widely in some respects, but are all simple organisms, and are mostly small in size. Included here are the Bacteria of very great importance to Man; the Algae, constituting a large group including Seaweeds and the scum-like growth of ponds and the silky, thread-like plants of streams; and the Fungi. The lower groups in the Thallophyta are on the border line between animals and plants, many of them having the animal characteristic of locomotion.

(b) *Bryophyta.* (Mosses, Liverworts)

Mosses and Liverworts are small, flattened or leafy plants and are most abundant in damp, shaded places. Our muskegs have been built up largely by the growth of one of the Mosses, namely, Sphagnum.

(c) *Pteridophytes.* (Ferns, Club Mosses, Horsetails, etc.)

The Fern group has rather few representatives in Alberta. Horsetails abound in places, one species being quite frequent in some of our wet grasslands. The members of this group, and likewise those of the Bryophytes, and several groups of the Thallophyta are propagated in the main by *spores*, minute particles of living substance that become detached from the parent plant and serve to produce offspring.

(d) *Spermatophyta.* (Seed Plants)

The Plant Kingdom

- Thallophyta
  - Bacteria
  - Blue-green Algae
  - Slime moulds
  - Diatoms
  - Green Algae
  - Brown and Red Seaweed
  - Fungi
  - Moulds
  - Yeasts
  - Smuts
  - Rusts
  - Mushrooms
- Bryophyta
  - Mosses
  - Liverworts
- Pteridophyta
  - Ferns
  - Horsetails
  - Club mosses
- Spermatophyta
  - Gymnosperms
    - Conifers
      - Pine Family
        - Jack pine
        - Larch
        - Black spruce
  - Angiosperms
    - Monocotyledons
      - Glumiflorae
        - Gramineae
          - Hordeum
            - Squirrel-tail grass
            - Barley
          - Phleum
            - Timothy
          - Triticum
            - Wheat
          - Avena
            - Oats
      - Liliflorae
        - Liliaceae
          - Allium
            - Onion
          - Hyacinthus
            - Hyacinth
          - Tulipa
            - Tulip
    - Dicotyledons
      - Salicales
        - Salicaceae
          - Populus
            - Balsam poplar
            - Trembling aspen
      - Centrospermae
        - Chenopodiaceae
          - Beta
            - Beet
          - Salsola
            - Russian thistle
      - Rhoeadales
        - Cruciferae
          - Brassica
            - Cabbage
            - Wild mustard
      - Rosales
        - Rosaceae
          - Pyrus
            - Apple
          - Rubus
            - Raspberry
        - Leguminosae
          - Trifolium
            - Clovers
          - Medicago
            - Alfalfa
      - Umbelliflorae
        - Umbelliferae
          - Apium
            - Celery
          - Daucus
            - Carrot
      - Tubiflorae
        - Solonaceae
          - Capsicum
            - Red pepper
          - Solanum
            - Potato

(1) Gymnosperms. (Spruces, Pines, Firs, etc.)

(2) Angiosperms, or Flowering Plants.

In contrast to the above groups (a to e) the Seed Plants propagate by seed dispersal rather than by spores.

In the *Gymnosperms*, the seeds are not enclosed in dry or fleshy cases, as in the Angiosperms, but are often borne on top of scale-like structures so arranged to form a *cone*.

Our most familiar Gymnosperms have their seeds in cones and hence are known as *Conifers*. They include the Jack Pine of northern Alberta, the Lodge-pole Pine of the foot-hills and mountains, the Black Spruce of our muskegs, the White Spruce which is common along river valleys and which covers large areas in western and northern Alberta, and the Larch, or Tamarack, which grows in swampy places. All of these Conifers have needle-shaped leaves, and all are *evergreen* except the Larch, which drops its leaves each year. Like the Willows, Cherries, Poplars, Birches and other plants that shed all their leaves each year, the Larch is said to be *deciduous*.

The Conifers are most valuable trees for lumber, pulpwood, etc., and constitute one of our greatest assets. Therefore, we should be very zealous in guarding against destruction of our forests by fire and other agencies.

The *Angiosperms* or *Flowering Plants* are divided into two classes, namely, Dicotyledons and Monocotyledons, based upon differences in seed, as we have already noticed, and in flower, leaf and stem. The typical distinguishing features may be set forth as follows:

Monocotyledons	Dicotyledons
Seed—One cotyledon.	Two cotyledons.
Flower—Parts in 3's or 6's.	Parts in 4's or 5's.
Leaf—Parallel-veined.	Net-veined.
Stem—Vascular bundles scattered in the ground tissue. No cambium in bundle.	Bundles dividing ground tissue into cortex and pith. Cambium present.
Habit—Prevailingly herbs.	Herbs, shrubs or trees.

The Monocotyledons and Dicotyledons are each divided into *Families*, according to the structure of the flowers, fruits and other organs. Each Family, in turn, contains one or more *genera* (singular, *genus*); and finally, each genus is composed of one or more *species*, the latter consisting of individuals which are like one another.

The system of classification is thus one of "groups within groups". By way of illustration, let us start with the smallest of the groups, the species. Cultivated Barley is a species; Squirrel-tail Grass (sometimes called Wild Barley) is another species. Since these two species are very similar in the structure of their flower-clusters and flowers, they are grouped together in the same genus, namely, *Hordeum* (the Latin name for Barley). Since *Hordeum* has much in common with Wheat, Oats, Rye Grass, Rye, Timothy, Corn, and many other genera, these are grouped together in one Family, the *Gramineae* or *Grass Family*. This Family in turn is one of about forty that make up the sub-class, Monocotyledons.

Scientific Names.—Each species is given a scientific (Latin) name, and by that name it is known to botanists the world over. The same species may have a dozen common names, even in the same district sometimes more than one. The scientific name is really made up of two names—the name of the genus to which the plant belongs, followed by the name of the species. The generic name is always written with a capital letter, while the specific name is usually not capitalized. Thus the scientific names of Cultivated Barley and Squirrel-tail Grass are *Hordeum vulgare* and *Hordeum jubatum* respectively.

Families of Flowering Plants

Although there are about three hundred of these families, only a few contain species of agricultural importance in Alberta, either as weeds or as cultivated plants. We may consider a few of the most important families at this point.

Gramineae (*Grass Family*).—This is a very large Family, numbering about 4,500 species, represented in all parts of the world. From an economic standpoint it is the most important of the plant Families. Among its species are the six major cereals, Wheat, Oats, Barley, Rye, Corn, and Rice. These constitute the basis of agriculture. Included in this Family also are many range and meadow grasses, e.g. Buffalo Grass, Grama grasses, Blue grasses, Slough grasses, Timothy, Red Top, Rye Grass, Brome Grass; the Sugar Cane, from which sugar is obtained; and many weeds, of which Quack Grass, Wild Oats, Squirrel-tail grass, Chess, Sweet Grass, and Darnel are very troublesome.

The Gramineae are Monocotyledons. In earlier chapters we have learned something of the root-systems, stems, and leaves of the grasses. The flowers are usually green in colour, and are arranged in a cluster at the top of the stem. The inflorescence (flower cluster) consists of groups of flowers; each group is called a *spikelet*. The spikelets are assembled in various ways, forming the following common inflorescences—*spike*, *raceme* and *panicle*. In a spike, the spikelets are not stalked but are sessile on the axis, *rachis*, of the inflorescence, e.g. Wheat, Barley. In a raceme, the spikelets are attached by short stalks to the rachis. In a panicle, the rachis is branched and the spikelets are attached to the branches, e.g. Oats, in which the branches are long, and Timothy, in which the branches are short.

Liliaceae (*Lily Family*).—To this family belong many ornamental plants such as Hyacinth, Tulip and the Lilies, and also two well-known food-plants, Asparagus and Onion. Among common native plants of this family are Solomon's Seals, Wild Onion and Western Tiger Lily. A native, poisonous plant which has caused considerable trouble among sheep and other animals is Death Camas. The flowers of members of this Family are usually bell-shaped.

Cruciferae (*Mustard Family*).—This family includes many of our weeds such as Wild Mustard or Charlock, Tumbling Mustard, Hare's-ear Mustard, Ball Mustard, Green Tansy Mustard, Stinkweed, Pepper Grass, Shepherd's-purse, and False Flax. On the other hand, the Cruciferae contains a number of valuable plants, e.g. Cabbage, Cauliflower, Radish, Turnip and Rape. The flowers of this Family have, typically, four sepals, six stamens, and two united pistils. The four petals, when expanded, suggest a Greek Cross, whence the name *Cruciferae*, meaning "cross-bearing".

Leguminosae (*Pea Family*).—This is a large Family and one that is abundantly represented in Canada. Certain members of the Family, particularly the Clovers, are of very great importance in agriculture, not only because of their value as forage, but because they may be utilized to enrich the soil (as is explained in a subsequent chapter). Among important cultivated plants of this group are Clovers, Alfalfas, Vetches, Peas, and Beans. Some of the *Leguminosae*, notably Loco Weed and the Lupines, which are of common occurrence on the prairies, are poisonous to stock. Children have been poisoned by eating parts of the Golden or Prairie Bean. A few members of the group are weeds of secondary importance.

The flowers of most *Leguminosae* that occur in this country are characterized by a conspicuous, irregular corolla. The upper petal, or *standard*, of the corolla is large and expanded. Below the two lateral petals, or *wings*, is a boat-shaped structure, the *keel*, composed of the two lower petals which are coherent by their outer edges. The keel encloses the stamens and pistil. The stamens are usually ten in number, of which nine are often united into a tube, the tenth one being separate. The ovary of the pistil commonly contains a number of ovules. When pressure is applied to the keel, the stamens and pistils spring out of their enclosure, and the flower is said to be "tripped". In some of the *Leguminosae* the flowers produce seed only if tripped; this is usually the work of insects.

Rosaceae (*Rose Family*).—This is a large Family and one of incalculable benefit to mankind, including so many, excellent fruits, e.g. Apple, Plum, Peach, Pear, Quince, Apricot, Cherry, Raspberry, Strawberry, and Saskatoon. Included also are several ornamental plants, e.g. Rose, Spiraea, Mountain Ash, and some weeds, e.g. Agrimony, Cinquefoil, Silverweed. The Prairie Roses that adorn many of our roadsides and meadows are frequently regarded as most troublesome weeds.

The flowers of members of this Family are regular, that is, the petals are practically alike in shape and size. There are usually many stamens inserted on the edge of a disk which lines the calyx tube.

Salicaceae (*Willow Family*).—To the Willow Family belong the Willows and Poplars, which make up a conspicuous part of the vegetation in certain districts of western Canada. Several species of Willow occur in our area, and two species of Poplar are of common occurrence, namely, the Balsam Poplar and the Trembling Aspen. Species that have been widely planted include Russian Poplars and the Cottonwood. The Willows and Poplars have staminate and pistillate flowers which are always borne on different plants. The seeds are furnished with tufts of down which enable them to be carried some distance by the wind.

Umbelliferae (*Carrot Family*).—The flowers of this family are arranged in a circle around the stem like the ribs of an umbrella. Useful plants of the Family are Celery, Parsnip and Carrot. Harmful plants include the Wild Carrot which is a bad weed, and Water Hemlocks, Poison Hemlock and Water Parsnip which are poisonous. The Water Hemlocks are the most dangerous of poisonous plants in western Canada. The poisonous substances are concentrated mainly in the roots and in the swollen base of the stem. Most fatalities among animals occur in the spring when the lower portions of the plant are consumed along with the tender, green shoots.

Compositae (*Thistle Family*).—This is one of the largest Families in the Plant Kingdom, consisting of over 10,000 species, grouped in about 800 genera. Nevertheless, comparatively few species are in cultivation; some of the more important are Garden Lettuce, Jerusalem Artichoke, Salsify (Oyster Plant), Endive, Sunflower, Dahlia, Cosmos, Chrysanthemum, Zinnia, Bachelor's Button, Marguerite, English Daisy, and China Aster. On the other hand, a large number of the *Compositae* may be classed as weeds, although only a few are of the noxious kind. Among the worst of these weeds are Canada Thistle, Perennial Sow-Thistle, Dandelion, Ox-eye Daisy, and Ragweeds, while some of the less important include Burdock, Poverty Weed, Golden Rods, Yarrow, Fleabanes, Blue Lettuce, Chicory, and Annual Sow-Thistle.

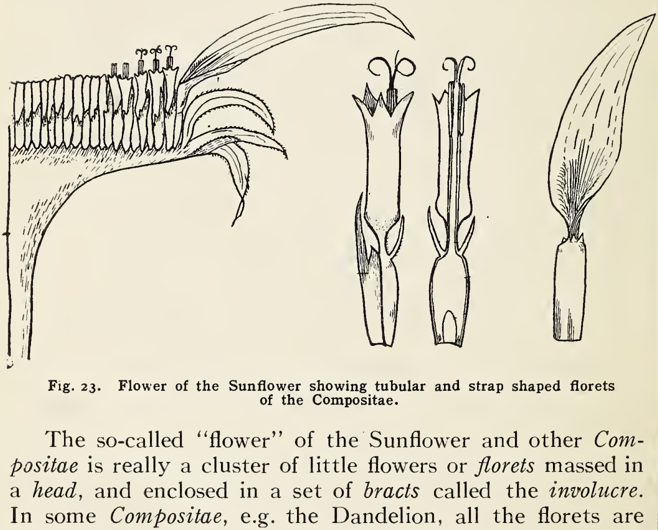


Fig. 23. Flower of the Sunflower showing tubular and strap shaped florets of the Compositae.

The so-called "flower" of the Sunflower and other *Compositae* is really a cluster of little flowers or *florets* massed in a *head*, and enclosed in a set of *bracts* called the *involucre*. In some *Compositae*, e.g. the Dandelion, all the florets are *strap-shaped*. In others, as the Canada Thistle, all the florets are *tubular*. In a third type, e.g. the Sunflower or Aster, the strap-shaped florets form a circle around the margin of the head, while the central part of the head is composed of tubular flowers. This third type has the misleading appearance of one large flower with a border of petals. (Figure 23.)

Chenopodiaceae (*Goosefoot Family*).—To this Family belong such troublesome weeds as Lamb's Quarters, Russian Pigweed and Russian Thistle. Here also are classified Spinach and the Beet; varieties of the latter include the Garden Beet, Mangels, and the very valuable Sugar-Beet.

Solonaceae (*Potato Family*).—Cultivated plants of this Family include the Irish Potato, Tomato, Tobacco, Egg Plant, Peppers and Petunia. A few members of the Family are poisonous; many fatalities have occurred among children who ate the seeds or fruits of the plants. Most of these plants grow in waste places and include Bittersweet, Thorn Apple, Black Henbane, Common Nightshade, and Three-flowered Nightshade.

Exercises.—(1) What are the two classes of seed plants? Distinguish these and give examples. Into what classes are the Flowering Plants divided and what are their typical distinguishing features? Name one family of the Monocotyledons.

(2) Name one of the genera of that Family. Name one species of that genus.

(3) Procure flowers of the following Families, and by means of diagrams illustrate the characteristics of each Family: Mustard, Pea, Thistle.

CHAPTER X

Fungi

Fungi differ from flowering plants in several respects. They contain no chlorophyll. Because they lack chlorophyll, they cannot carry on the process of photosynthesis and are therefore dependent upon some outside source for their supply of food. Fungi which obtain this food directly from the living bodies of plants or animals are called *parasites*, and the plant or animal attacked is called the *host*. Fungi which procure their food from dead bodies or from the products of living bodies are known as *saprophytes*. Among the common fungi are Mushrooms, Molds, Yeasts, Mildews, Rusts, and Smuts.

Mushrooms.—Most fleshy fungi that are good to eat are popularly known as Mushrooms; certain related fungi which are regarded as poisonous or as useless, are known as Toadstools. Botanically, Mushrooms and Toadstools are not dissimilar; for this reason we shall use the term "Mushroom" in the all-inclusive sense. As is well known, some Mushrooms (including not only cultivated varieties but many species that grow wild) are highly prized as articles of food. Many others are edible but, because of their toughness or disagreeable taste, or for some other reason, are not palatable. A few Mushrooms are poisonous. Since poisonous Mushrooms are of common occurrence, it is of the utmost importance that the collector of wild Mushrooms for food should be able to recognize the injurious species. Only by actually knowing the species collected, as one would know a Rose, or a Saskatoon, or Poison Ivy, can accidents be avoided. There is no such thing as a safe "test" by which dangerous and edible kinds can be distinguished. Unless a Mushroom is positively known to be edible, it should be regarded with suspicion as an article of food.

A Mushroom will serve to illustrate some of the characteristics of fungi. This fungus consists of two main parts: (1) the part above ground, the reproductive portion or fruiting body; (2) the part submerged in the soil, the vegetative portion or *mycelium*, popularly known as the spawn. The mycelium consists of a tangled mass of long, delicate threads, which digest and absorb food from the organic matter in the soil. When a supply of food has accumulated in the mycelium and if sufficient moisture is present in the soil, a number of fruiting bodies develop from the mycelium. The parts of a fruiting body are easily recognized by the vertical stalk or *stipe*, and the umbrella-shaped cap or *pileus*, on the under surface of which are numerous radiating plates, the *gills*. On the sides of the gills are formed myriads of minute bodies known as *spores*, which at maturity escape from the fruiting body and are dispersed by air currents. Under favourable conditions, the spores germinate, each growing into a new mycelium.

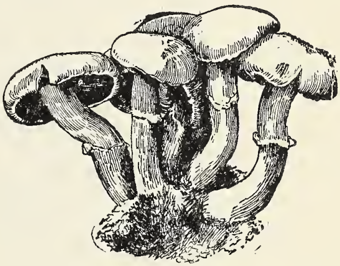


Fig. 24. A Mushroom.

Only brief mention can be made here of the cultivation of Mushrooms. As is well known, Mushrooms are produced under artificial conditions in cellars, hot-houses and other places. The beds upon which the fungi are to be grown must be carefully prepared, and special care taken that the manure used in the beds is properly cured and contains the right amount of moisture. The Mushroom "spawn" which is planted in the beds consists of manure (or a mixture of manure and soil) containing the mycelium of the fungus. The spawn may be obtained from some natural habitat of the Mushroom or from dealers who propagate the mycelium artificially. The manufactured spawn is put on the market in the form of flakes or bricks. The method of planting the spawn varies with different growers, as also does subsequent treatment of the beds. Temperature and moisture are very important factors in the growing of Mushrooms and must be carefully regulated throughout. After the beds have been planted, the manure is covered with a layer of loam soil to a depth of about two inches, which is then smoothed off and tramped down. When the mycelium has developed sufficiently in the beds a crop of Mushrooms appears. Usually a crop comes on well in six to eight weeks after the planting of the spawn. The growing of Mushrooms is an art which is best learned by practising on a small scale and by observing very carefully the conditions required for successful production.

Related to the Mushrooms are other fleshy or rather woody fungi, including Puffballs and the familiar bracket fungi that occur on the sides of trees and stumps. The bracket fungi and some Mushrooms are the cause of various rots of standing and fallen trees. The mycelium of the fungus sometimes extends through a considerable part of the tree, permeating and digesting the tissues until the tree is greatly weakened and rendered of little commercial value. After the mycelium has grown extensively and accumulated a supply of food material it may produce a fruiting body on the side of the tree.

Molds.—If a piece of bread is moistened and kept in a warm, dark place for a few days, one or more molds will likely develop. One of the common bread molds appears as a fluffy white growth which spreads rapidly over the surface of the bread, and later becomes grey or black in colour. Close examination with a lens shows that the flocculent mass is made up of slender branching threads, and that the dark colour is due to black spherical knobs that form at the tips of numerous upright threads. The threads are the mycelium, and the black knobs are the ripe spore-cases.

Another common mold is blue-green in colour, and forms a velvety coating over bread, jam, fruits and other foods. It must be borne in mind that the green colour is due not to chlorophyll but to another pigment. Molds, like most Mushrooms, are saprophytes. They obtain sugar and other foods from the material upon which they grow. If foods are not present in a soluble form, the mycelium may secrete enzymes which will digest insoluble substances like starch and cellulose, and the products of this digestion are then absorbed. In this way molds and other fungi decompose dead bodies of other organisms. Fungi, along with bacteria, are responsible for the various processes included under the general word decay. The part played by these organisms in the general economy of Nature is therefore of the greatest importance.

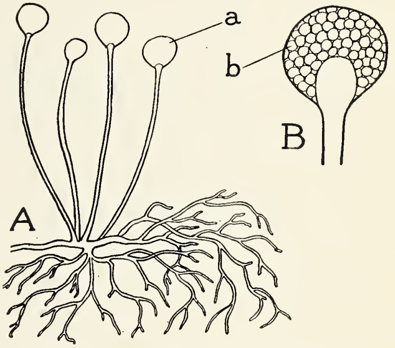


Fig. 25. Bread mold. B is (a) enlarged.

Potato Diseases

Potato Scab. This disease is caused by a fungus which produces scabs on the tubers of the potato. The actual damage done is quite small; it is confined to the production of the unattractive appearance of the tubers which lowers their market value, and to the breaking of the skin which causes them to be more susceptible to rot.

Scabby tubers, when planted, infect the soil so that the disease is readily spread to the new crop.

Damp, heavy soils and those containing a considerable amount of rotted organic matter appear to be conducive to the development of scab. The disease is best controlled by:

(1) Planting in clean soil. As the scab spores winter in the soil, the potato crop should be put on land which produced a crop other than potatoes the previous season. In other words, practise rotation.

(2) Using clean seed. If disease-free seed and clean land are used the possibility of producing a scabby crop is reduced to a minimum.

(3) Seed treatment. This is a safeguard against the disease. Tubers which are apparently free from scab may carry spores on their surfaces. By soaking tubers for two or three hours in a solution of either one pint of formalin or four ounces of corrosive sublimate in thirty gallons of water, the scab spores will be killed. However, the treatment will be useless if the potatoes are planted in diseased soil. The corrosive sublimate and formalin solutions are called *fungicides* because they are used to kill the fungus at some stage in its development.

Rhizoctonia (*Black Scurf*). The fungus which causes this disease attacks the tubers and also the underground portions of the steam. The lower parts of the stem may be so injured that passage of food material to the tubers cannot take place in the normal way, and consequently the tubers are stunted. The disease can be recognized by the presence of reddish-brown or black patches on the surface of the tubers. Like scab, Rhizoctonia may be spread by diseased tubers or by infected soil. The preventive methods used in the control of scab are applicable to Rhizoctonia, except that the formalin treatment is not effective. Treatment with hot formalin has proved beneficial, but this method requires careful management and special equipment.

Late Blight. This fungous disease led to the great Irish famine of 1845-1850. It occasionally attacks potatoes in western Canada. The green parts of the blighted plant wither, and the tubers either do not form at all or rot in the ground. The fungus may be carried over from one year to another in diseased potatoes that are used for seed. Late Blight may be kept under control by spraying the plants with a fungicide consisting of blue-stone (copper sulphate) and lime. Directions for making the fungicide may be found in government bulletins.

Rusts, smuts, and yeasts will be studied in later chapters.

Exercises.—(1) In what respects do fungi differ from Flowering Plants? Explain the meaning of the terms parasite and saprophyte as applied to fungi.

(2) Make a drawing of a Mushroom and label all the parts. Describe the function of each part. What are the steps in the preparation of a Mushroom bed?

(3) Describe the common fungous diseases of the Potato in Alberta and state how each disease may be kept under control.

CHAPTER XI

The Propagation of Plants

A knowledge of how to propagate plants is of great importance to everyone in western Canada because the opportunity of obtaining established plants is more or less limited. Many desirable plants can be started in one's garden as the methods used in propagation are simple, and elaborate equipment is not necessary.

Reproduction among plants occurs as follows:

(a) *By Spores.* Fungi, Ferns, Mosses, and various other plants reproduce themselves by spores.

(b) *By Seed.* This is commonly known as *sexual* reproduction, since seed production is the result of the union of a male cell (from the pollen tube) with a female cell (ovule) in the ovary of the flower. Among Seed Plants, this is the usual method of reproduction.

Seeds of many of our ornamental trees, shrubs, and flowers may be gathered and kept for future planting. Most seeds must be stored to prevent drying out and loss of germinating power. These should be gathered when ripe and stored in suitable containers, such as coin envelopes or glass bottles. Other seeds need to lie in the ground for a year or more to soften and reduce their impervious coats so that moisture for germination may enter, while others require special treatment to effect quick and abundant germination.

(c) *By Vegetative Means.* Vegetative reproduction is said to be *asexual* because there is involved no fusion of sex cells, the new plant being started from some organ, or portion of an organ, of a parent plant. As is explained below, Nature has made ample provision for vegetative reproduction by means of tubers, bulbs, corms, rhizomes, stolons, runners, layers, and suckers. These methods of *natural vegetative propagation* have been extensively used in agriculture and horticulture. In addition, Man has devised other vegetative methods of propagating plants, namely, by division of the root, cuttage, graftage, and layerage. These are described later in this chapter under the heading, *artificial vegetative propagation.*

Natural Vegetative Propagation

Under this heading are considered those methods found in Nature by which plants perpetuate themselves without the use of seed. Some plants propagate vegetatively so readily that seed is not produced in abundance.

Tubers.—A tuber is a modified stem having buds ("eyes") which are capable of producing new plants. The Irish Potato is a good example. Exposed to light and at a suitable temperature, the buds of tubers develop short, stubby, green stems instead of the familiar, long, colourless sprouts that grow in dark cellars. By allowing Potato tubers to sprout in the light before planting, as long as two weeks can be gained in the production of an early crop.

The Irish Potato is ordinarily propagated by planting pieces of tubers; the latter are cut so as to include two or more "eyes" in each piece, and are commonly called "seed potatoes".

True Potato seed occurs in little, globular, fleshy, fruits (Potato "apples") that arise from the flowers of the plant. New varieties of the Potato are obtained by growing this seed, and by making selections among the progeny over a number of years.

Certain plants, e.g. Dahlia and Tuberous Begonia, produce tuber-like roots which differ from tubers, in that they have no buds, but are classed as "tubers" for commercial purposes. The "tubers" are formed at the base of the old flowering stalk. Propagation is effected by placing the clump of "tubers" under favourable growing conditions until buds arise, and by then separating the "tubers" so that each has attached to it a piece of the old stalk and one or more buds.

Bulbs.—As explained in an earlier chapter, a bulb is a bud-like structure, having stem, leaves and flower telescoped together in a compact mass. Bulbs occur among certain plants that have a comparatively short growing season and a long resting stage. While in this resting condition they may be shipped great distances with safety. Bulbs grown in Holland and Belgium are commonly transported to Canada and other countries in the autumn and used for winter blooming.

Fig. 26. Tunicated and scaly bulbs.

There are two general kinds of bulbs, namely, the *tunicated* and the *scaly*. The tunicated bulb, as in the Onion and the Tulip, has the bases of the leaves closely overlapping each other, the whole being covered with a tightly fitting dry skin or *tunic*. The scaly bulb, e.g. Easter Lily, has thick overlapping *scales*.

Many bulbs multiply by producing small bulbs, *bulblets* within them, e.g. Multiplier Onion, while others produce *bulbels* around the base of the old bulb, e.g. Tulip. The Tiger Lily produces black bulblets in the axils of the leaves. Growers of Hyacinths in Holland have learned to increase the number of bulbels by cutting transverse notches on the base of the bulb, and also, by scooping out the base of the bulb until all the scales have been cut. The little bulbels which develop are separated and grown for a number of years until large saleable bulbs are obtained.

The growing of winter flowering bulbs has become popular because of the fact that flowers arise quickly when the bulbs are placed under suitable conditions. When bulbs are planted, they are kept (usually in a cellar) in the dark and at a temperature of about 40° F. until roots are formed. They are then transferred to daylight and to a place of higher temperature. Temperatures of 50 and 60 degrees favour leaf and flower production, respectively.

Corms.—A corm resembles a bulb in general appearance but is solid throughout. New corms usually arise on top of the planted one. Around the base of the new corm, small daughter corms develop. Some of the latter grow large enough to bloom the next year. The smaller ones must be grown for a year or two before they attain blooming size. Corms have to be lifted and stored over the winter. Plants that produce corms include Gladiolus, Cyclamen, Arum, Montbretia and Crocus.

Rhizomes, or Root-Stocks.—Rhizomes are root-like in appearance, but are really underground stems, bearing buds and scale-like leaves. They vary in size from the large ones

Fig. 27. A rhizome.

of Iris, and Canna, and some kinds of Begonia, to the smaller ones of the Couch Grass, Brome Grass, and other similar plants. They root readily and their buds are very tenacious of life. Propagation consists in cutting up the root-stocks and planting the sections in conditions suitable for growth; each section bearing a bud will produce a new plant.

Runners.—A runner is a slender prostrate stem terminated by a node which bears leaves and which is capable of taking root under favourable conditions. When the new plant is thus rooted it may be separated from the parent plant by cutting the runner. Runners are produced by the Strawberry, and by Mother of Thousands, a common house plant.

Fig. 28. Runner of the Strawberry.

Stolons.—The term "stolon" is applied to horizontal stems of two types. These, like the runner, are capable of taking root. They are:

(a) A number of grasses and other plants, e.g. White Clover, send out short horizontal stems that root readily at the nodes. These creeping stems are stolons. Propagation is easily carried out by severing and transplanting the rooted sections of the stolon.

(b) The Black Raspberry is a good example of the second type of stolon. In this plant a stem or cane grows upright at first and then gradually bends over until it touches the ground. If moisture conditions are favourable the tip of this cane then sends out roots and produces a new plant, the stolon. Advantage is taken of this mode of reproduction in the artificial propagation of the Black Raspberry. The ends of canes are pegged down and covered with a little earth to ensure the starting of roots. The tip of a cane thus rooted is sometimes called a *tip layer*.

Layers.—In cases where lower outside branches of certain plants are crowded to the ground by the central growth, roots will appear on these branches at the nodes when moisture conditions are right. A branch rooted in this manner is a natural *layer* and is of common occurrence in the Gooseberry, Dogwood, High Bush Cranberry, Grape, and many other plants. As soon as roots are established the branch may be severed, the new plant continuing growth independently.

Suckers.—Shoots that come up from the base of a plant are called *suckers* or "root sprouts". Many cultivated plants, e.g. Red Raspberry, are propagated by means of suckers. The roots of many trees and shrubs that have been injured through cultivation produce suckers in abundance. The Poplars, the Pin Cherry, Choke Cherry, Silver Willow, Snow Berry, and Flowering Currant are common examples. As suckers are well provided with roots, they are very readily transplanted.

Artificial Vegetative Propagation

Having described the various vegetative methods of propagation found in Nature we may now consider those which Man has devised. Some of these are very old, being mentioned in the earliest records; others are comparatively modern but many are really different methods of applying old principles. The various artificial methods may be grouped under four headings:

Division of the Root.—This method consists in dividing the plant into a number of parts, care being taken to have some roots and one or more buds in each division. Many ornamental shrubs, e.g. Dahlia, Delphinium, Pyrethrum, as well as Currants, Gooseberries and Rhubarb, are commonly propagated in this way. When plants are about four years old, overcrowding may be avoided and better bloom or fruit secured by applying this method.

Cuttage.—The term "cuttage" is employed to include all phases of making and handling cuttings. Cuttage therefore may be described as the process and practice of detaching a portion of a plant and placing it in soil or water to grow into a new plant. The portion separated from the parent plant is called a *cutting*. Cuttage is one of the most important methods of plant propagation employed by Man, because of the ease and rapidity of the method, and because the cutting produces wood, leaves, flowers and fruit exactly like the parent plant. On account of cross fertilization, reproduction by seed does not always give plants true to type. On the other hand, reproduction by cuttings may be depended upon to give plants true to type and, by using this method, the horticulturist has been able to perpetuate many "sports" (variations in leaf, stem or fruit) that have appeared. For convenience, cuttage is discussed under five headings:

(a) *Root-Cuttings*. As has been already explained, when a rhizome is cut into several pieces, a new plant can grow from each portion if it contains a bud. When a rhizome is lifted and cut into such portions for purposes of propagation, these divisions are known as "root-cuttings". True root-cuttings are used in the propagation of certain plants. For example, in the case of the Horse-Radish, the lateral roots are cut away from the main root and are used to produce new plants.

(b) *Tuber-Cuttings*. When a tuber is cut into several pieces for planting, these may be called tuber-cuttings. In Potato cuttings, two or more "eyes" are usually included in a piece. Tuber-like roots, also, are propagated by cuttings, as in the case of the Dahlia.

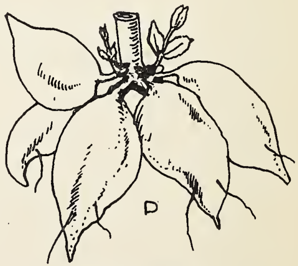


Fig. 29. Tuber.

(c) *Herbaceous or Softwood Cuttings.* These are popularly known as "slips" and are made in very large numbers every year. Nearly all common decorative plants are propagated, as a rule, by this method which is indeed a very simple one. A cutting is made from young, green, brittle wood; the best wood is from two to four inches below the tip of the shoot. It should have two or more nodes and should be cut just below

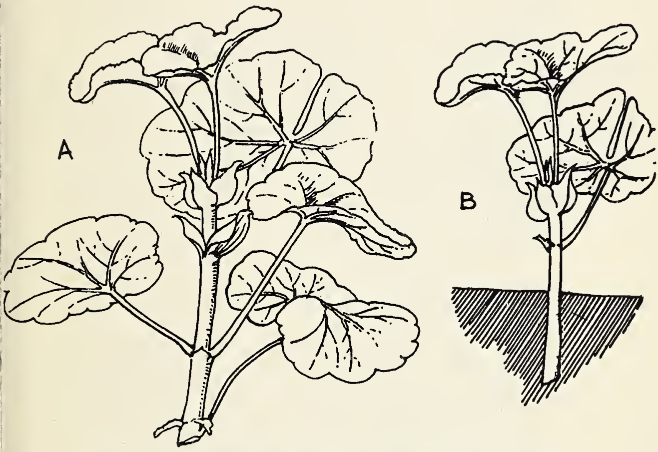


Fig. 30. (A) Herbaceous cutting. (B) Same cutting trimmed.

or through a node, because roots often develop better from the node. The knife used in making cuttings should be clean and sharp. In order that loss of water due to transpiration may be minimized, it is a good practice to remove the lower leaves, leaving from three to five at the top of the cutting.

(d) *Leaf-Cuttings.* Propagation by leaf-cuttings is limited to those plants with very thick, fleshy leaves like some of the Begonias. When a leaf-cutting is to be made, a leaf that is fully matured and in full vigour is chosen. The whole, or only a portion of it, may be used. When the whole leaf is used, the larger mid-ribs are partially cut through in several places on the under side. The leaf is then placed with this side in contact with moist sand and pegged down by means of wire staples placed over the ribs near the cut places. Sometimes a

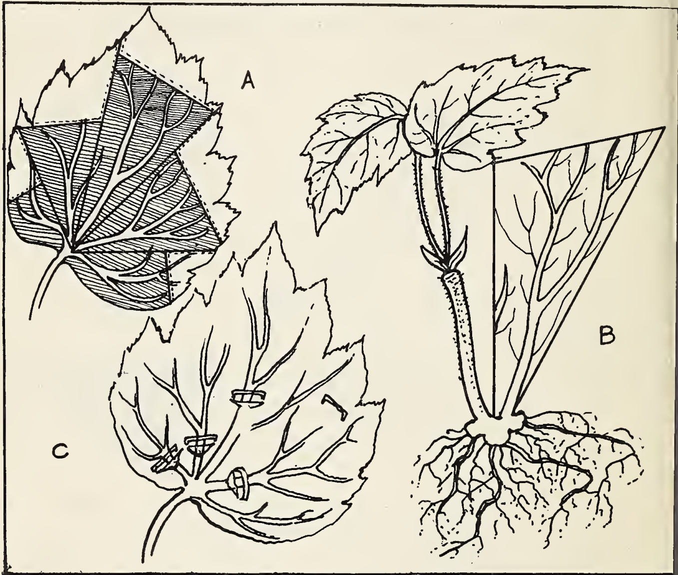


Fig. 31. (A) Leaf cutting; (B) cutting rooted; (C) leaf cut and pegged to moist sand.

leaf is cut into several triangular pieces each having a portion of heavy rib. These are set upright in the striking bench and soon root. (Figure 31, B.) Before roots are formed by a cutting, a spongy tissue, known as a "*callus*" usually grows over the cut surface, thus healing the wound. Conditions that stimulate the growth of this roll of new, covering tissue bring about the development of roots. When the roots of the cuttings are one-quarter to one-half inch in length, the cuttings should be transplanted to pots containing soil. A good potting soil for most plants consists of three parts of rotted sod, two parts of rotted manure and one part of sharp coarse sand. These materials should be thoroughly mixed and then passed through a half-inch sieve. In order that the roots of a cutting may be confined to a ball-shaped mass, the pot used should be a small one. When the roots fill this pot, the plant should be transferred to a larger pot, and additional soil added.

(e) *Deciduous or Hardwood Cuttings.* These cuttings are made of the ripened wood after growth has ceased, the leaves have fallen, and the buds for next year's leaves formed on the stem. The cuttings may be taken any time before the buds swell in the spring, but best results are obtained if they are made in the autumn just before severe frosts occur.

Fig. 32. Deciduous cutting.

The best cutting is made from the growth of the previous summer. The cutting should be six to eight inches in length and must have at least two buds, one at the bottom and one at the top. The lower cut is usually made about one-quarter of an inch below a bud and the upper cut about half an inch above a bud. If the stem is hollow or pithy, each cut should be made through a node.

The cuttings are tied into neat, orderly bundles of 25 to 100, with the butts together. They are then placed in boxes of moist sand, soil, sawdust or moss in a cool cellar and kept there until planting time in the spring. Care should be taken that they do not dry out during the winter. Another way to store the cuttings is to bury them upside down with at least six inches of well-drained soil covering the butts. When hard freezing weather comes a mulch of manure may be put over them.

By spring, the callus will have formed and roots may have started. When the soil is dry and sufficiently warm for growth, the cuttings are planted in rows, six to eight inches apart. They are set with one bud just at the surface of the ground. The soil must be tramped firmly around them so they will not dry out. In the following spring, they may be set out in their permanent places, or they may be placed farther apart in a new nursery row, to grow until large enough for permanent placing.

Many trees and most of our ornamental shrubs are propagated by means of hardwood cuttings. Willows and Poplars may be grown very readily in this way. Certain Ornamental shrubs and trees, usually propagated by hardwood cuttings, can also be grown from softwood cuttings taken from the tips of shoots and started on the bench in the green-house, although special treatment is required.

Fig. 33. Deciduous cutting set out.

Graftage.—Graftage is a term used to cover two very similar processes, namely, grafting and budding. Graftage may be defined as the process and practice of propagating plants by the insertion of a portion of one plant into the growing wood of another. The essential difference from cuttage is that the portion cut off, instead of being placed in soil or water, is fixed into another plant to grow. Under the latter circumstance, the two portions knit together into a perfect union, but each retains its own individuality of bark, wood, leaf, flower and fruit, though fed by the same food. This is the important feature of graftage.

So important is graftage that, if the art were lost to horticulturists, commercial fruit growing would practically cease with the orchard now standing. All named varieties of Apples, Pears, Peaches, Cherries, Plums, Quinces, Apricots, Lemons, Limes and Oranges are multiplied by either budding or grafting. When a new variety has been obtained there is no need to fix the type in order that it will come true from seed. By means of grafting for the pomiferous fruits and budding for the stone and citrus fruits, the new variety can be rapidly multiplied true to type.

In graftage, the part taken from a plant is called a *scion*. For budding, the scion consists of a single bud, and for grafting it consists of a short twig with two or more buds. The plant into which the scion is inserted is called the *stock* and is usually rooted. The stock may be (1) a small herbaceous plant, (2) a seedling tree or shrub, (3) a mature tree or shrub, or (4) a root, or a piece of a root.

The united scion and stock constitutes the *graft*. The first step in fusion is the formation of a callus over the cut surfaces in the graft. As the callus consists of growing cells, stock and scion are soon firmly united and interchange of food substances then commences.

(a) *Limitations of Graftage*. Many people have erroneous ideas about the possibilities of grafting. Contrary to popular opinion, it is impossible to graft distantly related plants, as for example, Apple on Poplar, Rose on Oak, or Pear on Plum. A successful union can be made only when there is a close affinity between stock and scion, that is, when they are closely related botanically. In general, varieties of the same species unite readily, while species of the same genus unite fairly well. Members of genera, e.g. Pear and Quince, in the same Family may be grafted in some cases, but members of different Families cannot be successfully grafted. The acid test of a union is that it will grow after the first winter. Grafting is further limited to those plants having a distinct bark and under wood, Dicotyledons. Monocotyledonous plants have never been grafted for commercial purposes, as their parts are not adapted for close union.

(b) *Uses of Graftage*. (1) To perpetuate a variety (new or old) or a new variation of any part of a plant.

(2) To increase the ease and rapidity of multiplication.

(3) To determine speedily the value of a new fruit. As an example, we will take the procedure followed in breeding

new varieties of Apple. Seed obtained from crosses between the selected parents is planted and, in the first summer, produces young trees, a foot or more in height. These trees, under ordinary circumstances, would not bear fruit for about four years. Experience has shown that only one in about ten thousand seedlings is better than existing varieties. Since so many seedlings must be grown, it is important to discover the promising ones as soon as possible. To shorten the time required to determine the value of a seedling, wood of the first year's growth is grafted on a bearing tree in the following spring, and fruit is produced the next year. If of value, the seedling is rapidly multiplied by both budding and grafting. Otherwise, it may be discarded and the space used for other trees. Luther Burbank is reported to have had several hundred new varieties grafted on a single tree for testing.

(4) To produce some radical change in the nature or habit of the stock or scion. A large, rapidly-growing variety grafted on a dwarf or slow-growing stock will be dwarfed. The common Lilac has an objectionable habit of throwing up a lot of suckers; by grafting this variety on a stock of a variety that does not send up suckers, the trouble is avoided.

(5) To adapt plants to adverse soils. The Plum likes a heavy soil and the Peach a light, sandy soil. By grafting, these plants can be made to thrive in otherwise unfavourable situations.

(6) To repair injury caused by animals or other agents.

(c) *Important Points in Graftage.* (1) Make the cambium layers of the cut surfaces abut, in whole or in part.

(2) Tie or fasten the scion in position so it will not move.

(3) Cover the junction with grafting wax to exclude air and rain, and to check evaporation from the cut surfaces, thus preventing drying out of the scion. A good grafting wax may be made from four parts of resin, two parts of beeswax, and one part of beef tallow.

(4) Use clean, sharp tools, in order that clean cuts may be made and bruising of the wood avoided.

(d) *Kinds of Grafts.* There are many ways of making grafts. We shall consider only two common methods. The *whip* or *tongue graft* is the most important of all grafts, and is the one employed in grafting Apples, Pears and Quinces. The stock and scion should be of the same diameter when this method is employed. The top of the stock is removed with a smooth slanting cut. The scion is then cut in a similar fashion. The stock is then cleft downwards at a point in the cut surface about a third of the distance from the lower end. A similar cut is made upward from the cut surface of the scion. The two are now fitted together, the tongue of the scion being forced into the cleft of the stock. The cut surfaces should come together in such a way that the cambiums of scion and stock are in contact, at least on one side. The graft is then tied with five or six rounds of raffia or waxed string, and may be waxed as well; in outdoor work the join should always be waxed.

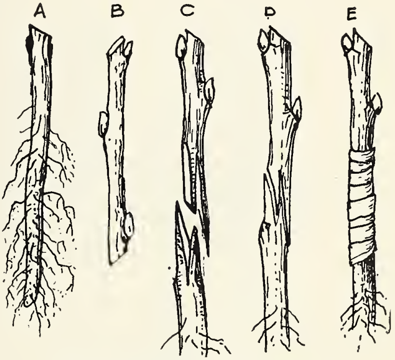


Fig 34. The whip or tongue graft.

Another important graft is the *cleft graft.* This is used in altering the tops of established trees, in order to change the variety of fruit produced. It is employed on limbs up to two inches in diameter. The cut end of a limb is split with a chisel to a depth of one and a half to two inches, and a wedge is inserted in the cleft. A special "grafting tool" which consists of a chisel and wedge combined, is commonly used for this operation. A scion about four inches in length and with two or three buds is prepared. The lower end of the scion should be wedge-shaped, and should have a bud just above the top of the slanting cut. The scion is inserted in

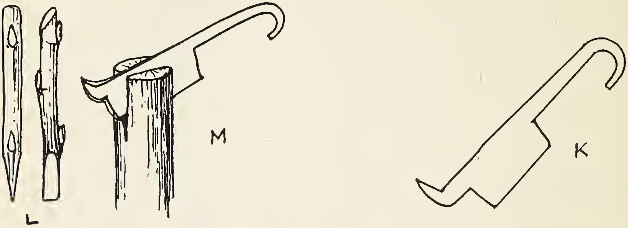


Fig. 35. The cleft graft—Preparation.

the side of the cleft of the stock in such a way that the cambium layers are in contact. A second scion may be inserted on the other side of the cleft. To be certain that the cambium

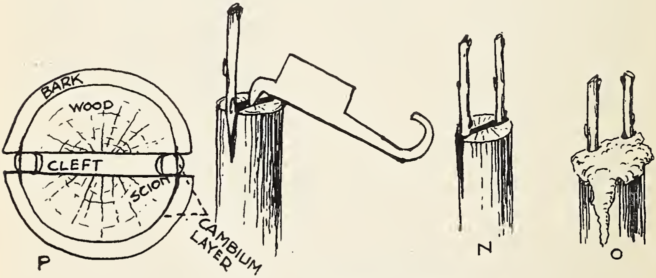


Fig. 36. The cleft graft—Completion.

layers are in contact at least at one point, the scions are sometimes set at a slight slant. (Figures 35 and 36.) When the wedge is withdrawn, the whole graft is covered with a good coating of wax. Not more than a third of a tree should be thus grafted in any one year, and the beginning should be made in the upper central p irt.

Budding. Peaches, Plums, and other stone fruits respond more readily to *budding* or "*bud-grafting*" than to the two methods described in the previous paragraphs. It differs from the other forms of grafting in that the stock, instead of

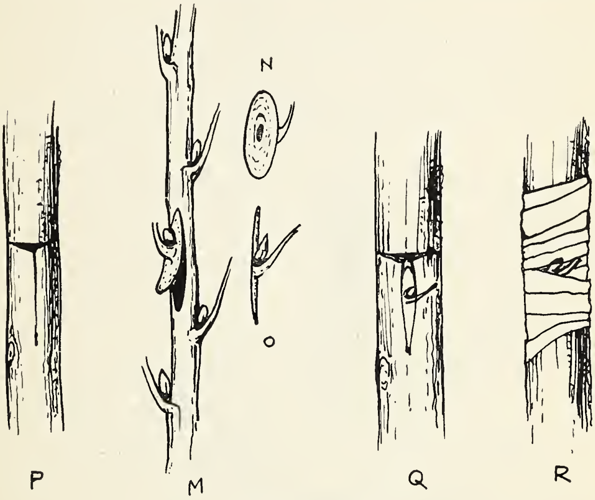


Fig. 37. Budding.

being dormant, is in a growing condition, and the scion is a single bud. The best time for budding is in the late summer or early autumn as the union of bud with the stock takes place rapidly at that season. In cutting out the bud, the stalk of the leaf which arises from just below the bud is usually left as a handle by which to hold the bud. The stock is usually a seedling plant, and the bud is inserted in the stock not more than two inches from the ground in order that it may be buried when the tree is placed in its permanent position. This is done because budding is bound to leave a more or less pronounced crook. A T-cut is made through the bark on the north side of the tree, and the bark carefully lifted with a knife. The bud is then inserted, and tied in place, care being taken to see that the cambium layers of scion and stock are in contact. If at the end of two weeks the bud has shrivelled, the "operation" has been unsuccessful. When growth starts in the bud in the spring, the stock is cut off about three inches above the bud.

Layerage.—Layerage is a method of obtaining new plants by covering shoots or limbs with soil, while still attached to the parent plant. When roots have formed, and the young plants can sustain themselves, the shoots are separated from the parent plant. Gooseberries, Grapes and Roses are often propagated by layerage.

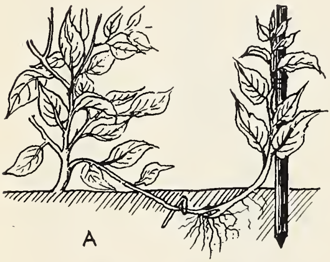


Fig. 38. Layerage.

Exercises.—(1) Classify the natural modes of reproduction among plants. Give your answer in the form of a schedule and mention one outstanding example of a plant reproduced in each way.

(2) What distinguishes seed-bearing plants from spore-bearing plants? To which class do each of the following plants belong: Horsetail, Cherry, Wheat, Corn, Mushroom, Cabbage, Sunflower, Fern?

(3) Distinguish seeds from spores.

(4) Using detailed, labelled diagrams describe each of the following: tuber, bulb, corm, root-stock, runner, stolon, layer, sucker.

(5) Name native trees and shrubs which may be grown from seed.

(6) Sweet William seed matures and ripens well in Alberta. The colours are white, pink, light and deep red, and variegated. What plan should be followed in the growing of this plant to ensure the seed coming true to colour? Give other examples of a similar nature.

(7) What are the "eyes" of potatoes? Describe the true "seed" of potatoes. How may early potatoes be secured? How are new varieties of potatoes obtained? Why is this not generally done?

(8) Sprout potato tubers in moist chambers in the classroom. Compare the sprouts obtained when light is admitted to the chambers with those that grow in dark chambers.

(9) Give some examples of flower and vegetable bulbs. Describe the structure of a bulb, and show that the bulb is a convenient means of obtaining new plants.

(10) Tulips, Hyacinths, Narcissus and Crocus are purchased for winter blooming in the house. How should these be planted and cared for to get successful bloom? Are these the conditions in Nature under which they bloom?

(11) Distinguish corms from bulbs. Give examples of corms.

(12) What are runners, stolons, suckers, layers? By which of these are the following propagated: Strawberry, Raspberry, Wandering Jew, Virginia Creeper, Fern, Poplar, Gooseberry, Flowering Currant?

(13) What are the various methods of artificial vegetative propagation? Give your answer in the form of a schedule and include a definition, labelled diagram, and an example of each method.

(14) What care must be taken with the cuttings of roots of Pyrethrum, Delphinium, Gypsophila, etc., for transplanting?

(15) What is cuttage? What is a cutting? Why is cuttage one of the most important methods of plant propagation? Show the particular value of cuttings in the case of rare varieties of plants. What are the four kinds of cuttings?

(16) Describe how to propagate Geraniums by slips. How may this be done in the case of Begonias? Propagate these plants from cuttings in the laboratory.

(17) When and how should hardwood cuttings be made? What care should be used in over-wintering and planting hardwood cuttings? What are the kinds of softwood and hardwood cuttings? Give examples of plants propagated by hardwood cuttings.

(18) Define graftage. What is the essential difference between graftage and cuttage? How important is graftage as a method of plant propagation? Define the terms: scion, stock, graft. Within what limits is graftage a success? What are the uses of graftage? What are the essential points for successful work in graftage? Name and describe with the aid of diagrams the different kinds of grafts.

(19) How does bud grafting differ from the other forms? What are the requirements of successful bud-grafting? Describe fully the method of budding.

(20) How are plants propagated by layerage?

(21) Why is it not best to grow Apples from seed for purposes of bearing fruit? What use is made of seedling fruit trees?

CHAPTER XII

The Plant and Its Environment

The Plant as a Machine.—In the preceding chapters we have been concerned with the form and structure, *Morphology*, of the plant, and with the functions and behaviour, *Physiology*, of its various organs and tissues. Regarding the plant as a machine, we have learned something of the construction and working of its parts, and have gained an insight into the energy changes that take place during the doing of work. Like other machines the plant obtains energy for doing work from fuel, but unlike all other machines the plant (at least the *green* plant) is able to make its own fuel.

Most of us admire the elaborate construction and smooth performance of a high-class automobile engine or modern locomotive and still more profoundly are we impressed by the delicacy of balance and intricacy of machines that do our most precise work. But much more intricate and nicely balanced than any machine invented by Man is the plant—a machine indeed about which we know comparatively little, partly because we have not been sufficiently attracted to a serious study of it and partly because of its complexity of construction and behaviour.

Now, many machines are markedly affected by the conditions under which they are operated. A gasoline-engine, for example, works most smoothly and effectively within a certain range of temperature and with a certain mixture of air and gasoline. The plant is also affected by surrounding conditions, but infinitely more so than any ordinary machine. Highly complex in general organization and delicately balanced in its various parts, the plant is played upon by a variety of external factors, among which are temperature, light, humidity of the air and conditions of the soil. The sum total of factors which affect the life of the plant constitutes the environment or the *habitat* of the plant. The study of plants in their habitats, including the way in which they react to their surroundings, is a branch of Botany known as *Ecology*.

As is well known, plants differ in their requirements and in their responses. Thus, under a certain set of conditions, one species thrives while another develops poorly or succumbs. For example, temperatures at which Turnips grow well would be very detrimental to Pineapples and *vice versa*. Again, climatic and soil conditions that favour the production of Oats are not best for the development of Corn and *vice versa*.

Environmental Factors.—Let us consider more fully the conditions under which the plant lives. The various environmental factors that affect the plant or group of plants may be classified as follows—*climatic*, *soil*, *physiographic*, and *biotic*.

(a) *Climatic Factors*. These factors include rainfall, humidity, temperature, wind, snow, light, length of frostless season, and the like. Several of these factors have a direct effect upon the rate at which water is lost by the aerial portions of the plant and thus affect the plants in a very vital way.

Of these various climatic factors, rainfall is one of the most important. In this connection, it is necessary to consider not merely the amount of precipitation in a year but also its distribution throughout the growing season. For example, heavy rains in June and early July are of immense value to the growing Wheat plant. If these rains do not come until late in August, not only do they fail to benefit the crop but often they cause considerable damage. The form in which precipitation occurs is also of importance. For example, a certain amount of moisture precipitated in the form of rain in early June is regarded as a boon, but if it comes in the form of hail serious damage to crops results.

The influence of temperature on the development of plants is well known but here again must be considered not merely the average temperature throughout the year of a region, but also its distribution. The average temperature for the month of August may be the same in two years. Yet in one year there may be a killing frost which does great damage to grain crops, while during the same month in the second year, the temperature may not drop to the freezing point. The extent of the frost free period (which, during a period of thirteen years has averaged 125 days in the Medicine Hat district, and but eighty days in the Peace River district) is a determining factor in the growing of certain crops. Several varieties of Corn which thrive in the southern part of the province do not mature in the Peace River district because of the shortness of the growing season.

(b) *Soil Factors.* The soil in which the roots of a plant do their work is a small world in itself, with a physical structure, a chemical composition, an atmosphere, and a host of minute plants and animals. These soil factors interact in a complex fashion and produce a profound effect upon the plant.

(c) *Physiographic Factors.* Included here are such factors as slope of the ground, altitude, erosion by water, blowing of sand and the like. The topography of a district and the character of the surface soil is often greatly altered by erosion and blowing, especially when the soil is not firmly bound by vegetation. The importance of preserving the natural cover of vegetation, especially on land that is not suitable for continuous cropping with cultivated plants, cannot be overemphasized. Soil that has been badly wind-blown and eroded is so deficient in moisture and in nutrient mineral substances that only certain weeds can subsist thereon.

(d) *Biotic Factors.* These factors are the direct result of the activities of plants, animals and Man. Among organisms which are active in this respect are earthworms and other animals in the soil, parasitic insects, mice, rabbits, gophers, grazing animals, birds, parasitic and saprophytic fungi, and soil bacteria. Flowering plants themselves are biotic factors because they alter the surrounding soil and affect one another in various ways. Like individuals in a human community, they are closely inter-related in their activities and are greatly affected by the fate of their fellows.

It will be readily seen that many of the factors placed in the different groups of the above classification are interrelated. Obviously climatic factors affect the biotic and soil factors; climatic and physiographic factors influence one another; also biotic and soil factors act upon one another. Thus, although we may find it convenient to classify these various environmental factors, we must realize that they are intimately related, and that the habitat is the result of their very complex interactions.

Competition Among Plants.—Let us suppose that plants are allowed to grow and reproduce without the supervision of Man, that is, to fight their own battles. For example, let us consider a field planted with Potatoes: we shall suppose that the ground has been properly cultivated but that it receives no further attention following the planting of the tubers. Potato plants will presently appear as also will numerous weeds. The former will not thrive very well whereas many of the latter will grow splendidly. By autumn the Potatoes and some of the weeds will have produced numerous underground stems. Also, most of the weeds will have produced thousands of seeds. During the winter, all of the Potato tubers will be killed, while the underground stems, roots and seeds of many of the other plants will withstand the low temperatures. In the following summer, therefore, the field will have a thick covering of plants, but among them there will be no Potatoes.

This may be considered an extreme case of the rapidity with which a cultivated plant is eliminated when thrown upon its own resources. But most of our familiar cultivated plants fare little better under like circumstances. Timothy and certain other introduced grasses as well as some of the Clovers do much better. They may persist for a few seasons but in most cases are gradually replaced by other plants.

It is apparent, therefore, that species differ in their ability to perpetuate themselves and to survive in competition with other plants. Many varieties that have been in cultivation for a long time are unable to persist without the aid of Man;

they have been so pampered that they are unable to withstand the buffeting of Nature. But apart from cultivated varieties, varying degrees of success are exhibited in the struggle that is constantly going on in Nature. There are those that are able to hold their own only under a very narrow range of environmental conditions; while some species are successful competitors in a variety of habitats.

In a particular habitat a certain species may be so successful that it becomes *dominant*, that is the most abundant present. Indeed, it may dominate so completely that all other species are excluded. Usually, however, a number of species occur in a habitat, one or more being quite abundant, others of frequent occurrence and still others scattered or rare.

Equilibrium in Vegetation.—In a habitat that has been fairly uniform in character for a considerable length of time, the vegetation becomes comparatively constant in the number and proportion of its species. When this state of equilibrium has been reached, species best suited to the habitat are dominant and cover most of the ground. Thus there arises a *plant community* or plant society which is fairly constant in its composition and which has, as a whole, a certain individuality.

Plant communities are of common occurrence in Nature and are of different kinds, each being the product of prevailing environmental conditions. A community on a large scale is illustrated by the *prairie* of western Canada. Within a large community smaller ones may exist. For example, in the prairie there occur *slough* communities and *river-bank* communities, each with a vegetation markedly different from the prairie type.

Now, we may well ask what happens when the equilibrium of a plant community is disturbed. This may occur suddenly, perhaps due to burning, volcanic action, the sudden change of a river course, or interference on the part of Man; or it may occur more slowly, due, for example, to slow climatic changes, and to certain of Man's activities.

Fig. 39. A Plant community. At least five distinct plant associations can be seen.

Let us consider the effect of drainage upon the rush-sedge-grass-community surrounding a prairie slough. If the water-level of the slough is lowered very slowly—only a few inches per year—the bordering plant community will *migrate* (mainly by the growth of rhizomes) inwards and will be succeeded by the plants of the adjoining prairie community. But if the slough is drained more quickly, the equilibrium of the bordering community may be considerably disturbed. Certain of the species may be unable to migrate inwards as rapidly as others, in fact some of them may finally succumb, owing to shortage of water, and thus the composition of the community may be gradually altered. Again, if drainage of the slough is quite rapid and thorough, the rush-sedge-grass-community will shortly disappear and its place will be taken by certain weed-like plants that scatter an abundance of seed. Plants which thus invade new areas are spoken of as *pioneers*. Rarely, however, are these pioneers permanent settlers. They will be gradually eliminated in the struggle for existence by other plants that come in more slowly but which are better equipped for successful competition under prevailing conditions. Presently the area under consideration will be invaded by the various plants of the adjoining prairie and eventually it will probably become part of the larger prairie community.

Some Ecological Problems.—In the practice of agriculture and forestry we have completely destroyed much of our native vegetation and have greatly disturbed the equilibria of many natural plant communities. The conditions thus created are in the main, suitable for the production of certain agricultural crops, each of which, by the way, presents its own ecological problems. In many instances, unfortunately, the conditions which arise favour neither a permanent agriculture nor the immediate return of the natural vegetation. For example, if we cut down or burn all the trees that cover a sand-hill district, the wind will beat upon the hills, the sand will be loosened, shifted and blown about, and the district will yield neither agricultural crops, nor, for many years, another crop of trees. On the other hand, if such a forest is properly utilized, and a certain percentage of the mature trees removed periodically, the area will certainly remain permanently productive.

Indeed, at almost every turn in the utilization of plants we encounter, or introduce, an ecological problem. If we would grow Wheat in the extreme northern part of Alberta we must develop a variety that will mature quickly. In solving this problem we may learn much from native plants that are hardy. In order to produce Tomatoes under glass we must supply the right conditions for their development. If we would increase the production of Alfalfa seed under irrigation, we must learn more about the effect of various conditions upon pollination, fertilization, and the development of the seed.

Drainage of lakes and muskegs will surely have far-reaching effects upon the surrounding vegetation and even upon the climate, and we can only guess, at present, what some of these may be. Great stretches of semi-barren country await reclamation; can we assist Nature in the process of stabilizing these areas and carpeting them with a permanent vegetation similar to the original covering? We should avoid the over-grazing of our ranges lest the more desirable plants be killed out and succeeded by inferior ones. By what signs may we detect over-grazing in its early stages? This is an ecological problem indeed.

How may we solve these and similar problems? We can discover much of value by experimenting with plants, by studying their behaviour under known conditions, and the like. We can learn much also from Nature's experiments which are everywhere about us. These experiments, if properly interpreted will tell us how to co-operate with Nature in securing results which we desire. If, for example, we wish to ascertain the agricultural possibilities of a new district, let us discover what Nature has been able to produce upon the land. The natural vegetation is an index of all the environmental factors and serves as an indication of the possibilities of producing other plants in the district. In other words, the natural vegetation of a region is an excellent meteorlogical instrument—in fact the best that we have, because it gives us a composite reading of the meteorological conditions that have existed there over a period.

It should be added, however, that this instrument is exceedingly difficult to read correctly.

Exercises.—(1) Define habitat and ecology.

(2) Discuss some of the ecological factors that affect plants. To what extent are these factors inter-related?

(3) What are some of the characteristics that enable some of our noxious weeds to persist? Refer to earlier exercises dealing with roots, stems and seed dispersal.

(4) What is a plant community? Describe an example to be found near your school or home. What factors may disturb the equilibrium of a plant community? When is a plant spoken of as a pioneer? What is meant by the dominant species of a community?

(5) What environmental factors affect: (a) A Wheat plant on the prairie. (b) A potted Fern in a living room. (c) A Spruce tree at a high altitude on the mountain side? In each case, what factors are most likely to limit the growth and normal development of the plant?

CHAPTER XIII

The Improvement of Cultivated Plants

For many centuries, it has been the aim of the agriculturist to increase the yield and to improve the quality of cultivated plants, because by so doing he is enabled to obtain more profitable returns on the basis of the cost of production. Varieties of the same species often differ widely in the quality and quantity of crop which they yield. For example, varieties of Sugar Beet differ in the amount of sugar that they contain. Within comparatively recent years, scientists have developed strains of beet in which the sugar content has been increased from about 12 per cent. to as high as 18 per cent. It is a well known fact that differences in productivity exist among varieties of Wheat. The development of a new variety of Spring Wheat namely, Marquis, by Dr. C. E. Saunders, resulted in a very great increase in the yield and value of Canadian Wheat crops.

The Origin of Cultivated Plants.—We are here confronted with the question of where and when Man obtained his cultivated plants. The places and time of origin of many of our cultivated plants have been determined by careful studies of plant distribution, ancient inscriptions, historical records and archaeological findings. It has been estimated that the cultivation of plants commenced over ten thousand years ago, probably in Mesopotamia and Egypt. At any rate it is certain that at least some of our cultivated plants have been nurtured by Man for several thousands of years.

Most of our cultivated plants differ markedly from their wild progenitors. For example, the Carrot of our garden has been derived from the Wild Carrot which is a troublesome weed with a stringy root. Our luscious Peaches are strikingly different from the small, hard, bitter, Wild Peach of China.

Indeed, some of the plants which Man has nurtured for hundreds of years have changed so completely that their wild originals, if still in existence, are unrecognizable. This is true of Barley, Corn (Maize), the Onion, and many others.

Also, certain familiar garden plants have come from a common ancestral form. For example, the cultivated Cabbage, Cauliflower, Collards, Kohlrabi, Kale, and Brussels Sprouts have been derived from the Wild Cabbage, which is a common seashore plant in western and southern Europe. It is thought, too, that our various beets—the Garden Beet, Swiss Chard, Mangel, and the Sugar Beet have a common ancestor in the tough and slender-rooted Sea Beet of the Mediterranean.

Brief mention may be made of the origin of other familiar cultivated plants. The Irish Potato originated in temperate South America and still grows wild in the mountain valleys of Chili. The ancestor of Wheat has been found in Palestine. Our cultivated Oats have been evolved from the common Wild Oat of Asia Minor. In addition to Wheat and Oats, many other important varieties originated in Asia Minor or in districts adjoining the Mediterranean Sea.

Heredity and Variations.—Having learned something of when and where our cultivated plants originated, we pass to consider the very difficult question of how they originated. But, before doing so, we must pause to consider certain principles or laws of Nature that are fundamental to the alterations that have taken place among cultivated plants. Obviously the production of a new variety depends upon deviation from the ancestral form. Deviations from a given standard or type are known as *variations*. It is a fact that off. spring differ (or *vary*) more or less from their parents- Although it is a general law of heredity that organisms tend to produce progeny like themselves, careful observation shows that in a multitude of individuals no two are exactly similar, and that there are some which vary quite perceptibly in one way or another from the majority.

Since the fact of variation is manifest, the real problem becomes one of accounting for these variations and of determining the manner in which they are transmitted from one generation to another. In other words, to account definitely for the origin of cultivated plants is to explain the origin and manner of inheritance of variations. The manner in which variations are inherited, may seem at first to present no difficulty; but when it is discovered that, while some variations are inherited, others do not seem to be transmitted to succeeding generations, it is evident that we are confronted with a very difficult problem.

Investigations of recent years have shown that variations arise in a number of ways. There are those variations which are traceable to the effects of the environment, such as the differences between plants of the same variety when grown in sunny and shady situations. Although there is no entirely satisfactory evidence that modifications of the body of an individual acquired in this way are transmitted to the next generation, it may well be that certain variations of this type are inherited. Also, there occur small individual variations which cannot be referred to the environment, although the environment may be the ultimate cause—variations which are inherited and which, moreover, tend to be continuous, that is, to occur in the same direction through a number of generations. Then, there are variations which seem to arise suddenly and sporadically, that is, without any previous noticeable change in that direction, and not necessarily followed by further modification in the same direction. These variations are frequently quite marked and obvious, and in these cases are known as *mutations* or "*sports*". Examples are double flowers, dwarf varieties and cut-leaf forms of various familiar horticultural plants. It is quite certain that many cultivated plants have arisen as variations of this kind—variations that have been preserved by Man when they would have perished perhaps under natural conditions. In addition to the true or seed mutation, there is the *vegetative* or "*bud*" *mutation*—a variation which occurs on a branch of a plant, and which may be propagated vegetatively by cuttings but rarely comes true to seed. A well known bud variant is the Navel Orange, which originated probably in Brazil, as a branch of an ordinary Orange tree.

Hybridization.—It will be gathered, then, that we really know very little about the fundamental causes that underlie the appearance of variations. But we do know that variations arise at times and that some of them are inherited. Given these heritable differences among the individuals of a species, it is comparatively easy to understand how new varieties may appear within the species. As a result of *hybridization*, that is, mating or crossing, progeny arise which show various combinations of the parental characteristics. Now, if in subsequent generations, certain crosses occur, there may arise *hybrids* which are decidedly different from the original parents, and which may be regarded as new varieties. Undoubtedly hybridization has been a very important factor in the derivation of cultivated plants.

A splendid example of the value of hybridization in the derivation of new varieties of plants is the famous Marquis Wheat. The early settlers in western Canada grew a variety of Wheat called Red Fife. This Wheat produced a strong, creamy-white flour, and brought the highest price in the world markets. Unfortunately it took so long to mature that in many years it was caught by frost. Dr. Wm. Saunders, Director of Dominion Experimental Farms, procured from the Himalaya Mountains in India an early ripening Wheat known as Hard Calcutta. This Wheat lacked the good milling qualities of Red Fife. Samples of Red Fife and Hard Calcutta Wheat were sent to a number of farms in the West for cross breeding. The cross from which Marquis Wheat was later developed was made on the Experimental Farm at Agassiz in British Columbia. In making this cross Red Fife was used as the male parent and Hard Calcutta the female parent. The seed obtained from this cross was sent to the Central Experimental Farm at Ottawa along with samples of other crosses between the same parents. At Ottawa the hybrid

Wheats were grown in trial plots for a number of years. Each year seed from the best plants was selected and used for further tests. Dr. Charles Saunders took charge of the critical work of making the selections and in 1906, gave Marquis Wheat to western Canada.

Artificial Selection—The work of Dr. Saunders with the offspring of the Red Fife and Hard Calcutta Wheats on the trial plots at Ottawa illustrates a second important method of crop improvement, namely, *artificial selection.* The term "artificial" is used to distinguish this method from that employed by Nature. Only the strong, vigorous plants survive in Nature, and give rise to new plants. This may be called *natural selection.*

By way of further illustration let us consider how the practice of artificial selection has been commonly employed to increase the yield of Wheat or other Cereals. The grower goes through his plot, selects plants with heads containing the largest number of grains, and saves these plants for seed. From the crop produced by this seed in the next season, he likewise selects the best yielding plants for seed. Thus, year after year he applies this method of selection until a variety more or less constant for high yield is derived. Undoubtedly, this method of *mass selection* was the one first employed by Man in his efforts to improve crop plants.

In later years, another way of artificially improving plants by selection was introduced. This we may term the method of *individual plant selection* or *pedigree culture*, because the procedure is to select a number of plants, which are propagated as distinct races, and later compared with one another for yield, earliness, hardiness, and other desirable characteristics. The most desirable of these races is selected and given a variety name. A variety thus evolved is likely to be more stable when grown on a large scale than are races obtained by the process of mass selection. Moreover, although the method of pedigree culture necessitates the keeping of careful and extensive records, the time required to make a distinct improvement is usually less than by the method of mass selection.

Modern Plant Breeding.—It will be gathered from preceding sections that the two important methods employed in breeding are selection and hybridization. The ways in which selection is practised, namely, by mass selection and by pedigree culture, have been explained. The latter is used in conjunction with hybridization in most of the modern work on plant breeding. As has been already pointed out, hybridization makes possible the assembling in the progeny of certain desirable features. Many new varieties have been produced in this way and doubtless many valuable contributions will be made in the future. Hybridization can also be used to very great advantage among plants that are propagated by cuttings, bulbs, grafting or other vegetative methods. A hybrid may combine certain very desirable features of both its parents, or it may have dropped some undesirable parental character. The characteristics of a hybrid can be perpetuated if the plant reproduces vegetatively, whereas progeny derived from the seed of a hybrid may be much less desirable. As is well known, hybrids are common among ornamental plants and among many of our fruits and vegetables.

Exercises.—(1) Why are attempts being made to develop new and better varieties of cultivated plants?

(2) Give examples of plants that have been markedly changed in cultivation, and state how they differ from their ancestors.

(3) What is meant by: (a) variation, (b) mutation, (c) heredity, (d) hybrid?

(4) Discuss the derivation of Marquis Wheat.

(5) Distinguish between mass selection and individual plant selection.

(6) Give an account of the methods now employed (a) in developing better varieties of cereals, and (b) in improving the varieties already in existence.

PART 2

GARDENING

CHAPTER XIV

Vegetable Gardening

The Origin of Vegetables.—The vegetables in general use to-day originated in many different countries. Most of our cool season crops, e.g. Beets, Turnips, Carrots, Cabbage, etc., came from the temperate zone; our warm season crops, e.g. Melons, Cucumbers, Tomatoes, etc., came from the tropics or sub-tropics. A few vegetables are of comparatively recent introduction; others are of great antiquity. They are mentioned in very early records, as is illustrated by the following quotation from Numbers XI: 5, "We remember . . . . the cucumbers, and the melons, and the leeks, and the onions, and the garlic (of Egypt)."

It would appear that the people of every land learned in time that certain plants, or portions of certain plants were suitable for food. Just how they learned of this can only be surmised; perhaps, through failure of their regular supply of food they were compelled to resort to them. Later, attempts were made to grow the plants so as to have them at hand when wanted, and under cultivation improved varieties were gradually developed. At any rate, each tribe or nation learned to use as food the leaf, stem and fruit, or root, of certain succulent plants. As travellers went from one country to another they learned about these plants and carried to and fro the seeds and roots of those they liked. Thus the use of these plants spread. To-day, plant explorers are at work in various parts of the world searching for plants which may be of value as food or ornament.

The Importance of Vegetables.—Vegetables have long been recognized for their food value. They contribute a variety of health-giving items to our diet. They are also important in the following respects:

(a) *For vitamins.* Certain essential elements of our natural foods have valuable health-giving qualities and are known as "*vitamins*". These are abundant in vegetables, particularly in the leafy portions.

(b) *For bulk.* Concentrated foods in excess lead to derangement of the digestive processes and, in the average diet, there is too great an amount of such materials as meats, white flour, pastry, and sugar. This lack of balance is best corrected by adding vegetables to the diet.

(c) *For their mineral salts.* Vegetables supply most of the mineral salts needed by the human body, such as iron, lime, potash, phosphate, and magnesia. The value of Spinach for its iron salts is well known.

(d) *For their medicinal value.* Besides supplying mineral salts, some vegetables act beneficially in keeping up the tone and vigour of the human system.

(e) *Relishes.* Cress, Mustard and Radish give flavour and variety to the diet and are used as relishes or appetizers rather than for their food value. Other vegetable relishes like Horse-radish and green Tomatoes are used as pickles.

Fresh vegetables taken from a garden are more palatable and also more wholesome than those used after storage. Owing to loss of moisture during storage they are more fibrous in structure, and have lost their crispness and hence they are less appetizing than when fresh.

Economy in the household demands that a kitchen garden should provide part of the food supply. The cost of vegetables for the family is from $75 to $100 if purchased at the grocery, and the garden is, therefore, the most profitable piece of land on the farm. There is added to this the satisfaction of raising one's own product, the convenience of the supply, as well as the enjoyment of planting, caring for, and surveying the vegetables in the garden.

The Home Vegetable Garden.—(a) *The Location of the Garden.* In a city or village there is usually little choice in the matter of location, but in the country, there is some opportunity to make a desirable selection. The chief points to be considered are:

(1) *Convenience.* The person who prepares the meals is likely also to be the person who gathers the vegetables; hence the garden should be considered part of the kitchen equipment, and should be located as near the house as possible. If the soil near the house is not quite satisfactory, it can be improved by the addition of sand in the case of heavy soil, or by the incorporation in it of some vegetable mould if the soil is a sandy one. In all cases, heavy applications of well rotted manure are beneficial.

(2) *Exposure.* A gentle slope to the south or south-east is best. This slope should be about four or five feet in one hundred feet. Sufficient drainage is thus provided to carry away surplus water quickly, without leaving standing pools. An additional advantage is that the land will dry off earlier in the spring, and will therefore warm up earlier. Sloping land is also less subject to summer frosts. Steep slopes should be avoided as being liable to wash with heavy rains.

(3) *Water.* A good supply of water should be conveniently near for use in connection with the hotbed and for ues at planting time or during periods of drought.

(4) *Protection.* Growth will be much more rapid and the germination of seeds more certain if the cold winds from the north and west can be checked by a shelter belt of trees. While a plantation of trees is being started, the garden may be protected by a few rows of hemp, sunflowers, or by a tight board fence. Such a protection will ensure a very much earlier garden and will prevent the drying out of the surface soil by the wind, which is often the cause of poor germination in the spring.

(5) *Fencing.* A suitable fence should be erected to exclude poultry and other stock.

(b) *Plan and Arrangement of the Garden.* The size of the garden will depend on several factors, such as, the size of the family, how fond they are of vegetables, whether it is desired to can or store supply for the winter, and so on. It is a good idea to make a plan of the garden, drawing it to scale. The varieties of vegetables represented in the plan, as well as the areas marked off for each will depend largely on individual preference. In general, either of two plans is usually in mind when the garden area is laid out: (1) A small area, the soil of which is heavily enriched with well rotted manure, the object being to grow a maximum crop on a minimum area. This appeals to many who desire outdoor work in spare time, and who take pride in a clean, attractive garden. (2) A larger area in which the rows are far enough apart to use a horse cultivator, hand labour thereby reduced to a minimum.

It is well to have the rows of the garden run north and south so that the sun can get at both sides of the row. Space should be provided along one side for perennials, e.g. Rhubarb, Asparagus and Horse-radish, and the small fruits, e.g. Raspberries, Strawberries and Currants, in order that these will not interfere with ploughing the garden. The long season crops such as Corn, Potatoes, Winter Turnips, should be together; and the short season crops, which are used from day to day throughout the summer, should be by themselves.

The practice which is common in districts with wet land of making raised beds, is not necessary in Alberta. With us, flat cultivation of the garden plot is desirable in order to prevent the drying out of the soil in a period of drought.

(c) *Preparation of the Seed Bed.* Ploughing should be done in the fall to allow the frost to pulverize the ground so that it will work down easily in the spring. Fall ploughing also exposes and kills those insects which hibernate in the ground over winter. The deeper the soil is ploughed, the more moisture and manure it will hold, and the more room the roots will have in which to feed. If ploughed in the spring, it should be done early, but not until the land has dried sufficiently. Land ploughed when too wet will bake and become lumpy. Land should be well worked down with a rake or harrow to obtain a fine seed bed suitable for small garden seeds.

Land intended for the garden should be fertilized with a liberal dressing of manure to ensure rapid growth. Liquid manure and nitrate of soda in small dressings give good results.

(d) *Selection of Seed and Seeding.* The importance of using good seed cannot be over-emphasized. It is folly, after preparing the land, to sow seed of doubtful germinating quality or to use a poor variety, when the same labour might produce a crop of much superior character. Good seed can be obtained from any reputable seed-house. From the long lists of varieties listed in seed catalogues only the variety which will fulfil the desire of the grower and which is well suited to the particular soil where it is to be grown should be chosen. Novelties displayed in the catalogues should only be tested out in a small way.

Seeding should begin about the time the grass begins to grow. Seeds of hardy plants, e.g. Radish, Cress, Lettuce, Spinach, are sown first in small amounts, to be succeeded by another seeding a week to ten days later, and other sowings in succession as required. Parsnip and Onion Seed and also Onion sets may be planted early. The first seedings of Carrots, Beets and smooth Peas should be made the second week of seeding and more a week or ten days later. Wrinkled varieties of Peas should not be sown until the third week of seeding, when the soil is drier and the danger of rot lessened. As the season advances and the soil becomes warmer, Beans and Corn may be planted. Early Cabbage started in the hotbed and hardened off in boxes or a cold-frame will be ready to plant early in May.

The depth of seeding varies with the size of the seed and with the season; the larger the seed, the deeper it may be sown, and later seedings should be deeper, owing to the liability of drying out in the hotter weather. As a rule, early seeds are planted about three-quarters of an inch to an inch in depth. Large seeds, as Beans and Peas, are usually planted at a depth of from two to two and a half inches. In all cases, uniformity of depth must be observed so that the seeds may come up evenly. The soil must always be brought into close contact with the seed, taking care, however, not to pack it too closely, if it is wet.

Thickness of seeding depends on the seed, the nature of the soil, and the object the grower has in mind. If a germination test shows that the seed has high vitality, it is safe to sow thinly, provided the soil is a loam or a sandy loam. In such cases there is usually far more seed sown than is necessary. If the soil is clay and there is danger of a crust forming over the seed row, a little heavier seeding is justifiable in order that the greater number of seedlings may, with their combined strength, push their way through the crust. Thin seeding, when practicable, makes the work of thinning much lighter.

(e) *Thinning*. Thinning is closely associated with thickness of seeding and with the distance apart of the rows. It depends on the amount of space required for the normal development of the plant, and to some extent also on the quality of the product desired by the grower. The farther apart plants are in the row, the coarser and larger most of them grow, but with root crops it is not size and coarseness but quality, that is wanted, and the latter is usually associated with medium-sized plants. Hence, if large Turnips, Beets, Carrots or Onions are desired, the plants are thinned out to six, eight and even twelve inches apart, but, if fine quality is wanted, they may be thinned to three or four inches or even less. This distance again will depend on the amount of fertilizer that has been applied, for the richer the soil, the closer the plants may be. Spinach, Beets, Lettuce, Carrots, and Chard may be thinned as they are used. Progressive gardeners are now giving attention to securing seed of high germination, preparing the seed-bed thoroughly, and then seeding to give a stand that will require no thinning. In this way, the usual set-back to the crop that accompanies thinning is avoided.

(f) *Cultivation.* The first object of cultivation is to keep down weeds, and should commence as soon as the row of seedlings is discernible. This is important in the garden, as many of the garden crops are quite delicate when coming through the ground and suffer from competition with other plants. In the case of plants whose seeds are slow of germination, a few Radish seeds will serve as markers to show where the row is.

The best implement to use for early cultivation is the garden rake. Cultivation should not be deep but the aim should be to kill the young weed seedlings that are starting, and thus avoid the necessity of later weeding. Later cultivation may be deeper, in order to conserve moisture, to liberate plant food, and to facilitate root development. All garden crops will respond to frequent cultivation—about once a week is not too frequent, and especially after every rain, the ground should be gone over to break up the slight crust that has formed, and to check evaporation.

(g) *Rotation of Crops.* The garden as well as the farm offers an opportunity for rotating crops. Rotation enables the crops to make the best use of the plant food available and in addition tends to ward off an attack of certain serious plant diseases and injurious insects. Root crops should not be followed by root crops, nor leaf crops by leaf crops; nor should crops follow one another that are related botanically, as for example, Cabbage, Cauliflower and Brussels Sprouts.

Plants vary greatly in their ability to gather plant food. Some are gross feeders, sending their roots in all directions in search of food, as for example, late Cabbage, which uses large amounts of nitrogen and potash, and is hard on the land. Others, like Celery and Onions are shallow-rooted, the roots extending only a few inches sideways and to no great depth. They are avid feeders if food is taken to them. The only nitrogen gatherers are Peas and Beans. Because of these differences, it is a good plan to rotate garden crops. The plan of the garden should be kept from year to year.

(h) *The Summer-Fallow.* In the more humid districts the annual rainfall is usually sufficient to grow a good garden yearly. In the drier districts, it is wise to have the vegetable garden twice the size needed, so that one-half of it may be treated as a summer-fallow each year. In this way extra moisture may be stored to assist the crop the following year.

Summer-fallowing has the additional advantage of assisting in the eradication of weeds in the garden area, and if carefully done, greatly reduces the labour in connection with vegetable growing. Hence, on a farm where economy of space is not a consideration, the vegetable garden is best left for fallow every second or third year. The land for Beans, Corn and Tomatoes should be cultivated several times before planting in order to warm it up. These are warm season crops which start more quickly in a warm soil.

Hotbeds and Cold-Frames.—A hotbed is a bed of soil surrounded by a frame covered with glass and heated by means of fermenting manure, or sometimes by furnace flues or hot-water coils. In the hotbed, plants are started to grow considerably earlier than is possible in the open. Market gardeners avail themselves of this means of getting their products on the market much earlier than is otherwise possible. By the use of the hotbed it is possible to grow and ripen products which would otherwise be checked before maturity by frost in the autumn, and also to obtain with annual flowers a long blooming period before the autumn frosts come.

The hotbed should be sheltered from the north and west winds by some kind of windbreak, such as a building or a high board fence, or a row of trees; it should have a southern exposure with the advantage of the direct rays of the mid-day sun, and should be convenient to a supply of water.

The frame, usually six feet square, is made of boards or planks. It should have a height of one foot on the front and eighteen inches at the rear. This gives a slope of six inches in the six feet of width. A standard hotbed sash is three by six feet and two of these sashes will cover a bed of suitable size for the average house. Substitutes for glass are sometimes used, for example, cotton painted with hot paraffin, called "glass cloth", heavy oiled paper, and even factory cotton.

Fresh horse manure is the only manure to use for heating. A pile is left a week or so until heating commences, and is then turned over so that the outside portions are placed in the centre, thus making heating uniform throughout. The manure is placed in the bed in six inch layers, and each layer

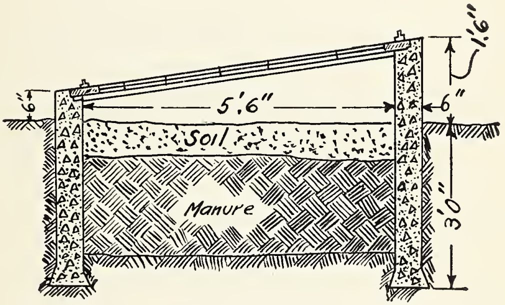


Fig. 40. Hotbed.
(Courtesy of Canada Cement Co., Ltd.)

tramped until a depth of about two and a half feet is reached. On this pile the frame is set and manure piled around it to prevent loss of heat. Sometimes a pit is dug in the ground and with the frame, either of wood or cement, this makes a more permanent fixture and requires less manure because of its greater protection. Earth is placed in the frame to a depth of about six inches. The sash is put on and heating allowed to proceed violently. When the temperature has dropped to 75 or 80 degrees, it is safe to plant the seeds.

The time to make the hotbed is about the last week of March or the first week of April. This gives ample time to grow and to harden off the plants before they should be planted out in the garden and subjected to weather conditions.

In the hotbed, Lettuce, Radish, Cress, and Mustard can be grown for the use of the household in early spring, and early Cabbage, early Cauliflower, Celery, Tomatoes and many annual flowers can be started, to be set out later in the garden or flower bed.

The cold-frame is similar in construction to the hotbed, but has no heat under it, the only heat utilized being that of the sun. It is chiefly used for hardening off tender plants taken from the hotbed before transplanting them in the open garden. At first the sash is kept on the frame except in the warmest part of the day, but soon it is opened by degrees until finally it may be removed. During this time the plants are watered less freely, with the result that they become stocky and hardy and will not suffer a setback when transplanted to the garden.

Transplanting.—Plants grown in the hotbed are too close together to allow them to develop properly. As soon as the plants are one and a half to two inches high the first transplanting, commonly known as "pricking out," takes place. A second, and sometimes a third, transplanting is made before plants are finally transferred to the open garden. By transplanting the young seedlings in the hotbed, sturdy plants are developed which give much better growth following the final transplanting than do individuals transferred to the garden from the original seed-bed.

Plants differ somewhat in the ease with which they may be transplanted; those having numerous fibrous roots are readily transplanted, but those having few fibrous roots when young, e.g. Cucumber, Squash and Melon, are difficult to transplant. The latter may be successfully transplanted if started in pots or inverted sods, making possible their transfer to the garden without disturbing the roots. Plants with pronounced tap roots, for example, Poppy, Turnip and Beet, are difficult to transplant when well established, but will transplant readily when only one or two inches high.

The essentials for success in the final transplanting are as follows:

(1) Well developed sturdy plants; these may be obtained only by giving each plant sufficient space for root development.

(2) Plants properly hardened off. Gradual exposure to outdoor conditions while in flats or the cold-frame will ensure this.

(3) Plants of proper age and size. Plants may be too old or overgrown and hence may be so set back by the shock of transplanting that smaller plants will surpass them. On the other hand, small plants in an otherwise well-developed lot may actually be weaklings or "runts" that would never have been successful under any conditions.

(4) Proper planting. Plants must be placed at the proper depth and the soil packed around them so as to be in close contact with the roots.

(5) Properly prepared land, that is, in a good state of cultivation and carrying sufficient moisture to give the plants a proper start.

In transplanting, the following precautions will greatly assist in making the work a success:

(1) Plants should be well watered a few hours before making the change so that they may be well supplied with moisture.

(2) Some of the leaves of the plant may be cut off, in order to reduce transpiration, thus compensating for the decreased absorption which results from disturbing the root-system. In this way, wilting may be prevented.

(3) Plants may be shaded from the hot sun for a few days by means of a shingle or other protection.

(4) Planting is best done before, during or after a rain. Transplanting after four o'clock in the afternoon gives best results because transpiration from the leaves is then on the wane, and the plants have a chance to recover during the night.

(5) Plants should be carefully watered in their new situation; cultivation around the plants will help to conserve soil moisture.

Storage of Vegetables.—A well planned garden should supply vegetables for canning and storage for winter use. Canning by the cold pack method is so simple that anyone may undertake to can vegetables, when they are at their best, and feel assured of success. The following vegetables may be canned, pickled or preserved:—Asparagus, String Beans, Brussels Sprouts, Cabbage, Cauliflower, Carrots, Chard, Citron, Sweet Corn, Cucumber, Onion, Peas, Peppers, Pumpkin, Rhubarb, Spinach, Squash, and Tomatoes.

Storage in the dry state in the average furnace-heated cellar is difficult unless a special storage-room well isolated from the rest of the cellar, is provided. Furthermore, it is impossible to store all kinds of vegetables under the same conditions with equal success. In the average cellar, however, storage can be arranged for quite a variety of vegetables, a large number of which can be kept throughout the winter season.

The following vegetables require cool, moist conditions with little or no circulation of air, the temperature ranging from just above freezing to forty degrees: Potatoes, Beets, Carrots, Parsnips, Winter Radish, Horse Radish, Swede Turnips, Salsify, and Cabbage. Potatoes should be stored in bins in the darkest corner of the cellar, owing to their becoming discoloured and acquiring a bitter taste if exposed to light. Cabbages should be stored on slatted shelves, and the rest of the above group should be covered with moist sand or earth to prevent their drying out. The earth absorbs any odours from individual roots which may spoil. Parsnips, Salsify and Horse Radish are not injured by frost and a part of the crop may be left in the ground until spring if so desired.

A second group, including Celery, Kohlrabi, Leeks, and Brussels Sprouts, requires cool, moist conditions but with a free circulation of air. Plants of this group should be dug up, leaving some of the roots attached to them, and placed in the cellar with earth around the roots. Water should be added to the roots from time to time. Care should be taken not to wet the leaves and stems, thus causing them to rot.

A third group, including Onions and Garlic, requires cool, dry conditions with plenty of air. Onions should be hung in crates from the ceiling.

A fourth group needs warm, dry conditions with plenty of air. Included in this group are Squash, Pumpkin and Vegetable Marrow, which soon decay in a damp place but will keep for three or four months in a warm, dry atmosphere.

Marketing.—The products of the home garden seldom find their way to the market; they are usually used day by day as they are ready. Commercial gardening is a business requiring considerable executive ability; one has to deal with various types of customers. Some gardeners sell only from a stall on the market; others sell to the retailer direct; and still other growers supply large hotels, restaurants, and the wholesale trade.

Products are placed on the market just as soon as they are saleable, for the first offering of the season always commands the best price. Market products which are usually sold in bunches include:—Radishes, Green Onions, Asparagus, Rhubarb, early Beets, Carrots, Turnips, Kohlrabi, Leeks, and Parsley. The number in the bunch varies according to the custom of the market. All root crops are washed either before or after bunching. Badly formed and small specimens are discarded, and the bunch made as uniform and attractive as possible.

Leaf crops are usually sold by the pound, although leaf Lettuce is frequently tied in bunches. The plants are cut off just below the crown and if dirty are washed.

Head Lettuce, Cabbage, Cauliflower, and Celery are usually sold on the market by the individual head, sometimes by the dozen. In harvesting they are cut off just below the crown and the loose, outer leaves are removed. The leaves of a cauliflower are cut off about an inch above the head in order to improve its appearance.

String or Snap Beans should be picked before they are tough and before the seeds have formed to any extent. Peas are picked when the pods are fairly well rounded out. Both are sold by weight as a rule, although sometimes by the measure.

Cucumbers should be picked before the seeds form, because the forming of seeds tends to make the plant less productive. The larger ones are sold individually, and those for pickling by weight or measure.

Summer Squash are used when large enough and while the skin will puncture with the pressure of the thumb nail. When the outer skin hardens they are unfit for use. On the other hand, winter Squash are not ready to use until the skin hardens until it cannot be punctured by the thumb nail. Both are sold by the individual specimen and by weight. Tomatoes are sold by weight and by the basket.

The fall roots such as Swede Turnips, Carrots, Beets, Winter Radishes, and Parsnips are sold by weight. They are not usually washed before marketing, and the tops are cut off about half an inch above the crown.

Potatoes are sold by weight. Early Potatoes are dug as soon as they are large enough. Late Potatoes are not ready till the tops are dead.

Early green Onions are sold by the bunch and late Onions are sold by weight. Late Onions are lifted when ripe. This is indicated by the tops drying off and turning yellow just above the bulb. Unripe bulbs will not keep.

Exercises.—(1) From what have the following vegetables been derived: Corn, Tomatoes, Potatoes, Onions, Melons, Turnips, Cabbage?

(2) What reasons can be given for including vegetables in our daily diet? Why is the kitchen garden a desirable accessory to every household?

(3) What are the requirements of the garden in the matter of (a) Soil, (b) Exposure, (c) Convenience, and (d) Protection? Why should the rows run north and south, and what grouping of the vegetables is most convenient?

(4) Which seeds are sown early in the vegetable garden? What is the danger in early seeding of Corn, Beans, Wrinkled Peas?

(5) Discuss the purpose and the practice adopted in thinning vegetables.

(6) What are the purposes in mind in cultivating the garden while the crop is growing?

(7) What principle is used in providing heat in the hotbed? Describe one suitable for home use. Give drawings showing side elevation and ground plan (Scale one-half inch to the foot). Where should the hotbed be located? Name vegetables which may be started in this way.

(8) Describe the various steps in transplanting.

(9) Name vegetables which in storage require:

(a) Temperature near the freezing point.
(b) Complete darkness.
(c) Slatted shelves or crates.
(d) Moist conditions.
(e) A covering of sand or earth.
(f) Warm dry air.

(10) In what form are the following marketed: Radishes, Spinach, Potatoes, Cucumbers, Parsnips, early Onions, Lettuce, Green Corn?

CHAPTER XV

Fruit Growing

There is a popular idea that fruits cannot be grown on the prairie owing to low temperatures and other conditions unfavourable to their growth. This is not so, for observation shows that fruit-bearing shrubs spring up naturally in sheltered, moist places, and the plantings of hundreds of settlers bear testimony to the fact that fruits, when sheltered by trees, can be grown on the prairie.

There is an old adage in horticulture that where wild fruits grow, the tame or cultivated varieties will succeed. Growing on the prairie in the shelter of clumps of Poplar and in other protected places the following fruits are found: Strawberry, Raspberry, Currant, Saskatoon, High-bush Cranberry (Pembina), Pin Cherry, Choke Cherry, Black Currant, and Gooseberry. Assuming the truth of the adage, the near relatives of these among the cultivated varieties should be easily grown. Experience is showing this to be true.

Fruit growing has been a comparatively late development following settlement in all parts of the continent. The newcomer must first become established before he can turn his attention to growing trees and fruits. In western Canada pioneers have already pointed the way, and to-day there is no reason why anyone cannot produce all the small fruit needed for family use and some of the tree fruits as well. The number of hardy varieties adapted to this climate will doubtless be increased in the near future.

Fruits may be classified into three groups.

(a) The small fruits, e.g. Strawberry, Raspberry, Currant, Gooseberry, Saskatoon, and High-bush Cranberry.

(b) The tree fruits, e.g. Apple, Crab-apple, Plum, and Cherry.

(c) The vine fruits, e.g. Grape.

(a) The Small Fruits

(1) *The Strawberry.* This most popular fruit is generally grown by planting in the spring strong, well-developed runners grown the previous season. The first and second plants on the runner are the best ones to take. The plant prefers a rich sandy loam but will thrive in any soil suitable for growing Potatoes. The soil should be well prepared and can hardly be too rich in plant food.

Strawberries are usually grown in rows three to four feet apart, and the plants set from eighteen inches to two feet apart in the row. As the runners develop, they are allowed to root in the space surrounding the mother plant and to form plants four to six inches apart. After the row has thus widened out to eighteen inches, any new runners are cut off as they form, in order that there may be left between the rows sufficient space in which to walk when picking the fruit. This is called the "*matted row system*".

During the first season, the fruit blossoms (flowers) must be picked off to cause the plant to make runners. Cultivation should be carried on to kill weeds and to conserve moisture.

As soon as the ground is frozen in the fall, the plants must be covered with two or three inches of straw which should be free of weed seeds. This covering, called a winter mulch, serves to hold the frost in the ground in the early spring, thus preventing repeated thawing and freezing, which is likely to kill the plants. Finally, before growth begins, this mulch should be removed, the ground cultivated, and sufficient straw again spread over the plants to prevent the soil being splashed on the berries during rains. While fruiting, the strawberry requires large amounts of water, a drought at this time may reduce the crop by as much as one-half.

Another method of growing Strawberries is that known as the "hill system". The plants are set out at intervals of eighteen inches in rows two feet apart. No blossoms or runners are allowed to develop. In this case the plant makes a big crown, and the next year will give a large yield

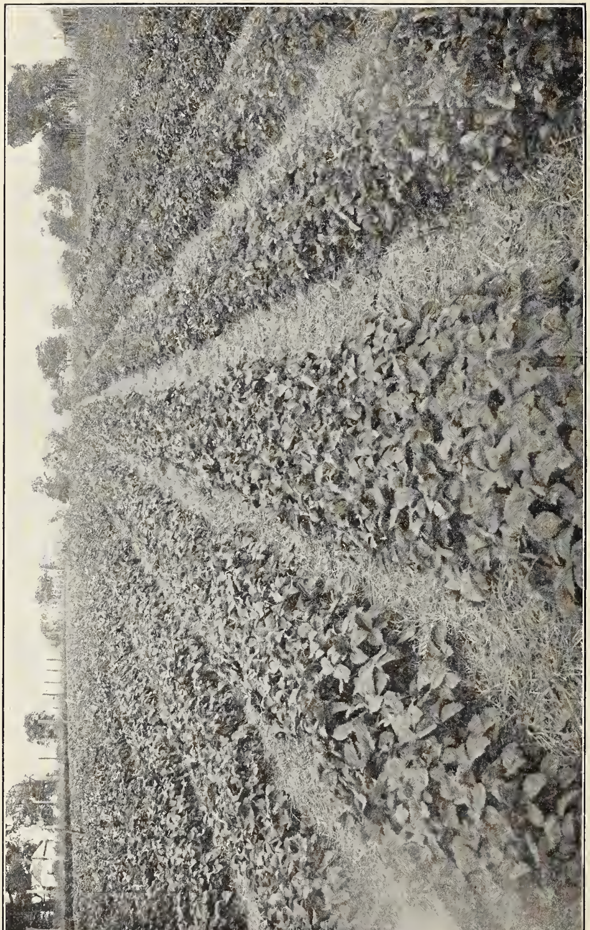


Fig. 41. Matted-Row System.

of berries. This is a very satisfactory method in that it makes possible clean cultivation.

In recent years a new type of Strawberry has been created, namely, the "everbearing". This type, instead of making runners after fruiting early in the season, forms another set of blossoms and ripens fruit before the end of the season. "Everbearers" are always grown in hills. Few runners appear except when forced by picking the blossoms. Some of the newer varieties, however, develop runners in sufficient numbers to make possible the renewal of the bed.

The best June bearing variety to grow is the Senator Dunlap, which is hardy, productive, of high quality, and a good plant-maker. After it has been grown successfully, other varieties might be tried. The best "everbearers" are Progressive and Champion.

(2) *The Currant.* Currants love a rich, moist and slightly heavy loam but will thrive in any good soil. They do best with a little shade. Even when much neglected they give a fair return, but will respond in a wonderful way to good cultivation and liberal manuring.

Vigorous one-year-old plants from cuttings are usually set out in rows six feet apart and four feet apart in the row. They will not fruit the first year, a very little the second year, and not until the fourth year will the plants produce a full crop. After that, a crop may be expected annually for ten or twelve years, the yield depending on the pruning, manuring, cultivation and general care given the bushes. It is then time to break up and renew the plantation, though bushes have been known to yield for twenty years.

Currants grow in either of two forms. In the tree form, only one shoot is allowed to grow and to become a miniature tree. This is a handsome and generally desirable plant, but, unfortunately, is subject to attack by a borer, which frequently brings about the loss of the plant. In the bush form, the plant is allowed to send up several shoots from the ground, thus producing a bush. This is not as clean and attractive as the tree form, but is less likely to be completely destroyed by the attacks of the borer.

Red and White Currants resemble each other in habit of growth. The fruit is borne on short spurs which grow on the two-year and older wood. Also, some fruit is borne on the one-year-old wood. The yield diminishes after the wood is four years old. Pruning is done in the spring, the aim being to form a bush with eight or ten main branches. Each spring, after the bush is two or three years old, some of the older wood is cut out, and a few of the one-year-old shoots are left to develop. The object is to have no shoots in the bush over three years old, and to have young shoots coming on to replace those removed.

Black Currants are vigorous growers. The best fruit is borne on the base of the one-year-old wood, and on the two and three-year-old wood, but no fruit spurs are formed. Heavy pruning is required and a more constant culling out of the older wood than with the red and white varieties.

The best varieties of Currant are:

White: Imperial, White Grape, White Dutch.
Red: Perfection, Red Cherry, Red Dutch.
Black: Black Naples, Lee's Prolific, Kerry, Boskop Giant.

(3) *The Gooseberry.* Gooseberries are grown from well rooted layers, and are planted, pruned, and cared for much as are Currants. They thrive best on heavy soils, and do only fairly well on sandy soils. They prefer shady and well-sheltered positions. The best varieties are Houghton, Pearl and Smith's Improved.

(4) *The Raspberry.* Raspberries are, next to Strawberries, the most popular of the small fruits. They like a rich, moist, sandy loam, full of vegetable matter, but will give excellent returns on any soil which is kept free of weeds and given proper care.

The Raspberry has a perennial root and a biennial cane. It is propagated by suckers taken from beside the mother plant, or sometimes by dividing the mother plant. The suckers are planted in rows six feet apart and eighteen inches to two feet apart in the row, and the plants produced are allowed to fill up a solid row a foot wide; or, in a small garden, they may be planted in hills three or four feet apart. When well established a planting is good for ten or twelve years, depending on the manuring, cultivation, pruning and general care given.

The fruit is borne on lateral branches of the canes the second year. After fruiting, the canes die and may be pruned out immediately after harvest to make room for the new canes, or, they may be left until spring and removed when thinning is being done. Thinning should leave canes four to six inches apart when grown in rows, or, six to eight of the best canes in a hill.

The canes suffer from the cold winds of winter unless so situated that snow will drift around them. On the prairie the canes are best protected by turning them down and covering with sufficient earth to hold them. The earth should be removed in the spring just before growth starts, but not so early as to expose the canes to heavy frosts.

The best varieties of Red Raspberry are Herbert, Latham, Cuthbert and Turner. The hardiest variety is the Sunbeam, but its quality is low and fruit seedy. For a home garden, which is in some measure protected, the Herbert stands first and the Latham second.

The Black Cap Raspberry has not proven very hardy in Alberta. The Blackberry or Thimbleberry (sometimes spoken of as the Bramble), requires too long a growing season to be successful in this region. The Loganberry thrives in the moist conditions of the Pacific Coast, but has not been a success in the higher and drier climate east of the Rocky Mountains.

(5) *The Saskatoon.* This is a native plant worthy of cultivation. The fruit is often canned for winter use, and has a particularly good flavour when preserved with Rhubarb. The Saskatoon is quite hardy and gives a yield equal to that of Currants. It can be grown and handled in much the same

way as the Currant. Good plants are lifted in the spring and planted in the garden four feet apart each way or, they may be set close together to form a hedge. Best results will be obtained if all the shoots are cut back to the ground and a new lot allowed to start.

(6) *The Pembina* (*High-bush Cranberry*). This is a hardy native species whose fruit is suitable for the making of jelly. Plants are easily moved in the spring from the woods and grow most luxuriantly in good garden soil. Bushes should be set out four to five feet apart. Because of the attractive colour of the leaves, particularly in the fall, the High-bush Cranberry is also suitable as an ornamental shrub.

(7) *The Cranberry*. The low-bush Cranberry, as it is popularly called, is another native fruit. It grows in muskegs and is capable of being commercialized in the same way as the well-known Cape Cod Cranberry which is now sold all over the continent.

(b) The Tree Fruits

The best known of these are the stone fruits, Plum, Cherry, Apricot, Peach, Nectarine; and the pome fruits, Apple, Crab-apple, Grape Fruit. Of these the only ones which can be grown on the prairie are the Plum, Cherry, Apple, Crab-apple, and possibly, the Pear.

(1) *The Plum*. The Plum is widely distributed over the north temperate zone, wild varieties being found in nearly every country. All the cultivated Plums of Europe and Eastern America are too tender for Alberta. Varieties have been introduced from China and Japan which are hardy on the Pacific coast, but they, also, are too tender for this province. They have, however, proved very valuable for hybridizing with native American stock, some of the hybrids being hardy enough to grow in Alberta.

Of the many American wild Plums, two are of value for the prairie, namely, the American Plum, which grows in eastern Canada and the northern States, and the Canada or black Plum, which grows on the northern fringe of the area occupied by the former. The Canada Plum grows wild in Manitoba and extends along the river valleys into Saskatchewan. It is also found in Alberta at several of the river crossings on the old hunting trails to the mountains, having been carried there, no doubt, by Indians from Manitoba.

Trees should be planted at a distance of eight to twelve feet in rows from ten to fifteen feet apart. Plums are largely self-sterile, and therefore, two varieties which bloom at the same time should be planted together.

(2) *The Cherry.* All the cultivated varieties of the Cherry are too tender for the prairie, but it is probable that, in the future, hardy cultivated varieties will be produced by plant-breeders. The only native wild species that has given improved fruit is the Sand or Dwarf Cherry. Very valuable work in hybridizing with this Cherry is being done by Professor Hanson, of South Dakota. During the last twenty years he has crossed the Sand Cherry with the Manitoba Wild Plum, the cultivated Plum, and the Chinese and Japanese Plums, and has produced some hybrid cherry-plums, a number of which are worthy of cultivation, bearing fruits an inch to an inch and a quarter in diameter and of a very fine flavour. Some of them have ripened in the University trial grounds at Edmonton, and also in many gardens throughout the prairies. The best of these plums are Hanska, Sapa, Opata, Champa, Kaga, Pembina, Tom Thumb, and Waneta.

(3) *The Apple.* It has been demonstrated by many experiments that the cultivated Apple will not grow on the open prairie. One of the first undertakings of the Dominion Experimental Farms was to obtain by breeding methods a variety of Apple which would be successful under the climatic conditions prevailing here. The hardiest known Apple, the Siberian Crab-apple, was introduced, and breeding work started. The first cross with well-known hardy Apples gave a few trees which bore fruit that could be used. The trees are almost as hardy as the wild form and have Apples (really Crab-apples) which measure an inch to an inch and an eighth in diameter and which make excellent jelly.

Another line of work has been that of testing hardy varieties from the colder parts of Russia. Nearly a dozen of these varieties will grow in the shelter of a tree plantation, some of the best being Hibernal, Charlamoff, Yellow Transparent, Blushed Colville, Longfield, and Tetofsky.

Also, there are two well-known varieties of Apple that are succeeding, namely, the Duchess of Oldenberg and Wealthy. The trees are grown in dwarf form; that is, they are made to branch at a foot to a foot and a half from the ground, and to form low heads. The trees should be set out sixteen to twenty feet apart each way.

(4) *The Crab-apple.* In addition to the Siberian Crab-apples and the hybrid varieties already mentioned, there are two well-known commercial Crab-apples which are succeeding on the prairie. These are the Transcendent and the Hyslop. They may be planted the same distance apart as other Apples, or they may be planted six feet apart in rows to form a hedge.

(5) *The Pear.* The cultivated varieties of the Pear are not hardy on the prairie. Recently, a wild Pear from Russia has proved hardy and has been grown successfully in a number of places. Starting with this wild species, the plant-breeder will be able to evolve a variety that is both hardy and productive of desirable fruit.

(c) The Vine Fruits

A wild grape which grows along rivers in Manitoba has been crossed with cultivated varieties and has given several hybrids that can be grown successfully under most conditions in western Canada. Beta is the most popular of these new strains. Further breeding work will doubtless develop varieties of greater value.

Exercises.—(1) On what assumption do we assert that the West will some day be a fruit growing country? What work is yet to be done that this may be possible?

(2) How are Strawberries propagated? Distinguish two types, the "everbearing" and the older varieties in respect to this. How are Strawberries placed in the beds? What care is needed?

(3) Name the varieties of Currants. What are their requirements as to soil and exposure? What annual care of the bushes is needed? How are they propagated?

(4) How are Gooseberries propagated? What is the best soil for them?

(5) What are the soil requirements of Raspberries? What winter care is needed for most cultivated varieties? Which canes produce fruit each year? Compare this with Currants and Gooseberries.

(6) Name some of the native fruits peculiar to the prairies. What is their merit as compared with those above named?

(7) Of the fruits, Apple, Pear, Plum, and Cherry, which seems to offer the greatest chance of success under our climatic conditions? Why? What provision for protection is necessary for any of these? Why should we always plant two Plum trees if we plant any at all? What other fruit is subject to the same peculiarity? How are new varieties of the above named tree fruits secured? How are unlimited numbers of a given variety obtained?

CHAPTER XVI

Floriculture

Almost everyone is interested in growing flowers in the home or in the home grounds, for the love of flowers is an inherent characteristic common to all civilized people. Varieties of plants have been developed by florists to meet all ordinary conditions, and so simple are the requirements of most of them that flowers can be had by anyone who is willing to give them a little care and study.

Growing Flowers in the House.—Flowers grown in the windows in the home are a source of pleasure and satisfaction and contribute much towards its refinement and happiness. The requirements for success are of the simplest, and are the same in general as those for outdoor growing. They are principally sunlight, suitable temperature, water and air, soil, and adequate care.

(a) *Sunlight.* A window facing the south is best as it has the longest duration of sunlight. An east window is next best, while a west window is less desirable. A northern exposure is not satisfactory for flowering plants, but answers well for those that are grown for their foliage, such as ferns, begonias, and English ivy. Few plants will do well when placed back in a room away from direct light. The best plants for these positions, if any are so placed, are those mentioned as suited for the north window.

(b) *Temperature.* The most suitable temperature for house plants is from 60° to 65° during the day, with a night temperature 10° to 15° lower. A variation greater than this is less favourable for plant growth. Plants may be moved back from the window at night in cold weather, and with storm windows closed and curtains and blinds drawn the temperature may be kept from falling too low.

(c) *Water and Air.* The soil in which plants grow must be supplied with moisture, but the roots must have air as well. By tapping on the outside of the pots one is able to judge from the sound whether the soil is becoming dry or is sufficiently moist. The need of water will depend on various factors, such as the kind of plant, whether it is in bloom or not, and whether growing rapidly or resting. Plants do better where the air of the room is moist, and this explains why plants have such a healthy appearance when grown in a kitchen or in a room off the kitchen.

(d) *Soil.* A good potting soil may be made of three parts of rotted sod, two parts of well rotted manure and one part of sharp sand. These should be well mixed and then passed through a half-inch sieve. The fibre and sand permit the roots to penetrate into the soil and prevent it from baking. When the fibre is all used up the soil becomes clayey and solid, making it necessary to re-pot the plant. Ordinary garden soil, when used in pots, soon bakes from the daily watering.

(e) *Adequate Care.* An occasional sponging of the leaves with tepid water is beneficial in removing the dust which has settled on them from sweeping the room. Spraying the plants or standing them in the rain for a short time is also beneficial. The presence of aphis, mealy bug and red spider must be watched for, as they thrive in the dry atmosphere of the house. If any of them are found, the plants should be sprayed with nicotine solution, or the insects destroyed wherever seen.

A certain amount of pruning must be done from time to time to keep the plants symmetrical in shape, and make them grow bushy. To encourage side growth the tips of the longer shoots should be pinched back, and also the plants given plenty of space in order that they may not be forced to grow tall and spindly.

Most house plants are propagated from "slips" or soft wood cuttings started in sand, soil, or water. For instance, with the geranium, cuttings taken in the spring make suitable plants for blooming during the winter, and cuttings taken in the fall just before hard freezing make the plants to go outside the following spring. Young bushy plants possess greater vigour, carry more bloom and generally do better than older ones. As soon as the cuttings are rooted they are potted in a two or two and a half inch pot. As soon as the roots fill the pot the plant is shifted first to a three-inch and later to a four-inch one.

Growing Flowers Outdoors.—There are two great classes from which to draw, annuals and perennials. Best results for the average garden will come from the use of varieties of both kinds so that a succession of bloom may be had from earliest spring to latest autumn.

(a) *Annuals.* These possess the great advantage of giving quick results and a fine display of flowers the first season after sowing. Some of them may be planted outside as soon as the weather is warm, e.g. Nasturtium, Candy Tuft, Mignonette, Poppies, Sweet Peas. Some are so slow coming into flower that it is necessary to start them in the hotbed in order that they may have a period of bloom before frost in the fall, e.g. Aster, Balsam, Cosmos, Nemesia, Nicotiana, Salpiglossis, Stocks, Zinnia, Clarkia. The usual procedure with plants grown in the conservatory or hotbed, when intended for outdoor planting, is the same as that used for vegetables. It has been carefully outlined in Chapter XIV. Planting of tender annuals in the beds where they are to grow should be done about the first week in June.

(b) *Perennials.* Perennials have the disadvantage of requiring an extra year's growth before flowering, but they have the great advantage that once established they continue to bloom for years. The seeds may be sown outside or started in the hotbed or greenhouse. When big enough, they are spaced from six inches to a foot apart in nursery rows, from which in the early fall, or the following spring, they are moved into their permanent places. Some bloom will appear the second year, increasing as the plant grows larger for four or five years. At the end of this time it is advisable with most perennials to dig them up and divide the root into several pieces and replant the portions separately. This will result in improving the quality of the bloom.

Perennials should be placed with careful consideration for their decorative effect. Delphiniums, being tall growers, are seen to best advantage against a wall or fence, Irises must stand in the open in order that they may bloom well. Iceland Poppies may be placed toward the front of the border. Lilies do well with other plants growing close around them, but most of the perennials are best grown in clumps with plenty of open space around them.

Suitable perennials to grow in Alberta gardens are: Perennial Alyssum, Sweet Rocket, Forget-Me-Not, Iceland Poppy, Peony, Bleeding Heart, Iris, Lily, Columbine, Delphinium, Gypsophila, Coreopsis, Oriental Poppy, Alpine Pink, Campanula.

Ornamental Gardening.—Beautifying the home grounds may be compared to painting or composing a picture in which the house is the centre of interest and the lawn, trees, shrubs and flowers are used to gain the effect of colour harmony, balance, unity, and the other qualities of the perfect picture. A good way to see the artistic possibilities of any landscape or garden is to study it from a short distance and form an idea of what arrangement of the different details would give the best effect when the growth of the trees is completed.

Experience has shown that best results will be attained by adhering to the following principles:

(1) Making and maintaining a good lawn is the most important single contribution to the beautification of the home surroundings. To do this it will be necessary to provide a top soil of black loam six or more inches in depth, and have this rolled and levelled with the greatest care. Seeding should be done with a good grade of lawn grass. White or Dutch clover may be added.

(2) Trees and shrubs should be planted along the borders of the ground and at suitable positions to give the appearance of a setting or to frame the picture, as it were, and to give

the necessary shade. It will probably be found best to have the trees and shrubs arranged in a border about the grounds at the side and rear of the house, thus leaving an open space in the middle of the lawn. The width of the border will depend on the size of the grounds. The shrubs should be placed between the trees and also in front of them in order to hide the bareness of the trunks. The whole planting should make a rising curve from the horizontal ground line over the lower and the taller shrubs to the vertical line of the taller trees. Shrubs should be grouped in two or threes of the same variety, each from four to six feet apart. The border line of grass and trees should not be a straight line, but an irregular or curved one.

(3) If the grounds are of large size, shrubs and flowers should be planted at either side of the entrance gateway and at prominent curves in the walks, the guiding principle being that there must be something planted at such points to justify the curve in the path.

(4) Foundation planting should be considered as part of any decorative scheme. This consists in placing shrubs along the foundations of the house at the corners of the house or verandah, between the windows, at either side of the door, and in any alcoves or bays. Taller shrubs should be placed where they will not obscure the light; smaller shrubs may be planted beneath the windows, but the foundation should not be entirely obscured, otherwise the house will appear to be set in shrubbery.

(5) Where possible, vines should be trained up the walls of the house and around the verandah. An outside chimney is an especially suitable place for a vine. The variety of Virginia Creeper known as the Engelmann will cling to walls of stone, stucco or brick without support. On wooden walls trellises of wire or slats may be provided. Around the verandah suitable climbers are the Hop, Virginia Creeper and Clematis among perennials, and the Wild Cucumber, Scarlet Runner and Canary-Bird Flower among annuals.

(6) Flowers may be planted in front of the shrubs in the borders to hide the bareness of the undergrowth and to brighten up the picture.

(7) Those who are planning an ornamental border should appreciate the decorative effect of such things as the colour of the bark, the colour of blossoms, the various shades of green in the foliage and the colour of the berries. By careful attention to these it is possible to have a constant succession of interest through the summer, autumn and winter.

The following list contains the names of shrubs and trees suitable for most localities in Alberta:

Cultivated trees: Russian Poplar, North-West Poplar, Golden Willow, Laurel Leaved Willow, Elm, Ash, Manitoba Maple, Pines, Spruce, Birch, Mountain Ash.

Cultivated shrubs: Lilac, Honeysuckle, Spirea, Caragana, Hawthorn, Flowering Currant, Elderberry, Mock Orange.

Native shrubs and trees: Saskatoon, Dogwood, Silverberry, Buffalo Berry, High Bush Cranberry, Choke Cherry, Pin Cherry, Birch, Poplar, Spruce and Tamarack.

Climbing plants: Virginia Creeper, Clematis, Perennial Hop.

Tree Planting.—The correct method of planting trees is something everyone should know. A well-planted tree makes much more rapid growth than one carelessly planted, even if the latter should finally survive, and the satisfaction derived from the planting when it is well done is sufficient reward for the attention and care that has been taken to get a successful result. The correct way may be described as follows:

First of all, dig the hole large enough and deep enough to accommodate all the roots without crowding them. Then place the plant in the hole with the roots carefully spread out. Fill in the earth with the fine soil first and the coarser soil on top, tramping each layer down, and then leave an inch or two of loose soil on top as a mulch. The tree should stand an inch or two deeper in the ground than it did before it was taken up.

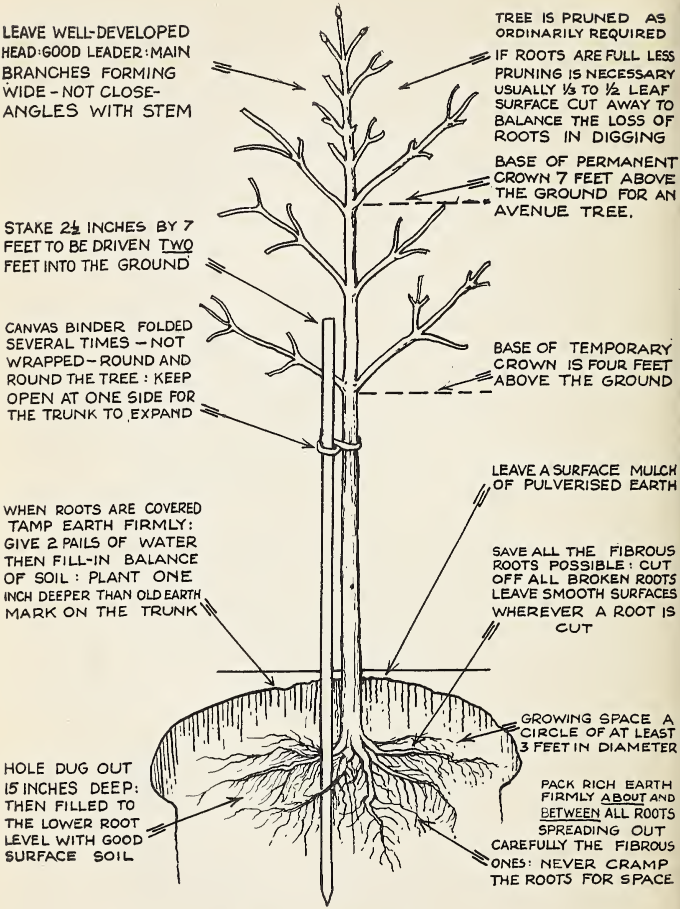


Fig. 42. Planting a tree.

Care should be taken not to expose the roots of trees which have been dug up for transplanting to the sun or air for any length of time. For this reason the change from one situation to another is best done in the evening or on a dull or rainy day, and the roots kept covered with sacking, or bedded in earth till planting can take place.

Most trees require heading back or pruning at the time of planting. The reason for this is that a balance must be established between the roots and the branches. The root-system, having been cut off in transplanting to a greater or less extent, there is not enough moisture taken from the soil to keep the leaves supplied if the whole top is left on the plant. Shrubs such as Spirea and Honeysuckle will not require this pruning; nor is the necessity so great with evergreens.

Windbreaks and Shelterbelts—On the open plains the winds have free sweep, and the climate is rendered inhospitable for people and for animals and many types of cultivated plants. With provision made for shelter the winters in the West are not nearly so inclement as they are sometimes supposed to be.

We distinguish between windbreak and shelterbelt, although the terms are often used as synonymous. Correctly speaking, a windbreak consists of one or two rows of trees or shrubs planted to break the mechanical force of the wind. A shelterbelt is much wider, having from six to fifteen rows of trees. It, too, breaks the force of the wind, but so much more effectively that there is comparative calm within the shelter.

The benefits of plantations of trees of this nature are as follows:

(1) They provide direct protection from the wind for house and buildings, as well as for stock and crops. Shelter for animals and for the farm premises in winter is always appreciated. It is not known as generally as it should be that protection of soils against drifting is one of the best

uses of the shelterbelt. Experiments of the Dominion Government at Indian Head have shown that during a windstorm in spring a shelter belt fifteen feet high protected the newly sprouted grain for a distance of 750 feet. Beyond this distance the crop was blown out completely. On the Dominion Forestry Farm near Saskatoon, Caragana hedges two and a half feet high and seventy-five feet apart protected the crop, while a short distance away on the same kind of land the crop was blown out.

(2) Snow is collected and held by the plantation of trees. This is valuable moisture for the soil in spring.

(3) Shelter belts, by checking the force of the winds in spring and summer, prevent drying out of the soil to some degree, and thus with their more extensive planting in the prairie country they are expected to make less severe the periodic crop failures due to drought.

(4) They may provide wood for fuel, for use on the farm, for parts of implements, for repairs, and for fencing. For the first, Poplar is of most value, since it grows rapidly; for the other purposes, Ash and Elm may be planted under the shelter provided by the poplars.

(5) A shelterbelt is valuable for ornament. It gives the farm premises a clothed look and makes them more attractive than the bare exposed surroundings of the average farm home.

(6) Trees attract the birds. Song birds and game birds find shelter when the trees have attained some size and their companionship, and usefulness in destroying insects are advantages to be considered.

Planning the Shelterbelt.—A plan of the whole shelterbelt should be made with relation to the farm buildings, and the planting then carried out by a series of additions over several years. It is necessary to consider the direction of the prevailing winds. The nearest building should not be nearer than about a hundred feet from the row of trees.

Sometimes it is planned to have a snow-trap. This is a single or double row of trees about a hundred feet away from, and outside, the shelterbelt. It checks and causes the snow to fall before it reaches the inner row of trees. In this case the trees of the inner shelter may be placed quite close to the farm buildings.

Planting.—Free trees are supplied by the Dominion Forestry Service at Indian Head to all farmers on the open prairie who make application for them, the only conditions being that the ground must be in good cultivation for the planting. The farmer may augment these with cuttings and one-year-old trees grown from seed. These are more quickly planted than older trees. No digging is required.

The trees are ploughed in; the plants are placed in rows four feet apart in the row. Cultivation should be continued until the trees completely shade the ground. This may be hastened by having the trees branch out near the ground.

Several varieties of trees should be selected for the farm plantation so as to give greater density in checking the wind. The Manitoba Maple is valuable for this purpose as it branches out freely from near the ground. The Russian Poplar is also valuable on account of its rapid growth and its branching habit. Trees should be planted with alternate rows of different varieties. Caragana may form the outer row. Longer-lived trees such as the Ash and Elm should be planted in the inner rows to form the permanent planting. Rows of Spruce may also be provided and some native shrubs such as Saskatoon, Choke Cherry, Dogwood, High-Bush Cranberry, will give greater density to the shelter, and add interest and variety to the whole group.

Exercises.—(1) Why are flowers grown? What is the effect of flowers on the home?

(2) What are the essentials of success in growing flowers in the house? How are house plants usually obtained? Which are suited to the shaded side of the house? How are insects kept in check? Name the worst of these, and describe them briefly. Why should plants be sprayed?

(3) What are the advantages of annuals over perennials, and what are some of the advantages of perennials? Name examples of each. Name annuals we must start in the hotbed. How are these treated before planting?

(4) What are the rules for planting trees and shrubs about the house and in a border for ornament?

(5) Name examples of each of the following: cultivated trees, native trees, shrubs, and climbing plants, suitable for ornament.

(6) Draw carefully with your ruler a plan of a farm home marking in the location of the trees and shrubs, the lawn, farm buildings, yards and shelterbelt.

(7) Tell how to plant a tree. Why should the branches be trimmed? Why is it desirable to do this early in the spring? What care is needed in regard to root exposure? Why is it best to stake tall trees firmly?

(8) Distinguish shelterbelt from windbreak? Do they serve to make the climate warmer?

(9) What advantages come from a shelter of trees about the farm buildings? Name kinds of trees which should have a place in it, and tell why.

(10) What is a snow-trap? Tell how it is provided. How are the shelters arranged with relation to the buildings? Why are the north and west sides most in need of protection by trees?

(11) How may trees be secured for the farm plantation? How should they be cared for? How are young trees quickly planted? How may additional trees be secured from these? In previous lessons you have learned how to prepare cuttings of young trees. Explain how it is done.

(12) Why should each of these have a place in the farm shelter belt: Russian Poplar, Manitoba Maple, Caragana, Ash, Elm, Dogwood, High-Bush Cranberry, Laurel-leaved Willow?

PART 3

INSECTS

CHAPTER XVII

Introductory

There are in Alberta several thousand kinds of insects. The activities of many of these have a very direct bearing upon our welfare. This is especially true in the case of agriculturists, but it applies, to a greater or less extent, to all of us.

It is chiefly in connection with the food insects consume that they are liable to attract the greatest attention. The individual insect is a small animal and, as such, rarely affects us very seriously. Some species, however, may occur in such vast numbers that, in the aggregate, they may consume a large proportion of our crops or of other materials required for our own use.

We must not, however, form the opinion that all insects are detrimental to our well-being. The injurious species undoubtedly attract the greatest attention, but the majority of the insects that live here either occur in such small numbers or their choice of food is such that their presence is not known to affect us to an appreciable extent. On the other hand, many insects are absolutely indispensable to our existence. These, for the greater part, are the insects that prey upon the injurious forms. In addition many kinds of flowers are unable to produce fruit or seed unless they are visited by insects, which feed upon the nectar stored at the base of the petals.

It is evident, then, that some insects are injurious, some have little effect upon our welfare, and many are very beneficial. How are we to judge which are our friends and which our foes? In order to answer this question we must know something about the activities of the insects, where they live, how they feed, and on what they feed.

Probably we already know that different insects have very different methods of obtaining food. Grasshoppers and Caterpillars bite off and swallow solid pieces of leaves, Mosquitoes drill small holes in our skin and suck up blood through tube-like mouths, while the House-fly may settle on a hard lump of sugar, which it is quite unable to bite, and yet it obtains food from it. Then, again, some insects feed only on the nectar that they obtain from flowers, others burrow into dead or living animals, while some live only in water.

When a number of different insects are compared we cannot but be impressed by the fact that in no two of them are the different parts of the body of exactly the same shape. In some the legs are long and straddling, in others they are short and flat. The wings of some insects are very delicate; those of others are so solid and immoveable that they are hardly recognizable as wings at all. Similar differences can be found in every part of the body. Why is this so? The answer is that every kind of insect lives a different life from every other kind of insect. The parts of the body are the tools with which it performs its life-activities and these have become modified till they are perfectly adapted to the work they have to do. Just as a carpenter must select the proper tool for some particular kind of work, so nature has selected, from an endless variety of mouth-parts, legs, wings, etc., the kinds best suited to the needs of that particular insect.

The Importance of Studying Structures.—When the tool-bag of a workman is examined one obtains a very fair idea of the occupation of the owner. We know, for instance, whether he is a plumber, a cabinet maker, a rough carpenter, or a builder. In the same manner, by studying the structure of a dead insect a great deal about the habits of that insect can be learned because the "tools" that are then examined are always very accurately selected for the work it performed during its life.

The Importance of Studying Living Insects.—The shape of the various parts of an insect's body may give a very accurate knowledge of *what* their particular use is, but we can never really understand *how* they are used unless we study the living insects themselves. We can do this by observing them at work in the place where they normally live, and also by confining a few in some kind of breeding cage in which we can keep a closer watch on some of their activities. Pupils should read all that they can about insects, but should never forget that more can be learned from studying the living insects themselves than has ever been written about them.

Collecting and Preserving Insects. — For classroom work we shall require some insects for examination. How are we to collect them and to preserve them? Send a post-card or letter (without a stamp—write O.H.M.S. where the stamp is usually affixed), addressed "Entomological Branch, Ottawa," and ask for the circular on "Collecting and Preserving Insects". This will give all the necessary information. With the help of this circular try to collect and to mount your insects properly from the start. Use the long black "insects" pins instead of house-pins, and always put a label on the pin, stating where and when the insect was caught. If everyone collects a few well-mounted insects your school will soon have a collection of which you will all be proud.

What to Collect.—For the school museum, collect all kinds of insects. For classroom exercises the following will be needed: Grasshoppers, Blue Bottle Flies, Butterflies, and Moths.

At any time in the summer one can catch all of these quite easily. Try to get large specimens and keep several of each so that, if some are spoiled in examining them, you will be able to take a new specimen with which to carry on.

Necessary Equipment.—A net, a killing bottle, a cigar box with a piece of corrugated cardboard or cork stuck to the bottom, in which to keep pinned specimens, and a piece of soft wood or cork about 6 inches square, on which to examine insects in class will be needed. The only other requirement is a pair of dissecting needles, which you can make for yourself. Get two large sewing needles and push the eye end of each into the end of a pencil or a penholder.

Breeding Cages.—If you wish to breed insects you can do so in the case of most insects in empty tobacco tins or in sealers. Put about an inch of just-damp sand in the bottom and give them a little of their normal food plant. Keep your "cages" clean. The biggest difficulty is to keep the moisture conditions right but it is possible to master this with practice.

Exercises.—(1) What is it in connection with insects that attracts our greatest attention? When does this danger become most serious? Are all insects detrimental to our well-being? Discuss. How are we to judge which insects are beneficial and which are injurious?

(2) What are the different methods by which insects obtain food? What is the importance of studying the structure of insects? Why should we study living insects?

(3) Explain fully what insects should be collected. When is the best time to make this collection? What equipment is necessary? How should insects be mounted? Describe the construction and care of a breeding cage.

CHAPTER XVIII

Characteristics and Structure of Insects

There are a great variety of small creatures which are often called "bugs" by people who do not know any better. Very few of these are bugs, and not all of them are insects. All of them, however (except the invisible Bacteria) are animals.

There are two very important kinds of animals:

(1) *Vertebrates.* Animals which have an *internal* skeleton composed of bones. These are sometimes called the "higher" animals and are represented by fish, reptiles, birds and mammals (four-footed animals and Man).

(2) *Invertebrates.* Animals that have no internal skeleton. They have instead a horny *external* skeleton which forms part of the body-wall. It usually consists of a number of separate, solid areas, called *sclerites*, which are joined together by flexible parts of the body-wall called the *connective membrane.*

There are several different *Classes* of invertebrate animals. All insects belong to the Class *HEXAPODA* (six-footed), and have the following characteristics in the adult stage, though these characteristics cannot be found in immature insects:

(a) Body composed of a number of rings or *segments.*

(b) Segments grouped into three regions, *head*, *thorax* and *abdomen.*

(c) *One* pair of *antennae* on the head.

(d) *Three* pairs of *legs* on the thorax.

(e) Usually *two* pairs of *wings* on the thorax.

(f) *No* legs on the *abdomen.*

Note: Of the characteristics listed above, *two* are possessed by no other adult animals, viz.: *six* legs and *three* body divisions.

Other insect-like Invertebrates belong to different Classes. Spiders, ticks and all other creatures that have *eight* legs and no head, antennae or wings are *Arachnida*. Millipedes and Centipedes have a head, but all of the body segments are similar and all bear legs. These belong to the Class *Myriopoda*. These, then are not insects.

The Structure of Insects.—Before we study any particular insect it will be well to note some characteristics which are common to all insects. Variations of these characteristics appear in individual insects as they have been specialized to do their several tasks in the life processes.

(a) *Head*. The structures of the head of an insect are adapted to feeling, seeing and food-getting. On the head are borne a pair of *antennae* which act as organs of touch and smell. If you watch an insect when it is searching for food you will notice that it waves its antennae about continually. In some insects the antennae are so short that they are hardly recognizable; in others, they are long and slender.

On each side of the head of nearly all insects is a large, immovable eye. Each of these eyes consists of hundreds of little eyes so crowded together that under a magnifying glass they resemble the cells of a honey-comb. Each little eye, or *facet*, sees only what is directly opposite it. The more swollen these compound eyes are, the more the insect can see at one time, because the facets then face in wider angles to each other: the insect sees, therefore, in a greater number of directions simultaneously. Just in front of the compound eyes you may see two small *simple* eyes. A third simple eye is usually present on the front of the head but it is difficult to detect without a lens.

There is a wide variation among insects in the types of mouths they possess, but it is convenient to group them as follows:

(1) *Biting*. Insects with biting mouths have a pair of horny jaws that open sideways. These are able to chew solid food.

(2) *Drinking*. A large number of insects cannot bite because their mouth consists of a soft tube through which food in the form of liquids is drawn. This type of mouth is found in Butterflies, Moths, and Bees, which roll up their mouths like watch-springs when they are not feeding. Many flies have drinking mouths which terminate in a pair of flat pads. These pads contain a number of tubes which open on the lower side. The liquid food is easily sucked up through these tubes. House-flies can feed on solids such as sugar, by dribbling saliva through these tubes. This saliva dissolves a little of the food and it is then sucked up by the fly in solution.

(3) *Piercing and Sucking*. The drinking mouths of many insects are horny and sharply pointed in order that with them they may pierce the protective walls of plants and animals and suck the internal sap or blood. The most common plant-feeding insects with piercing and sucking mouths are the plant-bees or Aphids. We are only too familiar with some of the blood-sucking insects, such as Mosquitoes and Gad-flies.

(b) *Thorax*. The thorax of an insect consists of three segments. They are called the *prothorax* (front segment), *mesothorax* (middle segment) and the *metathorax* (hind segment). These segments may be easily recognized as each bears a pair of legs. Nearly all mature insects have, in addition, a pair of wings on each of the mesothorax and the metathorax. There are, however, a few insects without wings, even in the adult stage.

(1) *Legs*. Legs consist of the following parts: *Coxa*—a short, more or less spherical segment by which the leg is attached to the body. *Trochanter*—a very small segment which is usually triangular. *Femur*—the largest segment of the leg. To this part are attached most of the leg muscles. *Tibia*—a slender segment which is almost as long as the femur. *Tarsus*—a group of approximately five short segments which form the "foot" of the insect. The last of these short segments usually terminates in a

pair of strong claws which assist the insect in retaining a firm hold while crawling. Between the claws many insects have a small pad called a *pulvillus*. This pad is covered with hollow hairs through which a sticky substance escapes. This sticky substance enables the insect to walk up smooth surfaces and to walk upside down across ceilings and other surfaces. The hind legs of Grasshoppers and some other insects are adapted for jumping, and they are therefore much longer and stronger than the two front pairs.

(2) *Wings*. The simplest type of wings is found on the Dragon-fly in which both pairs are similar in shape and size. They consist of transparent membranes strengthened by a number of thickened veins. In many insects either or both pairs of wings have been specialized to an unusual degree. In Beetles and Grasshoppers the front pair of wings is quite thick and tough. It is of little use in flying but serve mainly as a protection for the hind pair. It is called *elytra*. The hind pair is often membranous as in the Dragon-fly. In Beetles and Grasshoppers the hind pair is folded under the *elytra* when not in use. Moths and Butterflies have two pairs of wings, both of them membranous and covered with minute, flattened scales arranged on the membranes somewhat like shingles on a roof. These scales often give to the wings very brilliantly coloured patterns.

(c) *Abdomen*. The abdomen consists of a number of segments fitting into each other like the sections of a telescope. It can, therefore, be lengthened or shortened. This is done by muscles which are attached to the inner sides of the segments. By the lengthening and shortening of the abdomen insects are able to breathe. Each of the first eight segments of the abdomen has a pair of *spiracles*, one on each side of the body. There are also two pairs of spiracles on the thorax. These spiracles are entrances to *tracheal tubes* through which air is carried to all parts of the body. Each tracheal tube is lined inside with a continuous thread arranged like a coiled spring. This spring has a tendency to keep the tube round though it can be easily pressed flat. An insect's body is somewhat like a closed "bag" which is filled with liquid blood into which the digested food has passed through the walls of the stomach. This blood and the digested food within it are constantly in contact with these tracheal tubes, hence it is in contact through the tubes with the oxygen in the air. Muscular contraction causes the segments of the abdomen to telescope into each other. This reduces the volume of the "bag". The blood and solid tissues inside the body cannot be compressed; the trachea are compressed and the air expelled through the spiracles. When the abdomen muscles relax the pressure on the trachea is removed and the coiled threads cause the trachea to spring open and to draw in fresh air through the spiracles.

At the tip of the abdomen in the female insects is the egg-laying apparatus or ovipositor. This organ is modified in many insects depending upon the place where the insect normally lays its eggs. Butterflies and Beetles, which lay their eggs on the surface of leaves, etc., have very small and simple ovipositors. Grasshoppers which lay their eggs in the ground have digging ovipositors. Parasites, a large group of insects, usually lay their eggs inside Caterpillars or other insects. They have long, hair-like ovipositors which can be driven deeply into the body of the attacked insect before the eggs are laid. Worker-bees and Wasps do not lay eggs; in these insects the ovipositor is used as a sting.

Exercises.—(1) Show that the term "animal" used in its scientific sense includes many forms of life which are not popularly classed as animals. Why are insects included in the class "invertebrates"? State six characteristics of the bodies of all insects. What facts support the assertion made in this chapter that Spiders are not insects?

(2) Describe briefly the general features of the body parts of insects. What are the names of the three body parts? Give the name and position of the chief organs observed on each. What variety of forms occur of mouth-parts, eyes, wings, and legs?

CHAPTER XIX

Growth, Metamorphosis, and Life-cycles of Insects

Nearly all of the different kinds of insects reproduce by laying eggs, though a few give birth to living young.

Growth.—The insect's "skin" or *cuticle* is rather like a suit of clothes which cannot become larger as the body within it grows. It therefore has to be sloughed, from time to time, by a process called *moulting.*

When a young insect first escapes from its egg its cuticle is very soft and much wrinkled, but it rapidly expands to its full extent and becomes hard. The insect then proceeds to eat until the cuticle is completely filled and is stretched to its utmost. By this time, however, a larger cuticle has been formed inside the old one, which now splits just behind the head and along the top of the thorax. Through this opening the insect draws its body, clad in its new soft cuticle. When this has expanded and hardened the insect resumes its feeding till a second moult becomes necessary. The majority of insects moult between three and six times before they are full grown, or *mature.*

Metamorphosis.—Mature insects, or *adults,* only, have wings. Once an insect has developed its wings there is no further growth and no more moulting. Little flies never grow into big ones. All growth, therefore, takes place during the *immature* stages.

Immature insects are often very different in appearance and in habits from the mature insect. The change they must undergo during maturation is called the *metamorphosis.* According to the amount of change that takes place the different kinds of insects can be placed into two groups as follows:

(1) *Incomplete metamorphosis.* The immature insect, or *nymph* is very similar in shape, and usually in habits, to the mature insect except that it is smaller and has no wings. It is active from the time it escapes from the egg until it is mature. There are thus three stages in its development: egg, nymph, and adult. Examples are Grasshoppers and Dragon-flies.

(2) *Complete metamorphosis.* The structures, and usually the habits, of the immature insect, or *larva*, are so different from those of the adult that it is usually impossible to recognize them as belonging to the same insect. The transformation of a larva into an adult is so great that it can take place only if the insect is in an almost inactive condition. This necessitates a fourth stage, resting or *pupal* stage, in the development of these insects. The four stages are: Egg, larva, pupa, and adult. Examples are Butterflies, Moths and flies.

Since in the pupal stage they are very helpless the larvae of many insects spin around themselves a solid felting of silk before they *pupate*. This is known as a *cocoon*, and it must not be confused with the pupa which is inside it.

Life-Cycle.—Mature insects, only, can reproduce. When an insect has developed from the egg stage through the growing stage and has become an adult that is ready to lay eggs it has completed the *life-cycle*, and the next *generation* begins when it has deposited its eggs. The majority of insects have one generation a year; others, such as the House-fly may have ten or more generations in a year. A few insects, of which the Wireworms and White Grubs are examples, require about four years to complete their life-cycle, while that of the Cicada lasts for seventeen years.

Exercises.—(1) Explain fully how a young insect grows. Explain why "little flies never grow into big flies." When does growth take place?

(2) Define the term metamorphosis. Illustrate and explain incomplete metamorphosis, complete metamorphosis, and life-cycle.

(3) Why should we not consider the Cutworm a true worm like the Earthworm?

(4) Of what advantage is it to us to know that the life-cycle of the Wireworm (a destructive pest) is at least four years?

(5) What error is there in considering the pupa of an insect a "resting stage"? Name insects which are enclosed in a cocoon at this stage. What is the purpose of the cocoon?

(6) During the winter the student might collect cocoons from the limbs or under the bark of trees and place them in bottles covered with cheese-cloth. In the spring these cocoons will open. Why should the bottles in which the cocoons are placed not be tightly corked? Bees and Wasps in the larva and pupa stage may be seen in the cells of the comb.

CHAPTER XX

The Classification of Insects

Insects are classified chiefly upon the following characters: Type of mouth parts, shape and structure of wings, and the kind of metamorphosis they undergo.

Upon variations in these characters all the insects of the world are divided into about twenty-six *Orders*. Only eight of these are very important in western Canada, though representatives of several others occur here.

(1) *Orthoptera* (straight-winged). Mouth-parts biting; front wings narrow and leathery; hind wings fold like a fan when not in use; metamorphosis incomplete. Examples: Cockroaches, Grasshoppers, Crickets, etc. (See Figures 50–52).

(2) *Odonata* (tooth-mouthed). Mouth-parts biting; all wings membranous and similar in size; metamorphosis incomplete; nymphs live in water. Examples: Dragon-flies and Damsel-flies. (See Figure 43.)

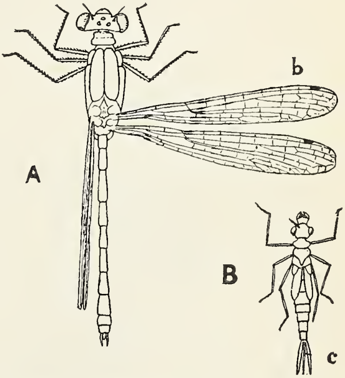


Fig. 43. Odonata. (A) Damsel Fly. (B) Nymph. (b) Both wings membraneous and similar.

(3) *Hemiptera* (half-winged). Mouth-parts piercing and sucking; front wings half leathery and half membranous;

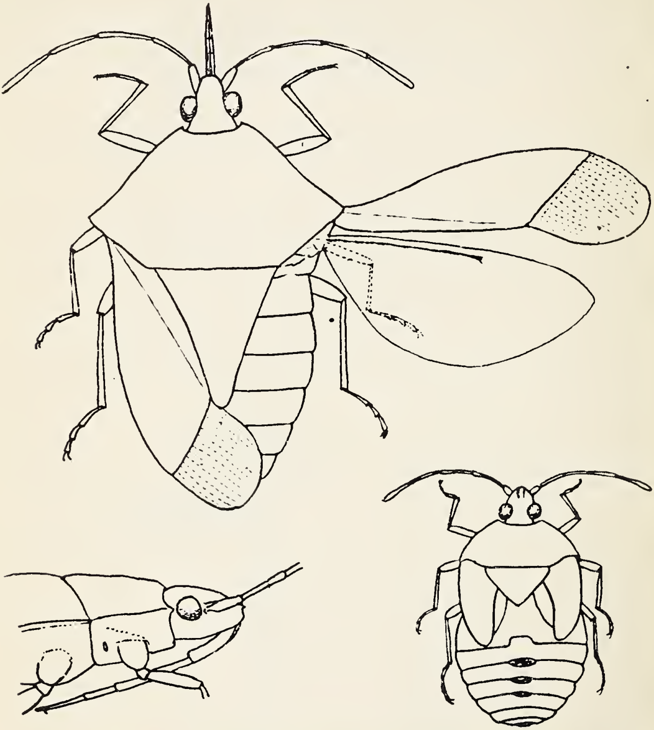


Fig. 44. Hemiptera. Adult Stinkbug: the nymph is shown at the lower right.

metamorphosis incomplete; many feed on plants, others on insects, and a few on blood. Examples: Bugs (Water bugs and Striders, Plant bugs, Bed-bugs, etc.). (See Figure 44.)

(4) *Homoptera* (uniform winged). Mouth-parts piercing and sucking; all wings membranous (many have no wings); metamorphosis incomplete; all are plant feeding. Examples: Plant lice (Aphids), scale insects, etc. (See Figure 45.)

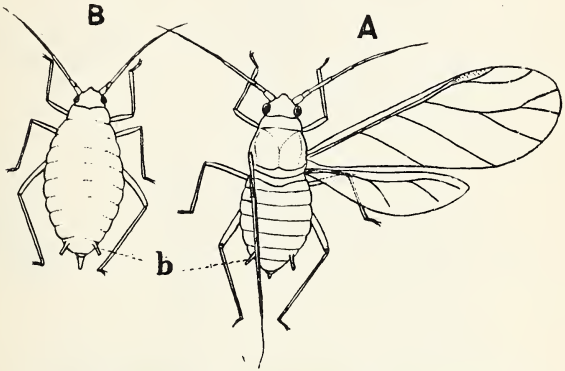


Fig. 45. Homoptera. (A) Winged Aphis. (B) Wingless Aphis.

(5) *Lepidoptera* (scaly-winged). Mouth-parts drinking; all wings membranous but covered with scales; metamorphosis complete. Larvae are Caterpillars with from two to five pairs of "false legs" on the abdomen; nearly all feed on vegetation; adults feed only on nectar of flowers. Examples: Butterflies and Moths. (See Figure 46.)

(6) *Coleoptera* (sheath-winged). Mouth-parts biting; first pair of wings horny (elytra), second pair membranous and folded under elytra when not in use; metamorphosis complete; feed on a great variety of materials, such as vegetation, other insects, dead animals, and manure. Examples: Beetles. (See Figure 47.)

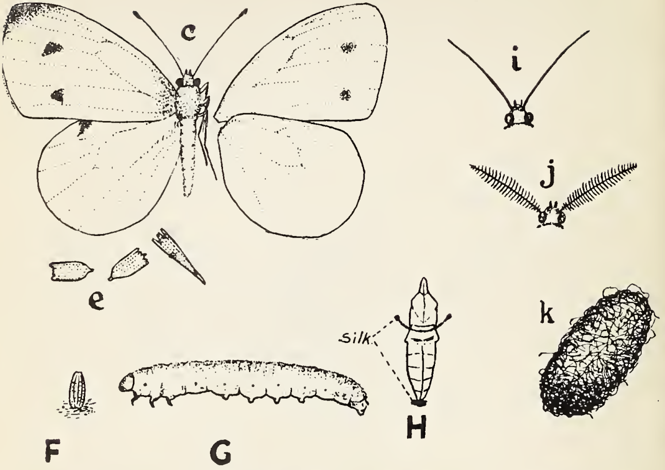


Fig. 46. Lepidoptera; (upper left) Adult Cabbage Butterfly. (F) egg; (G) Larva; (H) Pupa of Butterfly (never in cocoon); (e) scales from wing greatly enlarged; (k) silken cocoon containing pupa of Moth; (i) antennae of female moth; (j) antennae of male Moth.

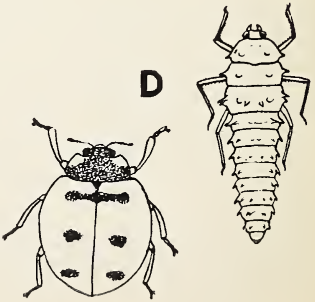


Fig. 47. Coleoptera.

(7) *Diptera* (two-winged). Mouth-parts either drinking or piercing and sucking; first pair of wings membranous, hind pair reduced to balancers; metamorphosis complete; larvae

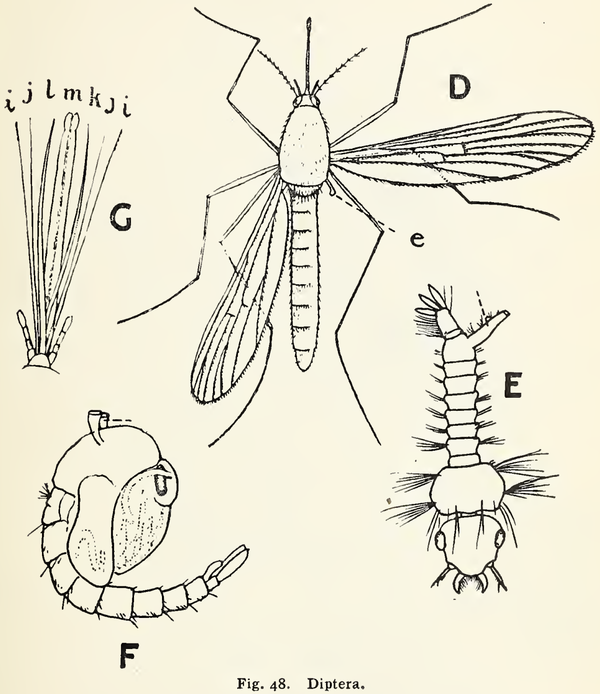


Fig. 48. Diptera.

may live in water (Mosquitoes, etc.), or in vegetation (Root Maggots, etc.), but majority live on decaying flesh, in manure or in other insects or animals; adults feed on exposed fluids or drink blood. Examples: Flies. (See Figure 48.)

(8) *Hymenoptera* (membranous winged). Mouth-parts either biting or drinking; all wings membranous, hind pair smaller than front pair, many are wingless; metamorphosis

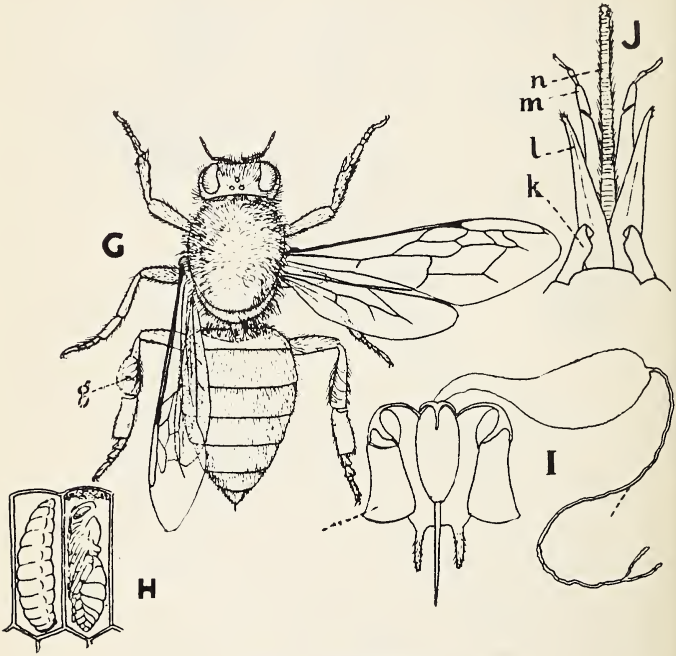


Fig. 49. Hymenoptera.

complete; larvae live on animal or vegetable matter, which is often fed to them by their parents or by "workers"; many live as parasites inside other insects. Examples: Sawflies, Bees, Ants, Wasps and Ichneumons. (See Figure 49.)

Study of Orthoptera.—The Grasshopper is a common member of this Order. A freshly-killed Grasshopper is soft and the parts of its body can be easily moved, but specimens that have been kept for some time must be softened, or re-

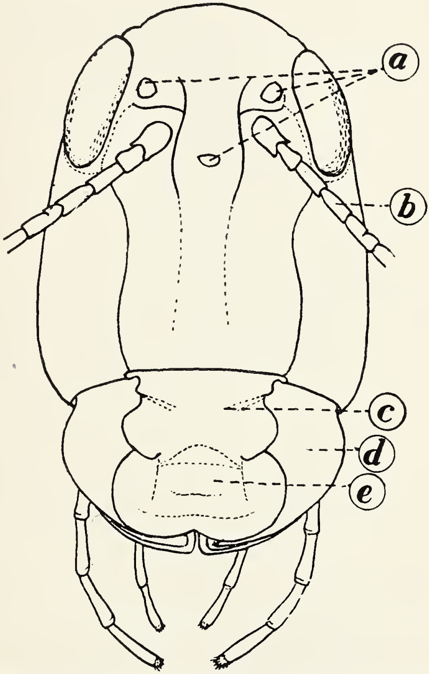


Fig. 50. Head of Grasshopper. (a) ocelli; (b) antennae; (d) mandible; (e) labrum.

laxed, before they can be examined properly. If a freshly-killed specimen is not available, relax your specimen by placing it in hot water, leaving it to soak until you can move the legs and the antennae in any direction without breaking them. After approximately ten minutes soaking, remove the specimen and dry off the surplus water with a piece of blotting paper. Place the specimen on its side and comparing it with the illustration (Figure 52) locate and examine the following structures:

On the head, notice the antennae, compound eyes, ocelli or simple eyes, and the mouth-parts. At the lower part of the

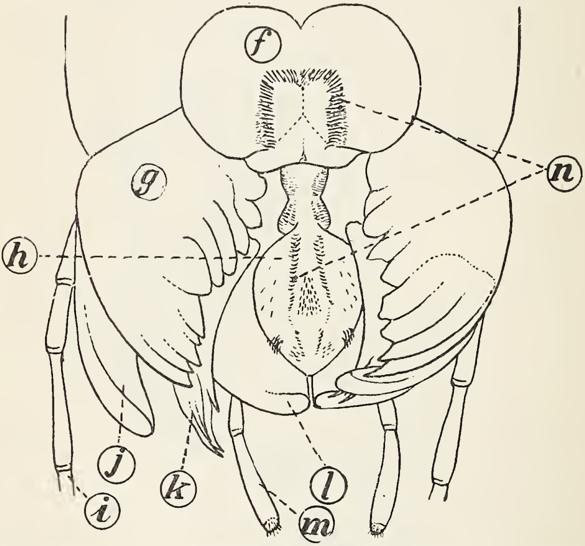


Fig. 51. Mouth parts of grasshopper. (f) labrum; (g) mandible; (h) hypophyrax; (i) maxillary pulp; (m) labial pulp; (n) hairs for tasting food.

front of the head is a movable flap, the labrum, hanging over the mouth. Raise the labrum with your dissecting needle. This lays bare the true jaws. These are mandibles which open sideways and have jagged teeth where they meet. The mandibles are used for cutting food. Immediately below the mandibles are a pair of soft jaws or maxillae, which are used for carrying food. Between the maxillae is the brown tongue with which the Grasshopper tastes the food he is about to swallow. At the back of the lower part of the head is the lower lip or labium.

The Grasshopper is an example of those insects which have biting mouth-parts.

The three segments of the thorax—the prothorax, mesothorax and metathorax—are fairly easily recognized. Each bears a pair of legs and, as is the case with all flying insects, the first pair of wings is on the mesothorax and the second pair is on the metathorax. The first and second pairs of

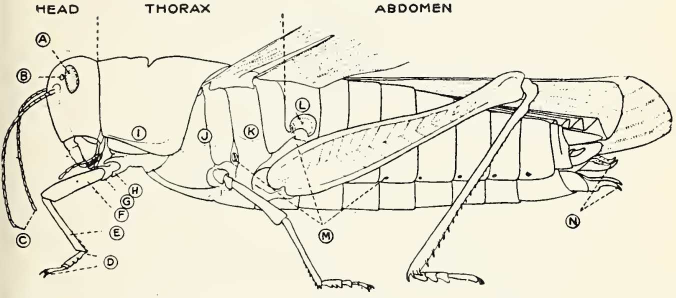


Fig. 52. Drawing of a Grasshopper. (A) Compound eye; (B) ocellus; (C) antennae; (D) Tarsus, (E) Tibia, (F) femur, (G) Trochanter, (H) Coxa, } Leg; (I) prothorax; (J) mesothorax; (K) metathorax; (L) ear; (M) spiracles; (N) ovipositor.

legs are used chiefly for crawling. Compare the length and strength of the hind legs with that of the two front pair. Observation of a live insect will explain why these legs are called the "jumping legs". If you examine the inner side of the femur of the third pair of legs with a lens, you will notice a row of small spines. The "singing" of the Grasshopper is produced by rubbing the outer wings against these spines.

The front wings are of the same colour as the rest of the body. They are narrow and leathery and serve largely as a protection for the second pair. If you spread one of the hind wings open, you will find that it is either transparent or else very brightly coloured. Notice also its width and delicate texture and how neatly it folds like a fan under the front wing when the insect is at rest. The hollow veins in the hind wings stiffen them for their work in flight. The drab colour of the outer wings renders the insect less conspicuous at rest than when the hind wings show, as in flight.

The abdomen consists of a number of very similar segments that fit into each other like the parts of a telescope. The spiracles are rather small, but they can be fairly easily seen at the sides of each of the first eight segments. At the side of the first segment of the abdomen, so far forward that it almost appears to belong to the thorax, is a large opening covered with a white membrane. This is the ear of the Grasshopper. Few insects have ears in this place: in the majority of them there are no special ears, but they have hearing organs scattered all over the body. In many insects most of these hearing organs are inside the front legs. If you are examining a female Grasshopper you will find the ovipositor at the tip of the abdomen. It consists of four movable claws. The tip of the abdomen of the male Grasshopper turns upward and is rounded.

Study of Lepidoptera.—Moths and Butterflies should be examined together. Note that a fine dust is removed by your fingers when you touch the wings. This consists of innumerable *scales* or flattened hairs which are arranged on the body and both sides of the wings like shingles on a roof. Carefully rub a piece of the wing between your finger and thumb and notice that it is transparent when the scales have been removed. The scales thus give the colour to the wings. They also shed water and strengthen the wing.

In order to distinguish between a Moth and a Butterfly it is only necessary to examine closely the tip of the antennae of a specimen which has not been injured. Butterflies always have the end of the antenna swollen or clubbed. The antennae of Moths are never clubbed, although some species have feathery antennae.

The mouth of the Butterfly is not prominent, as it is coiled up under the head like a watch-spring. Uncoil it with your dissecting needle, and you will notice that it consists of two maxillae which are joined together to form a long flexible tube. There are no toothed mandibles. Thus, Moths and Butterflies cannot bite but use the long tube to suck up liquid food such as nectar from flowers. The fact that Moths and Butterflies have sucking and not biting mouth parts is of great importance to agriculture, as it means that the insects can only do damage in the larva (Caterpillar) stage.

Study of Coleoptera.—We shall choose as our example in this Order the large Ground-Beetle, the Cutworm-destroy-

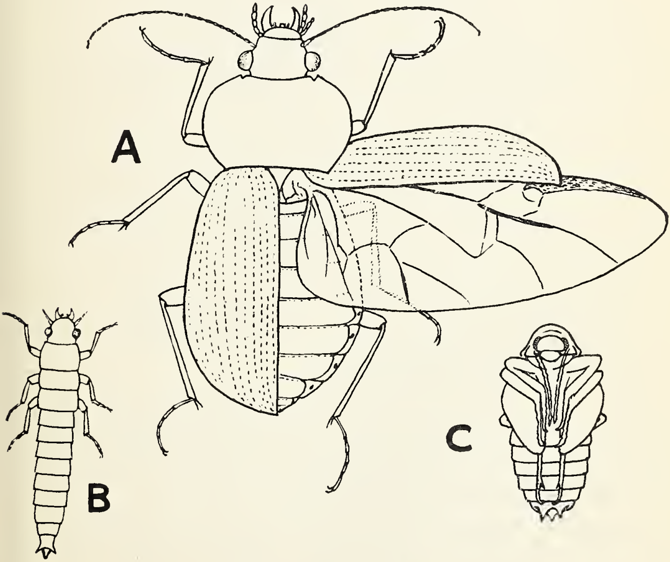


Fig. 53. The Ground-Beetle.

ing "Fiery Hunter". In other beetles the structures are somewhat different.

Relax the Beetle in hot water if it is not freshly killed. Examine it carefully and note that its body is entirely covered with *sclerites*. When the elytra are closed over the abdomen no connective membrane is visible.

The mouth-parts are essentially the same as those of the Grasshopper. Each individual structure is, however, slightly different in shape.

In a careful examination of the legs we shall discover the "ball-and-socket" attachment of the front legs. The coxae of the hind legs are very wide, flat and immovable. The trochanters hang down behind the femora.

Underneath the elytra are the hind pair of wings used for flying.

The spiracles are along the upper side of the abdomen. Do the segments telescope into each other? How does the Beetle breathe?

Study of Diptera.—A Blue-bottle Fly, because of its large size, is more suitable for study than a House-fly. Since these can be obtained alive at almost any time of the year it is advisable to examine one that has just been killed, and has not had time to dry out. Hold the wings of the fly at right angles to the body. Notice the two small transparent flaps on the sides of the thorax just behind the point where each wing is attached to it. These are part of the wing. Raise one of them, and underneath you will see a tiny organ that is shaped somewhat like a drumstick. This is a *balancer*, and is all that remains of the hind wing.

If you examine the legs closely you will see little white specks at the end of each. These are walking pads which are covered on the under side with hollow hairs through which a sticky material escapes. This enables the fly to walk up smooth surfaces, or even upside down.

Compare the length of the antennae of the fly with those of the Butterfly and Grasshopper. Note the bristle in the middle of the antenna. You can hardly distinguish the mouth-parts without the aid of a microscope, but if you place the specimen on its side on a piece of white paper and squeeze its head gently with the head of a pin. This will force down the mouth-parts. You can see a tube-like structure ending in a flat, blunt pad hanging from the head. This pad con-

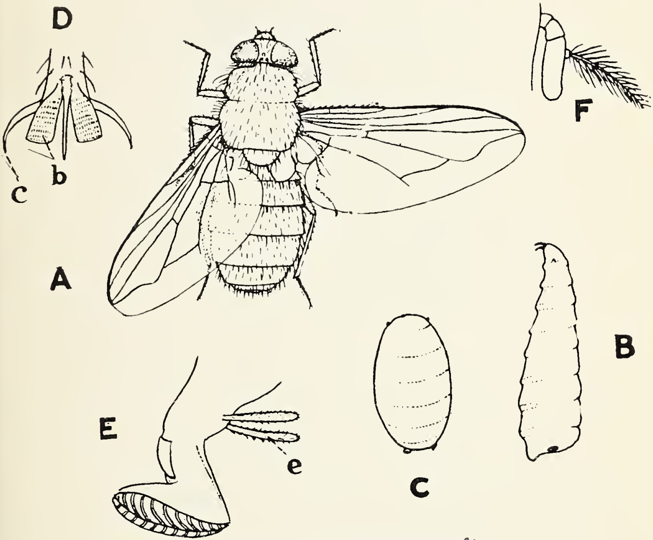


Fig. 54. The ~~House-fly~~. Blue-bottle fly.

tains a number of tubes which open on the lower side. Liquid food is easily sucked up into the mouth through these tubes, but as we have seen House-flies can feed on solid material, such as sugar, by dribbling saliva through these tubes.

Exercises.—(1) With what parts of the mouth does an insect taste its food?

(2) What organs close the front of the mouth of a Grasshopper?

(3) Which margin of a Grasshopper's front wing is uppermost when the wings are closed?

(4) How many segments are there in the abdomen of a Grasshopper? Are there spiracles on each segment?

(5) Are the mandibles of a Ground-Beetle of the same shape as those of a Grasshopper?

(6) The mouth-parts of a Grasshopper point downwards while those of a Beetle point forwards. Can you suggest any reason for this?

(7) What does a Beetle do with its elytra when flying?

(8) Why is a fly able to walk up a window-pane?

(9) By what structure can you always distinguish a Butterfly from a Moth?

(10) Why does a Bee die after it has stung anyone?

CHAPTER XXI

Beneficial Insects

Economic Classification of Insects.—In studying the effects of insects upon the welfare of the farmer we may divide these members of the animal kingdom into three great groups: (1) Injurious Insects which we may regard as our foes because of their damage to field and garden crops, shade trees and bushes, and farm animals. (2) Neutral Insects which do not appear to affect our welfare to any appreciable extent. (3) Beneficial Insects which render us service by either preying upon their relatives which are injurious to Man's interests, or pollinating flowers, or providing us with food. In this chapter we shall deal with the insects which are of most value to the farmers of the province.

Predators.—Insects which capture other insects and feed upon them are called *predators*.

(1) *Dragon-flies and Damsel-flies.* These rapidly flying insects feed entirely upon small insects such as Mosquitoes, which they capture while flying. The nymphs live in water where they eat both larvae and pupae of Mosquitoes.

(2) *Ladybird Beetles.* The Ladybird Beetles are small red beetles with black spots on the outer wings and are popularly known as "Lady-bugs". They spend the winter in the adult stage. In early spring they locate small colonies of Aphids (Plant-lice) upon which they feed. They lay clusters of orange-coloured eggs. From these eggs emerge oblong black larvae which feed even more voraciously on the Aphids than do the adult beetles. When the larva is mature it hangs head downwards, and the cuticle splits across the thorax, and the pupa is half-exposed from it. Here it hangs for about a week before the adult beetle escapes.

(3) *Ground-Beetles.* Nearly all the small very active black beetles that are found under boards or clods on the ground feed in their larval and adult stage on young Cutworms, Wireworms, Grasshopper eggs, etc. The larvae live almost entirely underground and usually are white with large brown heads.

(4) *Tiger Beetles.* These long-legged active beetles are found in the greatest numbers in sandy districts. Their larvae live in vertical tunnels in the soil. Both stages feed entirely upon other insects such as House-flies.

(5) *Wasps.* The common black and yellow "yellow-jackets" or hornets feed their grubs on House-flies, Blue Bottle Flies, etc. Another interesting insect is one of the Digger Wasps, a slender-waisted black insect with black wings. It is about three-quarters of an inch long, and can be seen in early summer running over the surface of the soil. It is one of the worst enemies of the Cutworm. The female Wasp searches here and there in cracks in the ground. Suddenly she is seen to be digging with great excitement. Soon a Cutworm is exposed. The Wasp paralyzes but does not kill her prey. She then drags it with her mandibles to a hole that she has already dug in the ground, pushes it into the hole, and lays an egg upon it. She then fills the top of the hole with earth. Later a larva hatches from the egg and at once begins to devour the helpless though living Cutworm.

(6) *Hover-flies.* The larvae of many of the black and yellow wasp-like flies which are so abundant on flowers in the fall are either yellow or green grubs that feed entirely upon Aphids.

Parasites.—(1) *Ichneumon Flies.* These are small wasp-like insects, usually red, or red and black in colour and armed with long ovipositors. They fly constantly from place to place hunting for Caterpillars. When they have found one they settle alongside, and suddenly thrust their ovipositor deeply into the body of the Caterpillar. The attacked insect usually whips its head around and bites at the Ichneumon. It is too late, however, as an egg of the Ichneumon has passed into its body, and the wary fly is already flying away rapidly. Soon a minute grub emerges from the egg inside the doomed Caterpillar. It grows rapidly without causing apparent damage to its host. When the grub is fully grown it kills its host, pupates, and later escapes as an adult Ichneumon. Sometimes several parasites can mature comfortably within one host, but many parasites are so large that there is room for but one.

(2) *Tachinids.* The Tachinids resemble Blue Bottle Flies in size, but their body bristles are much stouter. They are either grey, black, or red in colour. As a rule they have no ovipositor. They lay their eggs either on the surface of the host's body into which the maggot later bores, or else on the leaves on which it is feeding, so that the eggs will be swallowed with the food.

Honey Bees.—We all realize that honey production, which is rapidly becoming an important source of revenue to Alberta, will always be dependent more on the industry of the bee than upon our own. We are inclined to forget the service rendered by these insects in the pollination of the flowers of the Alfalfa, thus causing the seed to set.

Exercises.—(1) Which group of insects do you consider to be most useful to Man? Give reasons for your answer.

(2) Show how each of the following insects is a friend of Man: Bee, Ichneumon, Ladybird Beetle, Dragon-fly.

(3) Make a list of insects which do not seem to be the cause of any economic gain or loss to Man.

CHAPTER XXII

Injurious Insects of the Garden

Aphids or Plant-lice. Nearly every kind of plant is attacked by some kind of Aphid. They pass the winter on the plants as eggs, which hatch into wingless Aphids in the spring. These rapidly produce several generations of wingless Aphids which form dense colonies on the leaves and stems. They suck the sap from the leaves with their piercing and drinking mouths and may cause them to wilt and die. During the summer, winged specimens are produced. These fly to fresh plants on which they produce fresh colonies of wingless Aphids. Some kinds of Aphids, such as the Cabbage Aphids, fly only to other Cabbages at this time. The Aphids that attack Currant leaves, however, and many others, always fly in the summer to an entirely different plant, such as Dandelions, etc. In the fall, another generation of winged Aphids appears on the Dandelions, etc., and these fly back to the Currants in order to lay their eggs. The Manitoba Maple often suffers from an infestation of Plant-lice in Alberta.

Cabbage White Butterfly. This Butterfly is an undesirable immigrant from Europe. It first appeared in North America in the City of Quebec in 1860, and is now found throughout the continent. The yellow eggs are laid on the leaves of the Cabbage, Cauliflower, and other Cruciferae. The Caterpillar, which is velvety green with a faint yellowish stripe down the back and on each side, eats large irregular holes in the leaves of the plants upon which the eggs are laid. There are two generations yearly, and the winter is passed in the pupal stage. The pupa is not enclosed in a cocoon, but is attached to some support above ground by a loop of silk around the middle of the body.

Beet Webworm. This insect is rarely very injurious in Alberta, but it frequently attracts a considerable amount of

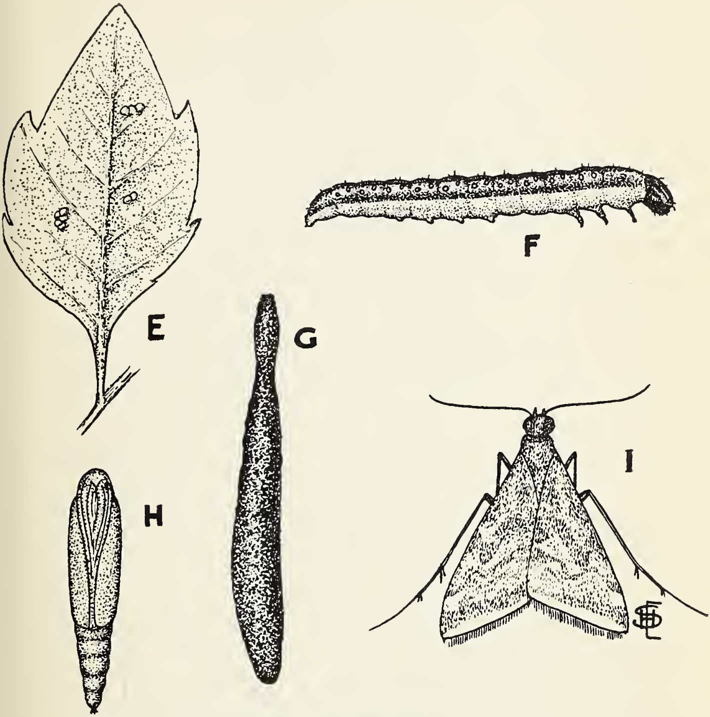


Fig. 55. The Beet Webworm.

attention. The full-grown Webworm is a slender Caterpillar of about one inch in length. It is green or yellow, with distinct black stripes and small circles on its body.

The pupal stage is passed in the soil in an elongated silken cocoon, which is placed in a vertical position. It is covered with fine particles of earth, is about an inch to an inch and a half long, and it resembles a small piece of stick or root.

The adults are the small light-brown Moths which fly along the sides of roads and are often so abundant that they rise in clouds when they are disturbed by a passing vehicle.

The eggs are laid most frequently on the leaves of Lambs' Quarters, upon which plant the Caterpillars feed. When they are very abundant they soon completely destroy these weeds and then move off in an "army" in search of more food. As they travel they feed on a great variety of plants. Migrating armies of these Webworms occur nearly every year in different localities in Alberta, and they sometimes consist of such vast numbers that they have occasionally been known to stop trains.

There are two generations a year, and swarms of these Caterpillars are liable to occur early in July and again towards the end of August. The winter is passed in the cocoons, either as larvae or as pupae.

Fortunately for us, Beet Webworms do not eat grain and, when they pass through a field of Wheat or Oats, they will remove all of the weeds but do no damage to the crop. For this reason they are very beneficial in grain fields. They will frequently destroy entirely dense growths of Lambs' Quarters, Russian Thistle, Pigweed, etc.

In gardens, however, they work havoc in a very short time, and will rapidly destroy all varieties of plants that are usually grown in them. They are also destructive to Beets, Flax, and Alfalfa.

If Beet Webworms are forsaking their good work in the destruction of weeds in grain fields and are entering gardens, or some susceptible crop, a deep furrow should be ploughed along the side from which they are entering. This furrow must then be treated with some poisoned bait. Grasshopper bait is very effective, but even better results can be obtained by the use of some green vegetation upon which they will feed readily. Moisten the vegetation, sprinkle a little Paris Green on it, and scatter it along the furrow.

Plants which are already attacked should be sprayed with Paris Green.

Colorado Potato Beetle. This insect is doing considerable damage in the southern part of the province. The adult Beetles are about one-third of an inch long, and are readily recognized by the black lines which run lengthwise on the orange or yellow wing covers. The bright orange eggs are laid on the under side of the Potato leaves. The larvae, often known as the "soft shells" are soft-bodied, hump-backed creatures, brownish-red in colour, which devour the leaves of the Potato. In July or August, the larvae work their way down into the ground, where they pass the pupal stage. When the adults emerge they also feed upon the Potato plant, and then spend the winter in the ground.

Red Turnip Beetle. These are black and red striped Beetles about one-quarter of an inch long. The eggs are laid in the fall below ground. The black larvae come to the surface and feed only at night-time. They attack Turnips and Cabbages in the northern part of Alberta. If these plants have been badly attacked they should be grown in some other part of the garden the following year.

Flea-beetle. These are tiny black Beetles, about one-tenth of an inch long, which eat small round holes in the seedling leaves of Cabbages, Turnips, etc. They are very active and jump like fleas when they are disturbed. They are controlled by spraying the plants with Bordeaux mixture.

Cabbage Root Maggot. In all parts of Alberta the roots of Cabbage, Cauliflower, Turnips, Radishes and other Cruciferous plants are frequently infested with small white Maggots. The Maggots are the larvae of a fly that closely resembles the House-fly. Early in May, the flies lay about fifty eggs on the surface of the ground or on the stems of the attacked plants. When the Maggots emerge from the eggs they burrow deeply into the roots. Cabbages that are severely infested wilt and die, while Turnips and Radishes are rendered quite unfit for human consumption. There are often three generations of these insects in a year, but the greatest damage occurs when the plants are small.

If small discs of tarred paper are placed around the stems of the plants they will prevent the flies fron laying their eggs upon the plants. As soon as Cabbage or Turnip seedlings appear above ground they should be watered with a solution of four ounces of corrosive sublimate in fifty gallons of water. Corrosive sublimate is a very deadly poison, and should not be used on Radishes that are to be eaten in less than a month's time after the application of the poison. The Onion Maggot resembles the Cabbage Root Maggot but it attacks Onions only. A solution of hellebore or of pyrethrum should be used on affected plants. Corrosive sublimate must *not* be used on Onions.

Insects Injurious to Shade Trees and Bushes

Forest Tent Caterpillar. This insect has done considerable damage to the trees in the central part of the province during the past few years. The adult Moths, which are light brownish yellow in colour, are found fluttering around the trees and lights in July. The eggs are laid in late summer in a compact mass around the twigs of Poplars and Willows and are covered with a protective shiny varnish. They hatch in the spring into bluish Caterpillars, with a row of conspicuous diamond-shaped white spots along the back. The Caterpillars attack the leaves of practically any trees other than the evergreens. When full grown they are about two inches long. Despite its name the insect does not construct a tent or web, as does the Tent Caterpillar which is a pest in the orchards of eastern Canada. The Caterpillar spins a silken cocoon about itself, and remains in the pupae stage for about two weeks. Fortunately large numbers of the pupae never emerge from the cocoon owing to the good work of parasites. Outbreaks are liable to occur every seven to twelve years, and usually last for three years.

Bark-beetles. These Beetles, which are rarely more than an eighth of an inch long make tunnels just under the bark of trees. They lay eggs along the sides of these tunnels and the larvae make short tunnels at right angles to the parent tunnel. These tunnels can be easily seen by removing dead bark from fence posts, etc. Thousands of trees are killed every year in the forested areas of Alberta by these Beetles.

Tree-boring Beetle. The larvae of several kinds of Beetles bore into healthy trees and often kill them. The most common are those of Beetles which have antennae that are longer than the rest of their bodies.

Currant Maggot. These insects are the larvae of a small fly. They live in Currants, and cause them to turn red, shrivel and to fall from the bushes. The only control known is to allow poultry to run among the bushes, and to pick up the fallen fruit.

Currant and Gooseberry Sawfly. This is a black spotted, yellow "false-Caterpillar," which has seven pairs of "false legs" on the abdomen, the larva of a somewhat wasp-like, yellow and black Sawfly, one-third of an inch long. The eggs are laid in slits cut along the veins of the leaves. The larvae rapidly strip the leaves from the bushes and pupate in the soil. There are two generations in a year. It is controlled by spraying the bushes with hellebore.

Caragana Beetles. One often sees slender, brilliantly coloured blue Beetles with purple wing covers on Caragana bushes. The adult Beetles destroy not only the leaves of the Caragana, but also those of the bean and other leguminous plants. The larvae feed, probably entirely on honey stored by wild Bees.

CHAPTER XXIII

Grain-Destroying Insects of Alberta

Grasshoppers. There are nearly one hundred different varieties of Grasshoppers in Alberta. Of these, very few are ever injurious to crops. Many feed only on prairie sod or certain weeds; others live only in wooded or swampy land; while many species are found in such small numbers that they cause no appreciable damage. *None of the Grasshoppers that have brightly coloured hind wings are ever very injurious in Alberta.*

The eggs of all injurious Grasshoppers are laid in the late summer and autumn, but do not hatch until the following spring. The female digs a small hole in the ground with her ovipositor and deposits about twenty eggs which are surrounded with a brown, frothy material that holds them in a compact *egg-pod*. Each female lays several of these pods. The nymphs, which hatch out in May or June, moult several times before they are mature. After the second moult they possess small wing-buds, which contain the folded wings of the adult.

The two species of Grasshopper which do the most damage in the province are the *Roadside Grasshopper* and the *Lesser Migratory Grasshopper.*

The former has about four irregular, brown patches on the semi-transparent front wings, and the latter has a row of about eight brown spots in a line along the middle of each front wing. The Roadside Grasshoppers rarely rise more than a few feet from the ground. The Lesser Migratory Grasshoppers may rise into the air until they are out of sight, and fly for many miles before settling.

The Roadside Grasshopper is usually found in the green sod along river bottoms or around sloughs in July and August where the eggs are laid. In normal years there are sufficient

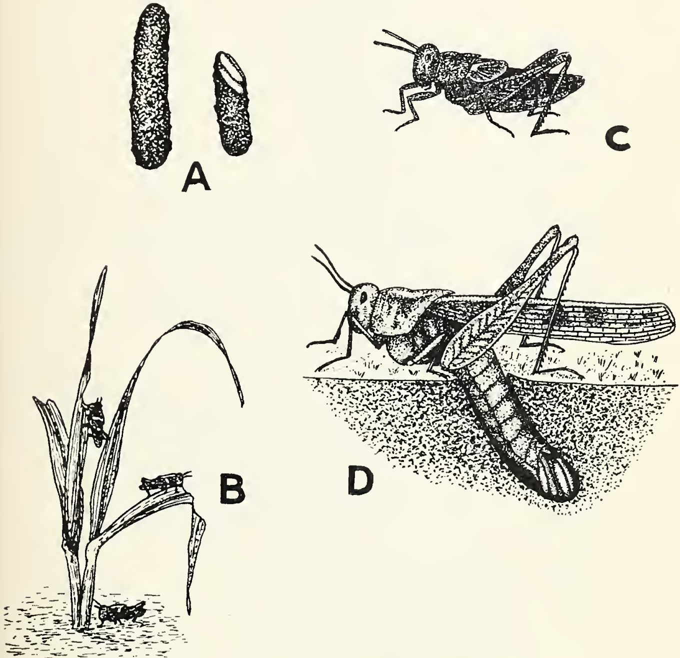


Fig. 56. A Roadside Grasshopper.

parasites to keep them under control. After a series of dry years the sod in these breeding grounds becomes parched, and the Grasshoppers migrate to grain fields where they feed until their eggs mature. They then move to the sod along the edge of the field, where they lay their eggs. Only a few of the parasites migrate to the grain fields with the Grasshoppers, and the Grasshoppers are thus able to increase rapidly in number for a few years. As the numbers of the parasites increase they finally become sufficiently numerous again to bring the Grasshoppers under control. This may require from five to twelve years. The eggs of the Lesser Migratory Grasshopper are laid in weedy summer fallows.

Man may assist in reducing grasshopper damage in three ways:

(1) Ploughing weedy summer fallows in fall or early spring to bury the eggs deeply. (2) Burning the weeds in summer fallow and in the sod around "headlands," as soon as the young Grasshoppers have hatched in the spring and are sheltering among them. (3) Using poisoned bait. (See Chapter XXV.)

Cutworms.—There are even more species of Cutworms in Alberta than there are of Grasshoppers, but only about three species have ever been found in sufficient numbers in grain fields and gardens to cause much damage. The eggs of nearly all of the species that are destructive in Alberta are laid *in the soil* during August and September. Some species of Cutworm Moths lay their eggs on vegetation, particularly on weeds, but none of these are injurious in this province.

The Pale Western Cutworm. This is the most injurious Cutworm in the wheatfields of Alberta. It occurs only on the open prairie, and does not inhabit the semi-wooded regions in the central and northern parts of the province. The Cutworms are light grey with practically no body markings. The head is yellow with a blackish inverted V-shaped mark in front. The eggs are laid just underneath the surface of loose soil, as the Moth has no digging ovipositor. Fields that have a firm surface during late August and September will thus be free from these Cutworms the following year. When the Cutworms hatch out in the spring they remain permanently below the surface in cultivated fields, unless the soil is very wet, under which condition they come to the surface. They rarely eat much of the plants that they attack, but, having destroyed one by biting through the stem, move on and destroy another. In years when there is abundant rainfall in May and June the Cutworms are forced to come to the surface, and are reduced in numbers by parasites. When there is

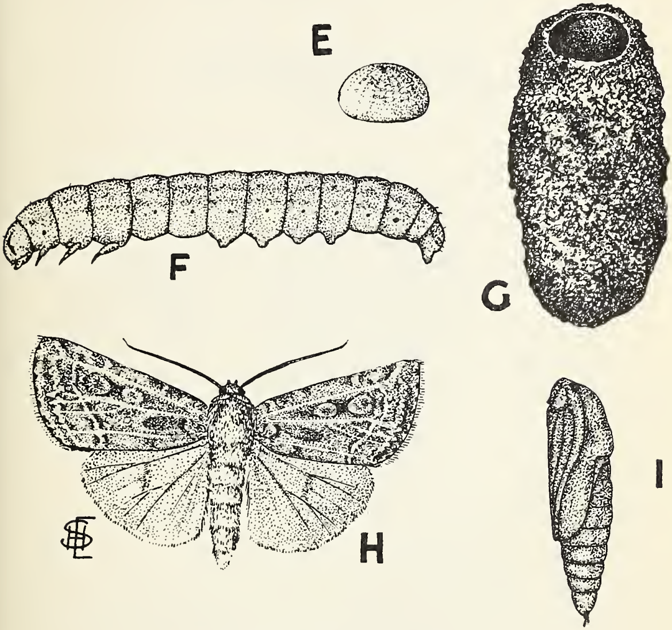


Fig. 57. Pale Western Cutworm.

little rain during these months the Cutworms can move about easily in the dry soil, where the parasites are unable to reach them. Two dry springs in succession will usually result in an outbreak of this Cutworm. When the Cutworms are full-grown they construct a small oval cell in the soil and change into a chestnut brown pupa. Early in August the adult Moths emerge. They are olive green, with a few white lines and irregular dark areas on the front wings. In the late afternoon they visit flowers, particularly Goldenrod, in search of nectar, and lay the majority of their eggs about sundown.

The most important control measure for the Pale Western Cutworm is summer fallowing. Deep fall ploughing on stubble will destroy some of the eggs laid there. Since they feed almost entirely below the surface of the ground they cannot be killed with poison bait.

The Red Backed Cutworm. This is dark green with a broad brick-red band along the back. It is found most commonly in fields of Alfalfa, Flax, or Sunflowers, and in gardens, although they are occasionally very destructive in grain fields. They are most abundant in the semi-wooded regions of Alberta, but occur all over the province. The Moths lay their eggs in harder soil than do those of the Pale Western Cutworm, and appear to prefer fields in which there is a fair amount of green growth at this time of the year. In districts where this Cutworm is abundant it is advisable to destroy all weeds on summer fallow by the end of July. The Red Backed Cutworms feed mainly above the ground at night, but occasionally come to the surface and feed during the day. Thus poisoned bait will kill many of these Cutworms in field crops and in gardens. Individual plants in the garden can often be protected from Cutworms by using a tin or paper collar around them.

Wireworms.—Wireworms are probably the most widespread pests of grain and garden crops in the province. These insects are the larvae of small Beetles popularly known as "Click Beetles". If the Beetles are placed on their backs on a smooth surface they jump into the air with an audible click. The beetles are rarely more than half an inch in length, and may be brown, grey or black in colour. The Wireworms are hard-shelled, slender, orange-yellow, inactive grubs. Nearly all of the Wireworms take between two and five years to mature. During this time they do not come to the surface of the ground. In the spring they burrow into the newly-seeded grain, and so prevent it from germinating. Later in the season they eat through the stems of young grain, and the various grasses below the ground. During the summer, as soon as the stems of the plants have become too tough for food they feed only on the roots, where they do very little

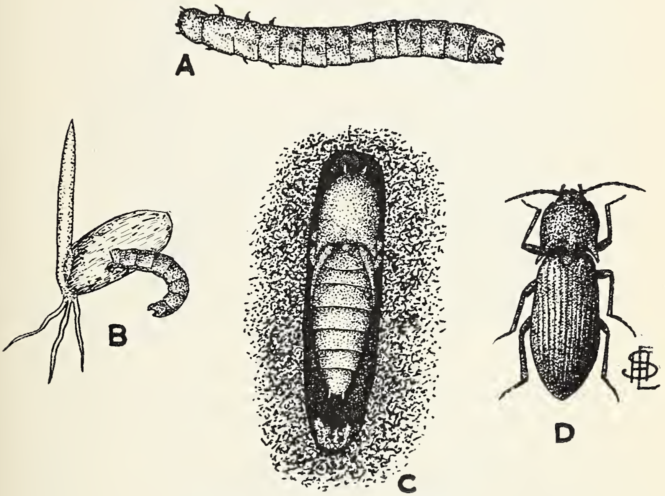


Fig. 58. Northern Prairie Wireworm.

damage. About the middle of July in the year in which they mature they form small earthen cells, and change into delicate white pupae. Although the majority grow into adults by early September, they do not come above the ground until the following spring.

The Northern Prairie Wireworm. This is the most destructive species in the grain fields and gardens of Alberta. Its body terminates in a pair of double claws. The shiny black adult Beetles come to the surface in April. Although they have a well developed pair of wings under their elytra they never fly, but wander over the bare fields until June. The females then burrow into loose earth to a depth of about five inches, and lay about 350 eggs. The eggs hatch in about a month's time, and it is believed that the Wireworms require any time between four and eight years to mature. Their numbers are liable to increase in fields which have been under cultivation for several years. Since they feed most extensively while the soil is moist Wireworm damage is most noticeable after summer fallow.

Frequent cultivation of summer fallows during the spring and early summer exposes many Wireworms to destruction by birds. When a field is known to be infested it should be seeded a little more heavily than is usual. Shallow seeding, provided that the seed is well down to moisture, reduces damage. Late seeded grain suffers less than does that which is seeded early. Cross packing the drill rows with a heavy ridged packer while the soil is moist prevents Wireworms moving easily along the drill rows. No method of treating the seed or the soil with chemicals is of any value for reducing damage.

The Wheat-Stem Sawfly.—To the order Hymenoptera, which contains so many beneficial insects, belongs one of the worst pests of Wheat.

The adult Sawfly closely resembles a slender black and yellow Wasp, though it is only about one quarter of an inch long. Unlike the true Wasps, it is armed at the end of its body, with a pair of saws instead of a sting.

The larva is a white, legless grub that lives inside the stems of Wheat and Grasses. It is about one-quarter of an inch long when full-grown and when it is removed from a stem it curls itself up into a shape resembling the letter S.

Early in June the Sawflies attack young Wheat plants and cut slits in the stems just below the forming heads. Through these they force minute eggs into the hollow straw.

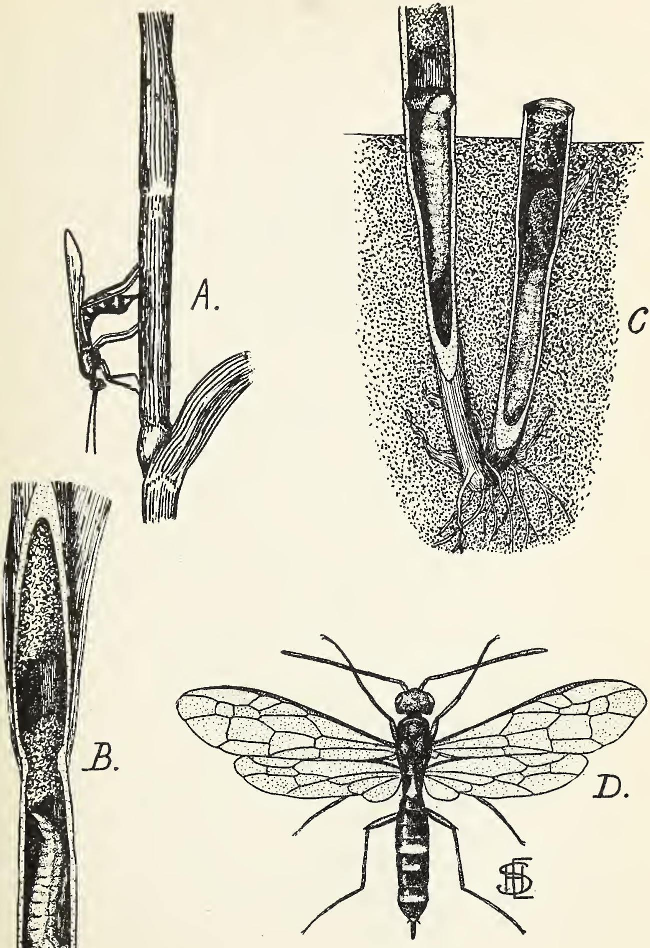


Fig. 59. The Wheat-Stem Sawfly.

A small grub emerges from each egg and it begins to feed inside the straw. As it grows it travels downwards, eating its way through the solid nodes, and leaving behind it a mass of fine dust that almost fills the hollow straw. By the end of July the grub has reached the bottom of the straw and is about two inches below the ground. It now turns around, so that its head is uppermost, and, as soon as the straw begins to ripen, it gnaws a ring around the inside of it, just above the level of the ground. The straw soon breaks from the plant at this point, and it falls to the ground. The grub now plugs the open end of the stub in which it is living with dust and remains in it till the following spring. Early in June it is transformed to an adult Sawfly which pushes the plug out of the end of the stub and escapes into the air. It is in order that the adult may escape in this manner that the grub cuts off the straw during the previous summer.

History of the Sawfly in Canada.—The Sawfly is a native insect and it normally lives in grass stems. In 1896, it was found that it had begun to infest Wheat stems in southern Manitoba. At that time it only occurred around the edge of the Wheat fields, and only about 10 per cent. of the straws were infested. Though many fields were infested, the damage did not appear to be increasing until 1914. In that year the Sawflies suddenly spread through entire fields, and in some instances as much as 30 per cent. of the Wheat stems fell to the ground just before harvest. By 1926, almost every field of Wheat in Manitoba and in eastern Saskatchewan had become infested, and in some as much as 90 per cent. of the Wheat stems contained Sawfly grubs.

In 1913, the edges of a few fields in Alberta were infested, and by 1926 the Sawfly was beginning to spread towards the centre of a few fields in the districts where the damage had first been observed.

Cause of Sawfly Increase in Wheat.—Sawflies are never very abundant in the grass stems to which they are native. Several small species of Hymenoptera, all of which are armed with long ovipositors, locate the grubs while they are travelling earthwards inside the grass stems and oviposit in them through the side of the stem.

A Wheat stem is much thicker than is a grass stem. Whether it is due to the ovipositor of the parasites being too short to reach a grub while it is inside a Wheat straw, or to some other reason, we do not know, but it is a fact that the parasites do not attack such grubs as are living in Wheat straws. The female Wheat Stem Sawfly lays about thirty eggs, and nearly all of those that are laid in Wheat survive, while most of those that are laid in grass stems succumb to parasites. From this you will see why the Sawfly increases so rapidly when it transfers to Wheat from grasses.

Control of the Sawfly.—*Fall ploughing.* The Sawfly grubs cut off the straws in the fall in order that the adults may be able to escape in the spring. We can imprison all of them if we plough in the stubble before these adults escape. Thorough fall ploughing is certain to close all of the open ends of the stubble with earth. Spring ploughing is less certain, but it is improved if it be followed with packing.

Early harvesting. The Sawfly grub never cuts off the straws until they are ripening. If the Wheat be cut at about a week before it is ripe none will be lost. The heads on infested straws are just as well filled as are those on uninfested straws. This prevents loss, but it does not destroy the Sawfly grubs, because they are already below ground in the stubble.

Immune Crops.—Oats, fall Rye, and Barley, as well as all solid stemmed plants, such as Flax, Alfalfa, Corn, etc., are not affected by Sawflies.

Trap Crops.—A single drill-width of Wheat seeded, as early as is possible in the spring around a field of badly infested stubble will attract most of the Sawflies in the spring and they will lay their eggs there instead of flying to neighbouring fields. This "trap Wheat" must be cut early in July.

Exercises.—(1) Why is it important that the student of agriculture should learn to distinguish the different species of Grasshoppers from each other? What habits and peculiarities of growth are common to all Grasshoppers?

(2) Describe the Roadside Grasshopper. Why are the outbreaks of these especially severe after a succession of dry years? What natural means serve to keep them in check? In what way may fire be used to destroy them? How is poison bait applied?

(3) How would you identify the Lesser Migratory Grasshopper? Why is it prevalent in sandy areas?

(4) What poultry are especially active in searching and devouring Grasshoppers? How are weedy headlands and summer fallows a menace? What birds have you noticed on the ground in pursuit of Grasshoppers?

(5) Grasshoppers show three sharply defined stages in their growth and Cutworms four. Explain the difference. Describe the Cutworm at each stage. At what time is it destructive? How do they feed? Why should the Moths also be considered as a menace?

(6) Name the common destructive Cutworms of Alberta. How do they differ in habits and appearance? Why are they more numerous some years then others? Which cannot be destroyed with poisoned bait and why?

(7) Make careful drawings of the species of Cutworm and Moth prevalent in your community. Make collections of the Moths of different species, if some book of reference is at hand for identifying them.

(8) The Sawfly belongs to the Order Hymenoptera. Name other insects of the same Order and state their value to us. What are the characters common to the body structure of all the Order?

(9) Describe the habits of the Wheat Stem Sawfly.

(10) Give its history. Being native to this country, why have they become in recent years destructive of crops?

(11) Describe means of combating the Sawfly. What is the advantage of early harvesting in regions infested? What is the nature of the damage it does to the crop? What is the natural means of checking the insect and why is this not effective in protecting the wheatfields?

(12) How would you identify the grub of the Sawfly, by its form and by its location or work?

(13) Give the life-cycle of the Wheat Stem Sawfly. At what season is the egg laid? When does it emerge as an adult fly? When is the destructive work done? At what point on the stem? How is its ravages at once noticeable?

(14) Sketch the life history of the Wireworm in so far as it pertains to all of the species.

CHAPTER XXIV

Insects Injurious to Live Stock

Bot-Flies.—Three species of Bot-Flies are found in the province, which live in their grub stage as parasites in the stomachs of horses. Here they do much less damage than one would expect. The adult flies of these species resemble Bumble Bees of medium size, and are clothed with brightly-coloured hair. They have neither well developed mouth-parts nor stings. Horses are instinctively afraid of the Bot-Flies, although the latter do not hurt the animals in any way when laying their eggs.

The Common Bot-Fly. This is brownish-grey in colour, with a smoky patch on each wing. The yellow eggs are laid on the mane, shoulders, and fore-legs of the horse, and hatch only when the horse licks them. The minute grubs pass from the tongue to the horse's stomach, and attach themselves to the inner walls of this organ. By the following spring they are full grown, and are loosened from the stomach wall. They leave the horse in its droppings, burrow into the ground, and change into the pupa stage.

Throat Bot-Fly. This fly has reddish hairs on the thorax, a black band surrounded by white hairs on the abdomen, and transparent wings. The flies hover between the horse's fore-legs, then suddenly dart upwards, and lay an egg on the throat of the animal. The horse nods his head up and down, or protects his throat by placing his head on the back of another horse or on a fence post. The eggs hatch without being licked, and the grubs crawl to the mouth in order to reach the stomach.

The Nose-Fly. The smallest of the three species, has dark hairs on the body, and red hairs on the tip of the abdomen. The black eggs are laid only on the fine hairs on the lips of the horse. This fly is most dreaded by horses.

When Bot-Flies are numerous grazing horses should have access to shelter, as the flies are active only in the sunshine. The eggs of the common Bot-Fly can be removed by clipping the hairs on which they have laid, or by scraping them off with a knife. Work horses can be protected from the throat and nose flies with wire or leather protections that cover the mouth and throat. All Bot-Flies in the stomach can be killed by pushing a capsule containing carbon bi-sulphide down the horse's throat.

Warble Flies. Bot-Flies which infest cattle are usually called "Warble Flies" because the grubs live just under the skin on the back of the animal, where they produce swellings known as warbles. The Warble Flies are larger than horse Bot-Flies, and have bands of red, yellow, and black hairs on their bodies. The yellow eggs are laid on the legs and the lower parts of the body, but never on the back. When the eggs hatch, the grubs burrow into the skin, and travel inside the body to the back-bone, where they produce warbles. In the spring, the warbles burst, the grubs escape, burrow into the ground, pupate, and later in the summer emerge as flies.

Warble Flies will not fly over water. Cattle often seem to realize this, and will stand all day in a slough in order to escape them. Shelter should be provided for the animals in the "fly" season, as the flies do not attack cattle which are not standing in the sun.

Exercises.—(1) Name the three different species of Bot-Flies that live in their grub stage as parasites in the stomachs of horses. Describe the adult fly, the egg, and the life-history of each species. What are the general methods of control for all horse Bot-Flies?

(2) Why are cattle-infesting Bot-Flies called "Warble Flies"? Describe these under the same headings as for horse Bot-Flies.

CHAPTER XXV

THE CONTROL OF INSECTS

When any species of insect has increased to destructive numbers there are several methods whereby we can reduce the damage that it is liable to do to us. The most obvious way is to kill as many of them as we can. For this purpose we can employ cultural methods, poisons, or mechanical destruction.

Cultural Methods.—(1) *Deep Fall Ploughing.* Many of our injurious field-crop pests pass the winter either in the egg stage or in the pupal stage just below the surface of the soil. Others hibernate as inactive larvae or adults among dead vegetation on the surface of the soil. In either case, practically all of these insects can be destroyed if the soil be ploughed to a depth of about six inches in the fall, in order to bury all vegetations, together with the surface layers of earth, as deeply as is possible. Cultivation with harrow, disc, or cultivator, is far less effective, however deeply it may be done; while early spring ploughing, unless it be followed by a packer, is not certain to imprison all of the insects.

(2) *Rotations.* Many insects cannot move a great distance in their immature stages in search of food. By avoiding growing the same crop year after year on the same field it is possible to starve out some insects. Unfortunately there are not many rotations that can be effectively utilized on the prairie.

(3) *Summer Fallowing.* A good summer fallow is often of great value in the control of certain insects. The method of cultivation that is to be employed must, however, be carefully selected with reference to the insect that is to be controlled by it. Few insects can be *killed* by summer fallowing and its main value is to make a field unsatisfactory to the adult insects for egg-laying purposes.

Poisons or Insecticides.—(a) *Stomach Poisons.* Insects that have *biting* mouths can always be killed with arsenic, provided we can get some of this into their stomachs. The simplest way to accomplish this is to spray or to dust some arsenical poison on the food upon which they are feeding. Usually the food is vegetation, and *soluble* arsenic is as destructive to plants as it is to the insects. We must, therefore, employ some arsenical compound that is insoluble in water, but which is soluble in the digestive fluids of the insects. For this purpose the most commonly used material in Alberta is *Paris Green.* This is a very fine green powder which can be spread, by two different methods, over the surface of vegetation on which insects with biting mouths are feeding.

(1) *Paris Green Sprays*—The insoluble powder can be held in suspension in water which is then sprayed on the plants. There is, unfortunately, a little soluble arsenic in Paris Green, and this is liable to burn tender foliage. For this reason *lime,* which makes an insoluble compound with this *free* arsenic, should always be added to the mixture.

Formula: Paris green, 1 ounce; Lime, 2 ounces; Water, 4 gallons.
Preparation: Use fresh stone lime. Slack in a little water. Make a paste of the Paris Green with a little water. Mix these together and add the rest of the water.

On cabbages or other plants that have a bloom on the leaves the spray is liable to collect into drops and run off. This can be prevented by dissolving a half-bar (4 ounces) of laundry soap in each four gallons of spray.

Spraying Equipment: In order to spread the poison evenly a spraying machine should be used. A small **atomizer** sprayer, such as is used for killing House-flies, is quite satisfactory for spraying a few plants around the garden. For more extensive work a knapsack sprayer, which costs about $20.00, is preferable; while for spraying field crops, such as Potatoes or Beets, a more elaborate, horse-drawn, sprayer is employed.

(2) *Paris Green Dusts*—Many people who wish to poison insects with Paris Green have no sprayer. They can get around this difficulty by applying the poison as a dust.

Formula: Paris green 1 part; and any fine dust, such as air-slacked lime, land plaster or flour, 12 parts.

Application: A hand-operated machine that will blow the mixture on the plants is on the market, and it costs about $20.00. This is, however, not necessary. Place the mixture in a small bag made of gunny sacking or cheese-cloth, and shake it over the plants. The bag can be attached to the end of a stick if more convenient. On a still day the poison will settle evenly on the plants. It is preferable to apply the dust while the leaves are wet with dew, or after a shower.

(3) *Hellebore*—Arsenic is, of course, as poisonous to us as it is to insects. It is quite safe to spray or to dust Cabbages with Paris Green because we do not eat the outside leaves, but it is unsafe to spray it on ripening fruit, such as Currants. For this purpose a vegetable substance called hellebore is used. This is the powdered root of a tropical plant which is deadly poisonous to insects, but it is quite harmless to Man.

(4) *Poisoned Baits*—Some insects, such as Grasshoppers and Cutworms, can be killed by giving them some poisoned material that they prefer to the plants on which they are feeding. These *baits* usually consist of bran which has been sweetened with molasses and is poisoned by the addition of Paris Green or White Arsenic. To prepare bait thoroughly mix 2 lbs. of Paris Green or White Arsenic with 50 lbs. of bran. Dissolve 1 qt. molasses and 2 lbs. salt in 5 gallons of water, and stir this into the poisoned bran. About 10 lbs. of this bait per acre is recommended for destruction of Grasshoppers.

(b) *Contact Insecticides.* Insects that have piercing and sucking mouths cannot be killed with stomach poisons because they feed only on the internal fluids of plants, into which the poison cannot be introduced. These must therefore be killed with some material that will enter their bodies through their *spiracles.*

(1) *Coal Oil Emulsion*—One of the best materials for this purpose is Coal Oil. This, however, is very destructive to vegetation, and if it is to be applied to insects which are living on vegetation it must be diluted in some manner so that, even though it will kill the insects, it

will not harm the plants. Coal Oil and water will not mix, but if soap is dissolved in the water it is possible to hold Coal Oil in it in very minute globules. This is the principle of Coal Oil Emulsion. The globules of oil will kill any insects that they touch but they are too small and scattered to affect the plants.

Formula: For Stock Solution: Soap, ½ pound; Water, 1 gallon; Coal Oil, 2 gallons.

Preparation: Heat the water and dissolve in it the soap, which has been sliced thinly to accelerate its solution; bring the solution to boiling temperature; *remove it from the fire* and pour in the Coal Oil. Now stir vigorously with a paddle till the mixture is milky white. The stock emulsion is now made and it should set to a jelly-like mass when it is cold. If any free oil should come to the surface, be sure to pour it off before diluting.

Dilution: When spraying for Aphids dilute this stock emulsion with ten times its volume of water.

Application: In order to apply Coal Oil Emulsion some kind of sprayer is essential. Remember that only such insects as are actually drenched with the emulsion will be killed.

(2) *Nicotine Extracts*—Coal Oil Emulsion is rather difficult to prepare, and better results can be obtained from spraying infested plants with nicotine extracts. Several of these are on the market, and full instructions for their use are given on the containers. These materials keep indefinitely and for use have simply to be diluted with water.

(3) *Dusting Contact Insecticides*—One big disadvantage of the majority of contact insecticides is that, since they are liquids, they cannot be applied as dusts. The only contact insecticide that can be readily employed in this manner is Pyrethrum. This is very useful in houses but is rather too expensive to be employed for the control of pests in the garden.

Exercises.—(1) Suggest methods of culture which will meet the following conditions with regard to insect pests:

(a) Sawflies are most prevalent in the wheat fields along the edge of the field.

(b) Grasshoppers are most common in old pastures and in fence corners.

(c) Onion and Cabbage Root Maggots are at their worst where these crops have been grown the previous year.

(d) Moths lay their eggs in the soil near the base of Pigweed and other weeds in stubble land in August. The Cutworms from these hatch in spring.

(e) The moth of the Pale Western Cutworm lays eggs in August on surfaces where the soil is loose and dusty, the Moths having no ovipositor.

(f) The Red Backed Cutworm of Northern Alberta lays eggs in summer on fallow or cultivated lands where there is a considerable amount of weedy growth.

(g) The grubs of the Saw-Fly remain in the straw or stubble till early spring.

(h) Wireworms rarely occur in sod. They attack oats less severely than wheat.

(2) Why is deep fall ploughing likely to be effective in checking certain insects? Why is discing or harrowing not so satisfactory? Name two insects which are checked by spring packing of the soil. Explain.

(3) What crops should be rotated in garden or field in order to escape a prevalent insect pest?

(4) Study the habits of the Pale Western Cutworm, the Red-Backed Cutworm, and the Lesser Migratory Grasshopper and state how summer fallow cultivation affects each of these.

(5) Distinguish the uses of stomach insecticides and contact insecticides. Which is applicable to the Currant Worm, the Cabbage Worms, the Aphids, and the scale insects on house ferns?

(6) Describe a method of applying Paris Green. Why is lime used along with it?

(7) What is hellebore and for what purpose is it suitable as an insecticide? Describe the composition and mode of application of poison bait for Cutworms and for Grasshoppers.

(8) Describe the preparation, application and action of Coal Oil Emulsion used to control the green Aphids on shade trees.

(9) Nicotine solutions, tobacco smoke and tobacco solutions are well-known insecticides. Under what circumstances can these be used and how are insects killed by them?

(10) Parasitic insects on birds are controlled by dust baths of road-dust or ashes. What is the effect of dust or ashes? Name a dust insecticide used in the household. Investigate the principle which makes modern household insecticides such as Flytox, Flyosan, etc., so effective.

CHAPTER XXVI

THE BALANCE OF NATURE

Number of Eggs Laid by Insects.—The number of eggs that an insect can lay varies very greatly in different species. Very few of them, however, lay less than 50 eggs. Grasshoppers usually lay about 100 eggs; Cutworm Moths and Wireworm Beetles lay about 300 while some flies lay over 5,000. Males and females are produced from these eggs in about equal numbers.

Possibilities of Increase.—In order to see how rapidly insects can increase in numbers we shall take a Cutworm as an example. The Pale Western Cutworm Moth lays, on an average, 300 eggs, and there is one generation a year. We shall start with one female Moth.

1st Year—1 Moth x 300 eggs = 300 Cutworms = 300 Moths, of which 150 are females.

2nd Year—150 Moths x 300 eggs = 45,000 Cutworms = 45,000 Moths, of which 22,500 are females.

3rd Year—22,500 Moths x 300 eggs = 6,750,000 Cutworms.

Nearly seven million Cutworms from one Moth in three years. This family is nothing compared with that of the Army Cutworm, the Moth of which lays 1,000 eggs. Think of the hundreds of different kinds of insects that you have seen in Alberta and then remember that all of them are capable of increasing their numbers along some such lines as these.

Although we must admit that the insects do lay enough eggs to enable their numbers to increase at this terrible rate, we know that, in so far as most kinds of insects are concerned, we see them around us in about the same numbers from year to year. Something, then, must be killing a great number of them every year before they have a chance to lay their eggs.

If we are to understand what it is that causes insect outbreaks and what terminates them, we must know what factors normally prevent the increase of plant-feeding insects.

Factors that Prevent Insect Outbreaks.—(1) *Shortage of food.* Naturally the amount of available food must limit the possible increase of any insect. We hope that this will never be a limiting factor to grain feeding insects in Alberta. It is, however, an important one to the parasites.

(2) *Direct effect of climate.* Every year many of our insects are undoubtedly killed by extremes of temperature or humidity. Native insects are, however, well able to withstand the normal variations in climate. Otherwise they could not be native.

(3) *Birds.* Insect-feeding birds destroy an immense number of insects of all kinds. Nearly all birds feed their nestlings on insects in the spring, even if they feed largely on grain and other seeds at other seasons of the year.

(4) *Diseases.* Insects suffer heavily from diseases under certain conditions. In Alberta the atmosphere is too dry for these diseases to kill many of our insects.

(5) *Predators and Parasites.* The manner in which plant-feeding insects are kept under control by predatory and parasitic insects has been discussed in Chapter XXI.

Protection from Enemies.—(1) *Protection from Birds.* A large number of insects are protected from destruction by birds because they possess stings or they have a very unpleasant flavour when they are eaten. Few birds will attempt to eat two Bumble Bees or two evil-tasting Monarch Butterflies. Experience with one is enough to warn them in the future to leave the insects alone.

(2) *Mimicry.* There are a large number of flies, that are quite desirable as food for birds, which so closely resemble Bees or Wasps that they must be carefully examined before one can be sure that they are quite defenceless. Similarly there is an apparently tasty Butterfly, called the Viceroy, which is almost exactly like the Monarch in its colour pattern. It is believed that these remarkable resemblances are not

accidental but that the defenceless insect *mimics* the protected ones in order that it will be mistaken for them by birds.

Protective Resemblance. Similarly, many defenceless insects very closely resemble their surroundings, in order, it is claimed, that they will not be seen by birds which otherwise would eat them. Common examples that are found in Alberta are Caterpillars that resemble twigs, and night-flying Moths that are so similar in colour to the bark of the trees on which they rest by day that it is extremely difficult for a human being, at all events, to see them.

How Equilibrium is Maintained.—Plant-feeding insects are kept to about the same numbers from year to year almost entirely by their predators and parasites. Occasionally, on account of variations in climate or for other reasons, the numbers of the parasites are seriously reduced in a certain year. As a result the plant-feeding insect has an opportunity to increase. In the following year such parasites as have survived find very many more hosts in which to lay their eggs, and as a result their numbers also begin to increase. The more rapidly they increase during the next few years the greater will be the number of the plant-feeding insects that they destroy, and this will continue to be the case until they have once more brought down their numbers to the normal proportions that existed before equilibrium was upset. This sometimes takes several years, and in the meantime we experience an *outbreak* of the plant-feeding insect.

How Man Upsets Equilibrium.—From what we have seen, under normal conditions the parasites never allow plant-feeding insects to increase in numbers for many years in succession. Unfortunately, the transformation of the prairie in Alberta into grain-fields has made it very difficult, in some cases, for the parasites to attack the plant-feeders and this has resulted in their increase. Cutworms are an example of this. On hard prairie they have to come to the surface in order to move from plant to plant, and while they are so doing the Ichneumons have a splendid opportunity to lay their eggs in them. In cultivated fields, however, they can move in the loose earth below the surface with the result that the parasites cannot reach them and are therefore reduced in numbers while they, themselves, are able to increase.

Exercises.—(1) What factors are operating to prevent the development of enormous numbers of any one kind of insect? Distinguish predators and parasites. Give examples. How does a Tachinid differ from an Ichneumon fly?

(2) Give examples of insects which became pests owing to the periodic appearance of large numbers.

(3) In what ways are some insects protected from attack by birds? Give examples of protective resemblance and of mimicry among birds.

(4) Why is the Lady-bird Beetle usually a bright orange with spots and the Wasp brightly banded with yellow? Why are the night-flying Moths dull in colour while Butterflies display a variety of colouration? (A protective effect is assumed in these cases.)

(5) How are plant feeding insects kept in check from year to year? Account for the plague of Caterpillars on the Poplars of Northern Alberta which lasted for three years. Explain how Man sometimes upsets the equilibrium in the insect world.

PART 4

BIRDS AND MAMMALS

CHAPTER XXVII

Introductory

Before considering birds and mammals by themselves and certain points about them in detail, let us make a brief survey of the kingdom of living things. It is generally a very simple matter to tell a plant from an animal and nobody would mistake a tree for an animal or a cat for a plant. But the plants and animals with which we are so familiar are only the higher representatives of these two groups. If we scoop a glassful of water out of a pond and examine it carefully we notice that it is full of life, but it would be probably impossible for us to name any of the hundreds of minute organisms that we can see in it. In fact it would even be impossible, in the case of many of them, to call them either plant or animal unless we knew something of them beforehand. But as a matter of fact, in addition to the life in our glass visible to the naked eye, a microscope would reveal many thousands of still smaller living objects and some of these even experts could not call for certain either plant or animal. These are the forms with which we are not so familiar and they bring us face to face with the fact that plants and animals, since the minor forms cannot always be identified precisely as the one or the other, have something in common and therefore show relationship with each other. That common property is what we call *life*. They are all, plant and animal alike, living organisms.

This introduces us to a fundamental idea that pervades the realms of biology. Just as plants and animals show relationship between them, so do all groups of animals. Thus we find a digestive system, a nervous system, a blood system and so on, running through the whole series of higher animals and linking them in such a remarkable manner as to leave no doubt in our minds as to their affinities. If this conception is grasped, it will not come as a surprise to note, as we shall do below, that in spite of the obvious differences in external appearance, the bony elements of a bird's wing are identical with those in the foreleg of a horse or in our own arm; that if we know the anatomy of a bird we have at the same time a working knowledge of the anatomy of a Salamander or ourselves; and so on. Every species has its own peculiarities and individuality. But everybody knows that our Striped Gopher, for instance, is closely related to the Common Gopher or the Brush Gopher even as these two are closely related to each other. But it is only if we extend the idea and acknowledge a fundamental relationship between birds and mammals that their striking similarities become comprehensible. It is so easy to note the differences and so simple to overlook the deep seated similarities. Yet for a true understanding of animal life it is vital that we should recognize them.

Birds and mammals are warm blooded, wherein they differ from other forms of life and resemble each other. The term "warm blooded" is a loose one of convenience, and suggests that the temperature of the animal is above that of its surroundings. The fact is better and more accurately expressed by use of the term "even-tempered". One of the most wonderful and important adaptations that birds and mammals possess is that they can regulate the temperature of the body and keep it even. It has made them the dominant land vertebrates of the present era for they are no longer at the mercy of the elements. We shall consider something of the mechanism concerned when we come to mammals. In the meantime we might note the great advantages involved. The cheery little Chickadee does not freeze to death even when the thermometer drops to 50° and 60° below zero, for its temperature remains at about 104° F. as long as it is provided with sufficient food. The Rock Wren is quite happy in the broiling summer sun in the parched Badlands when the temperature may be 130° or 140° for it can keep reasonably cool at its normal temperature of 104°. Hence we find that birds can colonize almost any portion of the globe that produces suitable food. Some species winter in the arctic and antarctic regions, while, on the other hand, the summer heat of tropical deserts does not deter them from breeding there. Sea birds are content with the ocean at all seasons. In other words, extremes of temperature—within certain limits—are no longer of serious importance to birds.

CHAPTER XXVIII

The Structure of Birds

Feathers.—Now it is quite plain that if birds are to maintain a temperature as high as 104° when the surrounding atmosphere may be as low as 80° below zero, they must be provided with a covering that to a great extent prevents the loss of body heat. And this, as we know, is found in the feathers. A feather bed is so warm in winter because it does not permit the heat of the sleeper to escape to the outside: it locks it in, so to speak. An important function of feathers, then, is to provide the body of the bird with a coat of non-conducting material that conserves the heat produced by the activities of the muscles. But this is not the only function of feathers. Delicate and light as is a feather, it is so marvellously constructed that the series borne by the wing is able to support the weight of the bird in flight. In spite of their delicacy they are therefore very strong and do not permit air to leak through them. Lightness and buoyancy are essential and characteristic of feathers.

Contour Feathers.—Not all feathers resemble each other in structure, and some of the differences between feathers of various parts of a bird's body and various periods of a bird's life are of sufficient interest to warrant closer scrutiny. The bird in the diagram (Figure 60) is an adult and is shown with its feathers on. These give the bird the typical shape and appearance with which we are all familiar. If we pluck the bird we find that its shape has altered very much as we can see from comparison of the pictures of the bird feathered and unfeathered. (Figures 64 and 65.) The plucked specimen has apparently no tail and it has lost much of its wings. In fact this specimen has not that familiar outline

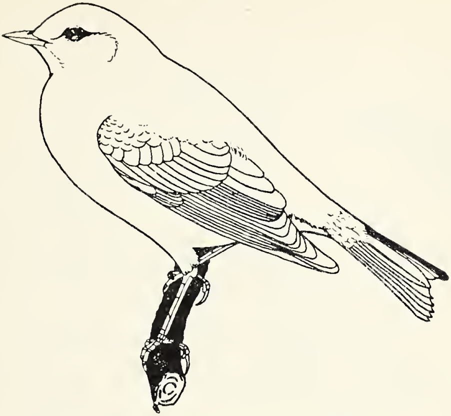


Fig. 60. A bird, showing arrangement of feathers.

that we know so well from seeing living birds around us. The shape has been destroyed by leaving out the feathers. And because they give the bird its outline the feathers that cover it are known as *contour* feathers.

Structure of a Feather.—We can see at a glance that not all the contour feathers are exactly alike. Those of the tail and wing, for example, are long and comparatively stiff, those on the body, short and soft. But in their general structure they are the same. Each consists of a central shaft, or *rhachis*, which carries the *web* or *vane* in two sections half on each side, so that the rhachis forms a dividing line down the centre. At one end the shaft is continued for a distance without the vane. This is the end

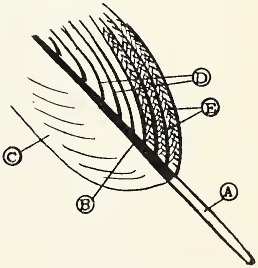


Fig. 61. Structure of feather.

Fig. 62. Feather showing the aftershaft at (A).

by which the feather is attached to the bird's body, and the piece free of vane forms the *quill*. The quill is hollow; the rhachis is solid. A good many feathers, like those of the grouse, have a small feather branching from the base of the rhachis on the under side of the larger one. This is called the *aftershaft*.

The vane of the feather is a remarkable structure. Springing from both sides of the rhachis is a series of delicate rods, called *barbs*, running right out to the edge of the web. These can easily be distinguished with the naked eye in any reasonably sized feather. They give the vane a ribbed appearance and they obviously stick to each other in some way. If we take a hen's feather in our hands we can readily pull these ribs apart and produce gaps. But if we then pass the web between our fingers we can restore the damage. The reason is simple although the mechanism is actually quite complex. Just as the rhachis gives rise to the barbs, so these in their turn carry secondary barbs, called *barbules*, along their borders. Similarly these carry series of minute hooklets, the *barbicels*. The barbicels along the front border of a barb hook onto those of the hind border of the barb in front and give cohesion to the entire web. So if we pull two barbs apart the damage is not irreparable. It can be made good again. We see thus that the web is not only extremely light and elastic, but also durable and these are all essential qualities in a feather.

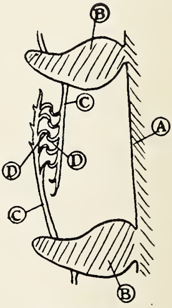


Fig. 63
Structure of a feather. (a) rachis; (b) barbs; (c) barbules; (d) barbacelles.

Feather Tracts.—As we proceed with the plucking of a bird we discover two more facts of interest with regard to feathering. First, we notice that the feathers do not grow all over the body. They are in fact confined to certain well defined *tracts*. Between these tracts are stretches of skin that are featherless. The feather tracts vary in arrangement

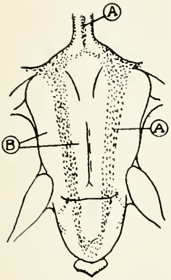
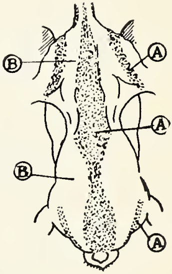


Fig. 64. } Feather Tracts.
Fig. 65. }



from group to group but the details need not concern us if we but remember the general fact. The mid-ventral line of practically all birds is featherless.

Down.—The second feature we notice is the presence of feathers beneath the contours that obviously differ from them in structure, for most birds possess an inner, rather scanty, coat of *down*. This is particularly well-developed in such species as ducks and geese. Down consists of small feathers in which the barbules are absent, wherefore the barbs do not interlock to form a vane, as a result the whole feather has a ragged and fluffy appearance. Down does not shed rain as successfully as do the contour feathers and it is therefore a matter of great importance that it should be kept dry, for a water-logged bird, if exposed to cold, would die in a short time. Down is particularly warm because it provides many minute air spaces and air is a very poor conductor of heat. Birds take considerable advantage of this; everyone is familiar

Fig. 66. Down.

with the appearance of small birds on a frosty morning; they puff their feathers out instead of wrapping them closely around the body. By so doing they increase the layers of air between the individual feathers. One might almost say that they put on more clothes.

Filo-Plumes.—Yet another type of feather is to be seen on the plucked body. It resembles mammalian hair in appearance, but there the likeness ceases, for structurally the "hair" of the bird is really a feather. Such "hairs" are plentiful and readily seen on a plucked fowl, as they do not come out easily in plucking and usually have to be singed off. They are technically known as *filo-plumes*. In a few birds, as in the Cormorants, they grow profusely in patches, and reach the surface, thus taking part in the work of the contour feathers.

Powder Down.—One more type of feather, *powder down*, merits passing mention. This may be seen on the breast and thighs of the Great Blue Heron, as well as on the Marsh Hawk. This type of feather produces a greasy powder which becomes scattered over the skin.

Feather colouration.—Feathers show many modifications related particularly to the owner's protection and to love displays. Many birds, males especially, are highly ornate and their feathers show the utmost complexity of design and colouration. The wonderful hues on the plumage of the Turkey gobbler and the way in which he displays them are familiar to everyone. But the Turkey's achievements are quite surpassed by those of many other species. The Peacock is a good example. Not only are the colours particularly brilliant and vivid but the tail feathers often reach a length of over six feet. These feathers are so wonderfully designed, that when spread fan-wise in display, not one feather hides the next and the wonderful rainbow coloured "eyes" form a gorgeous and regular pattern. In midsummer the males of many species of ducks found in Alberta moult into a plumage closely resembling that of the female. This is known as the "eclipse plumage". All the wing feathers are shed at the same time, and the birds are unable to fly until the new wing feathers appear. During the time that the birds retain the "eclipse plumage" they generally remain in hiding.

Protective Colouration.—In modifications of the colour scheme the feathers also provide the birds with a large measure of protection. Everyone must be familiar with the difficulty in detecting such a bird as the Pintail Duck or the Prairie Chicken on its nest right in the open. Its colour harmonizes with its surroundings and as long as the bird remains motionless it will escape notice.

The colours may be due to the presence of actual *pigments*, or they may be "*interference-colours*." The brilliant tones of the humming birds are of the latter type, for the colours change as one looks at the plumage from different angles. Of a similar type are most of the blues to be seen on birds. If the feather of a Bluejay be held up to the light so that the rays fall through it, it no longer looks blue, for it actually has no blue pigment. Other feathers owe their colours to a combination of both pigmentation and structure.

Moulting.—One more word about feathers. Feathers are not everlasting. They wear only for a certain period, after which they must be replaced. Renewal is effected by *moults*. At certain periods of the year—variable from group to group—the feathers are cast and replaced by new ones. The majority of birds moult, at least partially, twice a year. Penguins alone moult in patches. With other birds the process is a very gradual one and hardly noticeable, although there are exceptions. The flight feathers are never shed more than once a year. Successive plumages are not necessarily the same. Many birds have a special breeding dress which in males is often brightly coloured. Bright and plain then alternative, the former being worn during the breeding season. A newly hatched chick is generally clad in a nestling garb of down-like feathers. This is succeeded by a juvenile dress, often quite unlike any of the adult plumages. During the autumn this is shed and the first winter plumage replaces it. In spring this is replaced by the adult summer dress, and this in the fall by the adult winter, after which these two alternate. A very old female, especially among certain game birds, will occasionally assume a male-like plumage.

Wings.—There is one more adaptation that is peculiar to birds,—the possession of wings. Insects, many of which are winged, are not vertebrates and their wings are not comparable with those of birds except in so far as they enable the bearer to travel through the air. Among the vertebrates—amphibia, reptiles, fish, and mammals—forms occur that can travel for some distance through the air by various devices of the parachute type, but only bats, which are mammals, can really fly, that is, progress through the air for indefinite distances. They do it quite differently from birds and we shall have to consider their particular method when we deal with mammals. On the other hand, there are quite a number of birds that have lost the power of flight altogether and are permanently confined to the ground.

Structure and Use. The skeleton of a bird's wing can be divided into three parts. We can understand them better if we first consider our own arms, in which the divisions are easily recognized. Commencing at the shoulder is the first segment, the upper arm. It only has one bone, the *humerus*. Hinged to it at its distal end—at the elbow—is the forearm. This contains two bones side by side, the *radius* and the *ulna*. Beyond this comes the wrist, made up of several small bones, although we cannot feel them with any distinctness. They are collectively known as the *carpals*. Beyond them is the hand. This may be divided into palm and fingers.

All these elements are represented in the wing of the bird, but where we have five fingers, the bird has only three and they are not visible on the outside, although a few birds have retained claws on the thumb, and the ostrich has a claw on one of its fingers as well. These are, of course, externally visible vestiges of a clawed ancestry. Our arm has two joints, the elbow and the wrist and it is on the same two joints that the folding of a bird's wing depends. The elements of the hand, reduced in number, as we have seen, are both long and strong. Together with the two long shafts of the arm they carry the great feathers of flight. (The thumb remains separate and has a few small feathers of its own.) The flight feathers thus fall into three series. Those borne by the hand are called the *primaries;* those of the fore-arm the *secondaries;* those of the upper arm, the *tertiaries.* They form a continuous sheet arranged in such a manner that the first (counting from the outside) is overlapped by the second, the second by the third, the third by the fourth, and so on. Each is concave on its lower surface and when the wing is stretched it is itself hollow underneath and convex above. This makes the down-stroke—the one that pushes a bird forward through the air—extremely effective. As the wing comes up it is partially folded and so offers less resistance as a whole; also the feathers are slightly twisted to permit the passage of air between them. The continuous, impermeable sheet pressing on the air in the downward stroke thus becomes inffective on the return stroke.

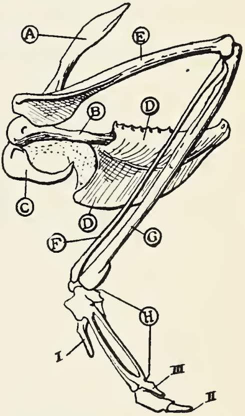


Fig. 67. Skeleton of the wing.

The only further point worthy of note is this: In our outline of feather structure it was stated that the beginning of the shaft, the quill, was free of vane. Where the flight feathers spring from the skeleton of the wing, therefore, there should be a series of gaps. This is actually the case, but the defect is remedied by the *wing-coverts*, an additional row of small feathers that grow over the bases of the flight-feathers and so cover up the spaces.

Exercises.—(1) What is considered the most wonderful and important adaptation possessed by birds and mammals? Comment on this adaptation and give examples.

(2) How is the bird protected against the loss of body heat? What is another function of this protective covering?

(3) Draw a diagram of a kind similar to the one in the text and label all the parts.

(4) What are the four classes of feathers? Describe each fully and state their purpose.

(5) Draw a diagram of a typical quill feather and label the parts. Show how the structure is suited for helping in flight.

(6) Give examples of colouration for, (a) attraction, and, (b) protection, among birds.

(7) Describe the process of moulting. Describe the changes that take place in the colour of the Mallard drake or some other type from the time of hatching to the adult. Is there any change from year to year?

(8) Explain how a bird flies. Describe the structure of the wing, the muscles controlling it, and the form and arrangement of the feathers.

CHAPTER XXIX

Classification of Birds

Diversity of Habit and Structure.—We have seen in the preceding chapter how birds have, in a great measure, achieved mastery over the elements, and can make themselves at home in practically all climates. Their successful existence, however, depends upon more than this. If all birds, for instance, ate the same food, however widely they could range, they would soon starve each other to death. If all birds nested in trees there would probably not be enough nesting sites for all. It is essential, therefore, that as a Class they should show diversity of habit. And diversity of habit infers diversity of structure. To hunt fish a bird must be adapted to an aquatic mode of life; to catch insects it must have a large gape and be swift in flight; to eat mammals it must be strong enough to catch and kill them and must be able to rend the meat; to eat seeds it must have a bill adapted to crush the husks. The more peculiar a bird's habits, the less does it have to compete with others for a living, and the greater is likely to be the success it reaps in the struggle for existence. But there are, of course, limits to this, for in spite of the reduced competition that specialization involves, the attendant risks are greatly increased. Thus, if a species has a particular source of food all to itself, but has lost the ability to avail itself of other kinds of food in the meantime, the failure of its special source involves the risk of extermination. *Diversity of habit and structure are therefore to be expected among birds and our expectations are liberally fulfilled.*

We can group our birds roughly according to external structure and devise an approximate classification, but not a precise one, for in order to do so we should have to take into account peculiarities of the skeleton, muscles, intestinal tract, vocal apparatus, and so on. Thus, both the large groups of hawks and owls are flesh eaters. They have generally been classed together, as they are even now in many bird books. Their habits are alike. As far as their beaks and feet are concerned, they are very similar. But anatomists have demonstrated that they are not closely related and merely resemble each other superficially through having similar feeding habits.

Let us then, for the moment, ignore the divisions of birds recognized by the scientist and create divisions to suit our present purpose, *based on adaptations of the bill to feeding habits.* In the case of a good many species it is essential that *the feet should be adapted as well as the bill.* It would, for instance, serve a Snipe nothing if it had a probing bill for insertion into soft mud, if the feet were so small that they failed to support the bird on the surface of the sticky medium from which he draws his sustenance. There must be a correlation in the majority of birds between feet and bill. *We may therefore consider foot structure together with that of the bill.*

Bill.—The bill is made up of bones encased in a horny sheath. The latter may be removed from the skull by soaking it in water, when the underlying bones are revealed. There are no teeth in modern birds, although their ancestors, as we have learned from fossal remains, possessed teeth.

Birds like the Crow have a generalized bill that in many respects resembles that of birds of earlier periods in the earth's history. It denotes an omnivorous feeder, or at least one whose diet has not become specialized. From a bill of this kind the more peculiar forms have been derived.

Feet.—In describing a bird's wing, its bony elements were compared with those of our own arm. In considering a bird's leg we can profitably repeat the procedure. The human leg consists of the thigh which hinges to the rigid bones of the hip and terminates at the knee, which is a joint. Beyond the knee is the shank, terminating at the ankle, another joint, and beyond that comes the foot. As the hand consists of a palm and fingers so the foot consists of a sole and toes. Moreover, the ankle, like the wrist, is composed of numerous small bones and the shank, like the fore-arm, contains two long bones side by side. Though so different in proportions the elements of our arm are therefore strikingly like those of our leg. We should expect the same in birds and such proves to be the case. But a bird's leg has become specialized and adapted to particular requirements and its constituent parts are not as easily distinguished as might be supposed. The thigh is there and springs from the hip but, like the hip, it is never visible for it is entirely covered by the body feathers, as also is the knee joint. The shank is mostly feathered but its distal end becomes visible and is in most birds covered with scales. Then comes that part of the leg which is both conspicuous and lengthy (also scaly) in most birds. In such species as cranes it is in fact excessively long. Seemingly, there is nothing in our legs with which to compare this main portion of a bird's leg. But this is only seemingly so, for if we look at a bird's leg carefully we see that beyond this limb there come only the toes. This suggests that the main part of the leg represents the long bones that lie in the soles of our feet and this is exactly the case. The ankle joint in a bird, although its many bones have undergone fusion, is what is popularly considered to be the knee. If we compare the leg of a horse with that of a bird we find the same extra long joint and it is derived in similar manner. Both the horse and the bird walk entirely on their toes, not on their soles as we do.

A bird's toes are generally four in number, the fifth one having disappeared. The first, corresponding to our great toe is always directed backwards, except in a single group of which our Cormorant is an example, where it is directed forwards and united with the other toes by a web. A good many birds have lost the first toe also, and thus possess but three, while the Ostrich is unique in having two only. Its loss of toes, as with the horse among mammals, is an adaptation to speed, and the Ostrich, which is flightless, can easily out-distance an ordinary horse.

So much for the normal structure of bills and feet. Variations are almost endless. Among the highest birds, the perchers, deviations from the pattern of the Crow, which itself belongs to this tribe, are but few. There are two main types, that of the *insect-eater*, and that of the *seed-eater*.

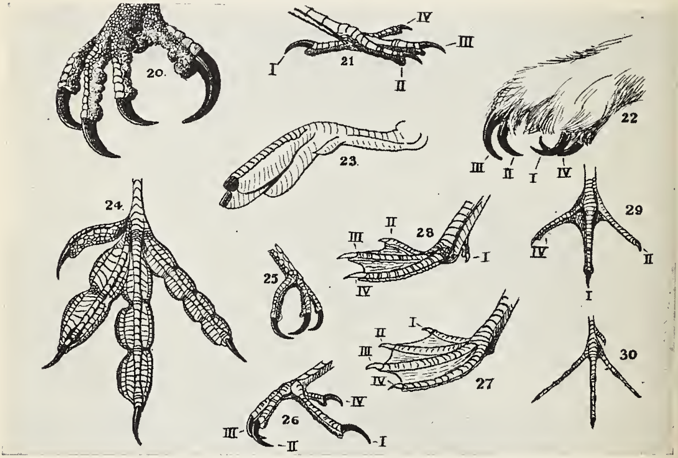


Fig. 68. Feet.

Insect-Eaters.—In insect-eaters, typically represented by the large group of Warblers and Vireos, the bill is rather slender, sharply pointed, and tends to curve downwards. Insectivorous birds with this type of bill hunt but little on the wing and collect their food mainly on tree trunks and branches. Our little Brown Creeper has this bill in its most exaggerated form. As a variant to this mode of securing insects is that adopted by the Flycatchers and Swallows which hunt almost exclusively on the wing. Instead of the thin

Even the House Sparrow, popularly miscalled the English Sparrow (there is no such thing really, though Sparrows of course are found in England), is insectivorous while it has young in the nest. The Grosbeaks, which feed on the larger seeds and berries, have the same bill except that it is shorter and heavier. A variant of the Sparrow's bill is found in the Cross-bills, which, like the Sparrows, are also Finches. In these, the mandibles cross each other at the tips instead of meeting exactly. This enables them to extract the seeds of various cones with great rapidity.

As the bills of most passerine birds are adapted for special purposes, so are the feet. They are primarily suited to perching, the hind toe being well-developed and affording (by opposition to the other toes) a good grip on twigs, but they are also admirably adapted to running or hopping on the ground.

Meat-Eaters.—Hawks and Owls are typical meat-eaters. The bill is not hooked for the purpose of catching the prey but for rending the meat. The feet, characterized by their massiveness, great strength and heavy talons, do the catching and often the killing, for as they strike and pierce the victim, they frequently even break bones, so powerful are they. Some meat-eaters like the Falcons, hunt almost exclusively on the wing and catch their prey in mid-air, their food being chiefly other birds. The Buzzards, on the other hand, which feed mainly on Gophers and other rodents, are more leisurely in their movements. A Golden Eagle can carry a burden as heavy as itself and probably much heavier, provided it can get a start, as for instance off a steep hillside. Birds of prey thus have a wide field open to them. Owls show a peculiar modification of the foot in that the fourth toe is reversible at will; it can be turned either backward or forward.

Aquatic.—Ducks, geese and swans form a more or less natural tribe and, generally speaking, resemble each other. They are all water birds, provided with webbed feet, and bills typically adapted to procuring aquatic vegetation. The latter are flattened and broad, and lamellated inside, the corrugations affording a good gripping surface, virtually acting as substitutes for teeth. Modifications from the normal are few amongst Alberta waterfowl. The most interesting are possessed by the Mergansers and the Shoveller. The former (three Prairie species) are fish-eaters. Instead of being flattened, their bills are narrow and high and provided with decurved tips. The serrations on the inside resemble two lateral rows of teeth with the points directed backwards. The tongue, as compared with other ducks is but poorly developed. The birds are expert divers and particularly expert at catching slippery fish. The Shoveller shows a modification of a very different type. The lamellae on the inside of the bill, which is particularly broad, are produced laterally into bristles which hang downwards. The tongue, very fleshy and thick in most ducks, is exceptionally so in the Shoveller. A large quantity of water is taken into the mouth and is then expelled by the tongue, the bill being closed in the meantime. All the small organisms taken in with the water are trapped by the bristles, which act like a strainer, and thus the Shoveller obtains its peculiar food. The Osprey or Fish Hawk, also subsists on fish, but it drops on them from the air and possesses only the ordinary equipment of hawks. The Great Blue Heron, another famous fisherman, catches his prey by standing immobile until he detects his quarry when his long neck is shot out at great speed and the fish is caught by the massive bill. The Kingfisher may drop from the air while in flight after the manner of the Osprey, but generally he combines the methods of Osprey and Heron, sitting on a perch over the water and then dropping from there on his prey.

The White Pelican, one of the largest aquatic birds of our province, has a striking adaptation in the form of a large yellow mandibular pouch. In this elastic receptacle, which has a capacity of several quarts, the bird stores fish for its young.

The Loons and Grebes (Hell-divers) are the representatives of the diving birds in Alberta. The visible part of the leg is much more flattened than in the case of the ducks and geese, and is attached near the back of the body. Consequently the birds walk with great difficulty, but secure their food and escape from their enemies by diving. Their bills are pointed.

Shorebirds.—The shorebirds, e.g. Snipes and Plovers, exhibit some interesting adaptations for specialized methods of feeding. Their legs are generally long and their feet often partially webbed and in several species the small hind toe is wanting. The Plovers feed largely on land or in very shallow water and have short, hard bills. The Killdeer is the commonest Plover in the province. The Snipes, on the other hand, feed typically in water and probe into mud, thus reaching a food supply not available to other birds. The bill is usually very long and thin and provided with a nervous supply at the extreme tip.

The bill of the Dowitcher may exceed three inches in length. It is obvious that when this is pushed into thick mud it could never be opened, for the weight and pressure of the mud would make it quite impossible. The difficulty is overcome by a simple adjustment of the muscles and bones of the skull which enables the extreme tip only to be opened and closed again on the food which is pulled to the surface and then eaten. The Dowitcher's beak is straight.

The Curlews have long bills that are decurved; the Avocet's is turned up. The Turnstone, a rather scarce passage migrant in the province, has yet another peculiarity. Its bill is short and stout, sharply pointed and turned up at the end and is used for overturning small stones and collecting the little organisms that have taken shelter there. It thus finds a food supply all its own by one of the very simplest devices.

Exercises.—(1) Account for the diversity of form and habit that exists among birds.

(2) What are the resemblances and differences between the legs of birds and those of an animal such as a horse?

(3) Distinguish the beaks of seed-eaters from those which catch insects on the wing and those which catch insects on the trees or ground. Give examples.

(4) Show how, in the case of the Woodpecker, the beak, feet, and other parts are adapted for its mode of life.

(5) How could you decide by the feet of a bird whether it is adapted for perching?

(6) State the characteristics of beak and feet which would identify examples of the following types: meat-eaters, aquatic birds, shorebirds, Loons.

CHAPTER XXX

Economic Importance of Birds

Unfortunately, too many farmers do not distinguish friend from foe, and often destroy members of the feathered kingdom which it is in their own interests to protect. The economic status of a particular species cannot be determined, solely, by observation of the habits of one or more members. Careful examination must be made of the stomachs of many specimens killed in different localities. Only when this has been done can we form a fair estimate of the economic importance of the species in question.

Insect Eaters.—Birds are considered one of the farmer's best friends, and there is little doubt that even if they do not accomplish all that they are credited with, many of them do render him trojan service. This applies particularly to meat- and seed-eaters. Insects are so much parasitised by other insects and destroy each other, when things are favourable, at such a rate, that the actual role played by insectivorous birds, since they destroy the beneficent parasite as well as its host, becomes a very complicated question. We will not attempt to discuss it here, but, having pointed out these facts, we can run through the list of birds and indicate their types of food.

The food of the Meadowlark, for example, consists largely of cutworms, wireworms, grasshoppers, and other insects which do great damage to crops. Another efficient ally is Franklin's Gull, which is often seen in great flocks following gang ploughs and cultivators. These Gulls do not confine their work to the spring months alone but may be seen in great numbers in the fields of green grain during the summer, where they take heavy toll of Grasshoppers. There is grave danger in some sections of the province that this Gull may disappear because of the draining and bringing under cultivation of all the sloughs that have provided nesting grounds for the bird. Grasshoppers are the favourite food of the American Sparrow Hawk, the tamest and most gaily coloured of our Hawks. The term Sparrow Hawk is a misnomer, as this beautiful bird of prey rarely attacks other small birds. The Flicker, the most familiar Woodpecker in the province, is probably the most effective destroyer of ants found on our farms. It is now common on the open prairie wherever telephone or telegraph poles provide it with a nesting place. The Robin and the Killdeer help to reduce insects in many districts.

The Kingbird and other flycatchers capture practically all their food on the wing, and thus destroy many forms of insects not taken by other birds. The Nighthawk and the Swallows are other well known birds whose food consists entirely of flying insects. The Woodpeckers, with the exception of the Sap-suckers, are very useful because of their destruction of all types of insects found on, or in, trees. Contrary to popular opinion, they do not attack sound trees. The Yellow-bellied Sapsucker damages many sound trees by making openings through the bark in quest of sap. The Chickadee, Vireos, and the Warblers live almost entirely upon insects, and leave few areas on trees or other plants unexplored while in search of food.

Weed Seed Destroyers.—In applying the term seed-eaters to many species of birds we must bear in mind that nearly all of the so-called seed-eating birds raise their young largely upon insects. When the breeding season is over these birds turn their attention to the seeds of weeds which are ripening. The seed-eaters which either remain in Alberta during the winter or migrate here from the north continue the "harvesting" of the weed crop during that season. The great family of birds known as the Sparrows takes first place as destroyers of weed seeds. In this family are included not only the Song Sparrow, Vesper Sparrow, Goldfinch, and many other birds which are summer residents in the province, but also the Redpolls and Snow Buntings (Snowbirds), which spend the winter here. There is one undesirable member of the Sparrow family, the imported House Sparrow. The principal objections to this common bird are that it is very dirty about the buildings and that it drives away beneficial insectivorous birds by monopolizing the food supply in the spring months, occupying the nesting places, and by making itself so obnoxious that few other birds care to live in the immediate neighbourhood.

From time to time farmers complain of the damage done to grain by the Prairie Chicken. Investigation of the food habits of this game bird conducted by authorities of the Provincial and Dominion Governments seems to show that the larger proportion of food found in the crops of birds shot in the grain fields during the harvest consists of weed seeds (Wild Buckwheat, Shepherd's-purse, Mustard, etc.). Much of the grain eaten by the birds is taken from the stubble, and would be lost to the farmer in any event. The grain in the stook seems to be attacked chiefly when the ground is covered with snow. During ten months of the year the birds are compelled to live on waste grain, weed seeds, buds, berries, and insects. There can be little doubt that on the whole this splendid game bird is valuable from the agricultural standpoint.

Birds of Prey.—One of the most remarkable facts in connection with birds of prey is that the vast majority of people believe that the members of this group should be killed at every opportunity. The indiscriminate killing of hawks in the province is gradually removing the most efficient remaining natural control of gophers and mice. The problem of identifying the different species of hawks is a very difficult one because the colour of the plumage of the male is often quite different from that of the female, and that of the young birds, different from that of the adults. We may, however, remember a few rules suggested by the well known Canadian authority, Mr. P. A. Taverner. He states that all black hawks are positively beneficial. Most summer hawks on the prairies are to be regarded as beneficial unless taken in a harmful act. Those of late autumn or winter may be treated as harmful without much danger to innocent species. The large hawks which we see soaring at great heights during the summer are all beneficial. The two species which do considerable damage to poultry are the Sharp-shinned Hawk, a small hawk about the size of the Sparrow Hawk, and Cooper's Hawk, a larger bird which is able to carry away a fairly well-grown chicken.

Periodically, the settled sections of the province are visited during the winter by large numbers of Snowy Owls and large hawks (Goshawks) which prey upon the Prairie Chicken and domestic fowl. The chief food of the Snowy Owl in the north is the rabbit. An epidemic kills off great numbers of these rabbits about every ten or eleven years, and the birds of prey apparently come south to secure food. The owls, as a group, are effective destroyers of mice. The Golden Eagle is rarely seen on the prairies except in the autumn, when its chief food seems to consist of rabbits. The Bald Eagle lives largely on fish, as does the Osprey or Fish Hawk. The quantity of fish eaten by the Heron, Pelicans, Loons and other water birds of the province hardly warrants our classifying these birds as harmful to Man.

Crows and Magpies are regarded as harmful by the sportsmen because of their wanton destruction of the eggs and young of many species of game and insectivorous birds. The Magpie also attack the open sores of horses and cattle, and in some cases causes the death of the animals. It is becoming a serious menace in parts of the States by the permanent adoption of this habit and annually accounts for hundreds of sheep and cattle. In Alberta, the Crow does little damage to sprouting grain, and must be given credit for destruction of great numbers of Grasshoppers. The Cowbird has an unsavoury reputation because it neither incubates its eggs nor cares for its young. The eggs are deposited in the nests of other birds, and later the young Cowbird monopolizes the food brought to the nest by the foster parents. As a rule, the young of the rightful owners are pushed out of the nest, and perish on the ground.

Domesticated Birds.—The Chicken, the most important domestic bird, has been developed from jungle fowl first found in southern Asia. The wild Mallard Duck is the original stock from which many of the common domestic varieties sprang. Many breeds of geese have been developed from a bird native to Europe. The Wild Geese of Canada have also been tamed by many people. The Turkey is the most recently domesticated of our common fowl. Its ancestors are the Wild Turkeys which are native to North America. The ancestor of the Pigeon is the Rock Dove of southern Europe and Asia.

Exercises.—(1) What birds are of most immediate benefit to Man? Give reasons and illustrations. Name at least ten of the most beneficial birds.

(2) Which are the most beneficial of the seed-eating birds? In what respect do they help the farmer?

(3) Discuss the economic importance of each of the following: Owls, Hawks, Fish-eaters, Crow.

(4) State how you would identify each of the following, assign it to one of the classes noted in this chapter, and state its economic importance, if any: Meadow-lark, Bittern, Downy Woodpecker, Horned Owl, Bluebird, Song Sparrow, Warbler, the Ruffed Grouse.

CHAPTER XXXI

Characteristics of Mammals

Like birds, mammals are warm blooded, but instead of having a covering of feathers, they have one of hair. Mammalian hair is a unique structure in the animal kingdom. While no other animals possess it, there are no mammals without it. They may not have much of it as, for instance, some of the whales which have only a few bristles around the snout, but, such as they are, they are true hairs, nevertheless. The filo-plumes of birds are not hairs, nor are the hair-like structures of insects and other invertebrates. They may look similar but they differ both in development and structure. Hair is thus one of the defining features of mammals. A second is the possession of milk or mammary glands. Mammals, and mammals alone, feed their young on milk. *We can, then, define a mammal as a warm-blooded vertebrate which possesses hairs and suckles its young.*

Structure of a Hair.—Possession of a warm-blooded body has proved of no less value to mammals than to birds. A hairy covering made it possible. Let us then examine a hair and try to ascertain wherein lies its wonderful secret. A single hair is a simple structure and reminds us in its essentials both of the scale of the reptile and the feather of the bird. It consists of a cylindrical rod made up of cells arranged in several layers around a central axis, and also of cells, large elongated ones, placed end to end. They are products of the outer skin but are fed by a small papilla belonging to the inner skin. This is the point of growth and as long as the hair remains alive it will continue to grow no matter how often it is cut off on the outside. In most animals hairs grow practically all over the body, though in various directions on different parts. As they grow they overlap each other and in so doing they imprison air in the meshwork produced, and thus, as in the case of feathers, the owner is provided with an insulating coat that prevents the escape of heat from the body. In some hairs the large cells of the central axis may be hollow and filled with air. This is the case with the hairs produced by sheep and many other Ungulates (hoofed animals). These provide us with what we call wool. It makes a particularly warm covering, a fact of which man has taken full advantage for the conservation of his own body heat.

Specialized Hairs.—On many mammals, particularly the fur-bearers, hairs are of two kinds, long, shiny, rather sparsely scattered ones known as *guard hairs*, and underlying short and soft hairs which constitute the actual fur. Commercial furs that have been "plucked" have had the guard hairs removed so that the soft under-fur only is left.

The whiskers on a cat or rabbit are specialized hairs, longer and stiffer than the hairs of the fur and provided with a special nerve supply. They have thus become sensitive organs of touch. Stiffness is carried still further in the bristles of the pig family, and further yet in the coat of the Porcupine, the spines being really exaggerated hairs that have taken on a protective function. The origin of the sheath of the horns of cattle is probably nothing more than a welding together of masses of hair.

As we have already seen, not all mammals possess an actual coat of hair. The whale is one of the most complete exceptions. It has found a substitute in fat, which forms a thick insulating layer all over the body.

Regulating Body Temperature.—We have seen, then, that feathers and hairs enable the bearers to conserve their body heat. This does not, however, explain how they manage to *regulate* their temperature. The blood temperature of most mammals is about 100° F. When an animal exerts itself it is giving its muscles extra work, and this extra work produces extra heat. We know that the raising of the body temperature is dangerous and soon leads to death. We, ourselves, never fail to call a doctor when our temperature rises above normal, which with us is 98° F. But it is obvious that we and other mammals must have a mechanism whereby the effects of ordinary exertion, particularly in hot weather, are instantly counteracted. In most mammals this is achieved by *sweat glands* which produce a liquid that evaporates on exposure to air, and as we know from our Physics lessons, evaporation involves loss of heat. The whole body is thus cooled down. If sweat is secreted only in small quantities, its production is not noticed. Only when it pours out so fast that it cannot evaporate as quickly as it appears, does it become obvious. There are however, mammals that do not possess sweat glands; birds have not got them. Evaporation then takes place through the lungs in which air is constantly circulating and the blood is cooled down there. If the temperature falls below normal, muscular exertion soon restores it. Shivering is an automatic response to cold; in order for the whole body to shiver, most of its muscles have to do some work and so they produce the heat that is needed. A starving animal, exposed to cold, soon perishes for it cannot make good the loss of heat, for food bears a similar relation to the body as coal does to a furnace. Neither can produce heat without fuel.

As an accessory factor in the regulation of temperature, a good many species shed much of their hair for the summer months and put on an extra thick coat for the winter.

Protective Colouration.—One more remark about hair. It not only makes mammals warm blooded, but by proving adaptable as far as its colour is concerned it is of great importance for protection. Species inhabiting deserts are coloured like the desert. The young of many forest dwellers are speckled with light-coloured circles that make an excellent imitation of sunlight falling through foliage. Coloured so, they escape observation more readily than they would were they all of one colour. The tiger is striped vertically and harmonizes wonderfully with the tall jungle grasses he frequents. In the north many animals don a white coat for the winter. This makes them quite inconspicuous on the snow on which they have to live. It is often suggested in books that the real significance of the white coat is not protection but warmth but it must be remembered that in the far north, just when animals have turned white, there are months with no sunlight at all, when a white coat would be no warmer than a black, but it would still be *protective*, for there is always a certain amount of light.

Exercises.—(1) What are the features common to all mammals? What is the purpose of the hairy covering, and how it is adapted for this purpose? Describe guard hairs, fur, cat whiskers.

(2) What is the source of heat of animal bodies? What mechanism is possessed by mammals so that when too hot the body may be cooled?

(3) Show the protective effect of the colouration of the Coyote, Rabbit, Tiger, Zebra.

CHAPTER XXXII

Classification of Mammals

The Class Mammalia is divided into various Orders of which about a dozen are now generally recognized. We need not concern ourselves with all of them, for only six are represented in the animal life, or *fauna*, of the Prairie Provinces, but we must make brief reference to the whale, an example of a seventh Order, in passing.

This animal is of exceptional interest, because it shows how wonderfully mammals are able to adapt themselves in spite of their many specializations. Whales have taken to the oceans and have become as thoroughly aquatic as fish, for their young are born at sea. They never have to come to land, and, in fact, have lost the ability to do so. Even the most aquatic of birds, such as the Penquins, have to come to shore to lay their eggs and hatch them. The whales breathe with lungs; they are warm blooded; they possess hairs; they suckle their young; they are true mammals. They have lost their hind legs altogether and propel themselves by means of their tails which are highly specialized for the purpose.

The following Orders of the Class Mammalia are represented in the Alberta fauna:

Insectivora—*Insect eaters.*
Carnivora—*Flesh eaters.*
Ungulata—*Hoofed grass eaters.*
Rodentia—*Vegetarians with claws on their toes.*
Cheiroptera—*Bats.*
Primates—*Man.*

Insectivora.—The Insectivora are but poorly represented, the little Shrews alone occurring within the province. They are all small, short-tailed, long-snouted, and with small but very sharp teeth especially adapted to piercing the hard coats of insects.

Carnivora.—The Carnivora are more plentiful and of great importance to Man, for they include the wolves, foxes, lynxes, bears, martens, minks, otters, fishers, skunks, badgers, weasels, and, in general, those animals that make our fur industry so valuable. The only two outstanding exceptions which do not belong to this Order but which are valued for

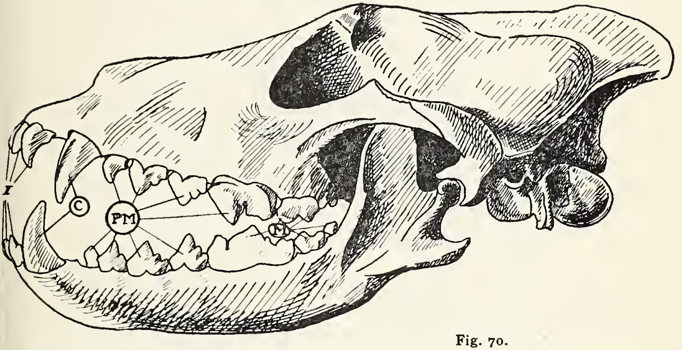


Fig. 70.
Skull of Carnivora. (I) incisors; (C) canine or dog teeth; (PM) pre-molars; (m) molars.

their fur are the Beaver and the Muskrat,—both Rodents. All these animals are meat-eaters, although bears are only partially so and subsist entirely on berries for part of the year. Carnivores are characterized primarily by their teeth which are adapted to a flesh diet. They are used for catching the prey as well as eating it and consist of four different kinds, At the front of the mouth, on both upper and lower jaws. are *incisors*, quite simple conical teeth, totalling about a dozen. Behind them, one on each side on each jaw, are two other simple teeth, very long and well developed. This, the *canine* or dog tooth, a very effective weapon of offense and defense, is followed by a variable number (usually six, or two dozen altogether) of *premolars* and *molars*,—cutting and crunching teeth.

Ungulata.—Teeth show great adaptability, and in the Ungulates, we encounter a very different kind. Here we are dealing with grass-eaters. The incisors are adapted to cutting and are of the same general shape as our own, though even broader. They may be wanting in the upper jaw and are, in fact, absent in practically all the ruminants, to which all our native Ungulates, goat, sheep, and the various deer, buffalo and prong-buck belong. Canines are also wanting but the premolars and molars are well developed. The latter present a broad surface that is ridged and grooved. The jaws of ruminants move sideways—like a cow chewing the cud—instead of straight up and down against each other. The grass is cut by the sharp edge of the lower incisors working against a horny pad above, and then ground up by the rough surfaces of the molars, which act like an old-fashioned stone mill.

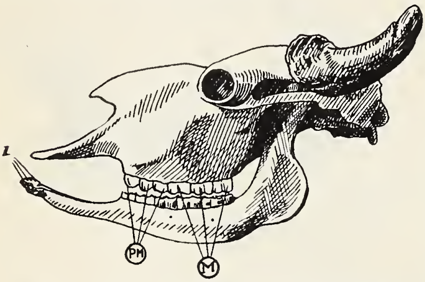


Fig. 71. Ungulata. (I) incisors; (PM) pre-molars; (M) molars.

The legs of Ungulates have much the same proportions as those of birds. The elbow in the front and the knee in the hind leg, are almost on the level of the body. The next joints down are the wrist and ankle respectively. Below that comes quite a long joint, and this, as in birds, represents what is the sole of our own feet. The pig walks on two toes only, while two more, one on each side, have become very small and fail to touch the ground. In the horse all the toes have disappeared but one and the horse walks on the tip of this.

In this connection the legs of the rabbit are of interest. The fore-foot has a reasonably small sole which is applied to the ground. In the hind leg the sole is somewhat elongated and only when the animals sits does it rest on the ground. In the horse the elongation has gone much further and is accompanied by the reduction of toes.

Rodentia.—The Rodentia are represented on the prairies by a number of forms such as the hares, gophers, squirrels, chipmunks, mice, voles, beaver, muskrat, woodchuck, porcupine, etc. The term Rodentia means literally gnawers, and they all certainly gnaw. Their teeth are characteristic, except in the hares and rabbits, the incisors number only a single pair above and a pair below. The hares alone have two pairs in the upper jaw and are unique in that the second on each side is placed *behind* the first instead of beside it as in all other mammals. Canines are wanting. The molars and premolars are rather like those of Ungulates, that is, they are ridged grinding teeth and not cusped. They vary greatly in detail from species to species. The incisors, however, are particularly remarkable, for they are so made that the more the animal gnaws the sharper does this keep them. They wear down, of course, as time goes on, but this defect is remedied by perpetual growth wherein they differ still further from ordinary teeth.

Two Alberta Rodents of particular interest are the Pocket Gopher and the Flying Squirrel. The former is popularly known as the Mole, but this is really a serious error, for the moles are Insectivores, an order, as we have already seen, represented in the province only by the Shrews. The Pocket Gopher lives almost entirely underground and is a great pest to gardeners for he is very fond of a root diet and his tunnels and mounds are a permanent nuisance. His fore-feet are specially adapted to digging and are armed with powerful, broad claws. The huge cheek pouches account for the name of "Pocket" Gopher.

The Flying Squirrel is of interest as a representative of those various vertebrates that have developed the habit of parachuting. He possesses a membrane stretching from the fore to the hind legs and this enables him to glide through the air for very considerable distances. At the termination of the glide he can direct himself adroitly upwards and so is able to "fly" from tree trunk to tree trunk, for he is chiefly arboreal. Being also nocturnal, that is, getting his living at night, he is seldom seen and is generally considered rare. As a matter of fact he is of very general distribution and, in places, extremely abundant.

Cheiroptera.—The Cheiroptera, or Bats, are on the whole poorly represented, only a few species occurring here. Bats

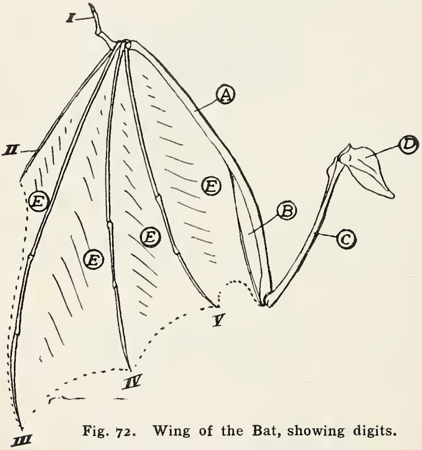


Fig. 72. Wing of the Bat, showing digits.

are remarkable because they can fly. They are insect-eaters and their teeth rather resemble those of the Insectivores. In our study of birds we saw that the bones of the hand have been reduced and partially united to afford the necessary rigidity for the support of the primary feathers. The Bat has no feathers to support. Such a modification would be useless to it. Instead, it has developed four elongated fingers (the thumb remaining small and free) across which a membrane is stretched, rather on the principle of the feet of ducks and frogs in which the toes are also long and webbed, for propulsion through water. But the Bat has carried the idea to an extreme, for a web large enough to form a powerful water paddle would be useless as a support in thin air. The membrane is continued to the hind legs and even the tail in some of our species. The Bat is nearly blind and flies at night by sound, not by sight. It has delicate sensory patches on the head and wing that enable it to detect very minute air disturbances and by means of them it can, even in complete darkness, evade thin wires stretched across a room.

Domesticated Animals.—The procuring of animals in the first place was merely a question of capture and taming. The idea must have occurred to many races, for cattle, for instance, have been domesticated in various parts of the world from different wild stocks. Our breeds are probably all derived from the European Aurochs. The humped cattle of India, the Yak of Tibet, the Gayal, etc., have been called into Man's service quite independently of each other. Commencing with his tamed Aurochs, European man has achieved wonders in producing strains to serve various purposes. He has produced beef breeds, milk breeds and general purpose breeds, the last being both good milkers and good beef producers.

Each breed has its own particular points of commendation and special value. While it is impossible to enumerate them here, the cat, rabbit, dog, sheep, goat, pig, ass, and horse are represented, like cattle, by numberless breeds, each of which serves some special purpose. The question we have briefly to consider is this: How was Man able to produce such varieties from his original stock?

Variations from the primitive types are continually occurring. As we learned in our study of plants, Nature selects those variations that are the most favourable, merely by giving them the advantage over their fellows and while the latter always come off second-best in the struggle for existence, the former come first. In time, they will replace their fellows altogether and a new race will have been evolved. When nature thus selects she does it very slowly and thousands of years may be required to establish a new race. We call this *natural selection.* Among Man's tamed cattle similar variations occur continually. But Man has them under his control and constant observation. If he wants a strain of beef cattle he breeds from those that show a tendency to good beef production. If he wants a dairy strain he breeds from the heavy milk producers. In a comparatively short time he has two very different strains, from his original beasts. He has made use of the occurrence of variations and applied *artificial selection* and produced two different animals. Variations in themselves would be useless if they were not inherited, that is, transmitted from parent to offspring. Development of species and natural selection depend upon heredity and variation. Man's artificial selection depends upon the same two principles. His methods are intelligent and purposive; his results comparatively speedy.

Exercises.—(1) Name six Orders of mammalian life represented in Alberta, and give familiar examples of each.

(2) Which fur-bearing animals of Alberta are flesh-eaters and which are not? Describe the teeth of the coyote, or fox, and state the purpose served by them.

(3) What animals belong to the Class called Ungulata? What are the Ruminants? Describe the teeth and the manner of chewing of one of this group.

(4) Describe the teeth of Rodents. What animals belong to this Class?

(5) Write brief descriptive notes on the Pocket Gopher, the Flying Squirrel and the Bat.

(6) From what animals have our cattle breeds probably been derived? What types of cattle has Man developed from these? What other animals have been domesticated? If each of these has been derived from a particular animal, how have so many varieties been produced from the original stock?

PART 5

BACTERIA

CHAPTER XXXIII

Micro-Organisms

Nature of Bacteria.—Bacteria belong to the lowest order of living things. It is customary to include them among the plants, but some believe that it would be better to look upon them as being in a class between the lowest plant and the lowest animal species. The names "germs" and "microbes" are popularly applied to many forms of bacteria. Some bacteria are motile, that is, they are able by their own power to move from place to place. They are so small that they can be seen only by means of a powerful microscope. Bacteria are to be found everywhere, in air, soil, and water.

Shape.—Bacteria are usually classified according to their shape. The four common forms are (1) *Cocci*, which are spherical or nearly so; (2) *Bacilli*, which are rod-shaped organisms; (3) *Spirilla*, which resemble a comma in shape; (4) *Spirochaetes*, which are spiral-shaped, like a corkscrew. Most of the names of bacteria contain one or other of these terms, so that from them one knows the shape of the bacterium under consideration.

Reproduction.—Bacteria increase in numbers by each bacterium simply dividing into two parts when it has grown to maturity. Under favourable conditions some types of bacteria will grow to maturity and divide as frequently as once every twenty minutes. Bacteria while multiplying in this fashion are said to be in the vegetative state.

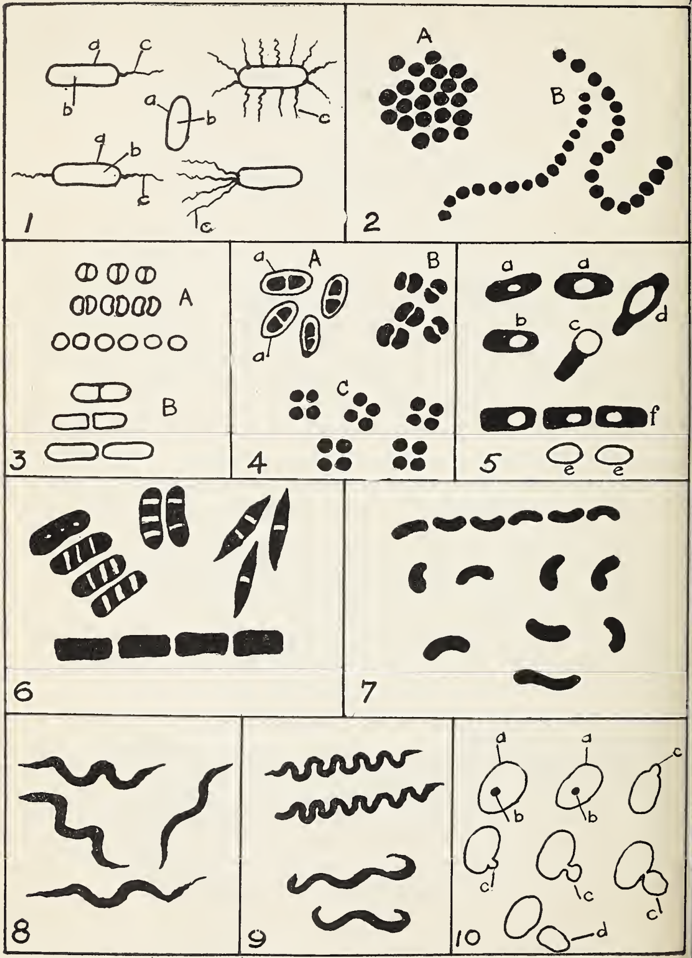


Fig. 73. Diagramatic representation of the form and structure of bacteria and yeast.

Certain species of bacilli and spirilla which are forced to cease multiplying by the vegetative method, on account of unfavourable conditions, form *spores*. These spores are round or oval with thick, tough walls. They form either in one end or at the centre of the bacterium. The spores are very resistant organisms and can withstand high temperatures, strong chemicals, etc. When favourable conditions are restored the spore sprouts and develops into the same kind of bacillus or spirillum from which it was derived.

Conditions Influencing the Growth of Bacteria.—

(a) *Temperature*. Bacteria that cause disease in Man or lower animals and those that are parasites on these thrive best at the body temperatures of their respective animal hosts, while those germs that normally live outside animal bodies, that is, in water, air, or decaying organic matter, grow best at ordinary summer heat.

High temperatures are detrimental to the growth and development of bacteria. Slight elevations above the normal for growth lessens vegetative reproduction and causes distortion of form and other abnormalities, while a very high temperature brings about their destruction. Most vegetative bacteria are readily killed by exposure to a moist temperature of 140° F. for ten minutes. Spores are more resistant but are killed by subjecting them to a moist temperature of 248° F. for about thirty minutes. Fortunately most bacteria causing disease in Man do not bear spores. Dry heat is less destructive to germ life than is moist.

Cold has little effect on most bacteria except to retard their growth. Vegetative reproduction ceases entirely at 32° F. A short exposure even to intense cold (283° F. below zero) will not destroy all germs, though storage in ice for several months will cause the destruction of many species in the vegetative state. Spores may resist freezing for years.

(b) *Air*. Some forms of bacteria (*Aerobic*) require the presence of free oxygen for their proper growth and multiplication, utilizing it in the oxidation of their food. Others

(*Anaerobic*) perish in the presence of free oxygen, for though they require oxygen they must obtain it by breaking down suitable substances of which it forms a part, for example, sugar. A third group can thrive either with or without free oxygen.

(c) *Moisture.* Bacteria require moisture for their growth. We are thus able to explain the good-keeping qualities of dried foods. Many disease-producing bacteria quickly die when dried.

(d) *Light.* Most bacteria thrive best in darkness. It has been found that direct sunlight is very destructive to germs in the vegetative state, many being killed by a very short exposure to the sun's rays. Diffuse daylight is less effective.

Yeast

The term yeast is applied to a class of plants a little higher in the scale of living things than bacteria. Although there is a great variation in the size of the different varieties of yeast, they are all much larger than bacteria. Yeasts, like bacteria, are widely distributed in nature being found on fruits, and grains, and in the soil. Yeasts reproduce by budding. Instead of the yeast dividing exactly in two as in the case of bacteria, a bud pushes out from the side of the mature yeast plant. Later, the bud breaks off and continues growth as a new yeast cell.

Yeasts are used in the manufacture of various alcoholic beverages. They form within their bodies substances which are called enzymes. These enzymes convert one sugar into another, and also convert sugars into alcohol and carbon dioxide. Each species of yeast has the faculty of producing the proper flavour in the beverage for the manufacture of which it is used.

In bread-making, the yeast serves the purpose of causing the bread to rise. The rising dough should be kept at a termperature between 77° F. and 86° F. as the yeast grows best within this range. Alcohol and carbon dioxide are formed in this instance as in the manufacture of alcoholic beverages. When the bread is being baked the heat causes the carbon dioxide in the air pockets in the dough to expand, and the whole loaf when baked is larger than the dough placed in the pan. Both alcohol and carbon dioxide are driven off during the baking. If too much yeast is used the air pockets in the bread will be too large. If insufficient yeast is used, or the temperature is maintained too low, or too high, the bread may take so long to rise that other organisms, mainly bacteria, will grow and produce deleterious changes, resulting in the making of an inferior product, for example, sour bread.

Exercises.—(1) What are bacteria? Classify bacteria according to their form. How do bacteria reproduce?

(2) Describe briefly the effect of heat, cold, air and moisture on the development of bacteria.

(3) What is yeast? In what respects does yeast differ from bacteria? Discuss the chief uses of yeast.

CHAPTER XXXIV

Dairy Bacteriology

Sources of Bacteria in Milk.—Milk as it is drawn from the cow always contains a certain number of bacteria even when the cow is healthy, clean and well cared for. Bacteria in milk are derived from several sources, among which are: (1) udder of the cow; (2) exterior of the cow's body; (3) dust in the atmosphere of the stable; (4) clothing and hands of the milker; (5) milking utensils; (6) water used in washing the utensils.

Types of Bacteria in Milk.—Bacteria found in milk may be divided into three large groups.

(a) *Lactic acid bacteria.* These bacteria are widely distributed in Nature, and are always to be found in milk. They produce enzymes which convert the sweet substance, milk sugar, into the sour substance, lactic acid. These bacteria, which grow best at a temperature of 86° F to 95° F., are responsible for the souring of milk. The presence of lactic acid is detrimental to the growth of many other types of bacteria. The production of this acid, by lactic acid bacteria, finally retards the growth of other bacteria which give undesirable odours and flavours to milk. This fact is taken advantage of in butter and cheese making.

(b) *The Colon group.* This group of organisms normally inhabits the intestinal tracts of animals and gain entrance to the milk, directly or indirectly, from manure. They, too, produce acid in milk by attacking milk sugar, and, besides, spoil milk for use in butter- and cheese-making by the production of foul flavours and odours. The presence of these bacteria in milk is undesirable for these reasons. Their growth is greatly encouraged by a temperature slightly higher than that required by the lactic acid group.

(c) *Bacteria that cause disease in Man.* The bacillus of tuberculosis often found in milk practically always comes from the cow. Bacteria causing other diseases come directly or indirectly from people who are either suffering from these diseases or are carriers of these diseases. Among these bacteria are those which cause typhoid fever, scarlet fever, diphtheria, and intestinal trouble.

Growth of Bacteria in Milk.—Milk is an excellent medium for the growth of bacteria because of the variety of food constituents it contains. Most bacteria found in milk multiply most rapidly at a termperature of from 68° F. to 95° F. Milk containing 5,000 bacteria per cubic centimetre was kept at a temperature of 69° F. for twelve hours, and was then found to contain more than eight million per cubic centimetre. It is easy to understand why milk spoils quickly in warm weather. If milk is kept at a temperature of 50° F. or lower few bacteria will develop.

Pasteurization of Milk.—Nearly all the bacteria in milk can be killed by boiling the milk for a time. This treatment gives an undesirable flavour to the milk. A more satisfactory method of treatment is that known as pasteurization. In this process the milk is brought to a temperature of 142° F. and maintained at that temperature for thirty minutes. It is then quickly cooled to a temperature of 46° F. to 50° F. About ninety per cent. of the bacteria, including those which carry disease, are killed by this process of heating, and those that are left are prevented from multiplying by the rapid cooling. The bottles, in which the milk is distributed to the consumer, are filled and capped by machinery in order to avoid the introduction of disease-producing bacteria by human handling. For the same reason, milk should never be delivered to consumers in open cans nor should shopkeepers be permitted to sell milk except in sealed bottles.

All milk sold by large dairies in cities is pasteurized. This process gives a safe milk supply and does not change the flavour or render the milk difficult to digest.

Bacteria in Relation to Butter.—Butter may be made from sweet or sour cream. Sweet cream butter is usually flat in taste having only the flavour of butter-fat. Its keeping qualities are not as good for the reason that it lacks the lactic acid found in butter made from sour cream.

As already mentioned the souring of milk and cream is due to acids produced by lactic acid bacteria. The lactic acid inhibits the growth of other undesirable germs. Some of the lactic acid and other substances formed by the lactic acid bacteria remain in the sour cream butter and help to preserve it. Besides, they give the butter a special flavour.

If milk or cream that is to be used for butter-making is improperly handled, and undesirable bacteria, e.g. the Colon group, are permitted to gain entrance and multiply in quantity they will greatly reduce the quality of the butter by causing undesirable flavours.

Bacteria and other organisms may gain entrance to butter not only from the milk but from water and apparatus used in the manufacture, working, and washing of butter.

Besides bacteria, molds and yeasts are found in butter and these can multiply even in the ordinary ice chest so that great care should be exercised to prevent their entrance during the process of manufacture. Butter to be kept for a long time must either be kept at very cold temperatures or be salted heavily.

Butter made from sweet, cleanly handled, pasteurized cream keeps best of all if properly stored, for the reason that even lactic acid bacteria cause more deterioration than few or no bacteria at all.

Bacteria in Relation to Cheese.—(a) *Cheese-making and ripening.* In the making of the ordinary Canadian hard cheese (*cheddar*) the following procedures are carried out:

(1) Ripening of the milk by encouraging the growth of lactic acid bacteria.
(2) Curdling of the ripened milk by the addition of rennet.
(3) Cutting, draining and pressing the curd.
(4) Ripening the cheese.

Bacteria and moulds take a very important part in the manufacture and ripening of cheese.

The ripening of the milk prior to the addition of rennet is brought about either, first by the encouragement of the growth of normal lactic acid bacilli present in the milk by proper control of temperature favouring their growth, or second, by adding to the milk a pure culture of lactic acid bacilli and developing them at a proper temperature.

These bacilli produce the acid that is necessary for the proper action of the rennet.

Rennet is obtained from the stomach of the calf and contains two enzymes, one rennin, which causes the curdling of the milk, and the other, pepsin, which dissolves a part of the curd during the process of ripening. Both of these enzymes require the presence of an acid in order to bring about their proper changes. This acid is produced by bacteria belonging to the lactic acid group.

Besides making conditions suitable for the action of the enzymes of rennet, the lactic acid bacteria, by the production of their acid, inhibit the growth of putrefactive bacteria. Temperature is very important. The putrefactive bacteria, prefer a temperature a few degrees higher than the lactic acid group, so if the temperature used during the ripening of milk and of cheese is higher than that suitable for the growth of lactic acid bacilli, the putrefactive bacteria will be encouraged and will develop undesirable flavours and perhaps completely spoil the cheese. The ripening of cheddar cheese is due mainly to the action of bacteria (enzymes). The growth of moulds is prevented during ripening.

In some cheese, such as Roquefort and Camembert, moulds take a very active part in the ripening process. The ripening process is carried out in comparatively cold places, cellars or caves, where the moulds grow well. The moulds develop in the presence of moisture and acid, which they use for food. The typical flavour and texture of each cheese is brought out by the action of the enzymes produced by the moulds.

(b) *Practical Results.* The results obtained will depend on the care in production and handling of the milk as well as the use of proper methods of cheese-making. If, in the production and handling of the milk, many undesirable bacteria are permitted to gain entrance, or the milk is held at temperatures favouring their development, an inferior product is liable to result. Proper attention to the development of lactic acid bacteria is necessary to obtain a good quality of cheese. The process of manufacture and ripening must be carried out in such a way as to encourage the growth of the organisms necessary to produce the characteristic flavour and texture of the cheese concerned.

(c) *Methods of keeping butter and cheese.* There are two principal methods in use for the preservation of butter: (1) Cold temperature. (2) Salting.

(1) Cold temperatures—Butter should be stored at 32° F. as this temperature interferes with both the growth of bacteria and the action of enzymes. At slightly higher temperatures, up to 50° F. it may be kept for a short period but will gradually deteriorate.

(2) Salting—Heavy salting, by the osmotic action on bacteria, will aid greatly in preservation.

Preservatives—Boric acid added to butter in one half of one per cent. quantities is not considered dangerous and will aid in its preservation, but it is still necessary to keep the butter cold. When preservatives of this nature are used there should be a statement to this effect on the outside of the package in order that the consumer may know. Though the use of boric acid and some other preservatives is permitted in some foods, their use is not recommended except in foods that are consumed in small quantities. Canada forbids their use in butter.

As an aid to preservation, cheese (cheddar) is dipped in melted paraffin. This prevents the entrance of air, which is necessary to the development of mould spores. Cheese is stored at temperatures as cold as used in the storage of butter.

It should be remembered that in the preservation of cheese and butter no method now in use will remove the undesirable flavours due to the presence of bacteria in the milk prior to manufacture of the article.

Exercises.—(1) Name the chief sources from which bacteria in milk are derived.

(2) Account for the souring of milk.

(3) Outline the process of pasteurizing milk.

(4) Why is sour cream usually superior to sweet cream butter? What are the common sources of bad flavours in butter? What is the effect of heavy salting as a preservative? What butter keeps best of all? Why?

(5) Describe the manufacture of cheddar cheese. Why is temperature important in ripening? What part have moulds in the production of flavours in different varieties of cheese? How is the result secured?

(6) Suppose a sample of cheese to be ill-flavoured. To what various causes might this be due? Why is the use of boric acid as a preservative less injurious in cheese than in milk?

CHAPTER XXXV

Bacteria in Relation to Other Foods

The Spoiling of Food.—Bacteria, yeasts and moulds, since they are so widely distributed in Nature, are found in great numbers on fruits. Growing fruits with firm sound skins, resist their entrance. Once, however, the fruit is injured, bacteria and other organisms may gain entrance and multiply.

The character of the fruit will determine to some extent, which of the three types of organisms will predominate and what will be the character of the change.

Before considering the action of these organisms, it is perhaps best to say something of fruits themselves. All living cells produce enzymes. Fruits are no exception. When fruits become overripe they soften, their flavour changes and they become inferior for our uses. These changes are brought about by the action of enzymes produced by the tissues of the fruit. These enzymes bring about the softening of the overripe fruit. When an apple is cut, the cut surface soon turns brown. This change is caused by an oxidizing enzyme in the juice of the apple. Bacteria, yeasts and moulds are nearly always present on the surfaces of fruits, having been carried there by the wind and insects. These at once begin to make inroads on the injured fruit and those organisms, which the conditions suit best, will predominate. Bacteria require or prefer lots of moisture, while yeasts and moulds grow better on drier substances.

Yeasts usually require carbohydrates for their best development, while bacteria and moulds will attack many substances.

Only those organisms for which conditions are suitable will grow. Many species of bacteria will not grow in acid fruit juices, while others will. Yeasts and moulds grow better than do most bacteria in slightly acid food. The spoiling of fresh fruit may therefore be said to be brought about, first, by the action of its own enzymes and later by the growth of bacteria, yeasts and moulds and the action of their enzymes.

The Preservation of Food.—Since the main cause of the spoiling of our foods is the growth in them of bacteria, yeasts or moulds, or a combination of these, the problem set before us in the preservation of food is to kill these organisms before spoiling takes place and to prevent others entering, or to arrange conditions so that they will be unable to grow. In preserving food it is usually desirable to retain as nearly as possible its fresh and original or customary flavour and texture or at any rate to obtain a good palatable food.

The method of preserving foods varies with the character of the food. Some foods may be preserved by several different methods, for example, berries may be preserved in sugar or canned. By either method, if properly done, the berries will keep, but the flavours will differ according to the method used. In general, food may be preserved by the following methods:

(a) *Drying*. Many foods can be dried and thus be kept for a considerable period without spoiling. One has only to recall to mind milk powder, dried apples, dried apricots, raisins, dried beef, and dried fish. The method employed in drying will depend on the nature of the food. It will be necessary to remove moisture sufficiently rapidly to prevent the growth of bacteria, yeasts and moulds during the process of drying. The methods employed are: *sun drying*—used where atmospheric humidity is low and there is plenty of sun at the right season of the year; *drying by artificial heat*—where climatic conditions are not suitable or where sun drying is not sufficiently rapid. Temperature must not be so high as to spoil the flavour of the food. With foods that are easily spoiled by high temperatures a *partial vacuum* is used with low temperature and this brings about rapid drying.

With some foods other methods of preserving are employed in conjunction with drying, for example, *smoking* and drying of meat, and fish. The smoke, from the wood fire, is antiseptic and greatly enhances the keeping qualities besides adding an acceptable flavour. *Salting* is used in conjunction with drying, as for example, in dried cod fish. The removal of water by *hydrostatic pressure* is used in the drying of some foods.

The preservative action of drying is due to:

(1) The extraction of so much moisture that there is insufficient left for the use of bacteria and the other micro-organisms, for example, dried apples. Grains such as wheat and oats resist the onslaught of micro-organisms by reason of their dryness.

(2) The concentration of the soluble substances in them, that is, the water that still remains in them contains substances in such concentration that the osmotic pressure is too great for the micro-organisms. Examples of this class are dried currants and raisins.

(b) *Salting*—as used in the preservation of fish and meats. In this method of preservation the salt is so concentrated that the bacteria cannot live. They die for the reason that the osmotic pressure is too great.

(c) *Acid.* That used for preserving food is acetic acid—vinegar. Most bacteria grow best in a very faintly acid medium. Some will grow in more acid media than others. As already seen the lactic acid bacteria produce sufficient action in milk to kill off many other species. Moulds will usually grow on media more acid than will bacteria.

(d) *Sugar.* If fruits are cooked with comparatively large quantities of sugar they are said to be "preserved." The concentrated sugar solution brings about a great loss of water from the bodies of the bacteria owing to osmotic pressure, and results in the death of the bacteria.

In the case of "canned" fruit, very little sugar is added. The fruit is packed in jars, the lid applied, and the contents sterilized by one of the methods indicated in section (e) below. If the jar is not sealed properly the fruit will spoil because of the entrance of bacteria, and their growth in the dilute sugar solution, which is a good food for them.

(e) *Sterilization.* By this term is meant the destruction of all life. In sterilization by heat, the temperature required and the length of time it must be maintained will be determined by the kind of organisms to be killed and the bulk of the material to be sterilized. Most vegetative bacteria are killed by heating to 140° F. for 10 to 20 minutes. A few vegetative forms are more resistant and spores require a much higher temperature, and longer heating. The more spores present, the longer the time required for sterilization. Sterilization may be accomplished by:

(1) The *discontinuous* or *fractional* method in which the jars packed with fruit and with lids on (but not sealed) are heated to 212° F. (the temperature of boiling water) for a certain period on each of three successive days. The idea behind this is that bacteria in the vegetative forms are killed during the heating and that, while the jars are cool between the heatings, spores will germinate and develop into vegetative forms to be killed on the next heating.

(2) Heating to the temperature of boiling water and maintaining sufficiently long to kill all life.

(3) Heating to a higher temperature by cooking in a pressure cooker. This is the method of choice to obtain sterility as temperatures of 248° F. or more may be obtained, and these are sufficient to kill all life. The temperature used must be controlled in accordance with the character of the food to be preserved. Fruits lose in flavour by preserving with very high temperatures, while vegetables and meat do not. Spores are found in greater numbers on vegetables than on fruit. After sterilization the jar must not be opened and should be promptly sealed to prevent the entrance of bacteria present in the air. This method preserves food permanently.

(f) *Pasteurization.* As already explained, this is heating to a temperature of 140° F. and maintaining this temperature for 20 to 30 minutes. This temperature kills only the majority of the bacteria that are in the vegetative state. Spores and the more resistant vegetative bacteria remain alive.

This method is used in the preservation of fruit juices and for milk. They will keep only for a short time, the milk only for a few days.

(g) *Refrigeration*. This method of preserving food is used for meat, fish, eggs, butter, and fruit.

The growth of most varieties of micro-organisms ceases when the temperature drops to 46° F. or 50° F. but even below this some micro-organisms will continue to multiply slowly and their activity does not altogether cease till 32° F.

For meats there are two methods of storing:

(1) Chilling. By this is meant the cooling of the flesh in a refrigerating plant to about 34° F. or 36° F. and maintaining this temperature. At this temperature the native enzymes are still active and a few micro-organisms multiply slowly so that there are some changes going on in the meat. These changes are spoken of as "ripening". The meat becomes more tender. It will sooner or later spoil.

(2) Freezing. The temperature is lowered and kept at 4° below zero Fahrenheit until the meat is frozen solid. It is then stored at 25° F., and will keep at this temperature indefinitely for there is neither action of native enzymes nor bacteria. The meat is not so good as fresh or chilled meat.

Eggs and fruit are usually stored at 34° F. to 36° F., hence they will not keep indefinitely.

Exercises—(1) Why are damaged fruits most likely to be spoiled? What organisms cause fruit to spoil? What conditions favour one form of organism and what another in this? What is the part played by enzymes?

(2) What two aims are usually in mind when preserving foods? What are the chief means of preserving used in the household?

(3) Name foods that are dried or evaporated for purposes of preservation. Name others where drying is combined with other processes. Give the cause of the preservative effect in each case.

(4) Give examples of foods dried in the sun, and of foods artificially dried. Why should the heat not be too high? Why should the action take place as rapidly as possible? How does the vacuum process aid in drying?

(5) Why are bacteria or moulds not likely to attack (a) Wheat in the bin, (b) raisins or currants, (c) hay in the barn?

(6) Why cannot bacteria live in (a) salted meats, (b) pickles?

(7) Describe three methods of completely sterilizing fruit or vegetables in jars intended to be kept for winter use. Discuss the effectiveness of each.

(8) Compare the effects of freezing and chilling meats to preserve them. How are eggs kept in cold storage?

CHAPTER XXXVI

Bacteria in Relation to Disease

Pathogenic Bacteria.—Many diseases from which Man, lower animals and plants suffer are the result of the invasion of their bodies by lower forms of life. Bacteria of various kinds must now be regarded as forming by far the largest class of these small disease-producers, though lower animal forms such as protozoan organisms, worms, lower plant life, yeast-like, and mould-like forms also are productive of some diseases.

Bacteria (or other organisms) that cause disease are said to be *pathogenic*. Bacteria pathogenic for animals are restricted in their disease-producing activities to one, or at most a few species of animals, the typhoid fever bacillus, for example, causes disease only in Man, while the bacillus of tuberculosis is able to produce disease in Man and some lower animals. Many pathogenic bacteria are so accustomed to growth within the body of the particular host in which they cause disease that though they may remain alive outside the animal body for a longer or shorter time they do not multiply, while others, on the other hand, may frequently find conditions suitable for growth and multiplication.

Bacterial Invasion and the Outer Defences of the Body.—Before disease can arise, bacteria must first gain entrance to, or invade, the body. The skin, being formed of several layers of epithelial cells, is a distinct barrier to invasion and in its uninjured state few organisms can pass through it. The mucous membranes of the nose, throat and digestive tract act in a similar manner to the skin though less effectively. These membranes, too, are washed by a secretion of mucous which, besides tending to wash away bacteria, has the effect of lessening bacterial growth or even killing some forms, the gastric juice is particularly destructive to some species though others will pass through the stomach unharmed.

It will thus be seen that to produce disease bacteria must first gain entrance to the body and invade the tissues. They accomplish entrance to the body by: (a) wounds, or by bites of insects, (b) inhalation, (c) food and drink.

Many communicable (*infectious*) diseases of our northern climate are transmitted from one person to another by *inhalation*. Among these are measles, scarlet fever, diphtheria, cerebro-spinal meningitis, and infantile paralysis. It is important to remember also that while the bacteria causing these diseases gain entrance to the body by inhalation they find exit from the body of the diseased in the expectorated sputum and in the fine droplets of mucous expelled during coughing, sneezing and loud talking. Many bacteria transmitted in this manner die quickly on drying and exposure to sunlight and fresh air, hence it is assumed that sneezing and coughing of the diseased person in the immediate vicinity of others is the usual manner of spreading these infections.

Among those diseases commonly caused by food and drink are typhoid fever and some food poisonings. The bacteria gain entrance to the food and water either by contamination by sewage or by diseased persons or those caring for the sick or by carriers contaminating the food by handling it with unwashed hands.

Carrier.—An important element in the spread of some communicable diseases is the carrier. By a carrier is meant a person who has had a communicable disease and has recovered but who persists in carrying in his body the causative bacteria and distributing them to people who come in contact or have dealings with him. A small percentage of those recovered from diphtheria and typhoid fever remain carriers of these diseases and are liable to infect others by coughing and sneezing in the case of diphtheria or by contaminating food which they handle in either case.

How Bacteria Produce Disease.—Bacteria produce disease by multiplying within the body and setting free poisons which are injurious to the cells of the host. These poisons, or *toxins* as they are called, may be divided into two groups:

(a) Those, commonly called *exotoxins*, that are secreted by the bacteria while they are still living;

(b) *Endotoxins*, or those that are released from the germs when their bodies are dissolved.

The Responses of the Body to Bacteria Producing Disease.—When disease-producing bacteria gain entrance to the body of a suscèptible person they may multiply or secrete their poisons so rapidly that the body cells may be very seriously injured and death quickly result. If, on the other hand, the invading bacteria are less aggressive or their toxins less poisonous and the individual attacked has some natural powers of resistance, the disease will be more prolonged and the cells of the body will respond by producing suitable substances to kill the bacteria and to neutralize their secreted exotoxins. In other words, a struggle ensues between the body cells of the diseased and the invading bacteria and continues until the one force or the other is overcome.

The substances produced by the body to kill off the bacteria and counteract their poisons are called "*antibodies*". Those that neutralize the poisons are called antitoxins, while those that kill bacteria receive the name "*antibacterial antibodies*".

Following recovery from one or other of many of the acute communicable diseases, for example, typhoid fever, scarlet fever, measles, diphtheria and some others, the individual is found to resist a second attack of the same disease. This resistance or immunity results because the body cells continue to produce the antibodies that enabled them to overcome the original infection. The length of time during which the body remains resistant varies with the different diseases but some convey to the recovered individual a lifelong freedom from further attacks of his previous illness.

Immunity.—(a) *Active immunity.* When a person is frequently exposed to a disease and does not contract it we say that he has an immunity to the disease or that he is immune. It has been pointed out already that immunity to some infections may be had by having those diseases and recovering. Such an immunity is referred to as an immunity acquired as the result of disease. Illness, however, is dangerous, distressing, and often a great price to pay for immunity. Hence people should not unnecessarily expose themselves to diseases to gain this end.

We know now that immunity to a number of infections may be obtained by much safer and easier means. In order to produce artificially an immunity that will last for several years, dead or weakened bacteria or bacterial toxins in small measured doses are introduced into the body by means of a needle. The more common diseases against which such protection may be had are diphtheria, scarlet fever, typhoid fever, and smallpox.

The following are the methods in use for obtaining this artificial immunity:

Diphtheria. The introduction of two small harmless doses of weakened diphtheria toxin (commonly called toxoid) under the skin, one month intervening between the two inoculations, causes the development of an immunity to diphthera that will persist for from three or four years in ninety per cent. of the people.

Scarlet fever. Scarlet fever toxin is injected, as in diphtheria, except at intervals of a week until four doses are given.

Typhoid fever. Dead typhoid fever bacilli (killed by heat) are injected under the skin at weekly intervals for three weeks.

Small-pox. Edward Jenner, an English physician, in the latter part of the eighteenth century, observed that when he transferred material from the blisters on the udders of cows suffering from cow-pox to fresh scratches on a child's arm, the child developed a mild disease with a sore just at the point where the arm was vaccinated. He further observed that a child so vaccinated with cow-pox was no longer liable to become ill of small-pox.

It is now believed that the disease cow-pox is due to the infection of the cow by the same micro-organism that causes small-pox in Man, and further that the growth in the cow has so modified the habits of the micro-organism that when it is again transferred to Man it is no longer able to produce small-pox but is still able to cause the production of immunity to that disease.

At the present time calves used for the making of small-pox vaccine are carefully selected, housed in clean stables and very carefully fed and attended. They are given cow-pox artificially and when the disease has developed to the proper stage, the fluid is collected from the little blisters, purified, mixed with glycerine to preserve it and stored in little glass tubes. The fluid in these tubes is called small-pox vaccine and is used to vaccinate people against small-pox.

It will now be seen that the above methods of artificially obtaining immunity to these various diseases are but imitations of the means which Nature employs in disease. In our artificial methods we utilize (1) the poison produced by the bacteria as in diphtheria and scarlet fever, (2) the dead bacteria as in vaccination against typhoid fever, and (3) the attenuated (weakened) living micro-organisms as in small-pox vaccination.

In all these cases the immunity obtained is spoken of as "active acquired immunity" for the reason that the body cells of the vaccinated take an active part in the production of the immunity.

(b) *Passive Immunity.* In a few diseases it has been found possible to immunize the horse, or some other suitable animal, to disease-producing organisms and to utilize the blood serum of the animal so immunized to cure or protect a person against such disease for a very short time.

Antidiphtheritic serum (diphtheria anti-toxin) is the purified and refined blood serum of a horse that has been immunized against diphtheria by repeated injections of diphtheria poison under its skin.

Diphtheria anti-toxin, when injected into a child suffering from diphtheria, will cure it of that disease by uniting with the diphtheria poison circulating in the child's blood. To obtain the best results, anti-toxin must be given early in the disease because it cannot undo any injury that has already resulted from the poison, but is able to prevent further injury.

Diphtheria anti-toxin is also used to prevent the development of diphtheria in a child who has been exposed to infection and is liable to contract the disease. The immunity conveyed by the use of diphtheria anti-toxin lasts a very short time,—about three weeks or less.

Tuberculosis.—(a) Tuberculosis is a disease caused by the bacillus of tuberculosis. It manifests itself in different ways; thus, one may have tuberculosis of the lungs, commonly called consumption, or one may have tuberculosis of the bones or joints, or of the lymphatic glands, or other parts of the body. Whatever part is affected it is always due to the bacillus of tuberculosis. The bacillus does not form spores and can be killed by heating to 140° F. for ten minutes.

There are three main types: (1) Human—affecting mainly human beings, (2) Bovine—affecting cattle but also human beings, (3) Avian—affecting birds, chickens, turkeys, etc.

There are two main routes by which this disease may be contracted: (1) by inhalation, (2) by food or drink—mainly milk.

People suffering from tuberculosis of the throat or lungs will for a longer or shorter period have in their sputum and in the mucous in their mouths live tubercle bacilli. When they cough, sneeze or talk loudly they will spray out small drops of mucous, which will contain living tubercle bacilli. These little drops of mucous may float in the air for some minutes and persons in the immediate vicinity may inhale them. Also people suffering from tuberculosis of the lungs or throat should be especially particular not to expectorate in public places. Their sputum should be burned or they should expectorate into a vessel containing a disinfectant. The habit of spitting indiscriminately in halls, buildings, cars, and on the streets is both disgusting and dangerous. It is dangerous in people suffering from tuberculosis for the reason that tubercle bacilli are quite resistant to the natural killing forces—light, drying, etc. When the sputum dries it is easily broken up and may be spread into the air as dust, carrying with it the live tubercle bacilli ready to be inhaled by other individuals.

Tuberculosis of other parts of the human body are not liable to spread among others as the tubercle bacilli do not get into the atmosphere at large.

Tuberculosis may be carried by food—meat and milk.

Meat is not as a rule dangerous for two reasons: (1) Government inspection ensures that dangerous carcasses are condemned. (2) Thorough cooking will kill tubercle bacilli.

Many cows used for milk suffer from tuberculosis and the tubercle bacilli gain entrance to the milk. This is important since the main food of young children is milk and they are very susceptible to tuberculosis. Cows suffering from tuberculosis should not be used for the supply of milk to human beings nor animals.

All milk should be pasteurized to ensure that should the milk contain tubercle bacilli or other harmful organisms they will be destroyed.

Exercises.—(1) What are pathogenic bacteria? How do such germs enter the body? Do any of these infect man and animals alike? What are toxins? Distinguish two types. What is the effect of toxins?

(2) What is the bacterium causing tuberculosis? How does it enter the body? In what way is a tuberculosis patient a danger to those about him? In what respect are the bacteria resistant? What are the usual means of prevention?

(3) Why are persons who have survived attacks of (a) typhoid fever, (b) diphtheria, immune for some years? How does vaccine for typhoid produce immunity? Why does anti-toxin do so for diphtheria? What is the nature of the vaccine for small-pox and what is its effect in causing immunity?

(4) Experiments with bacteria cultures:

Experiment 1—Make a mixture of beef broth and unsweetened, unflavoured gelatin. Heat this to the boiling point and pour out in three shallow dishes to a depth of about one-quarter inch. Sprinkle into one a small quantity of garden soil, into the second some baked soil, and leave the other unchanged. Cover and set in a warm place for a day. Observe the spots appearing in the first on the surface but not on the others. These are colonies of bacteria, and finally they cause liquefaction of the gelatin.

Experiment 2—Boil a pint of milk and allow it to cool. Separate into two cups or bottles which have been carefully sterilized. Into one pour a teaspoonful of sour milk. Cover both. Observe again in a day. Several other portions of milk might be experimented with at the same time to observe the effect of sterilizing solutions such as formalin, carbolic acid, boracic acid, etc.

CHAPTER XXXVII

Soil Bacteria

Classes of Soil Bacteria.—We should think of the soil not merely as a storehouse for food for the plant, but also as a busy factory where great numbers of bacteria and other organisms are constantly at work. These organisms are found in greatest numbers near (although not usually at) the surface, decreasing rapidly downward, and generally disappearing wholly at a depth of from seven to eight feet. The bacteria which have been studied chiefly from an agricultural standpoint are those concerned with the supply of nitrogen to the plant. We may divide these bacteria into three great classes, dependent upon the nature of the work which they perform.

Nitrifying Bacteria.—In our study of plants we found that the plant food in the soil must be dissolved in water before it can enter the plant. Most of the nitrogen in the soil is contained in the *humus* or partially decomposed vegetable matter. Before this nitrogen can be taken up by the roots of the plant it must be converted into nitrates, a form which dissolves readily in soil water. The bacteria which bring about this transformation of the nitrogen are known as *nitrifying bacteria.* Without their valuable aid little of the nitrogen in the soil would be available for use by plants.

Nitrogen-Fixing Bacteria.—If you dig up carefully the roots of Alfalfa, Sweet Clover, Wild Vetch, Caragana, or other leguminous plants you will find on them a number of small lumps. These nodules or tubercles are produced by bacteria, for which they serve as a home. These bacteria take the nitrogen from soil air and "*fix*" it in a form for use by the plant. They are therefore called "*nitrogen-fixing*" bacteria. If a legume crop is ploughed under, a valuable supply of nitrogen is added to the soil with little expense, and in a form that is readily available to other plants.

De-Nitrifying Bacteria.—Not all forms of bacteria in the soil are beneficial to Man. Some bacteria attack nitrates in the soil and either set free the nitrogen or convert it into a

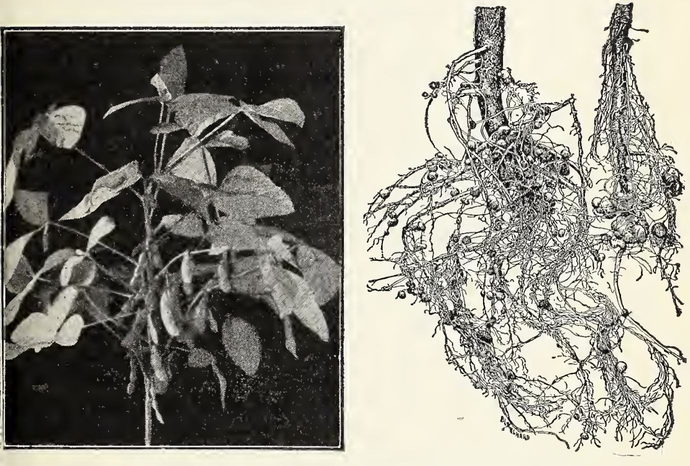


Fig. 74. The top and root of the Soy Bean plant. Note the Nodules.

form that cannot be used by plants. These harmful bacteria are known as *de-nitrifying bacteria.*

Conditions Favouring Development of Beneficial Bacteria.—Several conditions are necessary for the development of nitrifying and nitrogen-fixing bacteria. (1) A moderate amount of moisture is necessary. The activities of bacteria cease in a dry soil, and the presence of too much water shuts off the supply of air. (2) An abundance of organic matter is necessary to provide food for the bacteria.

(3) A favourable temperature, 65° F. to 95° F., is essential. Activity decreases as the temperature lowers and ceases at the freezing point, although the bacteria are not killed by freezing. Early tillage in the spring, drainage, and dark-coloured soil encourage bacterial action since they promote soil warmth. (4) An abundant supply of air is necessary for the work and growth of the beneficial bacteria. (5) Darkness is necessary, as the bacteria are destroyed by the action of strong sunlight. As a result they are not found at the surface of the soil. (6) A slightly alkaline soil is most suitable for the development of beneficial bacteria. Not only does acid retard their development, but they also, in the course of their work, produce acids which must be neutralized by lime or some other base. We are thus able to explain why Alfalfa and Clover do not thrive in sour, swampy soils.

Soil and Seed Inoculation.—If a legume has been grown in a district for some time, legume bacteria will be found present in the soil on the farms. If a new legume is being introduced one should see that the soil or seed is properly inoculated for the members of that group of legumes.

Soil may be inoculated by placing on the field some soil from a field in which either the legume to be inoculated or a member of the same group is growing. The top two-inch layer of soil should be discarded because of its dryness and exposure to the direct sunlight. Soil from the next four inches should be taken and applied to the field at the rate of three hundred to five hundred pounds to the acre. It should be sifted or drilled in or scattered on the surface and harrowed in at, or about, the time of seeding the legume. The inoculated soil should not be exposed to direct sunlight longer than necessary.

If the seed rather than the soil is to be inoculated the farmer should obtain freshly prepared cultures of the right kind of bacteria shortly before seeding time from the Division of Bacteriology of the Central Experimental Farm, Ottawa, or some other reliable source. Directions for inoculating the seed are sent out with the cultures. Milk is added to the culture just before using, and the mixture poured over the seed. The seed is then kept out of the sunlight for a short time to dry, and sowed as soon as possible.

Exercises.—(1) Name the three great classes into which soil bacteria may be divided, and indicate the importance of each.

(2) State the conditions which are favourable for the development of beneficial bacteria in the soil.

(3) Describe methods of inoculating soil and seed for the growing of leguminous crops.

PART 6

THE SOIL

CHAPTER XXXVIII

How Soils Are Formed

What Soil Is.—Soil, the "world's greatest treasure house", is a mixture of finely crumbled rock and decaying animal and vegetable matter. It is that part of the unconsolidated earth's crust that has been acted upon by organisms and climatic factors which have somewhat modified the character and appearance of the initial rock particles. The extent of these modifications are quite apparent where a vertical section, *soil profile,* to the depth of several feet is studied. Such profiles (Figure 75) show:

(1) the upper layer in which the greatest amount of organic matter occurs;

(2) a heavier layer containing more clay than is found above;

(3) a layer in which the limestone has accumulated due to the leaching of water;

(4) the unmodified parent material which may be either rock particles or unweathered rock.

In some parts of Canada bare rock rather than soil is found at the earth's surface; at other points there is a very scanty covering of soil on the bed rock; in the agricultural areas of our province the soil is usually several feet deep.

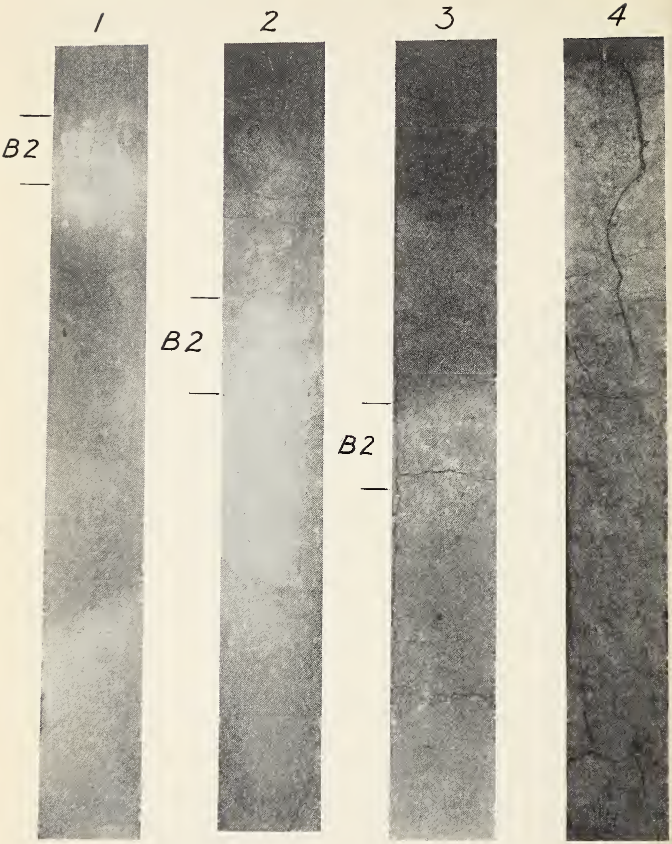


Fig. 75. Profiles (5 ft. deep) of four Alberta soils. 1. brown soils; 2. dark brown; 3. black; and 4. gray or wooded soils. Note the depth of B2 (lime layer) in these soils, indicating the degree of leaching. B2 is absent in No. 4 where leaching has been greatest.

Origin of Soils.—The mineral part of soils, which constitutes the greater portion of their mass, consists of broken and decomposed rocks. Examination of a sample of any soil with a hand lens will reveal the presence of rock particles of various sizes and kinds. These small particles are the result of the weathering of rocks and the agencies involved in the weathering processes have liberated various minerals which furnish such plant food elements as potassium, phosphorus, calcium, magnesium, iron, and sulphur. The pulverization of rocks has been the work of a variety of agencies, and has been in progress through long periods of time. Moreover, the work of soil-making agencies still continues, although it may be so slow as to be imperceptible.

The above paragraphs apply to the mineral soils which constitute the greater proportion of soils. However, in certain districts extensive areas of organic soils, e.g. peats, mucks, muskegs, are found. These have their origin in the accumulation of organic matter which has grown in connection with undrained areas. The organic matter of these soil deposits may be derived from mosses, sedges, and grasses. These soils are found chiefly in the forest belt and to a lesser extent in the park belt.

Formation of Soils.—The chief natural agencies which have brought about the conversion of rocks into soils are: water, glaciers, heat, frost, winds, leaching, atmosphere, plants, and animals.

When the above agencies convert rocks into soils the processes involved are known as *weathering*. Weathering consists of (a) physical changes known as *disintegration* and (b) chemical changes known as *decomposition*. Disintegration consists of the breaking of rocks into finer particles without causing chemical changes. It is due to the following agencies: water, glaciers, heat, frost, and winds. Decomposition consists of the breaking down of rocks and minerals by means of chemical changes and is caused by the following agencies: water, atmosphere, plants, and animals.

Disintegration and decomposition aid and accompany each other and the final result of weathering is to produce substances which are more stable than the original rocks and minerals. Thus the sand (SiO_2) and clay resulting from weathered rocks and constituting a considerable part of the soil may be considered as end-products.

(a) *Physical Agencies.*

(1) *Water.* As a physical agent water acts in two distinct manners; first, by means of its expansive property upon freezing and, second, as an abrasive agent when it is in motion.

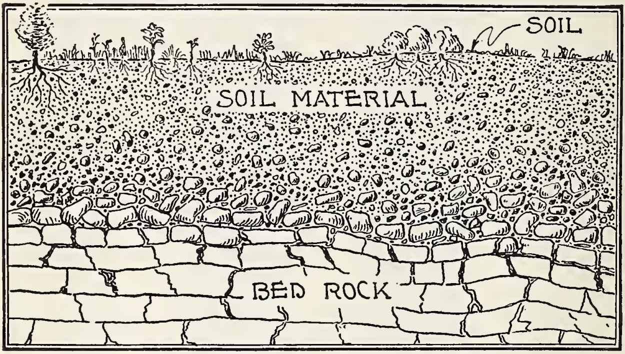


Fig. 76. The gradual transition of rock into soil by weathering.

Water on freezing expands, exerting a force when confined similar to that of a wedge. Rock crevices filled with water are thus enlarged when freezing takes place. Further thawing allows more water to enter and the process is repeated wherever rocks are in contact with water and successive freezing and thawing occurs. Enormous fragments of rock are thus loosened from the steep sides of mountains. The action of freezing water may be seen to operate in a less conspicuous but not less important way on the surface of any pebble or grain of rock.

(2) *Moving Water.* Flowing water is one of the most important physical agents in the formation of soil. Clear water abrades very slowly, but frequently the water of streams is loaded with clay, silt, sand, gravel, and even boulders. With the use of these tools the beds of streams are both widened and deepened, and the materials themselves ground into finer and finer particles. The work is most active in the rapidly moving torrents of mountainous regions, for the capacity for work of moving water varies with the square of the velocity. Smaller streams, however, even those which disturb the loose soil of the farm or garden after the spring thaws or after a rain, are soil forming agents of importance when considered in the total over a period of years. Observation of the effects of running water should be made by the student at this point. Among the projects he should undertake are the following:

1. Secure from a nearby river or creek-bed water-worn pebbles or boulders.

2. Secure samples of sand from a sand-pit and from the lake-shore. Examine these under a low-power microscope noting which consists of the more rounded grains.

3. Examine closely examples of erosion on the face of a slope. Bring to the class photos or other illustrations showing canyons, coulées or other examples of the effects of streams.

(3) *Glaciers.* On the slopes of the higher mountain ranges snow accumulates during the winter season to great depths. Under the pressure of the accumulation, the snow is compacted into ice which descends the slopes by its own weight. An ice-field or glacier is formed when the streams of descending ice unite in the upper valleys. Mingled with the snow and ice which have fallen from the mountain cliff are masses of rock which have been severed by the alternate freezing and thawing prevalent in the high altitudes. The rocks accumulating along the edges of the glacier become part of its mass and move along with it. When the fields of ice make at any

point a sharp angle of descent, cracks form in the ice into which the loose rocks fall. Streams of water pour also through these cracks or *crevasses* during the warm days of summer carrying mud and boulders to the bottom. The sides and bottom of the moving ice field are retarded by friction with the solid rock, but the middle is not thus retarded. There is thus an internal friction within the glacier grinding the rocks into powder, and along with this there is the external grinding of the mass on the bottom and sides of the valley. In the lower valleys the ice gradually melts, dissolving into a torrent whose waters are thick with mud and whose bed is strewn for miles with rounded fragments of rock. The floods which during the hot days of July fill the banks of the Peace, Athabasca, Saskatchewan, and Bow with muddy, ice-cold water have their origin in the ice-fields of the Rockies.

At the present time the work of glaciers is limited to a comparatively small portion of the earth's surface. During the glacial period the northern portions of North America and Europe were covered with an ice-sheet by the action of which rocks were ground up into fine soil-forming material which by the action of streams during that period and since has been distributed in beds of considerable depth over large areas. The agricultural soils of Alberta as well as those of the other Canadian provinces and the Northern United States are principally of glacial origin. At Lake Louise and in Jasper Park may be seen ice-fields, glacial streams, and moraines, and one can picture the conditions which probably prevailed over the whole country during the glacial period.

(4) *Changes of temperature as a factor in soil formation.* Temperatures beneath the earth's surface are fairly constant, but on the surface changes are often sudden and between wide extremes. In general, substances expand when heated and contract when cooled. There is a tendency in the case of large masses of rock, for the variable outer portion to become separated from the unvarying inner portion. In this way large slabs of rock become detached from the face of rock fissures. Moreover, there are varieties of rock which

contain substances of unequal expansion coefficients. Conglomerate and granite are examples. In such cases there is a tendency during the successive heating and cooling for these substances to separate from each other. Granite, although

Fig. 77. Map of North America showing area covered by the great Ice Sheets.

reputed to be one of the most solid and unchanging of all materials, is particularly liable to become shattered by sudden temperature changes, for the crystals of which it is composed, namely, quartz, feldspar, and mica or hornblende, expand and contract at different rates. In this way the hardest and most resistant of rocks is weakened and finally reduced by this and other agencies to soil materials. Among the causes of temperature changes are the alternation of night and day, the changes of the seasons, the change due to cloud and sunshine, and the sudden cooling of rock by showers and the subsequent evaporation.

Experiment 1: Procure samples of fine and coarse grained rocks. Experiment with these by heating them and then plunging them into cold water. It should be expected that the coarse grained rocks, i.e., granite, would be most affected by this, and that by repeating the heating and cooling disintegration would most likely occur in any case.

Experiment 2: Procure crystals of quartz, feldspar, mica, hornblende, calcite, gypsum. Note which may be split readily along lines of cleavage. Take a portion of granite. Identify the three or four constituent minerals.

Experiment 3: Apply dilute hydrochloric acid to several different kinds of rocks including limestone, and note which are attacked. What acid in nature causes solution of the minerals in rocks?

(5) *Winds.* The movement of air in winds is common to all countries and climates, but the effects of wind in the formation of soil are most apparent in arid countries or near the shores of the sea or lakes. Where the ground is covered with vegetation very little effect can be perceived of the action of this agency. Where rocks or soils are exposed to the wind, two main effects of winds can be noted. First, the materials loosened from the surface of the rock by other agencies such as frost, air, and temperature changes, if left in their place would tend to prevent further action of this kind, but their removal by the wind permits the action to continue. Second, although air itself, however rapid may be its motion, has little effect as an abrasive, yet when particles of sand are carried with it, their impact against rocks and against each other gradually reduces them into fine materials. The sand-blast is used in the shop for cutting patterns or letters on glass, and by a similar process in nature the glass, bricks, and boards of houses in sandy areas are worn thin by the winds.

(b) *Chemical Agencies.*

(1) *The action of the atmosphere in creating soil material.* The changes so far considered in this chapter have been for the most part physical in their nature, and such as are the result of mechanical action. Their effect is simply the breaking down or disintegration of the rock mass, forming, as the process is continued, finer and finer soil particles. The action of the air on rocks and soils is on the other hand largely chemical, leading to decomposition and permanent change in the substances acted upon. Two chief chemical agents forming a part of atmospheric air are responsible for the decomposition of rocks and rock minerals. These are carbon dioxide and oxygen. Carbon dioxide reacts with various sulphides, chlorides, and alkalis forming carbonates which are soft in character or somewhat soluble. A notable instance is the reaction which takes place between feldspar, the chief ingredient of granite, with the carbonic acid of the soil water. The residue left after the carbonate thus formed has been washed away is known as "*kaolin*" or pure clay. Limestone is also acted upon by carbonic acid, which is carbon dioxide combined with water. The caverns in the Selkirk mountains in British Columbia are evidence of the solvent power of carbon dioxide combined with running water.

The action of oxygen in decomposing rocks is seen most readily in those carrying iron, and is shown by a discolouration of the rock which is at first streaked with a reddish iron oxide. This is much softer, more easily removed by water, and more bulky than the original mineral, and the result is a loosening of the structure of the rock mass. Samples of such stained and decayed portions of rock may be found along the beds of creeks or in gravel pits.

(2) *Solution.* Water is the most powerful solvent in nature, and as such it has an important effect in breaking down rocks. The activity of water in this respect is greatly increased when the water absorbs carbon dioxide from the atmosphere and from the soil air. Limestone is especially

affected in this way, and the caves common in countries having a limestone formation are due to the dissolving effect of water with carbon dioxide in solution. In nature there is no such thing as pure water, but always water having various materials in solution, whether derived from the soil or from the air. These substances in most cases increase the power of the water to dissolve the minerals of rocks.

Rain water contains small quantities of carbon dioxide and upon entering the soil still more carbon dioxide is absorbed from the soil air forming an active solvent. As this water, charged with carbonic acid, moves downward it leaches salts of calcium, magnesium and sodium from the soil mass through which it passes.

When the leaching is confined to the upper few feet of soil, as in the case of the Prairie Provinces, the surface layers of soil are usually much lower in limestone and other salts than are those at depths of from one to three feet or even than the parent materials found at still greater depths. The limestone carried downward is deposited in a zone of concentration corresponding to the annual depth of water percolation. This is one of the most dependable characteristics of soils under semi-arid and arid rainfalls. Soils under low rainfalls are also those in which alkali salts are most likely to be found.

However, where leaching is excessive the salts dissolved are carried away in the underground drainage and are to be found in the waters of springs and rivers.

Experiment 4: Procure some lime water, or make it yourself by adding a lump of lime the size of an egg to a pint of water allowing it to stand till all reaction ceases, and then pour off the clear liquid. Now bubble the breath which contains carbon dioxide, by means of a tube through some of the lime-water contained in a test-tube until it becomes whitish in appearance. Continue to bubble. Observe that the lime deposit is again dissolved. The lime is first precipitated and then dissolved by carbon dioxide.

Experiment 5: Notice the deposit of carbonate of lime in the tea-kettle in which hard water has been boiled. The deposit is due to the fact that boiling the water drives off the carbon dioxide gas which has been dissolved in the water, with the result that the limestone settles to the bottom, since pure water will hold but small quantities of the mineral in solution.

Experiment 6: Look for evidence of minerals deposited where springs appear first at the surface. Incrustations of limestone and of iron are often noted at such places, as for example at Banff, and alkali springs in the prairie country. Consider why these minerals can no longer be carried in solution by the water.

Experiment 7: Add hydrochloric acid first to surface soil and second to soil taken from three or four feet below the surface. Vigorous bubbling indicates an abundance of carbonates (limestone). Explain why the surface soil usually contains less carbonates than the subsoil.

(3) *Hydration.* Water in combination with the minerals in rocks is a cause of their disintegration and decomposition. Most rocks contain water, not only in their pores, but also in combination as part of their structure. Thus, understanding that the chemical formula of water is H_2O, we see its presence in the crystals of gypsum ($CaSO_4.2H_2O$) and in limonite ($2Fe_2O_3.3H_2O$). The general effect of hydration is to make the mineral softer in structure and more easily affected by various agencies to which it may be exposed.

(4) *Plants.* Plants force their roots into crevices in rocks, and as the roots increase in size they widen the crevices, and break off fragments of rock. Mosses and lichens, as well as the higher plants, form acids which slowly dissolve the rock with which they are in contact. Bacteria also attack rocks to a certain extent.

(5) *Animals.* Gophers, Ground Squirrels, Earthworms, Ants, and other forms of animal life that burrow into the soil assist in the disintegration of rock by providing better circulation of air and water.

Exercises.—(1) What is the main source of soils? State an experience or an experiment which would go to show the truth of your statement.

(2) Is the process of changing rock material into soil continuing as fast in cultivated fields as in former ages, or is it going on at all? Discuss.

(3) In what ways is water an agent in disintegration and decomposition of rocks?

(4) Explain the action of freezing water in breaking up rocks.

(5) Discuss the statement that "moving water is a very active agent in forming our soils."

(6) Describe glaciers as they are seen in action in the mountains. How do the prairie regions show the results of similar conditions in past ages?

(7) What is hydration and what is its general effect on rocks?

(8) What constituents of rain water aid in the solution of rocks? Show how the deposit in kettles and the formation of caves are related to these facts.

(9) What substances in soil waters aid in the dissolving of minerals?

(10) Why do temperature changes result in disintegration of rocks? Why is granite especially susceptible to this action?

(11) How do winds wear down rocks on land and by the sea? Where is this not likely to occur?

(12) Name four constituents of atmospheric air which may have an effect in forming soil from rocks.

(13) Distinguish decomposition from disintegration in the process of soil formation. Name agencies causing each of these changes.

(14) Describe experiments to show:

(a) Temperature changes break down rocks.

(b) Acids decompose marble and limestone.

(c) Carbon dioxide helps dissolve limestone.

CHAPTER XXXIX

Physical and Chemical Tests Relating to Soil Constituents

Mention has already been made of several of the constituents which go to make up a normal soil. These, for the most part, have come from disintegrated and decomposed rocks, but important additions have been made to them from the air and from organic sources, chiefly plants and animals. It is proposed, in the sections which follow, to outline means of recognizing and of determining by tests the more important soil substances.

Clay.—Classified as a mineral, clay is aluminum silicate or *kaolin*, with the addition, usually, of finely divided particles of quartz, feldspar, or other minerals. Physically, clay consists of that part of the soil the particles of which can only be distinguished by the use of a microscope. Clay soils have the physical properties of tenacity, plasticity, and shrinkage in drying. Tenacity may be illustrated with a little moist clay in the hand. It is observed that it is adhesive, that it sticks together in the lump and to the hands. On being dried it hardens, shrinks, and develops cracks which give it a crumbling consistency. Plasticity is the best known property of clay, and since time immemorial mankind has moulded vessels of this material, or shaped it into bricks for building purposes. A test for clay is that of coagulation or flocculation. Shake up some granules of clay in a test-tube or bottle, and then allow it to stand for several days so that sediment has a chance to settle. It will be observed that the water is still whitish with matter in suspension. Now add to this some lime-water. Flakes will be seen to form which settle to the bottom leaving the water clear. This experiment may be performed in a different way: Place a drop of water, with clay suspended in solution on a glass slide under a microscope. Add a drop of lime water. The clay particles will be seen to collect in groups or "*floccules*".

Silt.—Silt is that group of soil particles slightly larger than clay but smaller than sand. In diameter the silt particles range from 1/500 to 1/5000 of an inch. Silt is smooth but neither sticky like clay nor rough and gritty like sand.

Sand.—Sand in a pure state is recognized by its granular appearance when observed with the naked eye or under the microscope. It has no tenacity when dried out, and it sifts readily through a sieve of suitable mesh almost of its own accord. Sand has its origin in the break-down of granite, when it remains as the residue grains of quartz in more or less fine division, or as the residue when limestone is dissolved or decomposed, or in the disintegration of sandstone. Sand which consists of pure quartz grains should show no reaction with any acids except hydrofluoric. Separation of sand from the other materials in a sample of soil may be done by several mechanical means, such as shaking the sample up in a test-tube with water several times, and decanting off the clay in suspension in the water.

Organic Matter.—This is the most valuable constituent of soils and consists chiefly of the remains of plant organisms which have lived both in and on the soil. In addition to plants, animals have contributed to a small extent to the formation of the organic matter. This soil constituent is the source of nitrogen for all non-leguminous plants. Besides improving the physical condition of soils it furnishes energy for the soil bacteria which in turn aid in making available the mineral plant foods. Its presence in soils is indicated by the black or brownish colour which it imparts.

Organic matter exists in the soil in all stages of decay, from the roots of recent plants to the very resistant material. Examination of a sample of soil with a hand lens will show the organic matter clinging to and coating the soil particles and again as separate masses. The simplest method of determining the organic matter present in soil is by ignition (Experiment 1, below). When a soil is burned sufficiently the organic matter together with any water that may be held is driven off and the mineral matter remains. The loss of weight represents the proportion of organic matter. This is a good test for peat and sand soils and is fairly accurate for intermediate soils unless they contain a relatively large proportion of limestone.

The term "*humus*" is frequently used when referring to the organic matter in soils. Its use sometimes implies the total organic matter content of soils whereas at other times only the well decayed portion is meant. Thus it is rather confusing unless a specific definition accompanies the discussion. It should be used only in connection with its narrower meaning, and apply to that portion of the organic matter which is soluble in dilute alkaline solutions.

Experiment 1: Determine the amount of organic matter in soil as follows: First, dry a weighed quantity of soil (at 105°C.) until it is freed from moisture; second, weigh to determine loss of water; third, burn in a crucible or evaporating dish until all blackness disappears. The loss of weight represents the proportion of organic matter.

Experiment 2: Show the presence of humus in soil by placing about 10 grams on a filter paper. Wash soil with dilute hydrochloric acid to remove lime. When the lime is removed (test filtrate with ammonium oxalate solution) wash a few times with water to remove the acid and finally wash soil with a four per cent. solution of ammonia. The ammonia dissolves the humus and the dark brown or black liquid should be collected in a separate beaker for the following tests: (a) Evaporate a small quantity to dryness, noting the colour of the residue. Now ignite and observe the change in colour. (b) To a small portion of the liquid add lime or lime water and stir vigorously for a few seconds. The lime precipitates the humus.

Alkali.—All soils are formed from weathered rock materials, and alkali salts come originally from decomposed rocks. Many of the stratified rocks such as shales, contain various salts because of their having been formed in salt waters. Soluble salts set free by the decomposition of such rocks tend to accumulate wherever the rainfall is not sufficient to dissolve and carry off the salts.

Alkali lands usually occur wherever the annual rainfall is less than twenty inches. Alkali is not generally apt to occur on hills or slopes, but rather in the valleys or depressions among the hills or undulations, where such depressions receive the drainage from the surrounding soils and there is no drainage outlet.

However, alkali frequently occurs on level land, if not too well drained, even though that land is elevated. Porous soils, like sands and sandy loams, other conditions being equal, are less apt to contain injurious quantities of alkali than fine textured soils.

The alkali salts are commonly classed as brown, black, or white. Brown alkali consists chiefly of the nitrates. Black alkali consists chiefly of the carbonate and bi-carbonate of sodium and owes its name mainly to the fact that when this alkaline salt is present it dissolves organic matter and produces a dark brown to black colour. White alkali consists chiefly of the neutral salts, such as sodium sulphate, sodium chloride, magnesium sulphate, magnesium chloride, and the similar salts of calcium, and even at times potassium. The main salts of both brown and white alkali are neutral in reaction and not alkaline, as is the case with black alkali.

Black alkali is the most toxic, and when present in quantities exceeding .1 per cent., is usually detrimental to plant growth. The white alkali is least toxic and seldom causes injury unless present in quantities exceeding .5 per cent. Black alkali deflocculates fine textured soils, and causes them to become tough and impervious.

The white alkali salts are the ones most commonly encountered in the alkali areas of the Prairie Provinces. In fact, brown alkali is very rarely encountered and black alkali is seldom found in toxic quantities.

A few simple experiments dealing with alkali salts will prove interesting and are easily performed.

Collect a sample (one or two quarts) of soil from an area where plant growth has been injured or where a salt incrustation has appeared on the surface during day periods.

Prepare the soil extract as follows: weigh out 50 grams of the soil (preferably air dry) and place in a quart self-sealing jar. Add 500 cc. of distilled water. Cover tightly. Shake vigorously for 10 minutes and allow to stand for 15 or 20 minutes when most of the soil will settle. Pass the liquid portion through a filter paper until it is free from clay. Portions of this filtered solution may be used for the tests in Experiments 1 and 2.

Experiment 3: Test for chlorides, e.g. sodium chloride (common salt), calcium chloride, magnesium chloride, potassium chloride. "White alkali."

To a portion of the above solution, presumed to contain a chloride, add a solution of silver chloride. Make two portions of this. Into one pour a solution of nitric acid; the precipitate should remain. Into the other pour ammonia solution; the precipitate should disappear.

(Note for Instructor)—Many of the alkali soils contain chiefly sulphates and are devoid of chlorides. In the event that no chlorides are found in the soil extract, the experiment should be repeated using a second portion of the extract to which a few drops of hydrochloric acid have been added.

Experiment 4: Test for sodium, calcium, and magnesium sulphates. "White alkali".

Sodium sulphate (Glauber's salts) and magnesium sulphate (Epsom salts) impart an undesirable taste to water when present in quantities.

To a portion of the above soil extract add a little of hydrochloric acid; heat to boiling and add a solution of barium chloride. A white precipitate indicates the presence of sulphates.

Experiment 5: Test for sodium carbonate or "Black alkali".

This is distinguished from lime or calcium carbonate with which it may be associated by the fact that it is readily soluble in water. The solution turns red litmus blue, showing alkaline properties. The general test for all the carbonates is, that there is effervescence of carbon dioxide when brought into contact with hydrochloric or sulphuric acid.

Acid Soils.—The decomposition of organic matter together with the removal of excess bases such as calcium causes acid soils. An acid soil is undesirable. Such crops as Alfalfa, Red Clover, Timothy, and Corn, which are of great value to the farmer, do not do well on such soils. Certain weeds such as Horsetail and Knot-grass flourish on sour soils. The remedy for acidity is the application of lime in any of its forms, quick-lime, air-slaked lime, crushed limestone or wood ashes. Acid conditions in a soil may be recognized by the

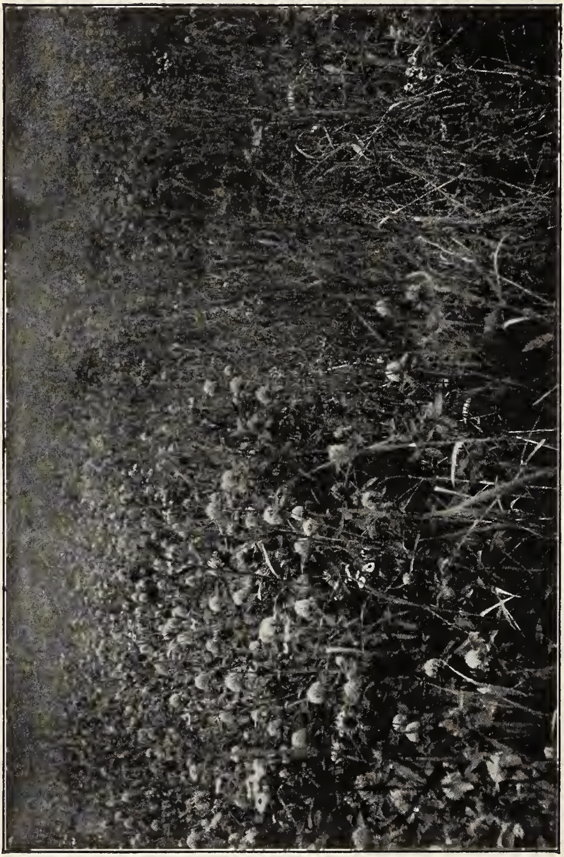


Fig. 78. Clover with and without limestone.

prevalence of certain weeds, by the failure to get good stands of Red Clover and Alfalfa, and by chemical tests noted in the following experiments:

Experiment 6: Obtain samples of acid and non-acid soils, a good grade of blue litmus paper, and a number of clean dishes, and clean smooth sticks for mixing wet soils. Mix one of the samples of soil with pure water to make it slightly sticky using a clean stick (not the hands), and fold it over a piece of blue litmus, allowing soil and litmus to remain in contact for 5 minutes. Then remove the paper. An entire reddening of the part of the paper in contact with the soil, or the appearance of red spots indicates acidity. Test each sample in the same manner.

Experiment 7: Test samples with litmus in the above manner obtained from the door-yard where Knot-grass grows, and also where the weed Plantain is growing. Determine whether these indicate sour soils. Note other plant indications of such soils.

Lime.—The term "lime" should be used only to indicate calcium oxide (CaO). In soils it occurs chiefly in combination with the silicates, carbonates or sulphates and to a small extent with phosphate. In acid soils the carbonate of lime (limestone) is entirely lacking. When it is found necessary to correct soil acidity, any of the following compounds of lime may be applied; finely ground limestone ($CaCO_3$), burnt lime (CaO), hydrated lime ($Ca(OH)_2$), marl, or woodashes.

Lime is usually found in sufficient quantities in most of the agricultural soils of Alberta; this is particularly true of the prairie soils and the park soils. On the other hand many of the soils in the forest belt and especially many of the peats are slightly acid.

The percentages of lime carbonate are, on the average, lowest in the surface soils and highest in the zone of lime concentration. This zone of concentration varies widely in its limestone content (from a few per cent. up to 25 per cent.). The following test shows the presence of limestone in soils:

Experiment 8: Test for carbonates. A sample of soil is treated with a few drops of hydrochloric acid. Effervescence indicates the presence of carbonates in sufficient quantities to be readily observed, usually more than 1 per cent. Test both surface and subsoil.

Phosphorus.—Phosphorus usually occurs in the soil in the form of calcium phosphate and in combination with organic matter. The greatest amounts are usually found in the surface soil especially where these soils are high in organic matter. The distribution of phosphorus is thus seen to be just the reverse of that of lime.

The phosphorus content of Alberta soils varies from about .1 per cent. in the black soils, to about .03 per cent. in the poorest of the forest soils. The upper limit is quite adequate; the lower limit is undoubtedly inadequate.

One or more of the following experiments may be used to show the presence of phosphorus:

Experiment 9: Use a solution of phosphate or phosphoric acid in a test tube. Neutralize with ammonia and then acidify with nitric acid. Now add a few cc. of molybdate solution and warm to about 70°C. A yellow precipitate should form, indicating the presence of phosphorus.

(Note for Instructor)—The molybdate solution should be prepared carefully as follows: Dissolve 1 gram of molybdic acid in 4 cc. of ammonia (1 part concentrated ammonia and 2 parts water). Add this very slowly and with stirring if necessary to 15 cc. of dilute nitric acid, 1 part concentrated nitric acid to 1.67 parts water, keeping the nitric acid cool, otherwise the molybdic acid may be precipitated.

Experiment 10: Bones are rich in phosphorus, containing from 45 to 65 per cent. of calcium phosphate. Ignite a small piece of bone to destroy organic matter. Digest in dilute nitric acid using heat, but do not boil. Filter and apply test to the solution as above.

Experiment 11: Ignite some garden soil until no black colour remains. Digest with nitric acid, filter and test for phosphorus.

Potassium.—The origin of the potassium is chiefly the feldspar from the parent rocks. It occurs in soils chiefly in combination with silicates. In general the amount of potassium found in the mineral soils of Alberta varies from 1.5 to 2 per cent. This is sufficient to meet the crop needs for almost an indefinite period. Some of the peat soils, however are deficient in potassium. There are no simple tests by which its presence in soil may be detected.

Exercises.—(1) Distinguish pure clay from pure sand in texture and in chemical composition. Give tests for clay.

(2) Suggest a means of separating the constituents of a common type of soil according to fineness. (Sift through different meshes, or stir up in water and graduate the sediment in a glass tube, etc.)

(3) What is the general meaning of the terms "humus," "organic matter"?

(4) Show by burning we may find the proportion of organic matter and of moisture in the soil.

(5) Give a chemical means by which the humus in a given sample of soil may be separated.

(6) What are physical means of recognizing its presence? (Colour, the microscope, etc.).

(7) Give common evidences of an alkali condition of the soil. Name and explain the composition of each of the kinds of alkali.

(8) Why are alkali lands met with only in arid and irrigated areas? What is the source of the salts of alkali lands?

(9) Give chemical tests for "Black alkali" (Na_2CO_3), "White Alkali," (Na_2SO_4).

(10) Why is "Black alkali" particularly toxic in its effect on plants?

(11) Account for the fact that strong solutions of a salt about the roots of a plant have the same effect as dry weather. What alkali salts act in this way?

(12) In the same way account for the fact that strong fertilizers sometimes "burn" plants to which they are applied.

(13) What is the cause of acidity in soils? How may it be corrected? How would you test for acidity?

(14) Acidity is due to absence of lime carbonate ($CaCO_3$). Show that the application of hydrochloric acid to a sample of earth will indicate the absence of acidity.

(15) Describe the ammonium molybdate test for the presence of phosphorus in soils. How is the absence of this mineral shown by the state of the crop?

(16) What observation as to the colour of the soil is evidence of the nitrogenous content?

CHAPTER XL

Classification of Soils

Size of Soil Particles.—The mineral portion of soils consists of particles of different sizes, named according to a graduated scale. According to this scale there are four main

Name	Measurement	Relative Sizes
Fine gravel	1 to 2 millimeters	
Coarse sand . . .	0.5 to 1 millimeter	
Medium sand . . .	0.25 to 0.5 millimeter	
Fine sand	0.10 to 0.25 millimeter	
Very fine sand . . .	0.05 to 0.10 millimeter	
Silt	0.005 to 0.05 millimeter	
Clay, less than . . .	0.005 millimeter	

Fig. 79. Diagramatic representation of sizes of soil particles.

classes of soil particles, namely, clay, silt, sand, and gravel. Clay consists of particles under .005 mm. in diameter, and are so small as to be scarcely visible as separate grains when examined with a high-power microscope. Clay particles when stirred up with water remain in suspension for some time.

Silt grains are classed as those which are between .005 and .05 mm. in diameter. These when stirred up in water will settle within a few minutes, but they are otherwise closely akin to clay when observed in the mass. Sand grains vary from .05 to 1 mm. in diameter. They are coarse enough to be felt when they are rubbed between the fingers and to be distinguished with the naked eye. Gravel consists of coarse irregular grains of rock of larger size than sand grains but not larger than 2 mm. in diameter for practical purposes in soil analysis.

Soil Types.—Soils are usually classified as sands, sandy loams, loams other than sandy, and clays. The following table shows the percentage composition of each of these types:

Sands contain less than 20 per cent. of clay and silt, and 80 per cent. or more of sand.

Sandy loams contain 20 to 50 per cent. of clay and silt, and the remainder of sand. Less than 20 per cent. should be clay.

Loams other than sandy loams are soils that contain 50 per cent. to 70 per cent. of clay and silt and the remainder of sand. Under this head are classed loams, silt loams, and clay loams. The loam quality of such soils is due to the large percentage of silt and the clay constituent does not exceed 20 to 30 per cent.

Clay Soils are those which contain more than 30 per cent. of clay, and the balance of sand and silt. The silt in such cases will form along with the clay the larger portion of the soil mass.

Characteristics of the Soil Types.—Sandy and gravelly soils are generally deficient in organic matter and the available elements of fertility. This fact is indicated by their light colour and the shallow depth of top-soil containing vegetable material. Several reasons may be given for the comparative lack of fertility of sandy soils. One of them is, that the natural growth on such soils has been less than on the heavier soils. Then, also, the sandy soils are subject to leaching, that is, the soluble food compounds are washed away by the rains or by the melting snows, when the water percolates rapidly through them and drains away. Soils of this type are subject to drought in dry seasons, owing to the fact that they have little moisture-holding ability, and also that the rise by capillary action is much less than in other soils. Sandy soils warm quickly and this is an advantage in growing certain crops such as vegetables and some of the small fruits.

Sandy loams, since they carry a higher percentage of fine soil particles than sandy soils, have fewer of the defects of the latter, while having all of their advantages. They will not crust or crack as the clay soils are liable to do. They are well aired, light, and easy to work. The saving of horse-power required is a considerable item in farming such land. Much of the best wheat land of the West is of this type of soil, and although there is the possibility of an early exhaustion of the fertility, the immediate profit in favourable years is great, first, because in their natural state they are prairie lands and easily broken up, and, in the second place, because of the greater areas which may be cultivated with a given amount of farm equipment.

Loams and silt loams are the most desirable of all soils for general farming. Soils of this type in Alberta are usually extremely fertile, and have great water-holding, and water-conducting capacity. Crops on these soils are not as apt to suffer from drought as on the lighter soils. There is little tendency to form lumps or crust, they are rich in organic matter, and they retain whatever fertilizers may be added better than the more porous soils Clay loams are heavier and stickier than silt loams, and working them while they are in a moist condition is liable to make them hard and lumpy. They are cool and not suitable for early crops, but are satisfactory for general farming and particularly for growing Hay, Oats, and Wheat.

Clay soils are not good farm soils. The labour of cultivating them is great and owing to the liability of causing them to "puddle" or bake they must not be ploughed when wet, and thus there is delay in getting on the land in the spring. Clay soils have good water-holding capacity, and are not usually deficient in available plant food Owing to the poor drainage from such soils the crops are liable to injury from standing water in wet seasons and in drying out and cracking of the soil which injures the roots in dry weather.

Peat soils are formed in marshes and are very high in organic matter. When well drained they become loose and light in structure. In this condition they are very fertile and productive, but are only adapted to the growing of the coarse grains, hay, or roots. Some difficulty is found in the handling of these soils owing to their light and powdery texture which makes it difficult to use the plough or seeder. They are greatly benefited in this respect by the use of a heavy roller or packer.

Soil and Subsoil.—We are accustomed to make a distinction between the top soil and that which is some distance below the surface. We use the term "soil" to designate the top layer of earth which is subjected to cultivation, in which the seed is sown, and in which the roots of the farm crops principally feed. The soil below this is known as the subsoil, and extends to various depths.

(a) *The top-soil.* The most obvious difference between this layer and those below it is the darker colour caused by the larger content of organic matter. Particularly when moist, as after a rain, the dark colour is intensified. The surface soil is made up of slightly coarser materials than the subsoil, owing to the washing down of the finer particles by percolating water, as well as by the run-off of surface water during heavy rains. The nitrogen content is highest in the surface and lowest in the subsoil. This is accounted for by the fact that nearly all of the nitrogen is held in the form of organic matter, and the depth of organic matter for soils varies from a few inches to about one foot. There is a gradual decrease from surface to subsoil. In our prairie soils there is from two and one-half to three times as much nitrogen in the surface as in the subsoil in each type of soil. Certain soil types, such as loam, silt loam, clay loam, and clay contains about twice as much as the fine sand, and about one and a half times as much as the fine sandy loam.

Calcium and magnesium are lowest in the surface soils and highest in the subsoils, whereas phosphorus and potassium are about equally abundant in the surface and subsoils. This is accounted for by the fact that the former two elements are much more soluble than the phosphorus or potassium, and any rain penetrating the soil carries them downward. Again the amount required to feed the native grasses and produce the farm crops is taken largely from the surface soil.

The potassium content is slightly higher in the surface than in the subsoil, but the differences are small.

(b) *The subsoil.* This extends to various depths, but we may think of it as that which extends from the top soil to a depth of a few feet. It is of great importance on account of the conditions which it governs in the matter of drainage, capillary action, root penetration, and drought. A hard-pan in the subsoil is not uncommon in the West, and is due to the stoppage of percolation by a "tight clay" stratum, or alkali salts and lime. The effect of this tight layer is serious, for it prevents the seepage of rains in wet weather, and the rise of water to the plant by capillary action in time of drought. Continuous ploughing at one depth may also cause a similar condition. This may be benefited by ploughing at different depths, the use of the subsoil plough, or often times by the use of a deep-rooting crop, such as Sweet Clover.

Inter-Relation of Soil and Subsoil.—This may be summarized from what has been said in the preceding sections:

(a) The top-soil is the great feeding-ground and storehouse for the annual plants which comprise the bulk of our crops. For trees and perennials there is considerable root-range in the subsoil.

(b) Moisture rises from the subsoil by capillary movement to replenish that removed from the top-soil by evaporation and by transpiration from the leaves of plants, or used by them in the plant body. Tillage conditions must be favourable in order that this may take place and at the same time moisture be conserved.

(c) Nitrates belong to the top-soil chiefly since they are here produced from the organic material. Lime and magnesium are in larger proportions in the subsoil owing to their being washed down by the rains. Phosphates and potash are about equally distributed between the two. The growing of perennials such as Alfalfa and Clover, which are fed on the farm and returned to the soil as manure should increase rather than diminish the stores of these minerals in the top-soil.

Exercises.—(1) What is the composition of soils classed as sands, sandy loams, loams, and clays, respectively?

(2) Distinguish soil and subsoil in respect to their position, composition, and colour. Why are there such differences?

(3) Intermediate soils such as loam and silt loam usually contain twice as much organic matter and nitrogen as do sands in the same district. Suggest the explanation for this.

(4) Describe the process of interchange between the surface soil and the subsoil. Does this take place most rapidly in cropped or tilled land?

(5) Give the characteristics of the chief types of soil found in Alberta.

CHAPTER XLI

Moisture in Soils

Importance.—All soils contain moisture under normal conditions. The water varies in its value depending on its relation to the soil particles. Soil water has also movement which means much to the welfare of the plant. Water is a solvent of plant foods and it enables the plant thus to take up mineral food from the soil, and allows it to circulate through the plant tissues. When this is done, the larger proportion of it is evaporated from the surface of the leaves, and it makes way for further supplies from the root. There is thus the necessity of renewing the supply of water about the roots if the plant is to continue to live and grow.

Determination of the Moisture Content of a Given Sample of Soil.—Take soil samples from different fields such as sod land, summer-fallow, and from grain, etc. Use a soil auger taking samples from the top-soil and subsoil. Place these in covered tin boxes. Weigh out the samples. Dry in an oven. Weigh again. Calculate the moisture as a fraction, or percentage, of the dry weight, and tabulate the results for the purpose of comparison. The experiment should be done in the dry weather in summer.

To Determine the Water-Holding Capacity of Soils.—Get samples of the various types of soils—clay loam or silt loam, sandy loam, and peaty soil. Provide brass cylinders with perforated bottoms, a foot long and two inches in diameter, or tin cans with perforated bottoms. Rub the dry soils through a sieve, twenty meshes to the inch. Place a cheese-cloth disc in the bottom of each can. Fill each with soil compacting them equally and filling within an inch of the top. Now weigh each and tabulate neatly for comparative results. Dip all in water until free water appears at the surface, letting the can go as deep as the soil on the inside. In removing from the water measure all water that drips and all that is held by the soil. In this way you will get the capacity of the soil to hold free water and also capillary water.

Kinds of Soil Water.—It has been demonstrated above that soils have pores which may be occupied by air or by water or it may be shared by both, for the water which runs out of the container in the above experiment is replaced by air in the soil. There are three forms of water here, the relation of each of which to the soil particles should be clearly understood.

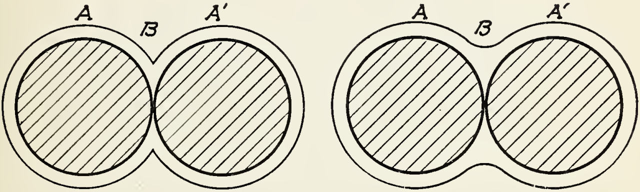


Fig. 80. Conventional diagram showing capillary water film. At the left, immediately after contact with the particles; at the right, after adjustment has taken place.

Hygroscopic and capillary water are both film forms, that is, they surround the soil particle and are held to it by adhesion while the film is held unbroken by cohesion. The hygroscopic film is very thin. When it is satisfied and more moisture is present, the capillary moisture film begins to form. The film thickens particularly at the points where the soil particles are in contact. Free or gravitational water is that which is in too great excess to cling to the soil particles and is drawn downward in the soil pores by its own weight and tends to drain away freely. Hygroscopic water can be of little value to plants since the film is so thin, and the quantity so small, and its adhesion to the soil particles is strong. There is nothing so dry that it does not have this film of moisture clinging to its surfaces. Road-dust when heated in an oven gives off this form of moisture and when cooled recovers it again from the air. Silk is sold in Europe with suitable allowance for hygroscopic moisture, which may affect the weight to the extent of ten or more per cent. Hilgard gives the following uses of hygroscopic moisture: Soils of high hygroscopic power can withdraw from moist air enough moisture to be of material help to the life of vegetation in rainless summers or in time of drouth. It cannot maintain normal growth, except in the case of some desert plants. It also prevents the rapid and undue heating of the surface soil to the danger point and thus often saves the crop.

Capillary Water—The most abundant and by far the most important form of soil moisture is capillary moisture. It is different from hygroscopic moisture in that it will evaporate under ordinary soil conditions, is not recovered when the soil temperature is lowered, and may move through the soil mass if conditions are favourable. The term capillary is derived from the fact that this movement may be seen in glass capillary tubes, that is, tubes of fine bore, when they are placed vertically with one end in water. The height to which the liquid rises is greatest in the smallest tube. The law expressing this action is: The height to which water rises varies inversely as the diameter of the tube. The reduction of the diameter to one-quarter would cause the water to rise four times as high. The movement of the water in the pores of the soil resembles to some extent the rise of water in a large number of fine tubes of various sizes.

The Forces Causing Capillary Movement.—There is a tendency in the case of films or drops of liquid for the surface to take the smallest area possible. This force is known as surface tension. Thus a drop of water assumes a spherical shape and the film around a particle of soil clings tightly to it. Where particles are in contact the film surrounds the whole group, is constricted at the contact points, and so is thickest there. These facts may be shown clearly by the following experiment:

Experiment 1: Soak wrinkled Peas for a minute in water and spread them out on a white plate. Pour ink over them so that the ink film covers them all. Tilt the plate slightly to drain away the free liquid. Separate one pea from the rest. Observe the film about it next the plate. Touch one side of the film with the corner of a blotter. Observe the movement thus caused in the whole film.

Now join several in a row with an ink film around the whole. Observe the narrowing and thickening of the film in the corners and the movement in the whole film when liquid is drawn off at one point by means of a blotter. Spread out the whole mass rather thinly and observe the air spaces and capillary form of the liquid in relation to the particles. Draw off the moisture and observe the movement throughout the whole mass, somewhat imperfect here, however, on account of the large particles and spaces.

The Movement of Capillary Water.—This may take place in any direction, but with greatest facility downwards owing to the force of gravity. This will have been observed while performing the experiment of the previous section. The rate and height of the movement depend on several factors:

(a) Near free water or a ready supply the motion takes place rapidly, and the film is relatively thick.

(b) Variations in the temperature of the water change its adhesive qualities, or viscosity. Increased viscosity retards the rate of movement and this would be the effect of low temperature. A simple experiment will show this: Stand two strips of blotting paper in tumblers containing hot and cold water. Observe that the rise of water is somewhat faster in the case of the hot water. Attempt the experiment with soil in glass tubes.

(c) Texture. In fine grained soils such as silt or clay, capillary rise is slow; in sand, it is fast. Black loams are usually the most effective in raising water by this means on account of their fibrous and absorbent nature. An experiment should be performed by the student in this connection.

Experiment 2: Provide size 30-inch glass tubes about an inch in diameter, a pan for holding water, a 30-inch rule, and samples of each of the types of soil compacting each equally, the bottoms being covered with cheese-cloth. Stand in water and begin recording speed of rise in the tubes at once. Observe also the total height of rise after movement has ceased. Tabulate the results for comparison. The results will probably show that coarse sands give quickest rise but least height, that clays show slowest rise but greater height, and that a good black loam shows medium rate and greatest height.

(d) Dry soils retard capillary movement. Where no film is already in existence the capillary film extends with difficulty. A dry mulch is therefore a protection to the store of moisture in the soil since it prevents loss by evaporation. Experiment with any of the tubes of soil used above by placing perfectly dry soil on top of one and humid soil on another, wet surfaces being below each. It will be observed that capillary movement is slow up through the dry mulch but rapid in the other.

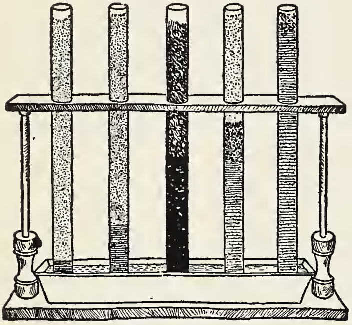


Fig. 81. Pan and glass tubes showing the rise of water by capillarity.

Control of Movements of Soil Water.—Control may be affected in two ways. The first is by making soil conditions such that there is a rise of water from the lower layers in the subsoil to take the place of that which is used by the roots of the plant; and the second is, to prevent surface evaporation. A third factor may also be considered, namely, that the roots of the plant will themselves seek the sources of moisture if proper tilth conditions exist. The question of how either evaporation or consumption of water by roots at any point causes a movement in that direction, should be considered. The answer is given in the series of experiments above, relating to the symmetry and balance of forces in the film about the particles. It was observed that if this is dried up at any point there is at once a movement due to surface tension to keep the film of even contour. A similar condition exists when a coal-oil lamp is lighted and the oil consumed at the top of the wick is replenished by that which rises by capillary action.

Compacting a soil may be done by means of a heavy roller, preferably one which leaves the surface in ridges or with a broken surface. Thick layers of straw or dry compost under the furrow are likely to interfere with the rise of water in the soil. An experiment with a garden plot and also with soil in tubes having chopped straw in the bottom should be tried in order to see the effect. A good surface mulch should be thoroughly dry, loose, and not too fine. About three inches of depth is suitable. The weeds should be kept down, and in gardening practice, at least, the formation of a crust on the surface should be prevented by light surface cultivation.

Methods of Conserving Soil Moisture.—This is to some degree a repetition of matters elsewhere discussed, and therefore a summary only is given. (See Chapter XLIII.)

(a) Dry farming is not practical without at least ten inches of rainfall annually.

(b) Evaporation is the main cause of loss of soil water. It is less in our climate than in the Dakotas or Texas owing to the cooler summers. This applies to the transpiration from the leaves of plants also, which cannot be controlled.

(c) Run-off water is that which drains away into the streams after the spring melting, or a heavy rain. To save as much as possible of this, soils should be kept in a loose condition.

(d) Percolation. This, in dry-farming areas is likely to be insignificant, except where the subsoil is sandy. Usually that which drains down through the soil is within reach of capillary action in the growing season.

(e) Transpiration. The loss of moisture from the leaves of the growing crop is unavoidable.

(f) Shade. The shade of the crop itself, ensures that there is lessening of evaporation from the soil.

(g) Tillage to prevent weed growth is the best means of preventing loss of soil water. Under the heading of tillage are included (1) moderately deep ploughing, (2) tillage of the growing crop to break up soil crust and kill weeds, (3) subsurface packing, (4) eradication of weeds, (5) summer-fallow.

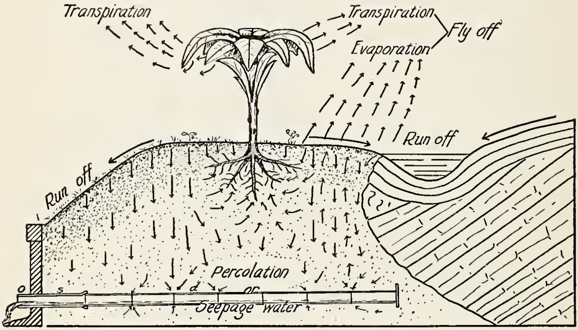


Fig. 82. Diagram illustrating the ways by which water may be lost through the soil.

Summer-Fallow.—The main objects of the summer-fallow are to conserve this year's moisture for next year's crop and to increase the available plant food. The practice consists in leaving the land for one year without cropping, but maintaining the surface cultivation after one ploughing early in the year. Weeds are strictly kept down. The ground is thus in good tilth for next year's crop, well stored with moisture and available fertility, freed from weeds, and ready for an early seeding with Wheat. In districts subject to drought summer-fallowing and crop should alternate. In more humid regions as in Central Alberta, one year of fallow in three or four is the usual practice.

Exercises.—(1) Show the part water plays in relation to plant growth. There are three chief points to be considered in this discussion.

(2) How is the supply of water renewed or made accessible to plants, (a) by processes within the soil, (b) by the plant itself?

(3) How would you determine the moisture-holding capacity of a given soil (a) in terms of weight, (b) in terms of volume?

(4) How would you determine the moisture-content of a soil sample?

(5) Distinguish the three forms of water in soils in reference to the manner in which water is related to the soil particles.

(6) Show by a diagram how capillary water exists as between the soil particles and the air spaces.

(7) What are the uses of hygroscopic water? How may the amount present in a dry soil be found? Whence may such moisture come?

(8) How does capillary water differ from hygroscopic in the form it takes and in its properties?

(9) Free water if not drained away after a short time is injurious to plant life. Why is this? How is it shown by the appearance of the crop? How does irrigation water become capillary water?

(10) What is the law of capillary movement? Show this by experiments.

(11) Why does evaporation at the surface cause movement of water toward the surface in the soil pores? Explain by reference to a simple experiment and by reference to the physical principle involved.

(12) Water does not readily soak into dry road-dust. How does this fact explain the action of the dust mulch?

(13) What are the advantages of a summer-fallow? When should it be ploughed? What further cultivation is needed? How often should it be done?

(14) What are the chief means of conserving moisture by dry farming practice? On what principle is sub-surface packing a benefit to crops?

(15) Describe experiments with soils to determine their relative properties: (a) The rapidity with which water rises in various types of soil; (b) The height to which it rises; (c) The amount of water held in a given volume of soil.

CHAPTER XLII

Air and Heat in Soils

Importance of Soil Air.—Soils contain air as well as water. Each of them occupies the spaces between the particles, and the greater the volume of the one the less that of the other. Water is the controlling factor; air occupies the space not occupied by the water. When the two are about equal in volume the condition may be said to be best.

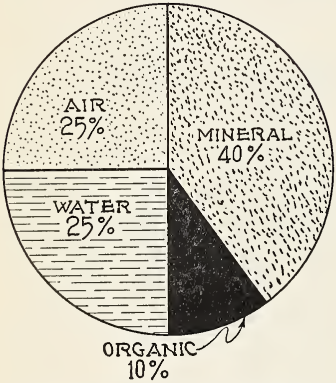


Fig. 83. Volume composition of loam soil in good condition for plant growth.

The Amount of Air in Soils.—The amount of air in soils depends upon the *porosity*. It would naturally be supposed that the greatest amount of air would be in the soil having the highest porosity but this may not always be true since soils with high porosity have also a high retentive capacity for moisture.

The porosity of soils may be easily determined on a volume basis by a simple method of displacement of the air by water. Use water-free samples of the various types of soils—sand, clay and loam, which have been sifted through a 20-strand mesh. Into glass jars or tin cans put a measured quantity, say 1,000 c.c. of each soil. Pack evenly by tapping the jars or cans equally on the table. Pour water into each container, noting the amount required to bring the level of the water up to the surface of the soil. The amount of water poured in is the volume of the pore space of that type of soil.

Use of Air in Soils.—The most important element in soil air is oxygen. It is as necessary to the life of a plant as it is to animals. Roots respire, or breathe, taking in oxygen and giving out carbon dioxide. The effect of shutting off this supply of oxygen is shown in water logged soils by the greenish-yellow colour of the plant growth. House plants set in cans without means of drainage do not thrive. Another reason for ensuring that soils are supplied with air is, that useful bacteria in the soil—nitrifying and nitrogen-fixing—require oxygen. Thus ill-ventilated soils afford insufficient nitrates for plant subsistence.

Soil Temperature

(a) *Importance to plants.* Plants grow most vigorously at temperatures ranging from 80 to 100 degrees Fahrenheit. Below this, growth is checked and at about 40° F. it ceases altogether for most plants. Heat is to some extent subject to control by the agriculturist or at least he is able to choose the conditions under which he carries on.

(b) *Sources of soil heat.* The chief source of heat is the sun's rays. When warm rain falls it carries into the soil with it large amounts of heat. This is often illustrated by the almost miraculous rapidity of the growth after a shower in the spring. Chemical changes bring heat such as occurs in a hot-bed or in a soil rich in vegetable material and at the same time well aerated.

Experiment 1: Using a soil thermometer take the temperature of soils at the surface and at depths of 6 inches and 10 inches in soil in the garden.

(c) *Relation of temperature to moisture content.* Excess of water in the soil is apt to cause the temperature to be low for two reasons: (1) Water is one of the slowest of all substances to warm up under the influence of a given quantity of heat. (2) The evaporation of water absorbs heat. Explanation of the former of these factors is based on an elementary principle in physics. Water is a substance of high specific heat, and requires about nine times as much heat to raise its temperature one degree as is required by the same weight of dry soil material. A wet soil is therefore a cold soil in the spring of the year when heat is needed for germination. The chief cause, however, which makes a wet or undrained soil colder than a well-drained one is the large amount of heat used up in evaporation. In elementary physics the fact is learned that to vapourize one gram of water requires 536 heat units. These heat units are for the time being lost as far as the soil is concerned. It is evident, therefore, that it is desirable that evaporation of water from the soil should be checked, but that good drainage should be provided.

(d) *The effect of cultivation on temperature.* The character and depth of cultivation has an effect on the soil temperatures. Deep cultivation permits the percolation of the warm rains of spring. It also promotes air exchange with the outside atmosphere with a resulting favourable condition for warmth. The whole aim in the matter of temperature is to get the soil warm as early as possible in spring to germinate quickly the seed and encourage vigorous growth.

(e) *Soil temperature and growth.* A warm soil is favourable for the action of beneficial bacteria, such as those concerned in the production of nitrates. Warmth, as we have seen, hastens the rise of capillary moisture. Absorption of soil solutions by the root hairs is more rapid under conditions of warmth. The vital functions of the plant are most active also, and the root in particular is more rapidly extended. Germination takes place most rapidly when the soil is at 70° to 80° F., and in fact it is best not to sow seed in cold, damp soil.

Exercises.—(1) Show the value of soil air to the plant (a) for its own use, (b) for the use of beneficial bacteria.

(2) Show by experiment a method of finding the proportion by volume of air in different samples of soils. How much air in soils is desirable? Under what conditions would there likely be too much, and what would be the effect?

(3) Show the effect of rains, cultivation, drainage, on the movement of soil air and on the amount of air present in the soil.

(4) To what extent is soil temperature beyond human control, and in what ways may warmth in the soil be increased?

(5) Wet soils are cold soils for two reasons. Explain what these are

(6) Cultivation in spring tends to promote early warmth in the soil. In later summer the effect is to leave it cooler than the near-by untilled land. Explain why these are approximately true, and the importance of the facts.

(7) Why is soil warmth necessary for the growth and nutrition of the plant?

(8) Show by experiment that osmosis takes place more rapidly in warm than in cold conditions. (Soak raisins, or beans, in cold and in warm water, or supply warm and cold water to roots of wilted flowers.)

(9) Describe an experiment to show that capillary movement is greater in warm than in cold conditions. (Try with strips of blotter in water, and also with soils.)

(10) Show that plants respire more rapidly in warm situations than in cool ones. Would this imply also more rapid plant growth?

CHAPTER XLIII

Cultivation of the Soil

Methods of Cultivation.—Proper preparation of the soil is essential in successful crop production. There is a right time and order at which each of the chief operations should be carried out, a proper depth of cultivation, and a suitable thoroughness or care with the operation so as to get a uniform fineness of the particles.

Ploughing.—Ploughing has been considered in all countries and in all ages the most important of the processes in preparing the soil for the growing of cultivated plants. The plough is used to break up the raw land or sod in order that the furrows may be conveniently pulverized by discs or harrows. In such cases the furrow is turned over flat, and while the furrow slice is only three or four inches in depth (except where roots have to be ploughed through) the width of the slice is rather wide, and varies from 14 to 24 inches. Ploughing of stubble land and bare fallow is done with a different aim in view, and each furrow slice is laid so as to overlap the previous one, and is cut to a depth of from 6 to 8 inches and a width of 10 to 14 inches. In this way the top and bottom portions of the soil are mixed together at each ploughing; stubble and weeds are turned under; and a great deal of the soil which has lain for a year or more at the bottom of the furrow is given its turn to receive the benefits of exposure to the atmosphere. The plough also pulverizes the soil as well as inverting it and mixing it.

The Province occupies an extensive area and is subject to such variations in climate, that it is impossible to lay down a definite rule regarding fall and spring ploughing which would apply equally well to all parts. In the South the stubble helps to hold the snow and in this way increases the moisture supply for spring. When ploughing is done in the fall the freezing and thawing action during the winter may so refine the soil that bad drifting may result the following spring. Experimental results and general observation seem to indicate that fall ploughing cannot be recommended generally in the South. In the central and northern parts of the Province where more rainfall and lower wind velocities are the rule, it seems to give equal and often better results than spring ploughing, when everything is considered. Fall ploughing enables the soil to settle forming a close seed bed, and the stubble and other materials left over from the previous crop have time to become incorporated with the soil. The moisture-absorbing capacity of the soil is increased owing to the fact that being loosened it acts as a reservoir for the fall rains and the snow. The eggs of larvae, Cutworms, White Grubs, Saw-flies, Grasshoppers, disturbed by the plough in the fall are likely to be destroyed by the winter frost, and there is a similar effect on many kinds of weed seeds. Then there is the advantage of having the ploughing done ready for spring so that the seeding, especially of Wheat, may not be delayed.

Notwithstanding its theoretical advantages there is comparatively small acreage of the stubble land of the Province ploughed during the fall months. One reason for this is that the system of threshing from the stook makes it impossible in many cases to plough the stubble before the heavy frosts come. Also, the land being usually quite dry in the late fall, there is difficulty in ploughing the land to the required depth. It is objected also that under such conditions seeds of noxious weeds are buried by the plough with the result that they are preserved rather than destroyed. If the fall were long and moisture abundant as in Eastern Canada such seeds would germinate after ploughing, and would then be killed by the winter frosts, and this is the basis of the claim that fall ploughing helps clear the land of weeds. With us, summer-fallow is a more effective means of doing this.

If ploughing is left until spring it should be done so as to conserve the moisture. The usual custom is to follow the plough with the harrows immediately, and seed the field as soon as possible so that practically all the moisture is available for seed germination, and early growth. If the soil is too loose, packing and harrowing will remedy this after the grain is sown.

Fall ploughing should be done fairly deep, although there may be circumstances which require modification of this rule, such as the need of varying the depth to avoid creating an impervious furrow bottom, or the desire to avoid bringing up to the surface, subsoil deficient in fertility.

Packing the Soil.—Soils very rich in organic matter and those ploughed late in spring are liable to have the defect of being too loose for making a suitable seed-bed although for certain crops, such as Potatoes, this condition is satisfactory. Seed grain, however, should be planted in a soil of firm texture so that the soil is in close contact with the seeds, and, also, so that moisture may better be held in the soil in which the roots of the plant are growing. It has been the experience of most farmers that in average years spring ploughing requires to be "worked down" by successive discing and harrowing in order that the crop may not suffer damage from occasional dry spells of weather. In some cases, soil packers are used for the purpose of "firming" the seed-bed, but their use has not shown any distinct advantage over ordinary methods.

Harrowing.—Harrows are of three main types, the disc harrows, drag-harrows, and spring-tooth harrows. Each of these serves to some extent a distinct purpose and they will be discussed separately.

Disc harrows are designed to pulverize the soil by means of revolving discs. They work into the soil deeply, and are most effective on tough sod or stubble land. The sharp edges of the rolling metal discs cut up the solid masses of soil which have been turned over by the plough. Owing to their curved form, and the fact that they may be set at an angle with the direction of motion there is a pulverizing and covering action as well, similar to that of the plough.

The drag-harrow is particularly useful in fining and levelling the surface soil. The main purpose of this is to make a good seed-bed, one in which the seeds will lie at an even depth and be in contact with fine soil in which the first roots will find most favourable conditions for growth. Drag-harrows are also used after ploughing as a means of conserving the soil moisture, their action on loose ploughing reduces the surface exposed to the winds, and renders the soil more compact, thus preventing to some extent the circulation of air through the soil. Another useful effect of harrowing on all soils is to destroy the sprouting seeds of weeds. It is at this time that destruction of weeds is most easily and effectively done.

Spring-tooth harrows are not commonly in use on prairie lands, but have been found useful where brush-land has been newly broken up, and also where weeds such as quack (Couch Grass) have to be combated.

The harrows have several rows of curved steel spring teeth, which are fastened to a frame. When roots of the noxious perennial weeds occur, the tendency of the spring teeth is to drag them to the surface without cutting them up, and in this way the roots may be removed from the soil. Where stumps or roots are encountered the spring-toothed harrow passes over them more easily than the drag-harrow.

Cultivators, Subsoil Ploughs, Weeders, Etc.—The longer a farm is under cultivation the greater is the number of problems the farmer must be prepared to meet. In the first place, there is the gradual deterioration of the soil; in the second place, there is the continuous war with weeds; in the third place, there is the necessity of maintaining cultivation at an increasing depth. To meet the needs of the pioneer for the first few years, the only implements required for cultivation are the breaking plough, the stubble plough, the disc harrow, and the drag-harrow. To these latter may be added a subsoil plough, if there is an impervious hard-pan below the furrow requiring to be loosened up. For more thorough cultivation wheeled cultivators are manufactured with teeth either of spring steel, or straight. The latter form is used where deep-rooting perennial weeds have to checked, such as Sow Thistle, and Canada Thistle. The spring teeth are of value in dragging to the surface the root-stocks of Couch Grass. Cultivators are also an economical means of keeping down weeds on summer fallow, and unsown headlands, and in maintaining these in a good state of tilth.

Various types of weeders are on the market, and the whole problem of dealing with weeds by mechanical means in the most economical way is still a matter for experimentation. The Rod Weeder or Rod Cultivator is intended for use on summer fallows in dry areas. A rotating square rod set on a frame with wheels is dragged beneath the surface soil, thus destroying the germinating seeds by tearing them free from their root-hold.

Another form of weeder provided with long steel teeth is used to destroy weeds among the grain in the early part of the season. The teeth also loosen up the soil crust. This is similar to the action of the drag-harrow noted above but is much less severe in its effect on the growing crop.

Conservation of Soil Moisture.—All parts of the prairie are subject at times to periods of dry weather in the growing season, which may materially affect the yield, and may in certain cases lead to partial or total crop failure. To be prepared for such conditions, and to cope with them in the most effective way, and with greatest economy of labour should be a matter of study and to some extent of experiment on the part of every one engaged in agriculture. Generally speaking, whatever is done should not be done for this alone, but should bring also additional benefits, such as the destruction of weeds, the improvements of the physical condition of the soil and the maintenance, and increase, of soil fertility. The usual methods of conserving moisture are the following:

(a) Summer fallow.

(b) Destruction of weeds.

(c) Careful cultural methods.

(d) Maintenance of the organic matter content of the soil.

(e) Fall ploughing.

Fall ploughing loosens the surface soils so that it absorbs the fall rains and melting snows readily. Discing and harrowing in the early spring helps to conserve this moisture by reducing the surface exposed to the drying winds.

Summer Fallow.—By summer-fallowing is meant the deep ploughing and cultivating of land during early summer months (June and early July) of land cropped the previous season in preparation for next year's crop. Land intended to be summer-fallowed may either be disced in the fall or in the early spring. It is not uncommon to disc immediately after the binder. By so doing, weed seeds are covered with soil, later germinate, and are finally destroyed by ploughing.

There are districts where it has been found necessary to summer-fallow half of the area cropped each year. These are the areas where the precipitation is lightest and where experience has taught that crops generally fail on all except summer-fallowed land or new breaking. Whether such frequent fallowing is advisable can only be decided by the individual in respect of his own land.

Advantages of Summer-Fallowing.—(1) By ploughing deep, a reservoir for moisture is produced and fresh soil turned up. It has been found that precipitation penetrates in summer-fallowed ground to about twice the depth that it does on unploughed stubble land. If the soil is compact and hard, rain water will run off the surface rather than penetrate the soil where it can be used by plants. The soil must be loosened in order to absorb moisture.

(2) By summer-fallowing a farmer avails himself of the surest and most effective way of combating noxious weeds. By cultivation throughout the summer, the weeds are uprooted and brought to the surface where they dry out.

(3) In the summer fallow, nitrification takes place through the agency of nitrifying bacteria. The nitrates formed are

stored to considerable extent for use by the next season's crop.

(4) Summer-fallowing more evenly distributes farm labour. From June to the middle of July is usually the slack season, and ground ploughed at this time avoids the great rush the following spring.

Disadvantages of Summer-Fallowing.—(1) Where the precipitation is quite adequate, the crop on summer-fallowed land is liable to go to tops and not ripen before the frost.

(2) To carry out a system of summer-fallowing each year, the farmer must have a large acreage of land. The capital investment is increased.

(3) In windy parts, the soil on summer fallow is liable to drift.

Moisture Needed for Each Kind of Crop.—Crop production is directly dependent upon moisture either as rainfall, snow, or water vapour. Cultivated crops vary greatly in water requirements and hence in their climatic adaptation. Shallow-rooted plants depend upon moisture in surface soil and therefore can be produced only where the rainfall is sufficient. Deep-rooted plants, even though having a higher water requirement, are better able to survive conditions of drought because they draw moisture from the subsoil and lower levels.

The following figures show the number of pounds of water required to produce one pound of various crops, at Madison, Wisconsin; Akron, Colorado, and Olds, Alberta:

Crop	Madison, Wisconsin	Akron, Colorado	Olds, Alberta
	lbs.	lbs.	lbs.
Wheat	....	507	271
Oats	541	614	306
Barley	388	539	227
Peas	477	800	240
Corn	350	369	179
Alfalfa	....	1,069	478
Sweet Clover	....	709	451

Crops in Relation to Soil Types.—(1) Light, sandy soils are warm soils and are best suited to quick-growing crops that require heat, and are able to make their growth before the soil moisture becomes exhausted by evaporation, e.g. Bean, Sand Vetch, Cowpeas, Soybeans, Sweet Clover, Crimson Clover, Millet, Yellow Trefoil, and Brome Grass. Once started, Alfalfa does well on these soils, but roots are apt to dry out the first year. Leguminous crops are necessary in handling light soils as they add nitrogen and organic matter which aids in retaining moisture.

(2) Loamy soils are well-balanced soils but not as early as the lighter soils. They are suited to almost all types of crops such as grasses, cereals, Corn, Sunflowers, roots, Potatoes, and legumes.

(3) Clay soils are cold, usually moist and heavy. They are best suited to pasture and hay crops, grains, Alfalfa, Red and Alsike Clover, and Sweet Clover.

(4) Muck soils are suitable for truck crops such as Cabbage, Celery, Lettuce, Onions, etc. Root crops do well on well drained mucks, also Timothy and Alsike Clover. Red Tops and Orchard Grass and Sweet Clover are suited to this soil.

Prevention of Soil Drifting.—In many sections of the country, considerable difficulty is experienced with soils being blown away, leaving fields bare to the bottom of the ploughed zone. Drifting is caused through the lack of humus or organic matter in the soil, along with very dry conditions. It is most common on fallowed land.

A fine, dry mulch cannot be used at all, but it is necessary to leave a surface of small clods which cannot be readily moved by wind.

(1) One effective means of preventing soil drifting is the alternate cropping and fallowing of long strips of land. A crop, such as Corn or grain is planted in long strips a few rods wide at right angles to the wind. Next to this comes a strip of fallow land, and then another of crop. In this way, there is no large area of fallow land in one body and the soil does not start to blow.

(2) Seeding to Brome Grass or Western Rye Grass, or to some permanent crop is sometimes necessary in places where drifting is very bad. The roots provide binding material in the soil.

(3) Crops, called intertilled crops, of Corn, Sunflowers, Potatoes, or roots are seeded in wide rows and cultivated during the summer between the rows. This method is also a summer fallow substitute, but the succeeding grain crop is usually lighter than on summer fallow land.

(4) Wind breaks are made by planting trees or shrubs at right angles to the direction of main winds. These are usually very expensive.

Exercises.—(1) Classify the soils in your locality. What are the characteristics of each?

(2) Describe the earliest soil in your district. The latest soil.

(3) What are the advantages of fall ploughing?

(4) Fall ploughing should be fairly deep. What condition may modify this? How is it overcome?

(5) Describe implements used in the preparation of the land and kinds used under varying conditions. Give reasons.

(6) State methods of conserving soil moisture and give reasons.

(7) Name important crops in your locality and describe soils which give best yields.

(8) What crops are adapted to sandy soils, loams, clays, and mucks?

(9) What important crops are not grown in your district, and why?

(10) What is the length of the growing season in your district? What is the total rainfall during the growing season?

(11) Where in Alberta and under what conditions is soil drifting prevalent. How may it be prevented?

CHAPTER XLIV

Soil Fertility

It is a well known fact that unless the fertility of the soil is maintained, crop yields are reduced. Agriculture, to be permanent, must be based upon practices which maintain or increase soil fertility.

Loss of Soil Fertility.—Plant food may be lost or removed from the soil by crops (including weeds), by leaching, by erosion (including soil drifting), and by denitrification.

Removal of Plant Food by Crops.—All crops require the same elements for their growth, but they do not all use them in the same proportion. Potassium is specially important in the production of Potatoes and root crops; grain crops need a large amount of phosphorus, and the legumes use considerable calcium. This is one reason why rotations are advisable. Phosphorus, potassium, nitrogen, sulphur, calcium, iron, and magnesium are seven of the ten essential elements for plant growth and these are obtained from the soil. The remaining three, carbon, hydrogen and oxygen, are taken from air and water. Those most generally deficient in soil are phosphorus, potassium, and particularly nitrogen. A deficiency in any one of the soil elements reduces the growth of the plant.

The quantity of mineral foods taken from the soil by different crops is shown in the following table*:

Mineral Foods Removed from Soil by Crop

Crop	Yield	Ash	Nitrogen	Potash	Lime	Phosphoric Acid
	bus.	lbs.	lbs.	lbs.	lbs.	lbs.
Wheat	30	172	48	28.8	9.2	21.1
Barley	40	157	48	35.7	9.2	20.7
Oats	45	191	55	46.1	11.6	19.4
Maize	30	121	43	36.3	....	18.0
Meadow Hay	1½	203	49	50.9	32.1	12.3
Red Clover	2	258	102	53.4	90.1	24.9
Potatoes	6	127	47	76.5	3.4	21.5
Turnips	17	364	192	148.8	74.0	33.1

*By Warrington, from *Principles of Agronomy* by Harris and Stewart.

Weeds are robbers of plant food in that they remove from the soil the same elements as the crops, thus using much of the available plant food.

Removal of Plant Food by Leaching.—The plant food in the soil must be in solution before it can be utilized by the plant. Under favourable conditions the plant takes up the greater part of this food as soon as it goes into solution. However, when there is rapid percolation of rain water or snow, a larger percentage of the soluble compounds is washed down before they can be used. This action, known as leaching, is more common on sandy and light soils because of rapid drainage. A gravelly or open soil makes leaching easier. The greatest losses occur during the spring and fall when there is the greatest amount of moisture percolating through the soil.

The elements of plant food most readily lost are nitrogen and lime. Potassium goes into solution slowly and is therefore not taken from the soil to the same extent. To prevent or at least, reduce considerably this loss, organic matter must be added to the soil to check the rapid percolation of water, or, plant food must be absorbed and held by growing plants as fast as it is made available. The fact that plants greatly reduce the loss of plant food through leaching is well illustrated by the following data from the Rothamsted Experiment Station as stated in "*Soil Fertility and Permanent Agriculture*" by Hopkins.

Nitrogen in Drainage Waters: Rothamsted Experiments Average of Twelve Years

Month	Rainfall (*inches*)	Bare Soil Drainage (*inches*)	60-inch Guage Nitrogen (*per million of water*)	Nitrogen (*pounds per acre*)	Wheat Land Nitrogen (*per million of water*)
Jan-Apr.........	8.24	5.40	9.0	10.95	2.8
May-Aug.......	10.61	2.95	10.6	7.17	.3
Sept.-Dec.......	11.36	6.70	11.8	17.52	4.2
Jan-Dec.........	30.21	15.05	10.5 (*Average*)	35.64	2.4 (*Average*)

From the table it will be seen that during the months from May to August, inclusive, which was the growing season of the crops, the amount of nitrogen leached from the Wheat land was very small in comparison with that from the bare soil. As soon as the crop was removed the loss of nitrogen greatly increased.

Removal of Plant Food by Erosion.—As the greater part of the organic matter and nitrogen is in the top twelve inches of soil, its removal by erosion causes much concern to the farmer. The chief agents effecting erosion are water and wind. The extent of the damage caused by water, either in the form of rain or melting snow is modified by certain factors. On a given soil type, the rate of erosion increases with the slope of the land. The rate at which water is absorbed by the soil is an important factor. Clay soils do not absorb water rapidly, therefore there is considerable run-off on sloping land. Gullying is quite common on such soils, and unless checked will cause considerable damage. Coarse-textures soils and those containing an abundance of organic material absorb water readily; consequently, little run-off occurs to cause erosion. The rate at which rain falls or snow melts is another factor. An inch of rain received over a period of a day may produce no run-off, while if the same amount of rain is received in an hour it may remove a large quantity of top soil. The vegetative cover is perhaps the most important factor in preventing either water or wind erosion. Plants open the soil so that it is able to absorb moisture quicker than bare lands; they also lower the rate of flow over the land, and the binding influence of the roots holds the soil in place.

The loss of soil fertility by wind erosion is greatest in drier areas, bare of vegetation, because of this lack of top growth to break the force of the wind and roots to hold the soil. Soil blowing on summer-fallowed land is an example of wind erosion. In southern Alberta the losses from blowing are great, and will continue until fibre is put into the soil to bind it. Seeding down to grasses with vigorous root-stocks is one of the surest preventives of soil blowing.

Loss of Plant Food by Denitrification.—The greater part, if not all, of the nitrogen which is used by the plant, is taken into the plant system in the form of nitrates. Denitrification is the breaking down of the nitrates into ammonia and free nitrogen, both of which pass off in the air as gas and are therefore lost. This process goes on through the activity of certain soil bacteria under conditions which are usually abnormal. Many of them only live in aneaerobic condition, such as water-logged soils where there is a large amount of undecayed organic matter. However, under ordinary conditions favourable to plant growth, the loss of plant food through denitrification is almost negligible.

Soil Fertility Increased.—Plants require a certain amount of available mineral plant foods, together with nitrogen, much of which is taken from the soil by continual cropping. In order to maintain the soil fertility the stock of mineral matter must be replenished in the form of green manures, crop residues, farm manures or commercial fertilizers. To do so effectively and economically a farmer must know the requirements of his land and substitute accordingly. A chemical soil analysis will give the amount of the various soil elements, but will not indicate the availability of these for plants; therefore, field tests are advisable to supplement such analysis.

Green Manures.—One of the most important methods of increasing organic matter in the soil is the ploughing under of growing plants. While the small grain crops are used to a great extent for this purpose, leguminous crops are best for they also add greatly to the supply of nitrogen in the soil. Legumes have the power of making use of atmospheric nitrogen through the agency of nitrogen-fixing bacteria which live and form nodules or tubercles on the roots. The bacteria gather free nitrogen from the soil air and convert it into nitrogenous compounds which are utilized by the leguminous plants. Such crops, when ploughed under, enrich the soil by giving to it the additional supply of nitrogen and also organic matter. However, if the bacteria are not present, the crop acts similarly to others by drawing its supply from the soil and when ploughed under does not add to the nitrogen supply. Under such conditions inoculation is beneficial.

In regions of low rainfall where decomposition is slow, the use of green manure crops may be a doubtful practice because it opens up the soil and allows for further drying.

Crop Residues.—Grain straw, Clover straw, stubble, and any other plant residues may be ploughed under and will prove almost as beneficial as a green manure crop. It is doubtful whether such a practice should be carried on in the drier districts.

Farm Manure.—The value of farm manure has long been known, yet many farmers neglect it entirely or waste a lot of its valuable constituents through carelessness. Manure adds to the plant food supply of the soil by increasing the organic matter and by making conditions more favourable for the work of desirable soil organisms. Both the liquid and solid parts should be saved as each contains valuable constituents of plant food.

The best method of avoiding loss is to spread the manure on the land when fresh so that the plant food may be washed into the soil. If stored for any length of time, it must be protected from leaching and loss through the activity of destructive organisms which are most active in their work of denitrification and heating when the manure is loose and fairly dry. Manure is too often left in a loose heap exposed to the action of rain and snow, consequently the readily soluble and most valuable constituents are lost. By keeping it under cover, either in pits or sheds or by putting it in well-built compact piles much of this loss in both cases is prevented. To obtain the best results from the use of manure, it must be spread evenly over the land. A manure spreader is the most satisfactory implement as well as a great saver of time and labour.

Fifteen tons to the acre is commonly used, though most soils can receive a much heavier application without injury. The amount available is usually the limiting factor.

Commercial Fertilizers.—Commercial fertilizers are of great value in maintaining the essential elements of plant food but do not add to the humus or organic matter. The elements most commonly deficient in the soil are nitrogen, phosphorus and potassium and in a few soils the supply of calcium is very limited. Commercial fertilizers are expensive and before using them the farmer should know what elements are deficient in the soil in order to make the most economical use of the fertilizer. Complete fertilizers containing nitrogen, phosphorus, and potassium may be obtained, but the use of these is often wasteful. The soil may be deficient in only one element and the addition of the others will be unnecessary. By buying fertilizers containing the necessary element and mixing them himself, the farmer saves a great deal. Here again, a chemical analysis of the soil, supplemented by field tests will also effect a great saving. Nitrogen is the element most readily lost from the soil and also the most expensive to buy in fertilizer. Among the leading nitrogen fertilizers are sodium nitrate or Chile salt-petre, which is imported from Chile; ammonium sulphate, a by-product of coal distillation; dried blood; dried fish; ground fish, and tankage. The nitrate is best applied just before seeding as it is very soluble and apt to leach away before utilized by the crop if applied too early.

Phosphorus is commonly applied in the form of super-phosphate (acid-phosphate), raw rock phosphate, bone meal, or as tankage. Rock phosphate is the most important source of phosphorus fertilizers since it may be applied directly after having been very finely ground or may be treated with an equal amount of sulphuric acid in the production of the super-phosphate. The raw rock contains from 12 to 14 per cent. of phosphorous whereas the super-phosphate contains but half this amount. The treatment with sulphuric acid renders the phosphorus much more soluble but at the same time increases the cost per unit. Probably somewhat more than 200 million dollars are spent by the different countries for phosphatic fertilizers in one year. A similar amount is spent for potash fertilizers and almost twice this amount for nitrogenous fertilizers.

The different countries spend annually a sum in excess of 700 million dollars for nitrogen, phosphorous and potassium fertilizers. At the present time the Canadian fertilizer trade amounts to only about four million dollars but ultimately we must use much greater quantities if we are to maintain our present state of productivity.

The most important potassium fertilizers are imported from Germany, where they are obtained from the Stassfurt deposits. Here are mined a large number of salts, all of which carry a high percentage of potassium. Kainit is one of the most common of these salts. Muriate of potash is a manufactured potassium salt which is imported extensively from Germany. Other important salts are potassium nitrate and potassium carbonate. Woodashes and seaweed contain considerable potassium and are used quite largely for fertilizers.

Soils are not commonly deficient in calcium, but are often improved by its application. It neutralizes acid soils and makes them more productive. Heavy soils and salts become compact and contain little air, a condition which is very favourable for denitrifying organisms. In such cases the addition of calcium tends to cause the fine particles to floculate, thus opening up the soil so that air can circulate. Calcium is generally applied in the form of burnt lime or finely ground limestone.

The soils of the greater area of the Prairie Provinces are initially very fertile but in certain parts such as the forest areas it will be necessary to apply both lime and phosphatic fertilizers in a relatively short time if satisfactory crop returns are to be expected.

Nitrification.—The nitrogen in the soil is almost entirely in organic compounds in the form of partially decayed organic matter. Plants are not able to utilize these insoluble organic compounds until they have been converted into nitrates through the process known as nitrification which is dependent upon the activity of certain soil organisms or bacteria. In general terms, three stages, each with its specific kind of bacteria are involved in the process.

(1) The nitrogen in the organic compound is changed to ammonium compound by ammonifying bacteria, and other organisms.

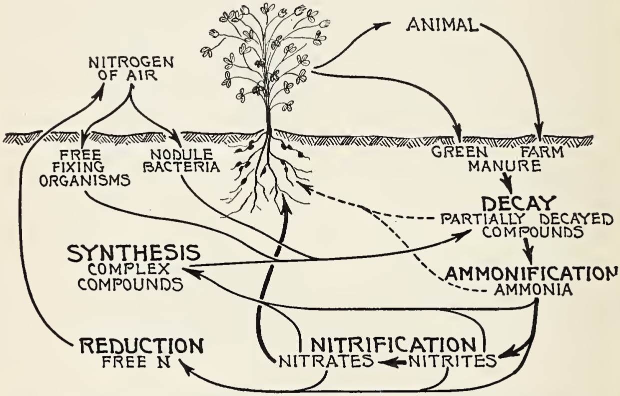


Fig. 84. Diagram representing the movements of nitrogen between soil, plants, animals, and the atmosphere. This is called the nitrogen cycle.

(2) The ammonium compounds are changed to nitrates by the nitrite bacteria.

(3) The nitrites are converted into nitrates through the activity of nitrate bacteria.

Technically, the first stage is ammonification and the second and third stages are nitrification proper. For nitrification to proceed, calcium or some other suitable alkaline element, and oxygen are necessary. The bacteria make use of the oxygen in the air, thus cultivation, which permits the free circulation of air in the soil, promotes nitrification. (Compare with denitrification.)

Phosphorus is necessary for the vital activities of nitrifying bacteria as well as being an essential element for plant growth. Therefore, the application of phosphorus fertilizer to soils deficient in this element not only supplies the plant with phosphorus but indirectly supplies nitrogen by promoting the activity of nitrifying bacteria.

Methods of Soil Cultivation to Stimulate Bacterial Activity.—Only a small part of the nitrogen in the soil is available at the time of seeding the crop. Under proper cultivation the nitrifying bacteria provide nitrates for the plants during their growth. The usual cultural methods for the conservation of moisture and eradication of weeds promote nitrification. In summer fallow nitrates accumulate. By cultivating between the rows of intertilled crops moisture is conserved, weeds are kept in check, but bacterial activity is increased by the loosening of the soil so that air can enter. Fallow usually contains from five to ten times as much nitrate as cropped soils at the end of the season.

Exercises.—(1) What are the ten essential elements for plant growth? Which are obtained from the soil and which from the air?

(2) By what means is plant food removed from the soil? In what way are weeds "robbers"?

(3) What effects have a one-crop system upon the soil? Compare with rotation system.

(4) Do you think the soils in your district lose much plant food through leaching? Why? What factor in the soil elements aid leaching? What elements are thus easily lost? How may they be replenished? At what season is the loss greatest?

(5) What are the chief factors which control or prevent erosion? Especially note soil-blowing in Southern Alberta.

(6) Define denitrification.

(7) State methods of increasing soil fertility.

(8) Under what conditions are green manure and crop residues most beneficial?

(9) Are full benefits being derived from farm manures in your district? Discuss storage methods fully.

(10) State ways in which a farmer may economize in the purchase of commercial fertilizers. What is the essential factor to be considered in the use of such?

(11) How is nitrogen obtained from the soil? What soil element aids nitrification? How is bacterial activity stimulated?

PART 7

FIELD HUSBANDRY

CHAPTER XLV

Farm Crops

Wheat.—Wheat is the most important of the farm crops of Canada. The yield on the farms of Canada amounted in 1927 to over 400,000,000 bushels, of which over 320,000,000 bushels figure in the country's exports. The chief demand for our Wheat comes from the following countries, in the order named: Great Britain (213,000,000 bushels) Japan (13,300,000 bushels) Germany (13,000,000 bushels) China (13,000,000 bushels) United States (10,000,000 bushels) Netherlands (10,000,000 bushels) Belgium (10,000,000 bushels). Over 60,000,000 bushels of the Wheat exported is made into flour before being shipped, and in milling for export Canada now leads all other countries. The grain trade is largely shaping Canada's development. Elevator facilities for millions of bushels are being provided at the terminal points on the lakes, and at the seaports. Railroads are being pushed into new settlements and in the direction of Hudson Bay, while millions of acres of Wheat land still await cultivation, and the coming of the agricultural type of immigrant.

The drier regions of the Prairie Provinces produce hard Winter Wheat, or hard Spring Wheat, which are best for flour. Eastern Canada having a more humid climate produces soft Wheat. There, the Wheat is generally sown in August or September, and having made considerable growth is able to withstand the winter, and is harvested about the following midsummer. Wheat of this kind is called Fall or Winter Wheat. In the Prairie Provinces the main crop is Spring Wheat.

Most of the Spring Wheat of the West is of the Marquis variety, which was originated at the Dominion Experimental Farm. Previous to this the Red Fife Wheat was the one commonly grown. Marquis is earlier than Fife, yields quite as well, and makes equally good flour. Much experimenting is being done to get earlier ripening Wheats which will escape the early frosts in the fall in the northern districts. Also a rust-proof variety is being sought for, since the damage from rust is causing serious loss to farmers in Saskatchewan and Manitoba. Some of the newer varieties being used are Renfrew, Garnet, and Reward. However new varieties should be very cautiously introduced and should be used generally only when they have clearly proven their superiority over old established varieties.

Oats.—Oats is second in importance among the Canadian grain crops.

This crop can be grown farther north than Corn or Wheat. It does best in a cool moist climate, and has been grown in Russia, and the Scandinavian countries for centuries. In the northern parts of the Prairie Provinces the weight often goes over 40 pounds to the bushel, and the yield under favourable conditions close to 100 bushels to the acre.

Oat varieties may be classified according to colour as white, yellow, and black. Only the white varieties are commonly grown, such as Banner, Victory, Abundance. Oats may be classified also as "open panicle" and "side panicle". The varieties above named are all of the former type.

Barley.—Barley adapts itself to wide variations in climate and soil. Being a plant of quick growth and maturity, it is suited for climates where the growing season is short. The varieties may be grouped as two-rowed and six-rowed. In America the latter is the kind commonly grown, while in Europe the first is preferred, owing to its use in making malt. The chief six-rowed varieties grown in Alberta are O.A.C. No. 21, Manchurian, and Bark's. Barley does best on rich sandy loams, but may be successfully grown in all parts of the

Prairie Provinces. Its chief use is as a food for Hogs and Cattle, when it is fed crushed and mixed with other grains.

Rye.—Rye bread is the main food of the common people in many of the countries of Europe. With us the Rye crop is used chiefly for pasture and for cattle fodder when cut green. Winter Rye is the variety used for this purpose. It is sown in July and is pastured both in fall and spring. If allowed to grow it may be cut at midsummer for hay, and the second growth which follows will furnish pasture for the following months.

Flax.—In Western Canada Flax is grown chiefly for seed, and though a satisfactory crop, is one of less importance than the cereal grains mentioned above. In countries having humid climates, Flax is grown as a fibre plant principally, and the stems of the plant are put through certain processes which prepare it for manufacturing into linen cloth. In a drier climate such as that of Alberta, the fibre is of poorer quality, and therefore the crop is chiefly grown for the seed from which linseed oil is obtained. This oil is used in the manufacture of paints and varnishes, and is therefore a very important industrial product. The residue after the oil is extracted is called oil-cake, and is used as a Cattle food.

Any good agricultural soil is suitable for the growing of Flax, but it does best on a rich, sandy loam. Owing to the small size of the seed, the seed-bed must be in a fine state of tilth, and the soil packed firmly, so that when sown the seed may be planted at a uniform depth. The land must be free from weeds, as the flax plants are easily smothered by a growth of weeds. Flax is often grown on spring breaking, since such land is free from weeds. Flax is usually sown at the rate of 30 to 50 pounds to the acre. The seeding is done after the middle of May so as to escape the late spring frosts.

Other Farm Crops.—*Green Crops* (*Soiling Crops*). Green crops are those which are cut when green, and while in this succulent state, are fed to livestock. These crops are particularly valuable for dairy stock and for finishing beef cattle or sheep for market in the summer or fall months. Sometimes the stock are turned into the crop for a certain length of time each day, so that a minimum of injury is done by tramping. In other cases the crop is cut and fed to the animals in a near-by feed lot. The advantage of this is that there is a second growth following the first cutting, although there is a loss cf fertilizing material and extra labour required.

The soiling crops in ordinary use may be any of the following: Corn, Oats, Rye, Millet, Brome Grass, Red Clover, Alsike Clover, Sweet Clover, Alfalfa, or Rape. Other crops have been tried out, but in this province they are in the experimental stage.

Hay and Pasture Crops. Hay crops are those which are cut and cured by drying before being fed to livestock. Hay plants are confined almost entirely to the Grass and Legume Families. Some of the more common are: Timothy, Rye Grass, Brome Grass; Oats, Barley, Rye, Wheat, Sweet Clover, Red Clover, Alsike Clover, Alfalfa.

Pasture crops are those upon which livestock graze. Besides the natural prairie grasses we have Timothy, Brome Grass, Western Rye Grass, Red Top, White Clover, Sweet Clover, Alfalfa, Winter Rye, and Rape as the chief pasture plants.

Crops for Silage. Silage is a succulent food for livestock, produced by packing the chopped stems and leaves of suitable plants in such a manner that the whole is practically air tight. Under these conditions a certain amount of fermentation takes place.

Silage is a valuable food during the winter when there is no available pasture, or during hot, dry seasons when the pasture becomes dried up.

Some of the important crops used for silage are: Corn, Sunflowers, Oats, and Peas.

Root crops. Root crops are those grown for their succulent roots. Those grown for human consumption are Turnips, Swedes, Carrots, Beets, and Parsnips. Turnips, Swedes, Mangels, Sugar Mangels, and Sugar Beets are food for livestock, chiefly dairy, and beef, Cattle. Carrots are grown for food for Horses. Sugar Beets are used in the manufacture of sugar.

Selection and Preparation of Seed.—In the selection of seed the following should be considered:

(a) Suitability of variety.
(b) Viability.
(c) Size and plumpness of seed.
(d) Purity.

(a) *Suitability of variety.* To be successful, a crop must be adapted to the conditions both of soil and climate, of the locality in which it is grown.

Some crops require a great deal of heat, but are killed by even very light frost. Others are not so exacting as to temperature and will withstand a certain amount of frost.

Grimm Alfalfa thrives much farther north than ordinary varieties; Alsike Clover resists much wetter soils than Red Clover, and Turkeyred Wheat is adapted to a dry climate.

(b) *Viability of seed.* Seeds that will not germinate are useless as far as reproduction is concerned. The aim should be to sow seed having high germinating power, for seed with a low percentage of germination produces a thin and uneven crop. Low viability may be due to several causes.

(1) *Age of seed.* Different kinds of seed vary considerably in the length of time they will retain their viability. Nevertheless, the tendency in all seeds is towards a lowering of germinating power with increasing age. As a rule the seeds of legumes retain their viability longer than grass seeds. After the second year the viability of most seeds decreases rapidly. It is therefore advisable to use seed of the previous year's crop.

(2) *Maturity of seed.* Extremely immature seeds even though viable do not produce as vigorous seedlings as mature seeds. Weak seedlings rarely withstand unfavourable conditions. Select seed free from green or shrunken immature seeds.

(3) *Storage.* Conditions of storage greatly affect the viability of seeds. The chief essential is dryness. While an even temperature is best, seeds will withstand a great variation of temperature without injury, provided they are kept dry.

The moisture content of the seed is very important. For proper storage the moisture content of most seeds should not be over 14 per cent. If over this percentage, the seeds are apt to become moldy and, in extreme cases, to heat. In both cases, the viability of the seed is impaired if not altogether destroyed.

(c) *Size and plumpness of seed.* The best seeds are large and plump, and consequently contain a large supply of stored food. This food nourishes the young seedlings until their roots become well established and the leaves sufficiently advanced to manufacture enough food to sustain the plants. In small seed the supply of reserve food may become exhausted before the seedlings are established.

(d) *Purity.* Purity in seed means freedom from weed seeds, and other admixtures.

The presence of weed seeds in a seed sample greatly lessens its value. Not only is the crop grown from weedy seed unsightly, but it is greatly damaged by crowding, and robbed of much of the soil moisture and available plant food. Also the cost of eradication of weeds is great.

Other admixtures in seed include seeds of other varieties of the same kind of crop, seed of other crops, and inert material such as chaff and dirt. Seed is sometimes adulterated with seed of less valuable varieties or that which closely resembles the chosen kind. Sweet Clover is very frequently found as an impurity in Alfalfa seed. Inert material, besides being useless, often carries the spores of fungus diseases such as smut and rust.

Germination Tests.—In making each of the three common germination tests either the rag-doll tester, sawdust or soil tester, or moist blotters are used.

(1) *Rag-doll.* Take a long strip of flannel or muslin about a foot wide. Dampen the cloth and scatter the seeds over the lower half so that no seed is touching its neighbour. Fold the remaining cloth over the seed, then roll and tie around the centre and ends with string. Place the roll in a bucket and cover with lukewarm water for several hours. Drain and cover the top of the bucket with damp cloth or newspaper and place in a warm room. On the seventh day the test is ready to be read. Count all weak or moldy sprouts and dead seeds, deduct from the total number and find percentage of germination.

(2) *Sawdust or soil method.* Fill shallow boxes with moistened sawdust or soil to a depth of about one or two inches. Cover with moistened cloth on which seeds are placed. Cover with a second moist cloth, on the top of which is then spread a layer of sawdust or soil. Place in a warm room and keep moist but not saturated. After seven days make count.

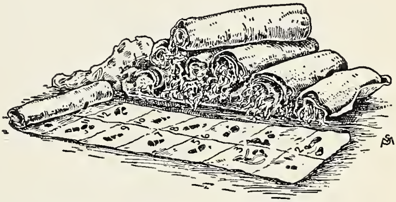


Fig. 85. "Rag Doll" Seed Tester.

(3) *Blotter Method.* Spread seeds between moistened blotting paper. Place on a plate or tin pan and cover with inverted plate or pan. Keep in a warm place. At all times the blotters should be moist but not saturated.

The Rag-doll and Sawdust methods are suitable for testing Corn, Beans, Peas, Wheat and similar large seeds. Clover and Alfalfa seeds are tested between damp layers of blotting paper while Timothy, Blue Grass, and Red Top are tested on top of damp blotting paper in a moist chamber.

Purchase of Seed from Reliable Sources.—Seed which is suitable to local conditions and gives a high germination test may be purchased from dependable sources.

Registered and certified seed may be obtained from seed growers who make a specialty of growing these classes of seed and they may be depended on to give practically always the highest degree of satisfaction.

There are many seed companies which put forward every effort to procure and distribute only seed of the highest quality. Seed from such firms may be a little higher in price but is usually economical in the end. It is a good policy never to try to get a bargain in seeds. Seeds offered at so-called bargain prices are liable to be quite inferior in purity and germinability and may be quite unadapted to the climatic conditions in which the crop is to be grown.

Preparation of Seed.—This includes cleaning, treatment and inoculation of seed.

(1) *Cleaning.* A good fanning mill is a very necessary piece of equipment on a farm. By properly adjusting the screens and air blast, light and broken kernels, dirt, chaff, and a great proportion of the weed seeds can be removed.

(2) *Seed Treatment.* It is advisable to treat seed grain for smut diseases as a prevalence of these diseases in the crop may cause serious loss. For methods of treatment see Chapter XLVI.

Preparation of Seed-Bed.—*Annuals* which are used for soiling, hay or pasture, do not require, as a rule, as well worked or as fine a seed-bed as biennials or perennials. As the annual crops used for these purposes are usually sown rather late, spring ploughed land is very often used. Spring ploughing should be fairly deep, and if the land is loose or lumpy, the packer may be used to advantage, followed by the spike-tooth harrow.

If not seeded at once, the land will probably need to be harrowed at intervals to keep the weeds in check. The smaller the seeds, the finer must be the seed-bed.

If spring grains are seeded, stubble land will often prove satisfactory, depending upon the moisture supply. The land in this case, is double disced and harrowed, then seeded. The chief objection to this method is the difficulty of controlling weeds.

Winter Rye is used considerably as a fall and early spring pasture. Spring ploughed land, fallowed until seeding time, is in excellent condition for this crop. It is necessary to keep the fallow free of weeds throughout the summer by means of a spike-tooth harrow or duck-foot cultivator. If the crop is seeded in August, it may be pastured lightly during the fall and again in early spring.

Corn is sometimes used for soiling but needs a seed-bed more carefully prepared than most crops used for this purpose.

Biennials and Perennials require well prepared seed-beds if the crops are to be successful. The first year is the critical year for such crops and unless they get a good start, they are greatly handicapped. The seeds of the hay and pasture grasses and legumes are usually small and require a firm and fine seed-bed.

The land should be ploughed as early in the spring as practicable and worked down with the packer and spike-tooth harrow at once to minimize loss of soil moisture through evaporation. As weed seedlings appear the land should be harrowed or shallow cultivated. This not only cleans the surface layer of soil from viable weed seeds but it packs the soil and pulverizes the surface. This cultivation should be repeated, until early in June when the seed may be sown.

Corn and Sunflowers. Corn and Sunflowers require similar seed-beds. Clover, Alfalfa or grass sod is very suitable for these crops. The land should be ploughed deeply in the fall to enable the moisture to penetrate well into the soil. In the spring thorough discing and harrowing makes the seed-bed fine and friable.

Root Crops. Very light or very heavy soils are to be avoided when choosing land for roots. The former has poor water-holding capacity, while the latter, because of its firmness, does not allow the roots to develop properly. Sod or stubble land is generally used for these crops. Deep fall ploughing gives the best results. In some cases, sub-soiling is practised to break up hardpans or to loosen compact subsoils. In the spring, the land is double-disced two or three times to firm the seed-bed and conserve moisture. The ground is then thoroughly worked with the spike-tooth harrow to fine and level the surface. As the seeds of the root crops are usually very small it is essential that the upper layers of the seed-bed be fine and firm in order that the seed may be in close contact with the soil.

Time, Rate, and Method of Seeding.—The following table indicates the time, rate, and method of seeding of the most important crops.

Crop	Time of Seeding	Rate of Seeding	Method of Seeding
Alfalfa	Early June.	8-15 lbs.	Drills or broadcast.
Red Clover	Early June.	6-15 lbs.	Drills or broadcast.
Sweet Clover	Early June.	6-15 lbs.	Drills or broadcast.
White Clover	Early June.	4-10 lbs.	Drills or broadcast.
Western Rye Grass	Early June.	10-15 lbs.	Drills or broadcast.
Brome Grass	Early June.	10-15 lbs.	Drills or broadcast.
Timothy	Early June.	6-10 lbs.	Drills or broadcast.
Kentucky Blue Grass	Early June.	10-20 lbs.	Drills or broadcast.
Oats, Wheat, Barley for hay or pasture	Last half of May, or as needed.	$1\frac{1}{2}$-$2\frac{1}{2}$ bush.	Drill.
Millet	Late May or early June.	15-30 lbs.	Drill.
Corn	May 20-30.	12-30 lbs.	Rows 3-$3\frac{1}{2}$ ft. apart. Hills 3-$3\frac{1}{2}$ ft. apart.
Sunflowers	May 5-15.	12-25 lbs.	Same as corn.
Rape	End of May and June.	4- 5 lbs.	Rows, drill or broadcast.
Turnips and Swedes	Late May and early June.	10-12 lbs.	Rows 24-30 inches apart.
Beets and Mangels	Late May and early June.	10-12 lbs.	Rows 24-30 inches apart.
Sugar Beets	Late May and early June.	12-20 lbs.	Rows 24-30 inches apart.

Cultivation During Plant Growth.—Annual crops, which are sown in drills or broadcast, are not usually cultivated during growth. In a few cases they are harrowed lightly when young, to kill weeds.

Biennial and perennial hay and pasture crops are not cultivated the first year, unless sown in rows fairly wide apart. Weeds are kept down by clipping back with the mower. If sown in rows the crop is kept clean by cultivating at intervals between the rows until the plants are so large that they may be damaged by further cultivation. In the spring of the second and subsequent seasons, the crop may be lightly disced or harrowed to loosen the surface soil and prevent plants from becoming sod-bound.

Intertilled crops such as Corn, Sunflowers, and roots require considerable cultivation to keep down weeds and maintain a loose friable condition of the top soil. Corn and Sunflowers may be cultivated quite close to the rows and deep at first, but more and more towards the centre of the intervening spaces as the plants develop in order to avoid root pruning. The main feeding roots of the plants are at the ends of the fibrous branches and the removal of these by the cultivator offsets any advantage that is obtained by loosening the soil. These crops are usually cultivated every two or three weeks until they shade the ground or would be damaged by further cultivation.

Deep cultivation is necessary for root crops. Their feeding roots are usually deeper and less extensive than those of Corn, consequently they may be cultivated quite close to the rows. The root crop must be thinned when the plants are about four inches high. Swedes, Turnips, Sugar Beets, and Mangels are first blocked to bunches about eight to ten inches apart by means of a sharp hoe. The bunches are then thinned to one plant. The strongest bunches are left when blocking, and the most vigorous plants left when thinning the bunches. Four to six inches is the usual distance left between carrots when thinning.

Harvesting and Storing of the Crop.—*Green Crops.* Green Crops (soiling crops) are usually cut when they have attained maximum growth but are still succulent. Cereal grains are cut when in the milk stage; the common grasses and clovers when in bloom. As a rule any one crop is not suitable for soiling for more than one or two weeks. A series of crops needs to be carefully arranged in order to keep green feed constantly on hand. Alfalfa is the best of the soiling crops and can be used almost constantly throughout the entire season. An alfalfa field, mowed part at a time until in full bloom, can be mowed over again in the same order, yielding excellent feed for the rest of the summer and fall.

Hay Crops. There are certain factors to be considered in determining the stage at which a crop may be cut for hay.

The crop should be cut when there is least injury to the succeeding cutting. This concerns only these crops which can be cut more than once in a season. As a rule, the later the first cutting is made the smaller the second cutting will be.

The crop should be cut when the greatest total yield of highly digestible forage can be obtained. If only the yield were to be considered, the crop would not be cut until almost mature for the total weight of plants usually increases until maturity. However, at this stage most plants become woody and less palatable. This is especially true of the biennial and perennial legumes.

Perennial grasses are usually cut shortly after blooming, and when the seeds are forming. At this stage they are sufficiently developed to give a high yield of nitrogenous fodder.

Peas and Oats are cut when the Pea pods have formed and when the Oats are in the milk.

The best quality of Clover hay is obtained when cut in full bloom or when the heads are beginning to turn brown; Alfalfa is usually cut when the crop is one-tenth to one-half in bloom. When cut in full bloom the yield is greater but the quality is inferior. Sweet Clover must be cut just before the blooms appear, otherwise a coarse stemmy hay is likely to result. The crop is usually from 24 to 30 inches high at this stage. Care should be taken to cut the Sweet Clover plants high enough, six to eight inches, so that the lower buds are not destroyed, as these give rise to the second crop.

All hay crops should be cured in a way that will most satisfactorily conserve their leaves, colour and palatability. Because of their succulent nature, legume hay crops, such as Clover, Alfalfa and Sweet Clover are somewhat difficult to cure. When exposed to hot sun and drying winds the leaves dry out quickly, become very brittle, and break off easily; thus the most valuable part of the crop is lost. The crop should be cut in the morning as soon as the dew is off the plants, and allowed to remain in the swath until wilted. Before the leaves have become dry enough to shatter, the hay is raked into windrows and allowed to remain for one or two days to cure. Many prefer to cure the hay in small cocks. Both methods are satisfactory but it is essential that the hay be handled as little as possible to avoid shattering. The perennial grasses, such as Timothy, and Red Top are generally allowed to cure in the swath, then raked into windrows for loading. This method, however, allows for considerable bleaching which spoils the appearance of the hay. The best quality of Timothy hay is secured in the windrow or cock rather than in the swath.

Hay is ready for stacking or placing in the mow when it is so dry that no moisture shows when the stems are twisted in the hands. If it is put in the barn or stack when too moist, it may be considerably damaged by heating, or in extreme cases, spontaneous combustion may take place causing total loss. Hay stored in the mow is usually of better colour and quality because of being out of direct sunlight. The hay on the outside of stacks is usually bleached and poor in quality. In order to preserve the quality of the hay, the stack must be well built. The most satisfactory type is one with upright sides and built solid from the ground up, with a top well rounded and firm in order to shed as much rain as possible and prevent loss due to blowing away.

Crops for silage. Silage crops should be cut when they will give the highest yield of nutritious fodder. Corn is at its best when the grain has become glazed and the lower leaves of the stalks have turned brown. Under Alberta conditions it is rarely possible to grow corn to this stage of maturity. Therefore it is not cut as a rule until after the first frost in order to allow the crop to come as close to maturity as possible. Sunflowers which are more frost-hardy than Corn, approach much closer to maturity. This crop should be harvested for the silo when the seed is forming and before there is much loss of leaves.

Corn and Sunflowers may be harvested with the Corn binder, a cutting drag, or by hand in small areas. The cutting drag is very simple and cheaply constructed. It is comprised of an A-shaped float having cutting blades on both or only on one side. This is drawn between the rows of Corn or Sunflowers.

A mixed crop of Peas and Oats makes good silage. These are usually seeded at the rate of one-half bushel of Peas and one and one-half bushels of Oats per acre. When the Peas begin to fill, the crop is ready to cut; this is most commonly done with the mower. A Pea harvesting attachment to the mower leaves the crop in windrows which is more easily handled than when in the swath.

Rye and Oats, when cut in the milk stage, make good silage if firmly packed in the silo. The hollow stems of the grain plants carry air which is apt to spoil the silage. Mixing with Clover or Alfalfa is said to improve the quality. Legumes such as Alfalfa, Sweet Clover, and Red Clover are not as satisfactory for this purpose because their high nitrogen content induces putrefaction rather than the desired type of fermentation.

Before placing in the silo, the plants are cut into small pieces, one-half to one inch long. This is important, as large pieces do not pack tightly, which is a condition essential to the production of the best silage. The chopped material is distributed uniformly within the silo and packed firmly to exclude air. A rise in temperature occurs which is accompanied by the production of large quantities of gas, chiefly carbon-dioxide. Later, acids are produced which not only give a characteristic flavour to the silage but act as a preservative as well.

Root Crops. Swedes, Turnips, and Mangels are generally harvested by hand. The roots are pulled, thrown into small piles, then topped and trimmed with a heavy knife. Sugar-Beets are ploughed up or harvested with a Sugar-Beet lifter. This implement lifts the Beets but does not bring them out of the ground. They are then pulled by hand and treated in the same manner as the Turnips and Mangels. Carrots and Parsnips are harvested with the plough or fork or hand-pulled. The tops are usually twisted off.

Roots should be stored in a well made root cellar or pit, which must be frost-proof and have adequate ventilation. A root cellar is best if kept at a fairly even temperature, a little above freezing. If the temperature is fairly high, the roots transpire rapidly which causes them to shrink and spoil. Roots will keep well in a pit if it is properly protected. The bottom of the pit is usually covered with straw, then filled with roots. A ventilation shaft, filled loosely with straw, should be placed at intervals of about ten feet along the centre line of the pit. The roots are then covered with thick alternate layers of straw and soil which should extend well beyond the sides of the pit to keep out frost. A final covering of manure aids greatly in this respect. The ventilators must protrude through the roof of the pit for some twelve to twenty-four inches, in order to give a free circulation of air.

Crops Suitable for the Different Parts of Alberta.—The length of the growing season and the amount of moisture are important factors which limit the kinds of crops grown in Alberta. In the southern and eastern parts of the province the growing season is quite long but the moisture is rather limited and only those crops which are fairly tolerant of drought are successful. Wheat, Oats, Barley, and Rye are grown, but the Wheat and Rye give the best returns. Western

Rye and Brome are the most suitable hay and pasture grasses. Sweet Clover is well adapted to this district. Corn and Sunflowers are grown successfully in certain parts. Recently some early maturing varieties of Sorghum have been tried and are showing some promise. However, this crop is very sensitive to the slightest frost.

In the irrigated sections the number of crops is considerably increased. Alfalfa, Red Clover, and root crops especially Sugar Beets are grown to a large extent.

In the foothill districts, where moisture conditions are more favourable Timothy is an important crop. The Pincher Creek district has become a Timothy seed growing centre of importance.

Central parts of the province have a greater rainfall, but the growing season is shorter. They are therefore, better adapted to quick-growing annual crops and hardy perennials. The main crops are Wheat, Oats, Barley, Rye, Western Rye Grass, Brome, Timothy, Red Clover, Sweet Clover, Peas, and Sunflowers. Corn is grown to some extent for silage but only the earliest varieties are successful. The squaw type of Corn is practically the only kind that will ripen seed. Turnips, Swedes, and Mangels are grown to a limited extent. Alfalfa can be grown successfully in certain parts.

The farther north a crop is grown the earlier and hardier the variety must be.

Crop Rotation.—It has long been known that the growing of one kind of grain crop continuously on the same piece of ground tends to decrease the soil fertility for the first few years. The supply of mineral and organic plant foods may be maintained by the use of suitable fertilizers, but the physical condition of the soil is so much impaired that profitable crop production is impossible. By using a proper crop rotation the soil fertility is not only maintained, but is often improved so that greater and better crops may be grown. Such a rotation will include:

1. A cash crop such as Wheat, Oats or Barley.
2. A restorative crop such as a legume.

3. A cleaning crop such as soiling crops, hoed crops or summer fallow. The last two also aid in the conservation of moisture.
4. A fodder crop such as hay or pasture. These add fibre to the soil.

This does not mean that the grain crops are the only cash crops for any of the other three types may be grown profitably irrespective of their value for soil improvement.

A common rotation throughout the dry farming districts of the West is as follows:

First year—Summer fallow.
Second year—Wheat.
Third year—Wheat, Oats, or Barley.

Only the conservation of soil moisture is considered in such a rotation. The grain crops take from the soil and add very little. Eventually, the soil becomes impoverished of plant food and fibre, and soil-blowing results. The addition of a legume would greatly improve such a rotation.

A few short rotations, suitable to the West, are as follows:

Rotation 1.

First year—Wheat.
Second year—Oats or Barley seeded down to Sweet Clover.
Third year—Sweet Clover for hay or pasture.
Fourth year—Intertilled crop such as Corn, Sunflowers, roots, or Potatoes.

This rotation is adapted to mixed farming districts where there is a sufficiency of permanent pasture outside the rotation.

Rotation 2.

First year—Summer fallow.
Second year—Wheat.
Third year—Oats or Barley.
Fourth year—Peas and Oats for hay or silage.

Rotation 3.

First year—Summer fallow.
Second year—Wheat.
Third year—Oats or Barley seeded to Sweet Clover.

Fourth year—Hay or pasture.
Fifth year—Wheat.

The two rotations given above are adapted to districts where mixed farming is followed, but where the emphasis is placed on grain crops—

First year—Summer fallow.
Second year—Wheat.
Third year—Oats and Barley.
Fourth year—Fallow early part of season. Seed to Alfalfa in June.
Fifth, Seventh year—Alfalfa.
Eighth year—Hoed crops.
Ninth year—Wheat.

Further rotations may be obtained by consulting Exhibition Circular No. 35, of the Dominion Department of Agriculture—"Crop Rotations for the Dry Farming Districts of Canada."

The Value of Rotation.—1. It maintains the humus supply by means of a grass crop.

2. It restores nitrogen by the growing of legumes. The supply of nitrogen in the soil can be maintained by growing a legume crop once in four years.

3. It alternates crops having different root systems and habits of growth, so that plant food is taken from different soil levels rather than only one.

4. It helps to control weeds, fungus diseases and insects. Summer fallow and intertilled crops are very effective in controlling weeds.

Many fungi and insects attack only one kind of crop, and by change of crop they are controlled.

Exercises.—(1) What factors should be considered when selecting seed? Why are seed "bargains" usually unsatisfactory?

(2) What conditions affect the viability of seeds? How?

(3) What is the value of a germination test? How would you make such a test?

(4) What is the purpose in cleaning seed?

(5) Describe the two common methods of inoculating legume seed.

(6) What are the requirements of a good seed-bed? How would you prepare a seed-bed for Alfalfa?

(7) Why is an intertilled crop cultivated during the summer?

(8) Compare the cultivation of Corn and root crops. Describe the method of thinning root crops.

(9) What conditions must be considered when determining the stage at which a crop may be cut for hay? At what stage of growth are Timothy, Red Clover, Sweet Clover, Alfalfa cut for hay?

(10) Describe the harvesting of Sweet Clover for hay, giving consideration to stage of growth, manner of cutting, time of day to cut, curing.

(11) When is hay ready for storing? How is it stored?

(12) Name some of the most important hay and pasture crops in Southern Alberta, in Central, and Northern Alberta.

(13) What is silage? When are Corn and Sunflowers at their best for ensiling?

(14) Describe the method of filling a silo.

(15) How are root crops harvested?

(16) What are the essentials of a good root cellar or pit?

(17) What are the three most important crops in Canada with respect to acreage and monetary value? In Alberta?

(18) What is the important hay crop in Canada? In Alberta?

(19) Keep a record of the date of the last killing frost in spring, the first killing frost in the fall; the length of the growing season between these frosts, the average temperature and average monthly rainfall during growing season, total rainfall for year. Give list of crops which have been successfully grown under these conditions.

CHAPTER XLVI

Smuts and Rusts

Diseases.—The damage done to crops by disease is equal to, if not greater than that caused by insects. In the Prairie Provinces where grain crops predominate the loss due to rust and smut is well known. There are very few crops that are not attacked by some disease and unless the farmer has a knowledge of how to combat such pests, he is bound to meet with crop failure.

Damping off of seedlings is due to a fungus called *Pythium*. The spores germinate in the soil and produce germ tubes which penetrate the tender epidermis of the seedlings. Once within, the germ tube branches and produces thread-like growths which feed on the sap in the infected region, causing the seedlings to topple over; the infection is spread by contact. The disease propagates by two kinds of summer spores which only attack the young plants. The winter or resting spores lie in the ground for several months before germinating.

Thin seeding and a moist but not saturated seed-bed are the best of preventives. Diseased plants should be pulled up and burnt. Deep ploughing buries the upper layers of soil which contain the resting spores thus putting them below the depth at which they can affect the seedlings.

Smuts

Oat Smut.—The spores of the fungus are already in the ground or planted with the seed. The spores and seeds germinate at the same time so that the germ tube of the fungus can easily penetrate the tender tissues of the Oat seedling. The mycelium, or thread-like structure of the fungus grows within the plant and is most active in the newest tissue. When the flower forms, the mycelium enters the ovary and there feeds upon the plant food which is being stored in the developing seeds. The fungus completely exhausts the supply of food in the seed and then produces innumerable spores so that the ovary becomes filled with a dark brown powder. The spores finally burst through the ovary wall, and are readily blown about in the wind. Some fall to the ground where they are in a very favourable position to attack seedlings; others adhere to the seeds of neighbouring plants. The spores are unable to cause infection until the following years, as the germ tubes are not strong enough to penetrate mature plant tissue.

The loose smuts of Wheat and Barley, though different species affect these plants in a manner similar to the Oat smut. The spores may lodge in the flowers of other plants and the germ tube penetrate the young seed. The mycelium lies dormant until the following spring when the seeds are planted.

The covered smut of Barley differs in that the spores do not break out from the Barley hull until after the crop is harvested.

Bunt or Stinking Smut of Wheat.—The smut spores germinate and attack the Wheat seedlings as in the loose smut. Young plants affected with bunt are usually of a darker bluish-green colour and appear more robust than healthy plants. When the head is ripe it remains erect and the kernels are quite plump, being full of a black, disagreeable smelling moist powder. Flour which is milled from Wheat containing bunted grains is darker in colour and has an objectionable odour and flavour.

Seed Treatment for Smut.—Bunt, loose smut of Oats, and covered smut of Barley can be controlled by the same treatment. The spores of these smuts adhere to the surface of the kernels and are killed by external treatment.

Formalin Treatment.—This is the commonest and usually the most effective method of control. Before any seed is treated it should be thoroughly cleaned with a fanning mill to remove smut balls or inert material which may carry disease spores. A solution made up of one-half pint of formalin (40 per cent. formaldehyde) in twenty gallons of water will be sufficient to treat from 25 to 30 bushels. The grain is sprinkled with the solution until all the kernels are wet. It will be necessary to shovel the grain thoroughly to

Fig. 86. The Formaline method of treating Wheat for smut.

permit all the seeds to come in contact with the formalin. When this is accomplished, it is left in a heap and covered for about four hours, after which it is spread out to dry. When dry enough to run through the drill, the seed should be sown. The drill and all bags used should be thoroughly disinfected, otherwise the time and labour involved in treating the grain is lost through reinfection from these sources.

Some prefer dipping to sprinkling. In this case the seed is dipped into the solution for 10 to 20 minutes, stirred occasionally to float off any smut balls which may be present, then drained, put into piles and covered for several hours, and finally spread out to dry.

Copper Sulphate (Bluestone) Treatment.—The solution is made by dissolving two pounds of bluestone in twenty gallons of water. This is sprinkled on the seed in the same manner as the formalin. Bluestone is not as effective as formalin and there is greater danger of lowering the germination of the seed.

Dusting with Copper Carbonate for Bunt.—This is more expensive than either the formalin or the Bluestone treatments. Dust applied at the rate of two ounces or more to a bushel of seed has proved effective in killing the bunt spores. It is essential that the seeds be thoroughly covered with dust, and to accomplish this a dusting machine is necessary.

Treatment for Loose Smut of Wheat and of Barley.—External treatments such as are used for bunt, are ineffective for these forms of smut. The seed must be treated in such a way as to kill the fungus threads which lie within them. As yet, this has been successfully accomplished only by the hot water treatment.

The seed is immersed in water, for four to six hours, the temperature of the water being kept constantly at 86° F. During this period the fungus mycelium becomes active, growth begins, and it is then in a sensitive condition and readily killed—when placed in an unfavourable environment. After the allotted time, the seed is transferred to another vessel in which the water is kept at a temperature of 112° F. where it remains for fifteen or twenty minutes. This warms it up in preparation for the third and final immersion.

It is then placed in a third vessel containing water kept at a temperature of 120° F. and left for ten minutes. A longer time than this is apt to lower the vitality of the seed.

The killing temperature of the fungus is between 124° and 127° F. the seeds are damaged at 131° F. which emphasizes the necessity for careful management during the last stages of this treatment. The temperature must be high enough to kill the fungus and yet not damage the seed. Should the temperature of the water drop to any extent during the process, hot water must be added, preferably with a sprinkling can, care being taken not to pour directly on the seed. After the ten minutes have elapsed, the seed is drained thoroughly, then spread out thinly to dry. By turning it with a shovel or hoe drying will be hastened. It should be sown as soon as dry enough to run through the drill. The soaking may have started germination activities, which if checked by further drying may result in the death of the seed.

Precautions in All Wet Treatments of Seeds.—

(1) Do not soak seed longer than the specified time.
(2) Dry as quickly as possible by spreading it thinly and turning it over frequently.
(3) Protect the seed from frost while drying, otherwise the germ will probably be killed.
(4) Bags and seed drill should be disinfected before putting treated seed in them.
(5) When sowing, allowance must be made for the swelling of the seed which may enlarge to one and a half times the original size.

Rusts.—Rusts cause an immense annual loss to the grain farmers of Western Canada. The fungus does not grow and replace the kernels as in the case of the smuts, but weakens the host plant so that it fails to produce seed, or if so, the kernels are light and shrunken.

There are two general classes of cereal rusts: stem rusts which produce rust spots on the stems of the plant, and leaf rust. The former is the more dangerous type.

Stem Rust.—This fungus attacks Wheat, Oats, Barley, Rye, and certain of the wild grasses. However, each host appears to have its own variety of rust, for cross-infection between these hosts is not always possible. The life history of all the stem rusts is practically the same so that only the Wheat stem rust will be considered. This disease has two hosts, the Wheat and the Barberry. It is first noticed on the Wheat stem in the form of long red lines which are composed of a multitude of small red summer spores. This is termed the red rust stage. The spores are blown long distances and the disease is spread by directly infecting other Wheat plants. Later in the season, black streaks will be seen on the Wheat stems due to the appearance of the black winter spores. These are thick walled and do not germinate until the following spring when they infect the Barberry. On the under surface of the

Fig. 87. Part of Wheat Plant showing stem rust.

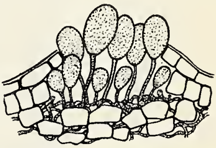


Fig. 89. Wheat-Stem rust, showing spores breaking through the epidermis.

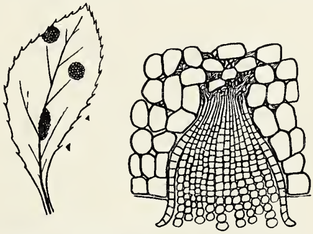


Fig. 89. Showing under side of Barbary leaf and a cluster cup.

Barberry leaves cluster cups are formed in which orange coloured spores are produced, which in turn infect the Wheat plant and produce the red rust stage.

Unfortunately the disease may be carried over from one year to the next without the presence of the second host, the Barberry. In the southern United States, Wheat is in a growing state during the winter months. The red rust spores are blown northward and infect the young crops. The disease propagates rapidly, new spores are produced and the rust again travels northward. By a number of these successive leaps the rust finally reaches Western Canada at a time when the young Wheat crop is susceptible to attack.

Fig. 90.
Two stages of infected heads.

When rust spores lodge on a Wheat stem it germinates and pushes out a small tube which enters the stem through a pore. Once inside the plant the disease kills the nearby cells. Spores are borne just underneath the epidermis in the region of a pore. Finally the epidermis breaks and exposes the spores. When a plant is badly infected with rust, it becomes greatly weakened and stunted and produces small shrivelled seeds, or none at all.

As the seed is not known to carry the disease, treatment such as that used against smut is of no avail. Practical methods of combating this disease are preventive rather than any direct treatment to kill the fungus, and such control practices are applied along one or more of these lines:

(a) The destruction of the Barberry plant will eliminate any infection from that source. After going through the Barberry stage the fungus seems to have become exceedingly virile, the spores being much more capable of infecting Wheat.

(b) In rust infected areas, the hastening of maturity of the Wheat crop is essential. The aim should be to have the crop far enough advanced before the arrival of rust so that little or no infection takes place. This is accomplished by:

(1) Seeding early varieties.
(2) Seeding on land that is early and well drained. Wet and shady spots lengthen the growing period of the crop and such spots are usually very heavily rusted and serve as a centre for the spreading of the disease.
(3) Early seeding. Reports from various experimental stations in Manitoba and Saskatchewan show that the early seedlings of wheat are infected with rust to a much lesser degree than late seedlings.
(4) Heavy rates of seeding. A thick stand of plants hastens the maturity of a crop and thus reduces the degree of rust infection.
(5) Sowing seed which is well filled and free from disease or mechanical injury. Such seed will germinate quicker and the seedlings will become well established in a much shorter time than those developed from small shrunken seed.

(c) The use of rust resistant Wheats has received a great deal of attention during the past decade. The durum, or macaroni Wheats are much more rust resistant than the common bread Wheats. However, because of their poor milling quality, they are unpopular in the grain trade. Plant breeders throughout the West are endeavouring to hybridize the common and durum Wheats, hoping to obtain a good milling variety which is rust resistant. So far, none of the hybrids produced have been wholly successful.

Exercises.—(1) Tabulate for comparison the outstanding features in the life history of the various smuts studied. Complete table showing treatments. Note especially those requiring internal and external treatment.

(2) Describe the formalin and copper sulphate treatment. Give reasons for preference, if any.

(3) Describe the hot water treatment, stating accurately the water temperature. Why is this necessary?

(4) List precautions necessary in all wet treatments of seed.

(5) What crops suffer from the ravages of stem rust? Describe what takes place when a red rust spore adheres to a Wheat stem. Note result. State the preventive measures.

CHAPTER XLVII

Weeds

A weed is any plant growing where it is not wanted. In a field of Wheat, Oats and Ball Mustard are both weeds. However, the term is usually confined to those plants which are injurious, troublesome or unsightly, and at the same time are useless or comparatively so.

Weeds which are the hardest to control are termed noxious weeds because: (a) They crowd out the crop and rob it of much of the soil moisture and plant food. (b) They propagate rapidly by producing a great number of seeds or by vigorous root stocks, or by both. (c) They may produce seeds which have such a protective covering in order that they may remain in the soil for many years, and still retain sufficient vitality to germinate when brought to the surface of the soil. The Alberta "Noxious Weeds Act" lists the following as noxious weeds of the province: Tumbling Mustard, Hare's Ear Mustard, Wild Mustard, Ball Mustard, Tansy Mustard, Wormseed Mustard, False Flax, Shepherd's-purse, Pigweed (Red Root), Canada Thistle, Stinkweed, Russian Thistle, Ragweed, Wild Oats, Russian Pigweed, Blue Bur, Tumble Weed, Purple Cockle, Perennial Sow Thistle, Blue Lettuce, Cockle Bur, Common Barberry, and Toad Flax.

Identification of Weeds.—*Tumbling Mustard.* This is one of the commonest weeds in southern Alberta. The young plant has a rosette of pale green, downy leaves resembling those of Dandelion, and is likely to be confused with Shepherd's-purse at this stage. The mature plant is from two to four feet high, with branches growing from the main stem to form a spherical-shaped head. It changes to yellow at maturity, the stem breaks off at the base, and the plant is

Fig. 91. Tumbling Mustard.
(Courtesy of Seed Branch, Toronto)

carried along the ground by the wind for great distances. The whitish or pale yellow flowers, about one-third of an inch in diameter, distinguish Tumbling Mustard from Tumbleweed, while the spherical shape and tumbling habit prevent it from being confused with the other species of Mustard. The small, greenish yellow seeds are contained in the long slender pods many people mistake for branches.

Ball Mustard. The flowers of the Ball Mustard are orange yellow in colour, and are smaller than those of the Tumbling Mustard. The plant is easily recognized by its conspicuous, spherical seed pods, which are about one-twelfth of an inch in diameter. Each pod contains but one pale, yellow seed.

Fig. 92. Ball Mustard.
(Courtesy of Seed Branch, Toronto.)

Pigweed (*Red Root*). This plant should not be confused with the familiar weed of the garden, Lamb's Quarters, which is popularly, but incorrectly, called Pigweed. Pigweed is easily distinguished from Lamb's Quarters by its pale pink root, from which it derives the common name, "Red Root". The seeds of both plants are shiny black when ripe. That of the Lamb's Quarters is flattened on one side, while that of Pigweed is flattened on both sides.

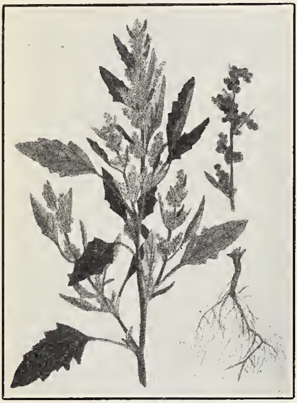


Fig. 93. Pigweed.

Fig. 94. Canada Thistle.

(*Courtesy of Seed Branch, Toronto.*)

Canada Thistle. This is one of the worst enemies of the farmers of the province. Canada Thistle may be recognized by its clusters of purple, pink, or white flower heads, which are from one-half to one inch in diameter. This thistle is dioecious, that is, staminate and pistillate florets are borne on separate plants. We can thus understand why many of the plants do not bear seeds. The seeds are light brown, oblong, and about one-eighth of an inch long. A white, feathery pappus attached to the seed assists it in drifting through the air for great distances.

Perennial Sow Thistle. Perennial Sow Thistle, one of the most difficult weeds to eradicate, is now found in almost every district in the province. The plant may be easily distinguished from the Annual Sow Thistle by its long underground root stocks. It is usually found in patches, and no matter how high the grain is, the weed almost invariably grows to an equal height. The hollow stems contain a bitter, milky juice. The bright yellow flower heads, from an inch to one and one-half inches in diameter, resemble those of the Dandelion. The oblong seeds are about one-eighth of an inch long, are dark reddish brown, and are ridged lengthwise and wrinkled crosswise. Fine silky, spreading hairs are attached to the top of the seed.

Fig. 95. Sow Thistle.
(Courtesy of Seed Branch, Toronto.)

Fig. 96. Blue Lettuce.
(Courtesy of Seed Branch, Toronto.)

Blue Lettuce. This plant is increasing very rapidly in Alberta, and large patches are frequently seen growing in grain fields where they have completely choked out the grain. Blue Lettuce plants resemble those of Perennial Sow Thistle in many respects, but are easily recognized by the pale blue flower heads, which are about one inch in diameter. The seeds are about one-quarter of an inch long, and are reddish brown in colour. They are club-shaped, with thick ridges down each face, and have a short beak at the end of which is borne a tuft of white down.

Blue Bur. This weed is very troublesome to sheep because the burs stick to the fleece. The plant has an objectionable odour, and stock will not eat it. The paleblue flowers are arranged in long, rather one-sided clusters, and are about one-eighth of an inch in diameter. Each "bur" is composed of four greyish-brown, pear-shaped seeds about an eighth of an inch long, with the margin covered with hooked spines.

Fig. 97. Blue Burr.
(Courtesy of Seed Branch, Toronto.)

Wild Oats. This common weed closely resembles some varieties of cultivated Oats. The seeds vary in colour and size, and may be various shades of grey, yellow, black, and brown. The best means of identification of the seed is by the presence of the horse-shoe shaped scar at the base of the seed. Stiff bristles surround this scar, but are sometimes broken off during threshing. The seeds on the upper part of the head ripen early and are usually shelled out before or during the harvest. The later maturing seeds are harvested with the grain crop, and remain in the commercial Wheat, Oats, and Barley.

Stinkweed. This weed has a disagreeable and characteristic odour. Like the Mustards, Stinkweed belongs to the Cruciferae; the small flowers have four white petals in the form of

Fig. 98. Wild Oats.

Fig. 99. Stinkweed.

(*Courtesy of Seed Branch, Toronto.*)

a cross. The seeds are borne in a flat pod, about half an inch across, and notched at the top. The reddish-brown seed is easily recognized by five or six loop-like lines running around it and terminating at the notch at the base.

Russian Thistle. This is very prevalent in Southern Alberta. Despite its name it is not a thistle, but a member of the Pigweed family. When young the leaves and branches are thread-like in form and dark green in colour. As the plant matures, it assumes a spherical form and turns reddish-yellow. When ripe the plant breaks off easily at the base and "tumbles" across the prairie. The inconspicuous flowers are borne in the axils of the leaves. The conical seed is about one-sixteenth of an inch in diameter, and has a greyish, ragged outer coat. When this is removed, the seed has the appearance of a small snail shell.

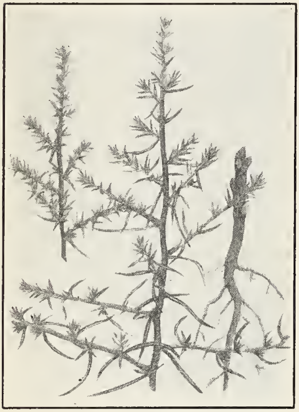


Fig. 100. Russian Thistle. Fig. 101. Russian Pigweed.
(*Courtesy of Seed Branch, Toronto.*)

Russian Pigweed. This plant, like the Russian Thistle, is an undesirable immigrant. It is a tall, coarse, leafy plant that is pale green when young but turns light golden when it matures. The pale yellow flowers are very small. The oval, greyish-brown seeds are about one-twelfth of an inch long, and have the surface minutely lined and wrinkled lengthwise.

Classification.—(a) *Annuals* grow from seed, blossom, produce seed, and die the same season. They usually have fibrous roots, and produce a large quantity of seed. Examples are Russian Thistle, Russian Pigweed, Wild Oats, Wild Mustard.

(b) *Winter Annuals* germinate in the autumn, remain green throughout the winter, and continue their growth in the spring. They complete their life history within one year. The following are winter annuals as well as annuals: Tumbling Mustard, Stinkweed, Ball Mustard, Blue Bur, False Flax, Wormseed Mustard, Hare's Ear Mustard.

(c) *Biennials* require two years to complete their growth. During the first season a small plant is produced and nourishment stored up. Flowers and seeds are produced during the second year. Grey and Green Tansy Mustard are examples of this type.

(d) *Perennials* live more than two years. They propagate both by seed and underground root stocks that often go out great distances from the parent plant. Perennial Sow Thistle, Blue Lettuce, and Canada Thistle have deep-rooted root stocks, while Quack Grass and Sweet Grass have shallow root stocks.

Method of Eradicating Weeds.—A farmer who sows clean seeds has won half the battle against weeds. The greater part of the weeds on a farm have been sown by the farmer when seeding his crop. While he cannot control the seeding of wind-blown seed, he does not have to sow weeds. There is plenty of good, clean seed on the market, and though it may be higher priced, it is cheaper in the end.

Farm animals which are fed screenings should not be allowed to run at large over the farm unless the screenings have been finely ground or boiled to kill the weed seeds.

The method used to eradicate weeds depends upon the growth habits of the plants. Annuals and winter annuals are usually quite easy to control. They depend entirely upon their seeds for propagation, thus anything that will prevent them from maturing seed will keep them under control. This type of weed usually has a small fibrous root, but produces an abundance of seed. The principle involved in their eradication is the hastening of germination and the destruction of the young plants before they produce seed. Fall germination may be induced by light cultivation if a moist seed bed can be procured. When the plants are a few inches high they may be harrowed or ploughed under. Fall ploughing leaves the land in excellent shape for the early germination of annual weed seeds which usually germinate well in advance of the seeding of the crop. Many of the seedlings are thus killed by frost. The cultural methods necessary for the making of a good seed bed for the crop destroy weeds.

Biennial weeds generally start growth in the summer and before winter produce a short tap root and a rosette of leaves which lies close to the ground. The second year flowering stalks are produced and the seed ripens in early summer. The best time to act is when they are in the seedling stage. If too sturdy to be uprooted by the spring-tooth harrow, a thorough working with the duck-foot cultivator may solve the problem. These which survive the winter should be attacked early in the spring. They should be pulled out with the duck-foot cultivator or ploughed under. If this is impracticable, mowing must be done at intervals to prevent the plants from setting seed.

Perennial weeds are the most difficult to control. Some are shallow rooted, other deep rooted. Some produce underground stems or root stocks, which, if broken into pieces will produce new plants from each piece. The shallow rooted types may be controlled in a manner similar to the biennials, but for the deep rooted weeds, deep ploughing is necessary. If this is followed by the harrow and narrow spring tooth cultivator most of the roots will be brought to the surface where they may be allowed to dry out, or be gathered and drawn off the field. To cope with weeds which produce root stocks the land should be ploughed to a depth just below the level of the root stocks. This is followed by the spring tooth cultivator to bring the roots to the surface. These should be gathered, taken off the land and burnt. The disc should not be used on land infested with much weeds, such as Couch

Grass, for the root stocks will only be cut into pieces and the land will be in worse condition than before. It is practically impossible to eradicate these weeds during wet weather.

Perennial plants store food in their underground parts during the summer. The following spring, when growth is renewed, the new shoots, especially the flowering stems, draw upon the reserve food for their growth. The plant is at its critical period, that is, in its weakest condition, when the reserve food supply is almost exhausted and before it has become replenished. This period is reached when the flowering stalks are fully developed but before the seeds have formed, and by ploughing them, the plants are most easily killed.

Summer fallow is a very effective way of controlling weeds. Their seeds germinate rapidly on such land and the young plants are killed by frequent cultivation. By cultivating to a lower depth each time new seeds are brought to the surface. In some extreme cases, where perennial weeds predominate it may be advisable to allow the plants to grow until they are in flower and then mow them down. After the tops have been removed the land is ploughed and cultivated to bring the roots and root stocks to the surface before they grow again. Cultivated crops, such as Corn and Sunflowers are a splendid substitute for summer fallow. The frequent cultivation given to these crops destroys the weeds. Early maturing crops are very useful whether pastured or cut for feed, in that they are utilized before the weeds produce seed. Seeding down to grass has proved successful in many instances, because it crowds the weeds and usually is cut before the weed seeds mature. Pasturing, especially with sheep, is very effective in controlling persistent weeds.

No one method is effective in controlling all the weeds. A well planned rotation which includes them all is most satisfactory and will be permanent. The following rotation is recommended by Professor Harrison of the Manitoba Agricultural College.

(*Manitoba Department of Agriculture, Extension Bulletin No. 73.*)

First year—Wheat, seed down to grass.
Second year—Hay and pasture.
Third year—Pasture and break.
Fourth year—Wheat.
Fifth year—Oats and Barley.
Sixth year—Fallow (or cultivated crops if land is clean).

Along fences and on waste lands weeds of all descriptions abound and unless kept cut down their seeds will infect the neighbouring fields. Too much attention cannot be given to such places because all the work spent on cleaning up the field may be in vain if migration of these weed seeds is not prevented.

Loss of Moisture and Soil Fertility. — Weeds are plants and as such draw upon the soil for food and water. As the amount of these necessities is limited and usually only enough for the crop, that which is removed by weeds means a direct loss to the crop. Weeds occupy space that should be used by useful plants, thereby reducing the yield to a very great extent.

The presence of weeds in the harvested crop greatly reduces its value. Hay containing a lot of weeds is poorer in quality and brings a lower price on the market. Grain is reduced in price according to the amount of useless material present which is largely composed of weed seed and small pieces of weed plants. Many weeds are green and succulent at the time the crop is harvested and cause considerable trouble by clogging the machinery.

Labour Cost of Weed Eradication.—It is very difficult to estimate the actual cost of eradicating weeds, nevertheless it is enormous. While cultivation is performed largely to control weeds, it also benefits the crop by loosening the soil and permitting better aeration. However, on clear land the cultivation need not be nearly so frequent. On foul land extra ploughing, cultivating and, even hand pulling are necessary. This calls for much labour and extra expense. In many cases the farmer is obliged to fallow a piece of land in order to fight weeds, whereas this land would otherwise be producing a remunerative crop. Not only time and labour should be charged against weeds, but also additional machinery.

(For the use of implements in connection with cultivation for weed eradication, see Chapter XLIII.)

Exercises.—(1) Define the term "weed".

(2) Name some of the common annual, biennial and perennial weeds. Name and classify the weeds found in your own locality.

(3) Discuss the methods of eradication for annual, biennial, and perennial weeds.

(4) Discuss the dispersal of weed seeds by outside agencies.

(5) In what ways can a farmer control weeds?

(6) Give reasons why some weeds are termed "noxious".

(7) What crops in a rotation greatly assist in the eradication of weeds? How?

(8) Under what conditions do weeds crowd out the crop and under what conditions does the crop crowd out or smother the weeds?

(9) In what way do weeds effect a direct loss to the crop?

(10) Discuss the monetary loss to the farmer each year by weeds, and estimate how much of this he could eliminate.

(11) State how you would identify the growing plants and seeds of the following weeds: Perennial Sow Thistle, Russian Thistle, Tumbling Mustard, Blue Lettuce, Blue Bur, Stinkweed, Wild Oats.

PART 8

CHAPTER XLVIII

Irrigation

In certain areas of the country where the soil is very fertile, farming has been unprofitable due to the lack of sufficient moisture to support the crops. Some of these areas have now been transformed from arid areas to thriving farm districts by irrigation. Two requirements must be satisfied before irrigation can be made profitable.

(1) The supply of water available must be large enough to meet all the demands of the crop.

(2) The topography of the land must be such that water can be applied economically.

Given these conditions the degree of success is largely in the hands of the farmer and depends chiefly upon the preparation of the land and the proper use of the water.

Levelling and Smoothing the Land.—This is essential if the best use of the water applied is to be obtained. Small knolls must be cut off and all depressions filled by the use of scrapers and floats. The scraper cuts off the high places and spreads the soil over the low spots and the float smooths and levels the surface. Proper levelling cannot be too strongly emphasized as it results in a more economical and uniform application of water and increases the possibility of good yields. If the land is left uneven, the high places will be dry while the low parts will be over-irrigated, and both conditions lessen the yield of any crop.

Ditches.—The head ditch holds the water supply for all the irrigation of the farm. From it, the lateral ditches extend to all parts of the area to be irrigated. When making the lateral ditches two factors must be considered.

(a) *Grade.* The usual grades lie between one-tenth and one-fifth of a foot in 100 feet. Grades of one-fifth of a foot or more are too steep and apt to cause erosion on tight soils.

(b) *Distance apart of ditches.* The distance between the lateral ditches depends on several conditions:

(1) The irrigation head available, that is, the rate at which water can be applied; it is measured in cubic feet per second. This is dependent upon the height of the head ditch above the land to be irrigated, and the volume of water in the ditch.

(2) The character and porosity of the soil. In open soils the ditches must be closer together as the water seeps into such soils more quickly than into heavier soils. If the ditches are too far apart, the land near the ditch is over-irrigated while that farther away does not receive sufficient water.

(3) Smoothness of the ground surface. The smoother the surface, the quicker and more uniform will the water spread over the land.

It is advisable to have the ditches close enough so that light irrigation of uniform depth may be applied quickly. The results obtained from such frequent irrigations more than make up for the additional area used by the close spacing of ditches.

Methods of Applying Water to the Soil.—Irrigation is most commonly accomplished by free flooding, and the various methods used are only the modifications most readily adaptable to the topography of the land and the kind of crop grown. Apart from the free flooding methods, the furrow system is becoming more and more important because of the increased acreage planted to intertilled crops.

(a) *The free flooding method by contour ditches.* This method is most common, especially in new projects, as it requires less grading than most other methods. It is most suitable to land that is rolling or too steep for proper laying out of other systems. The lateral ditches follow closely the contour of the land and the distance between the ditches depends largely on the slope; the steeper the slope, the closer the ditches must be placed. The chief objections to this method are:

(1) The difficulty of applying the water uniformly. Adjacent laterals are not always the same distance apart so that the water is distributed unevenly over the intervening area.

(2) The irregular shape of the land between the ditches. This necessitates more labour in harvesting such areas.

(b) *The border ditch system.* This is adapted to flat lands where the slope is gradual. Straight ditches are run across the field parallel to one another and usually directly down the slope. However, if the land is too steep, the ditches must be run at an angle down the slope in order to lessen the grade and to avoid erosion of the ditch banks. A system of this kind divides the field into rectangular strips. By means of canvas dams, the water is turned into a strip from both sides and allowed to cover a piece of land one hundred or so feet in length. Then the dam is moved further down and another portion irrigated. This process is repeated until the whole area has been covered.

Water can be applied more evenly with this system than with either of the other flooding methods, also the long rectangular strips make general farm practices easier.

(c) *Border dyke system.* This system is the most costly to instal and is therefore best suited to those crops which remain down for a number of years, such as Alfalfa and permanent pastures.

The field is divided into long narrow strips by the building of low, flat dykes or levees which confine the water to a single strip. The strips usually run in the direction of the greatest slope, the water being let in from the upper end. The land between the levees is carefully graded so that the water spreads uniformly over the strip. The levees, when properly constructed, are about five feet wide, six inches high and rounded over. The distance between the levees varies from thirty to sixty feet; forty feet is common on average, smooth land. The length of the strips depends on:

(1) The openness or porosity of the soil. The more porous the soil, the shorter must the strip be.

(2) The slope of the land. On land having very little slope the strips are longer than on land with a steeper grade.

(3) The irrigation head, that is, the rate at which the water can be applied. The length of the strip is increased in proportion to the irrigation head.

As the levees are not high enough to interfere with harvesting machinery, a whole field may be harvested at one time, thus reducing the harvesting costs. The border dyke method is not adapted to grain growing as the ploughing of the land each year destroys the levees.

The Furrow or Corrugated Method.—This method differs from the free flooding systems in that the water runs down furrows which are placed close together so that the soil becomes soaked by seepage through the walls of the furrows.

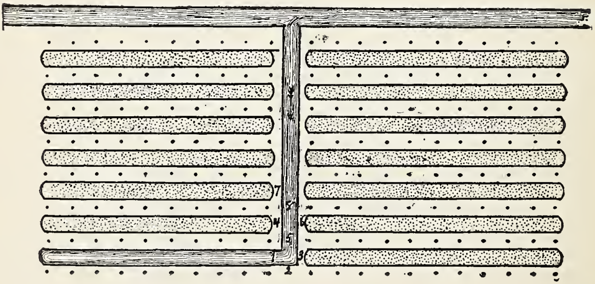


Fig. 102. Plan of furrow flooding by successive rows.

In Alberta, this system is used mostly for hoed and cultivated crops, such as Potatoes and Corn. The furrows are placed between the rows of the crop and should be straight and run in the direction of the slope. The head ditches should run almost directly across the slope or nearly at right angles to the furrows. The distance between the ditches depends upon the slope of the land and the porosity of the soil and varies from 250 feet in very sandy soil to 600 feet in medium soil.

The advantages of such a system are:

(1) A small head of water can be used to advantage.

(2) The baking of the surface is prevented as only a small area is flooded.

(3) There is less surface evaporation of water than in the case of flood irrigation.

(4) By cultivating as soon as possible after irrigating, nearly all the moisture is conserved.

(5) In comparison with flooding, there is less danger from the rise of alkali.

Irrigation During the Period of Plant Growth and Fall Irrigation.—To obtain the best results, irrigation must be carried on so that at no time during the development of the crop must it suffer from lack of moisture. However, care must be exercised in the application of water, for over-irrigation is dangerous. It is not only a waste, but, unless there is excellent underdrainage, it will cause a rise in the water table and the crop will suffer from lack of proper root development. It is better to put on frequent, light, rapid irrigations of about four inches than one heavy one.

It is almost impossible to adhere to a definite schedule for irrigating for one must consider the need of the crop which will vary with the season. Water should be applied when most needed and will do most good. There is usually sufficient soil moisture in the spring to germinate the seed. As the season advances and the weather becomes warmer there is greater evaporation; also as the plants develop there is more leaf surface exposed so that transpiration is increased. The crop makes its greatest demands usually during June and July, a time when evaporation is probably the greatest and it is during these months that irrigation is most beneficial.

The condition of the crop is not a safe indication of when to irrigate, as the crop does not show the effects of a deficiency of soil moisture for several days.

The soil is a more reliable guide. If a handful of soil, taken from about a foot below the surface, is squeezed in the hand and remains in a ball showing the imprint of the fingers, there is sufficient moisture to last for some time. If, however, the earth falls apart, irrigation should be started at once.

Fall irrigation is advisable whenever it can be practised· The water thus stored in the soil is usually sufficient for the next year's crop—until about the middle of June. It not only gives the crop optimum conditions during its early growth but it acts as a safeguard against a dry spring when germination and growth would otherwise be slow.

Suitable Crops for Irrigation.—Irrigation greatly increases the number of crops that can be grown in a district. Under irrigation, the water requirements of almost all crops can be satisfied, so that the number of crops that can be grown is limited only by temperature and soil conditions.

The following table gives the most important crops grown under irrigation in Alberta:

Crop		Method of Irrigation
Small grains	Wheat, Oats, Barley, Rye	Contour and border ditch
	Peas, Flax, Corn, Sunflowers, Potatoes	Border ditch
Roots	Sugar-Beets, Mangels, Turnips, Carrots, Timothy	Furrow
Perennial hay crops	Brome, Red Top, Western Rye Grass, Meadow Fescus, Alsike Clover, Alfalfa	Border dyke
Perennial pasture	Kentucky Blue Grass, White Clover	Border dyke

Of the hay crops grown under irrigation in Alberta, Alfalfa is the most important. Unless absolutely necessary, this crop should not be irrigated until immediately after the first cutting is made. If the Alfalfa is irrigated in the fall there is usually sufficient moisture in the soil to support the crop until after the first cutting. Over-irrigation must be avoided as the roots are soon killed by a high water table.

Relation of Irrigation to Intensive and Mixed Farming.—The capital and labour involved in irrigation farming necessitate the use of smaller farms than would otherwise be used under dry farming conditions. The owner must make each acre produce bigger crops to offset the reduction in acreage, consequently he must practice intensive farming methods. He must increase, or at least maintain, the soil fertility by proper rotation of crops—a system which fits in excellently with irrigation farming. In order to apply water at the right time the farmer must be present to care for the crop from seeding to harvesting. As all crops do not require attention at the same time, the growing of different crops spreads the labour over a longer period. The water requirements of the crops differ; therefore, the water can be used economically.

To obtain the best use of many of the crops, the raising of livestock, or mixed farming, is essential. While grain, Potatoes, and Sugar-Beets may be marketed directly, others such as Corn, Sunflowers, roots, hay, and pasture are best marketed in the form of meat, wool, eggs, milk, and dairy produce. Mixed farming spreads the labour throughout the whole year, giving the farmer a profitable occupation both in summer and winter, and at the same time increases the soil fertility by the returning of plant food to the soil in the form of manure and leguminous hay and pasture crops.

Irrigation makes farming sure and permanent. The income is not dependent upon a single crop as is so often the case in dry farming. In the latter, a crop failure frequently means ruin to the farmer. This is not so with the irrigation farmer, for if his grain crop fails he is still able to draw an income from his other crops.

Irrigation has a great influence in the development of social life in rural districts. Because of the smaller farm units, the number of families within a district is greatly increased. Social activities may be carried on with the direct result of promoting a strong community spirit.

Exercises.—(1) What two requirements must be met before irrigation can be made profitable?

(2) Describe how you would level and smooth the land for an irrigation system. Why are levelling and smoothing necessary?

(3) In the construction of lateral ditches, what factors must be considered? Why?

(4) What systems of irrigation are in use in Alberta? How do they differ? Which is practised in your district? Why?

(5) Write a brief note on irrigation during the growing season. When is irrigation most beneficial? Why? What are the advantages of fall irrigation?

(6) Name the important crops grown under irrigation in Alberta. What method is most suitable for each kind of crop?

(7) When should Alfalfa be irrigated? In what way does over-irrigation affect this crop?

(8) Write a note on the relation of irrigation to intensive and mixed farming.

(9) What influence has irrigation on rural life?

PART 9

ANIMAL HUSBANDRY

CHAPTER XLIX

Cattle

Types of Cattle.—Cattle were one of the first animals to be domesticated by Man for purely agricultural purposes. In earlier times they were kept only for their meat and hides, later for the milk they produced, and still later for draft purposes.

Two main types have been evolved as a result of centuries of selection by cattlemen. These are the beef and dairy types. Wherever breeders have tried to combine the milking and beef tendencies, they have rendered the resulting progeny less efficient for each of these special purposes. These so-called dual purpose cattle have only a fair value either as milk or beef producers. Examples are the dairy Shorthorn and the Red Poll breeds.

The dairy breeds include Holstein-Friesian, Ayrshire, Jersey, French Canadian, Brown Swiss, and Guernsey. The first three of these are common in Western Canada.

The beef breeds include Shorthorn, Hereford, Aberdeen Angus, and Galloway.

Although these two classes are generally termed special purpose breeds, they are to some extent dual purpose, for the dairy breeds have some value as beef animals, and the beef breeds have a corresponding value as milk producers.

General Characteristics of All Beef Cattle.—The beef breeds have certain general features which mark them as distinctly different from the breeds of dairy cattle. In form, ideal beef cattle are deep, broad, low-set, and smooth with a strong top line and a straight under line. In general appearance they must be thick and blocky, and the conformation should be rectangular whether viewed from the top, side or front. Additional characteristics of the beef type are: (1) large muzzle with big, open nostrils; (2) plenty of width between the eyes; (3) a prominent but placid eye; (4) short neck with well-filled neck-vein; (5) smooth shoulders,

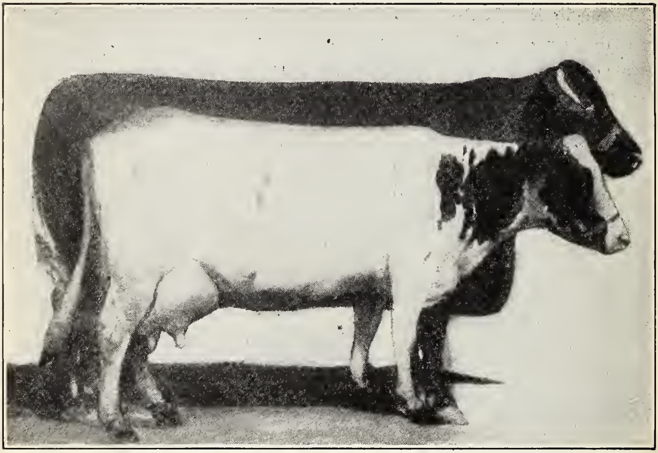


Fig. 103. Comparison of the beef and dairy type in outline.

well covered with flesh; (6) large heart girth indicative of a good constitution; (7) good spring of ribs to provide a large feed capacity; (8) loin wide and heavily covered with flesh; (9) thick through the thighs and low in the twist with meat carried well down to the hocks; (10) fine in the bone, yet strong and large enough to carry the animal easily when in high condition of flesh.

STUDENT'S SCORE CARD

BEEF CATTLE

Scale of Points—For Steer	Perfect Score	Student's Score	Corrected Score
GENERAL APPEARANCE—38 points:			
1 WEIGHT, score according to age	8		
2 FORM, straight, topline and underline, deep, broad, low set, symmetrical, not paunchy, stylish	10		
3 QUALITY, hair fine; skin pliable, bone clean, head medium size, body covering smooth, mellow touch, yet sufficiently firm to indicate a large proportion of muscle	10		
4 CONDITION, development of flesh and fat; degree of fat indicated by spinal covering, rib covering, fullness of flank, purse and tongue root	10		
HEAD AND NECK—9 points:			
5 MUZZLE, broad, mouth large, jaw wide, nostril large	1		
6 EYES, large, clear, quiet expression	1		
7 FACE, short, clean cut	1		
8 FOREHEAD, broad, full	1		
9 EARS, medium size, fine texture	1		
10 HORNS, fine texture, oval, medium size	1		
11 NECK, short, thick, throat clean	3		
FOREQUARTERS—8 points:			
12 SHOULDER VEIN, full, plump	2		
13 SHOULDER, covered with flesh, compact on top, smooth	3		
14 BRISKET, advanced, wide, neat and trim	1		
15 LEGS, straight, short, arm full; shank fine, smooth	2		
BODY—32 points:			
16 CHEST, full deep, wide, girth large, crops full	6		
17 RIBS, long arched, thickly and smoothly fleshed	8		
18 BACK, broad, straight, thickly and smoothly fleshed	8		
19 LOIN, thick, broad, smooth	8		
20 FLANK, full, even with underline	2		
HINDQUARTERS—13 points:			
21 HIPS, smoothly covered, distance apart in proportion with other parts	2		
22 RUMP, long, wide, level, even, tail head smooth, not patchy, pin bones not prominent, far apart	3		
23 THIGHS, full, deep, wide	2		
24 TWIST, deep, plump	2		
25 PURSE, full, indicating fleshiness	2		
26 LEGS, straight, short, shank fine, smooth	2		
TOTAL	100		

STUDENT'S NAME.................................

ANIMAL SCORED.................................

DATE.................................

The Shorthorns.—This breed of beef cattle was developed in the northern counties of England and in southern Scotland, where the markets, the prevailing crops, and the nature of the land caused cattle breeders to concentrate on the development of a profitable beef type. Among the early improvers of the breed were the Collings brothers, Bates, the Booths, and the Cruickshanks, whose work of improvement was carried on between 1780 and 1870. The Shorthorn families developed by Bates are of the dual purpose type, having milking qualities besides having the general form of the beef type. Families of the latter type were developed by the other breeders named, particularly by Cruikshanks of Aberdeen, Scotland, and as a result we have to-day the smooth, compact, low-set, thick fleshed Shorthorn, of which breed there are in Alberta more cattle than of any other breed.

The general characteristics of the breed are as follows: It is red, white, or roan in colour, or may even be a combination of these. The muzzle is light—a dark or blackish muzzle being regarded as an objectionable characteristic. The head is short and broad, with the horns rather flattish and fine, coming out from the top of the skull, and bending inward and forward.

The Herefords.—The breed originated in south-western England, in Hereford and the surrounding counties. It is one of the oldest breeds of cattle. The first to improve the breed were the Tomkins, father and son, between 1740 and 1800. By careful selection they developed animals which matured earlier, were more refined, and were more thickly fleshed along the back as compared with the native cattle of the district.

The breed is slightly larger than the Shorthorn in size. It is of a uniform colour, the face, breast, top of the neck, legs from the knee down, the switch, and sometimes the belly being white, and the rest of the body a cherry red. The muzzle is light in colour, the head short and broad, the horns slightly heavier than in the Shorthorn, bending upward somewhat in the cows, and down in the bulls.

Fig. 104. Champion Shorthorn Steer, and Grand Champion Steer, at the Royal Agricultural Winter Fair, Toronto; and Champion Shorthorn Steer at the International Live Stock Exposition, Chicago, 1927 (*Courtesy of University, Alberta*).

Fig. 105. Fourth Hertford Group at Royal Agricultural Winter Fair, Toronto, and Fourth Hertford Group at the International Live Stock Exposition, Chicago, 1927 (*Courtesy of University, Alberta*).

The Hereford is a strong competitor with the Shorthorn for popularity among breeders of cattle. It is claimed that it excels in ability to take on fat at an early age, and therefore is to be preferred in the production of baby beef; also that it is hardy and maintains its size and other characteristics of the breed when used for the improvement of the stock on the open range. The Herefords are less docile than the Shorthorns. From the butcher's point of view they are not always desirable, being often light in flesh on the back and thighs, and showing some coarseness of bone, and excess of flesh on the neck.

Fig. 106. Four Champion Steers (*Courtesy of University, Alberta*).

Aberdeen Angus.—This is a polled or hornless breed of beef cattle which originated in the north-eastern counties of Scotland, particularly in Aberdeen. The improvement of the breed was brought about in much the same methods as Tomkins, Collins, and others used, namely, by scientific in-breeding and selection. This was done in the case of the Aberdeen Angus between 1800 and 1850 by Hugh Watson, and others.

This breed is slightly smaller than the Shorthorns. It is black in colour, has a black muzzle, and is hornless. The head tapers at the poll, and is somewhat prominent in the forehead. The body has a rounded appearance due to the fact that the spring of the ribs is more cylindrical in shape than in the other breeds.

The Aberdeen, due to its fine quality of flesh and low percentage of waste in the carcass is in great demand by packers and butchers. It is a highly specialized beef breed, suited for stall feeding, and for crossing with the other beef breeds, to produce a high-grade beef animal.

General Characteristics of Dairy Cattle.—All breeds of dairy cattle show certain general characteristics which distinguish them from the breeds of beef cattle. They do not show the breadth, thickness of fleshing, and general rectangular form common to the beef breeds. They are fairly thin, and angular, and do not appear as low set. In general appearance the dairy cow is wedge-shaped when observed from three points of view: (1) From the front, the floor of the chest is wider than the top of the withers; (2) From the side, the distance from the top of the loin to the bottom of the belly and udder is greater than the depth of the body at the heart girth; (3) When viewed from the top, the width of the hip bones is greater than the width of the withers.

Dairy cows should show a *dairy temperament*, or, in other words, a disposition to produce milk. A beef animal's disposition is to produce beef. A dairy cow should not be fat, and all the food eaten should be turned into milk, except what little may be required to maintain health and normal development. The face and neck should be "clean cut" and free from fleshiness. The neck vein should be smooth, and not filled with flesh as in the beef type. The heart girth

STUDENT'S SCORE CARD

DAIRY CATTLE

Scale of Points—For Cow	Perfect Score	Student's Score	Corrected Score
GENERAL APPEARANCE—17 points:			
1 FORM, inclined to be wedged shaped...	6	....	....
2 QUALITY, hair fine, soft; skin mellow, loose, medium thickness; secretion yellow; bone clean, fine..................	5	....	....
3 TEMPERAMENT, nervous, indicated by lean appearance, when in milk......	6	....	....
HEAD AND NECK—7 points:			
4 MUZZLE, clean cut; mouth large; nostrils large..........................	1	....	....
5 EYES, large, bright, full, mild..........	1	....	....
6 FACE, lean; long; quiet expression.....	1	....	....
7 FOREHEAD, broad...................	1	....	....
8 EARS, medium size, yellow inside, fine texture............................	1	....	....
9 HORNS, fine texture, waxy............	1	....	....
10 NECK, fine, medium length, throat clean, light dewlap..................	1	....	....
FOREQUARTERS—5 points:			
11 WITHERS, lean, thin................	1	....	....
12 SHOULDERS, light, oblique..........	2	....	....
13 LEGS, straight, short; shank fine......	2	....	....
BODY—24 points:			
14 CHEST, deep, low, girth large with full fore flank..........................	10	....	....
15 BARREL, ribs broad, long, wide apart; large stomach......................	10	....	....
16 BACK, lean, straight, open jointed.....	2	....	....
17 LOIN, broad........................	2	....	....
HINDQUARTERS—47 points:			
18 HOOKS, far apart, level..............	2	....	....
19 RUMP, long, wide, level..............	2	....	....
20 PIN BONES, high, wide apart........	2	....	....
21 THURLS, wide apart.................	2	....	....
22 TAIL, long, slim; fine hair in switch....	1	....	....
23 THIGHS, thin, long..................	4	....	....
24 ESCUTCHEON, spreading over thighs, extending high and wide; large thigh, high ovals..........................	1	....	....
25 UDDER, long, attached high and full behind, extending far in front and full, flexible; quarters even and free from fleshiness..........................	20	....	....
26 TEATS, large, evenly placed..........	6	....	....
27 MAMMARY VEINS, large, long, tortuous, branched with double extension, large and numerous milk wells.........	5	....	....
28 LEGS, straight, shank fine............	2	....	....
TOTAL....................	100	....	....

STUDENT'S NAME..............................

ANIMAL SCORED..............................

DATE..

should be large to ensure a good constitution. The ribs should be well sprung to give greater capacity for food if the cow is a heavy milker. The loin should be wide but not heavily covered with flesh. The rump should be level and broad. The udder should be large and well proportioned, soft and pliable to the touch, and with teats of good size. The udder veins should be long, tortuous and branching. The skin of the ideal dairy cow is thin and pliable.

Holstein-Friesians.—These are the largest of the dairy breeds. They came in the first place from Friesland, a province of Holland, a flat, fertile district where for centuries the people have specialized in the production of milk, butter, and cheese. The cattle of this area are mostly black and white and spotted, with well-defined patterns. The horns are white, usually with black tips. The head is rather long and lean. The body does not show the smoothness nor the refinement of the other dairy breeds.

In point of numbers the Holstein-Friesian is the leading dairy breed in America. Cows of this breed have surpassed all others in the quantity of milk and butterfat produced. The milk, however, is not high in percentage of butterfat as compared with the average of most other breeds. They are fairly hardy, are quiet in disposition, and fit in well with the conditions on the average farm.

The Jersey.—This breed of dairy cattle comes from the island of Jersey in the English Channel, where they have been kept free from mixture with other strains for centuries. The Jersey is famous as a butterfat producer, and its popularity is in a great measure due to the rich milk it provides, although the quantity is not as large as is usual with the Holstein. The Jerseys are small animals, and so they consume relatively smaller quantities of food.

Jerseys are of fawn colour, shading to yellow, gray and brown. The head is rather short, with the face slightly dished. There is a great width between the eyes and over the forehead. The horns are white or amber coloured.

They are comparatively short, and curve forward, upward, and slightly inward. The body is very refined showing quite decidedly the wedges mentioned above. It is neither coarse in bone nor body.

Ayrshires.—This breed of dairy cattle was developed in the County of Ayr in south-western Scotland. Various breeds have been combined to produce the type, probably Jerseys, Shorthorn, and the Highland cattle, but this was over two centuries ago, and the cattle have been definitely established as a dairy breed for over a century and a half. The breed has an outstanding merit, namely, that it is hardy.

In size the Ayrshire is smaller than the Holstein-Friesian. It is red and white in colour, the colouring appearing in spots. The head is rather long and lean. The horns are white with black tips. They curve outward and upward and are turned back at the tips in the female. The udder is well-proportioned, having good length, and being quite flat beneath.

Cattle Feeding

The Calves.—Beef calves are usually allowed to run with their dams, during which time they suckle their mothers and share the same roughage or pasture their mothers feed on. Dairy calves are usually taken away from their mothers at birth but are fed their own mothers' milk throughout the first three weeks. After this time the whole milk is gradually replaced by skim-milk until the calf is six to ten weeks old. From this time it is fed skim-milk as long as the skim-milk lasts. From the first, calves should be allowed all the hay and oats they will eat but should not be forced to subsist on pasture or hay alone.

The Young Stock.—Calves of all kinds should receive sufficient food for normal development and growth. Many animals are permanently stunted during this period through want of the proper quality or amount of food. Between six months and one year of age a calf cannot secure sufficient food from pasture or dry roughage alone. Beef calves usually suckle their mothers during part of this period but dairy calves require about a pound of grain daily in addition to hay or pasture.

From two years of age and after the use to which the animals are to be put determines how they should be fed. Beef cows that are being kept to produce calves each year need only be fed a good quality of hay, or hay and silage during the winter. Straw alone during the winter is not advisable, because they will become weak, and unable to ward off disease, and will in all probability give birth to weak, dead, or abnormally developed calves. In summer a good pasture is all that is required.

Dairy cows are kept to raise calves also, but their chief use is to produce milk. It is important that they receive food of the right kind and in the proper amounts so that they can do this and still have a sufficient surplus to keep them in good health and in a normal condition of flesh. Milk contains a large amount of protein, and as a consequence dairy cows must receive sufficient amount of protein foods, such as bran and linseed meal. A dairy cow should receive two pounds of hay daily for every hundred pounds live weight, and in addition one pound of a good grain mixture daily for every three or four pounds of milk produced. If silage is fed, three pounds of silage will replace one pound of hay.

Some suitable grain mixtures are here given:

(1) With prairie or Oat hay:

525 lbs.	Barley	625 lbs.	Oats
250 "	Oats	125 "	Linseed oilmeal
225 "	Linseed oilmeal	250 "	Bran
1,000 lbs.		1,000 lbs.	

(2) With Alfalfa hay:

600	lbs.	Oats
350	"	Barley
50	"	Linseed oilmeal
1,000	lbs.	

Fattening Cattle for Beef.—They may be taken at any age for this purpose. They should be fed sufficient quantities of the right kinds of foods to make them gain in weight rapidly. It is usual to fatten them during the winter so that they can be sold in the spring when the price usually is highest. Fattening animals should receive liberal amounts of roughage and grain. The proportion of grain to feed depends on how rapidly the farmer wants the work to be finished. Calves require from 150 to 200 days; yearlings from 100 to 150 days; two-year-olds 60 up to 100 days. Cattle that are being rapidly fattened will eat the following amounts of grain daily: calves 6 to 8 pounds; yearlings 8 to 10 pounds; two-year-olds 10 to 13 pounds.

Suitability of Foods.—Each kind of hay, silage, and grain affects cattle in a different way. Some foods induce the animal to fatten more than others. Some are better for inducing milk flow than others. They should be selected carefully to achieve the results desired.

Suitability also depends upon whether or not animals relish certain foods. Tankage is not relished by cattle. Straw is not relished by cattle as much as well-cured grasses or leguminous hays. These foods can therefore be classed as unsuitable for cattle. Only when rations which cattle relish are fed will proper digestion take place and the maximum nourishment be secured from the ration.

Another reason for classing a food unsuitable is the effect the food has on the flavour of the milk in the case of dairy cattle. If dairy cows are pastured on Rape or ripening Rye the milk will be tainted and become unsuitable for sale either for market milk or to be manufactured into butter or cheese.

Foods most suitable for growth and milk are foods containing higher amounts of protein than Corn or Barley. Alfalfa, Clover, Oats, and silage lead in this respect. Commercial food by-products such as bran and Linseed oil meal are necessary for normal growth and high milk production when Alfalfa or Clover hay is not fed. Foods most suitable for fattening are the more carbonaceous foods. Barley and Corn are the outstanding concentrates which induce animals to fatten. Certain foods keep the digestive system in working order and the animals in good health. Examples are bran, Linseed oilmeal, and mineral foods (bone meal, salt, etc.).

Roughages are those foods which have a high fibre content but are now in digestible nutrients. The most common dried roughages are, according to their nutritive value:

1. Grasses and cereals, e.g., Corn fodder, Red Top hay, Brome hay, Timothy hay, Prairie hay, Millet hay, Oat hay (green feed), Corn stover.

2. Legumes: Alfalfa, all the Clovers.

Silages are succulent roughages, e.g., Corn silage, Sunflower silage, Oat silage.

Concentrates are foods that are low in fibre and high in digestible nutrients:

1. Carbonaceous concentrates, e.g., Corn, Barley, Wheat and Wheat screenings, Oats.

2. Nitrogenous concentrates, e.g., feed by-products, such as Linseed oilmeal and bran.

Roots closely resemble a concentrate in that they have a low fibre content, but their digestible nutrient content is also low. Those grown in this province are Mangels, Turnips, Sugar Beets, and Carrots. In the neighbourhood of a beet-sugar factory wet and dry beet pulp are fed to cattle.

Selection and Combining of Foods.—The most important consideration in feeding is satisfying the requirements of the animal. A study of the requirements is therefore necessary in order to feed scientifically and economically. All stock must digest (or absorb) a definite amount of protein carbohydrates, fats, minerals, and vitamines for the following purposes:

1. *Maintenance*—Tissues are broken down and body substances are burned up daily to keep the animal warm and keep the vital organs in operation. Carbonaceous foods are chiefly required for this purpose.
2. *Growth*—Growth requirements are mainly protein for increase in muscle tissue, mineral matter for bone growth, and vitamines for normal development.
3. *Fattening*—After the animal has used a definite amount of the digested food for growth and maintenance the excess of the digested nutrient is converted into fat. Carbonaceous foods are needed for this purpose.
4. *Reproduction*—For the proper development of a fœtus protein and mineral foods are required. The amount of food required for this purpose is relatively small.
5. *Milk Production*—In feeding dairy cattle the feed requirements are in proportion to the size of the animal and milk and butterfat produced. Cows cannot be expected to produce milk unless the ingredients of milk are in the foods given them. The solids in milk are chiefly protein, and relatively smaller amounts of carbohydrates, fat, mineral matter, and vitamines. All of these must be supplied to the cow with the possible exception of fat because milk fat can be made from carbohydrates.

To be sure that cattle receive the proper amounts of these nutrients it is always a good practice to feed liberally a variety of foods each day.

Most early spring pastures make ideal rations supplying all the nutrients that are required by cattle for any purpose. Dairy cows producing large amounts of milk need grain in addition to pasture. But in the winter time when there are no pastures, rations should be selected which are as similar to pasture as it is possible to get them, in order that they will supply not only the nutrients required but possess the other desirable characteristics such as palatability and succulence.

Cows should be watered twice daily. They should have access to salt when in the pasture or in the barn yard.

The cost of the ration must also be considered because the amount of profit that will be made depends largely upon the cost of the feed. When all the requirements are supplied then, and then only, will the most efficient and economical results be secured, the growth of animals will be normal, less feed will be required to produce each unit of gain or milk, calves will be born strong and healthy, and production from the herd will be done as economically as possible.

By combining the information given previously the student should know what foods to supply in the ration of:

1. a three weeks' old calf.
2. a dry beef or dairy cow.
3. a heavily milking dairy cow.
4. a fattening steer.

Types of Stables and Shelters

Beef cattle prefer the yard or open shed to a closed barn. This is because beef cattle have a layer of fat below the skin which protects them from cold or stormy weather. Beef cows that give birth to calves in the winter time, however, need additional protection from adverse weather conditions, not so much for the comfort of the cow as of the calf. Dairy cows not having this layer of fat to use for protection need a warm well-ventilated barn during the winter.

An enclosed cattle barn of the type suitable for dairy cows and calves as well as for a calving barn for beef cattle should be comfortable. There should be plenty of bedding. The floors should be level and the stanchions or stalls should allow the animals plenty of freedom of movement.

The stables should be warm. A temperature ranging between 40 degrees and 50 degrees Fahrenheit is regarded as the most suitable.

They should also be well-ventilated and free from drafts. Each mature cow breathes in about 117 cubic feet of air per minute. Ventilation should be such as to provide fresh air at all times to the animals.

All stables should be well lighted. Sunlight kills germs. Cows kept in a well lighted barn are generally in better health than those confined in a poorly lighted one. Good lighting will help in maintaining cleanliness also. Manure should not be allowed to accumulate, as the odours and the fermentation are detrimental to the health of the animals. For the same reason the barn should be dry. If a barn has these requisites the health of the herd will be ensured and milk production will not be impaired.

A barn with all of the above features is not necessarily an expensive one. A barn equipped with steel stanchions and pens is excellent but more expensive than the average farms can afford at first. Some of the biggest milk records have been made in barns with but simple equipment.

Barns should be so arranged as to conserve both space and labour. There should be an alley for feeding and an alley through which the manure can be hauled. In a barn with two rows of stanchions, cows can be faced in to the centre, and both rows of cattle fed from the centre feed alley, or, the cow may face away from the centre and therefore be fed from both sides of the barn leaving only one alley from which manure can be removed. Facing cows to the centre is the more common barn arrangement. Fresh air flues should be so placed that the movement of air will be from the front to the rear of the cows. Stanchions for mature cows should be about 3½ feet in width and about 4 feet 8 inches in length.

Beef cattle barns or shelters are more simple and can be built with less expense. They are generally open on one side and can be made from either lumber or Poplar poles and straw. If lumber is used only one ply is needed. Shelter should be so placed that there will be good drainage to prevent the accumulation of too much moisture. They should be kept clean and plenty of bedding allowed for the comfort of the animals. No stanchions or stalls are necessary. Feeding from bunks is more economical than feeding on the ground.

On the ranges and on some farms sufficient shelter is secured from corrals or yards that are bounded on at least three sides by high board fences. Natural shelters in the form of wooded bluffs or deep ravines are satisfactory. Beef cattle can stand only a certain amount of extreme cold. They cannot do well without some form of shelter.

Exercises.—(1) Name the two chief types of cattle. State the general and particular characteristics of each breed.

(2) Classify the different dairy and beef breeds and state the special characteristics of each.

(3) What and how should dairy and beef cattle be fed at the different stages of their development?

(4) Name the factors that determine the suitability of foods and discuss each fully.

(5) Define and classify roughages and concentrates.

(6) What are the various purposes for which foods have to be selected and what are the most suitable foods and combinations of foods that will achieve this result with the greatest economy and efficiency?

(7) What or how would you feed the following:
- (a) a dairy calf two weeks old? a beef calf?
- (b) a dairy calf eight months old? a beef calf?
- (c) a beef cow in calf during the winter months?
- (d) a dairy cow during the winter? during the summer?

(8) Describe a suitable barn or shelter for:
- (a) dairy cattle.
- (b) beef cattle.
- (c) range cattle.

CHAPTER L

The Dairy

Care of Cattle and Stables.—There are certain duties that must be performed if the maximum return is to be secured from the keeping of dairy cattle. The dairy cow is an animal of habit; *exercising*, *feeding*, *milking*, and *grooming* should be attended to each day at as near the same hour as possible.

All cows should be given regular exercise. This helps digestion and keeps the animal in a more healthy condition than when too little or no exercise is given. Especially during extreme cold or stormy weather the farmer must choose whether or not to exercise his cattle. Storms and extreme cold would no doubt affect the milk flow more than lack of exercise. At such times the farmer will be well advised to keep his cattle indoors. Where an hour's exercise may sometimes be quite sufficient in winter, twenty-four hours or a whole day, with the exception of milking time, will be required in summer when there is plenty of pasture. The method of bringing cows to and from pasture should not vary from day to day. Occasional use of the dog excites the cattle and affects the milk flow adversely.

Sudden and frequent changes of rations should be avoided. Before silos were invented many farmers in Europe preserved some of their green forage crops by gathering them into heaps or storing them in pits. These methods of preserving green forage crops are still practised. Ever since the value of silage in providing a uniform ration throughout the year has been realized every green forage plant has been ensiled.

Silage provides succulent food for stock during the winter. Less food value is lost then when crops are cured for hay.

In addition there is less wastage by the stock. It has been found that dairy cattle give more milk when being fed silage than without it. There is also the great advantage that an acre of any crop can be stored in a smaller space than would be required if it were cured in hay.

Cows should be watered twice daily. An automatic watering system in the barn saves a great deal of labour, but contrary to popular impression does not increase the flow of milk to any great extent. The water should never be ice-cold. Even in winter it should be warmed to 50 degrees Fahrenheit. Salt is necessary for digestion and free access should be allowed to a block or box of salt. Three-quarters of an ounce to one and one-half ounces should be the daily consumption per cow.

Considerable practice is required in order to become a good milker. Persons with soft hands are usually more efficient milkers than are those whose hands are hard and course. Women and children are usually better milkers than men.

The operation of milking should be uniform, rapid, and continuous until practically all the milk has been drawn. The hands should be dry at all times. Milking with wet hands is a very unclean practice.

The operation consists of an upward followed by a downward pull with pressure. The whole hand should be used and not merely one or two fingers. Stripping by the use of two fingers should never be resorted to unless to get out the very last portion of milk.

Frequency of milking depends entirely upon the amount of milk the cow is producing. A cow producing more than 50 pounds of milk should be milked more than twice daily. If restricted to two milkings the cow will reduce her milk flow to a point where no discomfort is felt. The periods between milkings should be equal and the same cow should be milked by the same milker every time.

Very few farmers know how much the grooming of their cattle increases milk production. It is just as important to groom cows as horses. The method should be to rub the cow vigorously with a stiff brush or curry-comb then to clean off with a cloth or brush. This keeps the skin in better condition, makes it pliable, and aids in the excretion of waste through the pores.

Cows should be allowed from five to seventy days between each lactation period in order to recuperate. A good dairy cow uses up a great amount of energy while producing milk and is generally in a subnormal condition at the end of the lactation period.

Horns are only preferable on show cows—or on purebred cows kept for breeding purposes. Calves should be dehorned when from ten to fifteen days old by the application of caustic potash. Horns are removed from older cattle by saws or forceps. They should be cut close to the head and a disinfectant applied as soon as the operation is completed.

Cows that are out most of the time wear the hoofs down so that little attention is required. Cows kept in stables ought to have hoofs trimmed whenever necessary.

Bedding is not only used to make the cows more comfortable but it is an important factor in the production of clean milk.

Silos and Silage

The walls of a silo must be strong and smooth without ledges or projections of any kind as these cause air pockets which will spoil the silage. The foundation must be sufficiently strong to support the great weight when the silo is filled. While a roof is not essential in an upright silo it keeps out the snow and rain and helps to reduce the amount of freezing. All doors on an upright silo must be air-tight and flush with the inside walls. The only system of ventilation needed may be provided by the removal of the doors as the level of the silage is lowered. The heavy gases formed from the silage such as carbon dioxide will pass out.

Types of Silos.—Trench or pit silos are the cheapest and most easily made. Any farmer can construct one provided the soil is not too light permitting caving-in. They are rectangular in shape, eight to fourteen feet in depth. The front is usually sloping to allow a team and wagon to back in.

Upright silos are built above the ground over a six to ten-foot pit walled with concrete. They are usually cylindrical as corners are difficult to fill. They are built of different materials as follows:

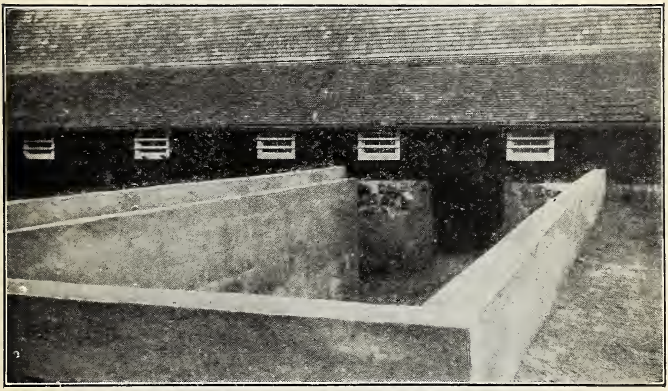


Fig. 107. Concrete trench silo.
(*Courtesy of Canada Cement Co., Ltd.*)

(1) *Wooden Staves Silo.* Constructed of long wooden staves, tongued and grooved at the ends and wedged together horizontally by steel hoops fastened around the circumference.

(2) *Concrete Silo.* Constructed of solid concrete by the use of wooden moulds. The moulds are usually about four to six feet in depth and when set in place are filled with concrete. When the concrete is set the moulds are removed and placed higher up when they are again filled. This is

continued until the desired height is reached. Steel rods or wires should be used for reinforcing or it will be necessary to support a concrete silo from the outside to prevent bursting. Another form of concrete silo is that made of cement blocks.

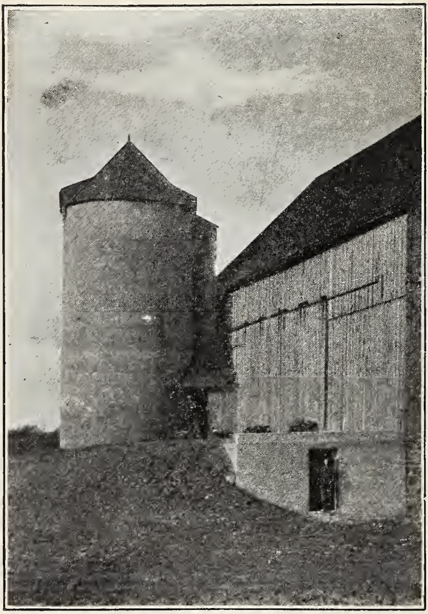


Fig. 108. Upright Cement Silo
(Courtesy of Canada Cement Co., Ltd.)

It is usual to place steel hoops around the outside for support. As the blocks are usually hollow it is claimed that they reduce the amount of freezing. Hollow tile is sometimes used instead of cement blocks. The smooth surface of glazed tile is not attacked by the acids formed in the silage. Brick silos are usually too expensive to merit serious consideration.

Crops that Can Be Ensiled.—Silages differ in food value, palatibility tendency to mould, and other minor differences. The following are some of the crops that have been ensiled:

1. *Corn*—Mature corn silage is the most popular silage in Eastern Canada and the United States. It is one of the easiest to preserve and therefore one of the safest. It has a high feeding value.
2. *Corn stover silage*—After the good ears have been removed from Corn the remainder is cut into the silo. It has a lower feeding value than Corn silage because the ears have been removed.
3. *Oat silage*—Oat silage is becoming popular in Northern and Central Alberta. It has almost the same feeding value as Corn. It is cut when in the early dough stage and makes a very palatable silage for all classes of stock.
4. *Sunflower silage* is popular in Western Canada where Corn cannot be satisfactorily grown for silage. Big yields can be secured. It is as palatable as Oat silage but does not have as high a feeding value.
5. *Alfalfa silage*—In many instances, Alfalfa is ensiled with success, but often a poor, vile-smelling silage is produced. It has a very high feeding value.
6. *Clovers*—More easily ensiled than Alfalfa, are lower in feeding value.
7. *Millet*—Has less feeding value than Corn silage.
8. *Barley*—Similar to Oat silage.
9. *Fieldpea*—Similar to Clovers.
10. *Rye*—Similar to Oat silage.
11. *Sugar-beet tops*—Low in feeding value.

Herd Records and Babcock Test

Many dairy cows in Western Canada do not give sufficient milk to pay for their care and feed. Although the principles of successful selection, feeding, and care of dairy cattle may be known to farmers, cows that do not pay for their keep are being retained in herds because the owner does not know how much or how little the cows are producing. Some farmers do not realize that if they sold the "boarders" their profits would be materially increased.

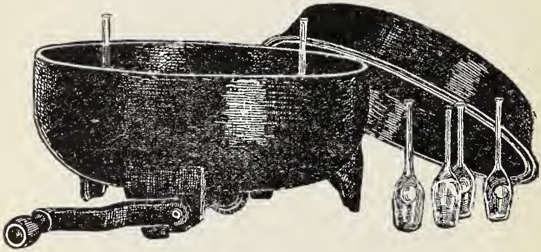


Fig. 109. Babcock tester.

A profitable dairy cow cannot be determined by its dairy conformation alone. In some cases it cannot be determined by the amount of milk produced. If cows are being kept as a business proposition the farmer should be willing to keep the business accounts of his herd in a form in which each individual cow is shown as an asset or a liability to his dairy business.

To know exactly the profit or loss that any cow or herd is returning, the owner must credit the cow with all the milk or butterfat she produces at the market price received for these products and deduct from this amount the value of feed and labour. To know these facts a farmer must

1. Keep accurate account of the milk produced.

2. Test each cow's milk occasionally throughout the year to find out the amount of butterfat produced.

3. Keep records of the prices received every week or month for each 100 pounds of milk or pound of butterfat.

4. Keep accurate records of the hay, silage and grain fed and the market values of these throughout the year.

Not many farmers have time to do all the work necessary to find the exact profit and loss of each cow. It has been found, however, that an almost exact estimate of each cow's net income can be determined by

1. Weighing the milk two days in the middle of each month and using that amount as a basis for determining the total milk produced during the month.

2. Taking a sample of milk from each cow during the same two days and testing it for its butterfat content, or sending it to the cheese factory or creamery to have it tested.

3. Saving all milk and cream checks to record the price received.

4. Weighing the feed for each cow during the same two days and estimating the amount each cow eats during the month.

5. Keeping records of feed prices from the local newspaper.

The Dominion Department of Agriculture assists the farmers in keeping yearly records of cows, providing the farmers send in monthly milk, feed, and test records. It also is promoting cow-testing associations in which a tester visits the farm every 6 or 8 weeks and collects the information and keeps records on the production, feed, consumption and income of each cow.

All records for each cow must be kept for 12 months because the feed eaten during the dry period must be charged in addition to the feed eaten while giving milk.

Testing for Butterfat.—The Babcock test is the method ordinarily employed for the determination of the percentage of butterfat in milk. The process is as follows:

1. With a special pipette measure out 17.6 c.c. of milk and place in a Babcock whole-milk testing bottle.

2. With a small measuring glass measure out 17.6 c.c. of concentrated sulphuric acid and pour it carefully into the testing bottle with the milk. Be careful not to spill any or drop any on the hands or clothes because it burns.

3. Gently whirl the bottle in your hand until the mixture in the bottle becomes dark reddish brown.

4. Place the bottle in the centrifuge (whirling machine) and operate for five minutes as directed on the handle of the machine. Put in enough bottles in the machine to balance it.

5. Fill all the bottles just up to the neck with hot water.

6. Whirl bottles in the machine for three minutes.

7. Add hot water *very slowly* to each bottle till the water reaches to about one inch from the top of the bottle.

8. Whirl the bottles in machine for one minute.

9. Take out the whole milk testing bottle and place it in a pail of very warm water for a few minutes without allowing any water to enter the top of bottle.

10. Remove the bottle and by use of calipers measure the height of the fat column in the neck of the bottle from the bottom of the column to bottom of the upper disc.

11. Keep the arms of the calipers in the same relative position to each other and shift them until the lower pointer is at the zero graduation on the tester. The upper pointer will then point to a figure giving the actual percentage of fat in the milk.

Note.—When possible have the district agent or creamery man demonstrate the process to the class.

Care of Milk to Prevent Contamination

Milk is easily contaminated with bacteria and odours. Bacteria get into the milk if the cows are dirty when milked, or the milkers' hands and clothes are dirty, or the utensils are not carefully cleaned. When milking is in progress there should be no feeding of hay or other work causing dust in the air.

If there is a bad odour in the barn while the cows are being milked, or if an open can of warm milk is left standing in a room with a bad odour there will be contamination. The most common odour which contaminates milk is a silage odour, caused by feeding silage to the cows while they are being milked. It is also believed that cows pastured on Rape, ripening Rye, will produce milk with the characteristic odour of each kind of plant eaten.

Bacteria multiply very rapidly in warm milk so that in a few hours hundreds of thousands of bacteria may be present in one cubic centimeter. Warm milk absorbs odours more quickly than cold milk. For these reasons milk should be cooled immediately after milking to prevent the absorption of odours and the multiplication of bacteria.

Contaminated milk sours rapidly, has a bad taste, and is not suitable for human consumption.

Farmers may prevent milk from becoming contaminated by observing the following precautions:

1. Keep the cows clean.
2. Wear clean clothes.
3. Use clean utensils.
4. Keep the barns clean.
5. Wash the hands before milking.
6. Cool the milk soon after milking.
7. Prevent bad odours in the barn.
8. Keep cows out of Rape or ripening Rye pastures.
9. Keep pastures free from weeds that taint milk.
10. Do not feed silage before milking.

11. Do not allow an open can of milk to stand where there is a bad odour.

12. Dispose of the milk as soon as possible; do not allow it to stand.

13. Do not cover milk cans tightly because this causes a metallic flavour.

14. Cover the tops of open cans with a clean cloth to prevent flies and dust from getting in the milk.

15. Strain the milk into the can. This removes hair and dirt and avoids additional contamination.

Consumers are willing to pay more for clean milk and for butter and cheese made from clean milk. Cleanliness pays abundantly.

The Marketing of Milk, Cream and Butter.—Owners of dairy cattle derive an income from the sale of their dairy products as follows:

Milk to be used for human consumption is sold direct to the consumer in pint or quart bottles, or in bulk to milk distributing companies. The price received by the farmer for milk or cream depends on the percentage of butterfat it contains; milk is sold to cheese factories where the price received by the farmer is dependent on the market price of cheese and the percentage of butterfat in the milk. Where the cheese is made on a co-operative basis, the cheesemaker usually pays to the farmer in direct proportion to the amount received for the cheese less running expenses. Cream is sold to creameries, or in bulk to cream distributing companies. The price received depends on the market price of butter and on the richness of the cream. Co-operative creameries pay on the same basis as co-operative cheese factories.

The fact that dairy products are perishable adds greatly to the expense of marketing them and to the list of marketing services required. The farmer must have ready transportation for dairy products to the receiving people of the distributing companies. At this depot the products are inspected, tested and graded. Pasteurizing, bottling, etc., are also carried out at this point, as it is necessary to put the milk or cream in saleable form for the market. After these processes are completed, they are ready to be distributed either directly to the consumer or to other manufacturing companies, sometimes many miles distant.

If cream is taken directly to a creamery, it is inspected, tested and graded before it is made into butter. Great care must be used in the packing and in the temperature at which it is transported or stored. Quite frequently, manufactured butter passes through many distributing agencies before it reaches the consumer.

In the case of cheese, the marketing services are much the same as for butter.

Co-operative organizations have done much to reduce the number of middlemen handling dairy products. The purpose behind co-operative organizations is not to reduce the price to the consumer, but to eliminate a portion of the profits of the middlemen and to increase the price received by the farmer by the amount of these eliminated profits.

Exercises.—(1) Describe fully how cattle and stables must be cared for if the maximum income is to be secured from the keeping of dairy cows.

(2) What are the advantages of silage?

(3) Write a full note on silos under the following heads: (a) Essentials necessary; (b) Types of silos; (c) Crops that may be ensiled.

(4) Write a full note on Herd Records under the following heads: (a) The purpose of keeping such a record; (b) Sources of advice and direction; (c) Details of the record; (d) The Babcock test.

(5) Describe what precautions should be taken to prevent contamination in milk.

(6) Write a full note on the marketing of dairy products under these heads: (a) The products of milk; (b) The services connected with the marketing of each product.

(7) Discuss co-operative marketing.

CHAPTER LI

Horses

Uses of the Various Breeds of Horses.—The draft breeds, Clydesdale, Percheron, Belgian and Shire, are used chiefly for the work of hauling loads (draft). The Shires and Belgians because of their greater weight can generally pull a heavier load than the smaller Clydesdales or Percherons.

Stallions of the four draft breeds are being used to improve the grade draft horses on the farms or in the cities of Canada. Shire stallions are used to develop size. Small, long, rangy mares are bred by Belgian stallions to produce offspring that are heavier, shorter and more compact.

The light breeds of horses are used chiefly for racing horses, or for light delivery or saddle. The thoroughbred is used in mounted races where the gallop gait is desired. The standard breds are used in harness races, either as trotters or as pacers.

Stallions belonging to these light breeds have been used for crossing with draft mares to produce smaller, general purpose farm horses.

Other breeds not studied in this chapter but whose uses are indicated by their names are as follows:

1. American Saddle Horse.
2. The Hunter.
3. Coach Breeds, (a) French, (b) German, (c) Cleveland Bay.
4. Hackney—useful for all purposes, driving, saddling, light draft, etc.

Draft Breeds

Clydesdale.—Animals of this breed are not as massive as the Belgian or Shire but are slightly heavier than the Percherons. They vary in weight from 1,600 to 2,000

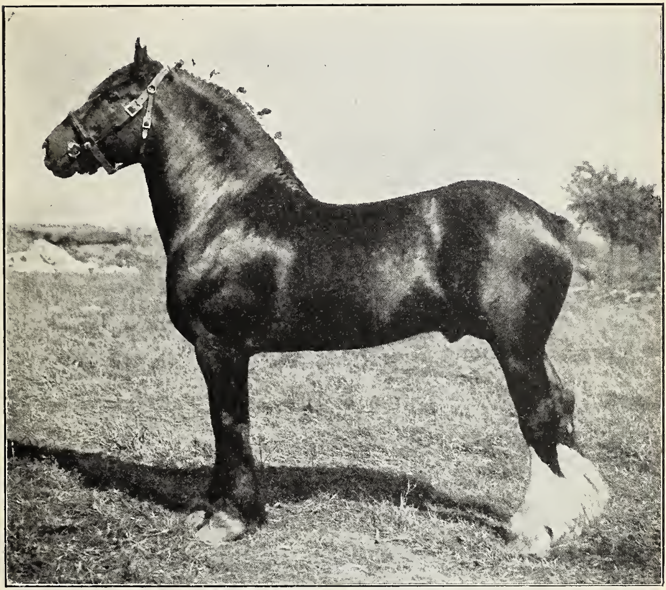


Fig. 110 Clydesdale stallion.

pounds. The popular colours are bays and browns, but gray, black, chestnut and roan are sometimes found. There is generally considerable white on the face and lower part of the legs. The feather, or hair above the hoof is of medium length. In the Shires this is quite abundant and in the Percherons and Belgians there is little or none.

In conformation the Clydesdale is inclined to be rangy though lighter in body, narrower in the chest, and with a relatively longer body than the other breeds of draft horses. The top line is inclined to be more level than in the other breeds of draft horses.

The action of the Clydesdale when walking or trotting is superior to that of any of the other breeds.

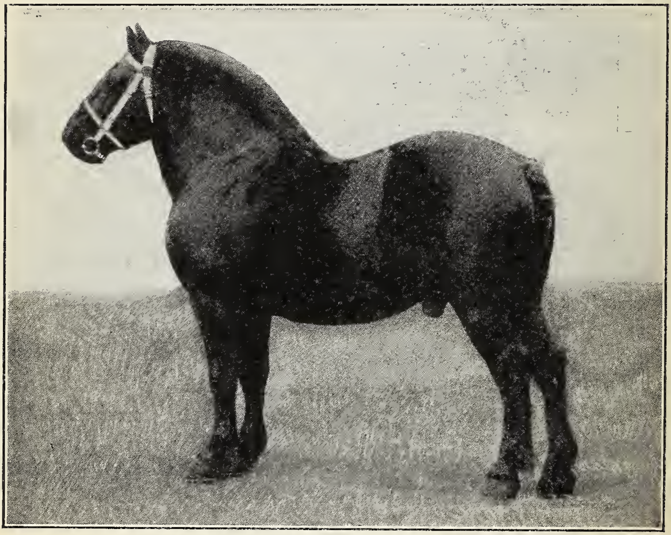


Fig. 111. Percheron draft horse.

Percheron.—This breed is slightly lighter in weight than the Clydesdale ranging from 1,500 to 1,900 pounds. The colour is gray and black, though a few of them are bay or brown. This breed has no feather.

In conformation the back of this breed is shorter than the Clydesdale though longer than the Belgian. The chest is broader than the Clydesdale though narrower than the Shire or Belgian.

The action is not quite as good as the Clydesdale in straightness of stride. It is however the most active of all the draft breeds. The walk and trot are both smart and elastic.

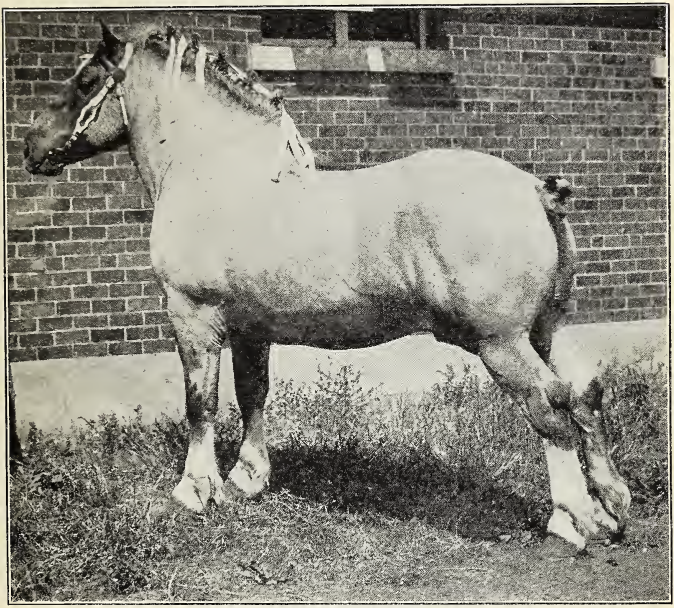


Fig. 112. Belgian draft horse.

Belgian.—This is a more massive type than either the Clydesdale or the Percheron. In height it is exceeded only by the Shire. The two most common colours are roan and chestnut. It has little or no feather.

In conformation it has shorter legs than the other breeds; the body is short but broad; and it has well sprung ribs which give a well-rounded appearance to the body.

When trotting it has a fairly good action but when walking there is a tendency to roll due to the width of the body.

Fig. 113 Shire draft horse.

Shire. —This is the largest and heaviest of all the draft breeds. Its weight varies from 1,700 to 2,200 pounds. The most common colour is bay with white markings. Some individuals are black, chestnut, roan or gray. This breed has quite a pronounced feather. The hair about the feet is longer and denser than in any of the other draft breeds.

In conformation it is bigger in bone and body than any of the other breeds; the loin, hind quarters, and legs above the hocks are larger and more heavily muscled than in the other breeds, but it lacks the quality and refinement of the other breeds.

Its action is rather sluggish due to its size and conformation.

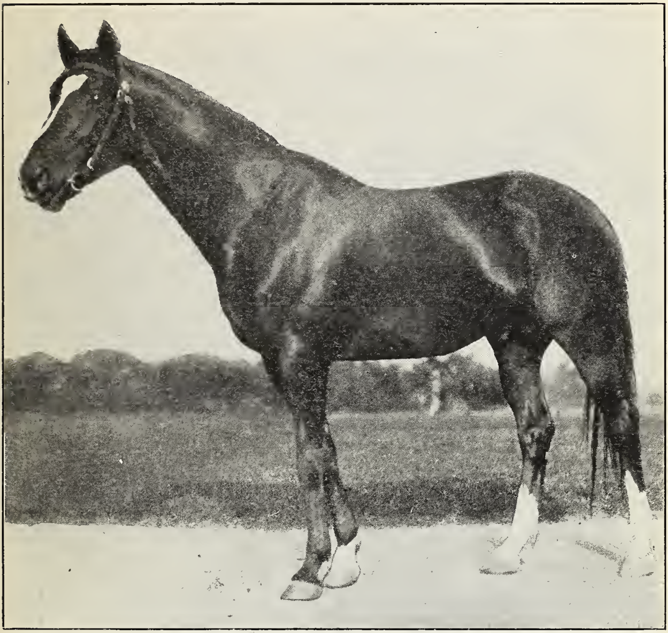


Fig. 114. Thoroughbred stallion.

Light Horse Breeds

Thoroughbred.—It is larger than the standard bred averaging from 1,100 to 1,200 pounds. It is bay, black, or chestnut in colour. Grays and roans are rarely seen.

In conformation it is more upstanding than the standard bred; the body is short and well-turned, and shows more refinement than the standard bred.

The thoroughbred has three natural gaits, walk, trot and gallop. The trot is neglected in training and no attention is given to the walk, but at the running gait it is the swiftest of all horses.

Fig. 115. Standard Bred.

Standard Bred.—These are smaller than the thoroughbred averaging in weight from 900 to 1,200 pounds. The most fashionable colours are chestnut, black and bay, but many other colours are found in various individuals of the breed.

In conformation they are not so long-legged as the thoroughbred; they are plainer and lack the refinement so characteristic of the thoroughbred.

This breed is trained to be trotters and great care and attention is given to secure the action that develops the greatest speed. They may also be trained as pacers.

The student should study the pictures of individuals of these breeds and distinguish the special characteristics noted above.

Feeding Farm Horses

Working Horses.—The food of the mature working horse has two purposes: (1) to repair the bodily tissues (maintenance) and (2) to supply energy with which the body can do work. The amount of food required by a horse depends on the amount of work the horse is to do.

A farm horse doing an average day's work requires $1\frac{1}{4}$ pounds of bright, clean hay and about 1 pound of good grain for each 100 pounds live weight. Horses at hard work should receive almost as much hay but should be fed more grain. Up to 1.4 pounds per 100 pounds live weight may be fed daily.

Timothy hay and whole Oats are the most common and satisfactory feeds for horses, but Alfalfa hay, Clover, or Clover mixtures may be substituted. Shorts, bran, or a small amount of Barley and Wheat may be substituted for a part of the Oat allowance. On days when work horses are idle, the grain should be reduced to about one-third of the regular amount, and a bran mash substituted for one of the meals. They should also be turned out for exercise on those days.

Growing Horses.—They require food for maintenance and growth. During the first four weeks the colt does best on the mother's milk. After four weeks it will begin to nibble at the hay and grain fed to the mother. As soon as the colt learns to eat it should be given a special box and manger and fed preferably Alfalfa, or Clover hay. When 5 or 5½ months old it should be weaned. Afterwards it should be fed all the hay it will eat and in addition about one pound of grain for each 100 pounds of live weight.

Young horses should be well fed from the time they are one year old until they are put to work. Only on exceptionally good pastures will they be able to get sufficient food for normal development.

Care and Management of Farm Horses

The efficiency of the work horse depends upon the kind of care and management that it receives.

Handling.—The horse is a very sensitive animal. It should be handled gently. Excessive shouting and striking causes it to lose confidence in its masters and renders it more difficult to teach. Much energy which might be used for useful work is wasted by unnecessary physical action and nervous excitement.

Grooming.—Thorough and careful grooming is necessary to remove the waste material left through the evaporation of the perspiration and to keep the pores open and skin healthy. Aside from the better appearance which results proper grooming pays in the greater efficiency of the hard-worked animal.

Sudden changes in temperature, as well as cold rains, and heavy winds, are very exhaustive on the work horse unless protective measures are taken in the use of blankets. Horses are made more comfortable and tractable during summer if fly nets are used. Horses should have plenty of comfortable bedding.

The teeth of horses are subject to many irregularities which prevent the proper mastication of food. These irregularities and sharp edges may cut or lacerate the tongue or cheeks, causing them to become sore. These sharp edges should be rasped down with a guarded rasp.

Proper care of the feet from one year to maturity will in nearly every case ensure well-developed hoofs. All foreign material such as nails, stones, etc., that collect in the cleft along the frog should be removed. If the hoof tends to dry out, a hoof ointment should be applied. A clay mud pack applied over night may be sufficient. The hoofs sometimes become broken or worn in such a way as to interfere with the proper action of the horse. Such hoofs should be levelled off as deformity and poor action may become permanent.

Hoofs grow an average of one-third of an inch each month. The edges should be trimmed off frequently to prevent the breaking off or cracking of the hoof.

Heavily working horses should be shod to prevent excessive wear on the hoof. Should the hoof wear off faster than it grows soreness will result. Shoes prevent slipping on ice or mud, and tend to improve the action. Shoes are designed for many purposes—particular kinds of work, feet deformities, or to correct bad action.

If harness that fits the horse is used more efficient work will result.

Feeding Horses on Ranches

Large numbers of mares are kept on ranches. In summer they pasture on the open range. In winter though forced to forage for their food they usually have access to straw piles which besides offering some nourishment afford a certain amount of protection from cold winds and low temperatures.

Stallions that are used on ranches are kept in barns, although in some instances where possible they are afforded access to pastures near the barns. They are cared for in the same manner as ordinary farm horses on the small farm. During the breeding season the stallions receive large amounts of grain. The ration fed at this time corresponds to that specified above for heavy work horses on the farm.

Care and Management of Horses on Ranches

Practically no attention is given to the mares. During the breeding season they are grouped by themselves; during the foaling season, if there is any likelihood of loss of mare or foal due to unfavourable weather conditions, the mare should be corralled and given whatever feed and attention may be required. Mares are usually sold when four or five years of age unless they are good breeding mares when they are kept longer. Male colts are usually sold when two or three years old.

All range horses are branded for purposes of identification at the annual "round up." On account of the conditions under which ranch horses are raised they never attain their full size and development; they are therefore classified as "farm chunks." Ranch horses are sold in the spring for farm use or in the fall for use in the lumber camps.

Exercises.—(1) Classify the different breeds of horses.
(2) State the characteristics and uses of each breed.
(3) Discuss fully each of the following:
- (a) The feeding of farm horses.
- (b) The feeding of growing horses on the farm.
- (c) Care and management of farm horses.
- (d) The feeding of ranch horses.
- (e) The care and management of ranch horses.

CHAPTER LII

Sheep

Classification of Sheep.—Sheep are usually classified according to the length and fineness of their wool. The three classes are the fine or short wool, the medium wool, and the long wool. The long wool breeds are not raised in Western Canada to any great extent. The fine wool sheep are the best wool breeds, and the medium wool sheep the best mutton breeds.

Fig. 116. An Oxford sheep.

Medium Wool Breeds

Oxford.—These are the largest of the mutton breeds. The colour of the hair on the face, ears, and legs varies from

STUDENT'S SCORE CARD

MUTTON SHEEP

Scale of Points—For Market Lambs	Perfect Score	Student's Score	Corrected Score
1 AGE			
2 WEIGHT			
GENERAL APPEARANCE—30 points:			
3 FORM, deep, broad, low set, compact, straight, topline and underline, not paunch, stylish	10		
4 QUALITY, fine bone, silky hair, fine skin, clean cut head, fine fleece, smooth in form and fleshing	10		
5 CONDITION, deep even covering of firm flesh, especially in region of valuable cuts. Points indicating condition or ripeness are thick dock, back thickly covered with fat, thick neck, full purse, full flank, plump breast, well covered ribs	10		
HEAD AND NECK—7 points:			
6 MUZZLE, fine, mouth large; lips thin; nostrils large	1		
7 EYES, large, clear, placid	1		
8 FACE, short; clear-cut features	1		
9 FOREHEAD, broad, full	1		
10 EARS, fine, erect	1		
11 NECK, thick, short; free from folds	2		
FOREQUARTERS—7 points:			
12 SHOULDER VEIN, full	1		
13 SHOULDER, covered with flesh, compact on top, smooth	3		
14 BRISKET, projecting forward; breast wide	2		
15 LEGS, straight, short, wide apart, strong; forearm full; shank smooth and fine	1		
BODY—32 points:			
16 CHEST, wide, deep, full, indicating constitution	6		
17 BACK, broad, straight, thickly and firmly fleshed	10		
18 LOIN, thick, broad, and well covered	10		
19 RIBS, well arched, deep, thickly and firmly covered	6		
HINDQUARTERS—12 points:			
20 HIPS, far apart, level smooth	1		
21 RUMP, long, level, wide at tail head, thickly and firmly fleshed	4		
22 LEG-OF-MUTTON, full, deep, wide, plump	6		
23 LEGS, straight, short, strong; shank smooth, fine	1		
WOOL—12 points:			
24 QUANTITY, long, dense, even, completely covered, abundant yolk	4		
25 QUALITY, fine, pure; crimp close, regular, even, sound	4		
26 CONDITION, bright, clean, soft, lustrous	4		
TOTAL	100		

STUDENT'S NAME....................................

ANIMAL SCORED....................................

DATE....................................

steel gray to dark brown. The *wool* does not extend to the nose and there is very little of it in front of the eyes; it grows to a length of from 3 to 4 inches in 12 months, making up a fleece weighing from 10 to 12 pounds. The wool is coarser than that of the other breeds in the medium wool class.

In appearance this breed is rectangular in shape, and more upstanding than the other breeds in the same class. It has a straight profile—not Roman-nosed.

Fig. 117. Champion Hampshire ewe at the Royal Agricultural Winter Fair, Toronto, 1927
(Courtesy of University, Alberta.)

Hampshire.—This breed is slightly smaller in size than the Oxford. The hair on face, ears, and legs is black in colour. The wool in the American breed Hampshires extends in front of the eyes; in the English bred Hampshires there is little or no wool in front of the eyes. It grows to a length of 2½ inches in 12 months, making up a fleece averaging in weight from 7 to 9 pounds; the wool is finer in quality than the Oxford breed but is generally coarser than that of Shropshires, Suffolks, or Merinos.

In appearance this breed is not as rectangular in shape as the Oxford, nor as round as the Shropshire. It is not as upstanding as the Oxford but is lower set than the Shropshire. It is Roman-nosed—which feature is more distinct in the males. This is the earliest maturing of all the breeds mentioned in this chapter.

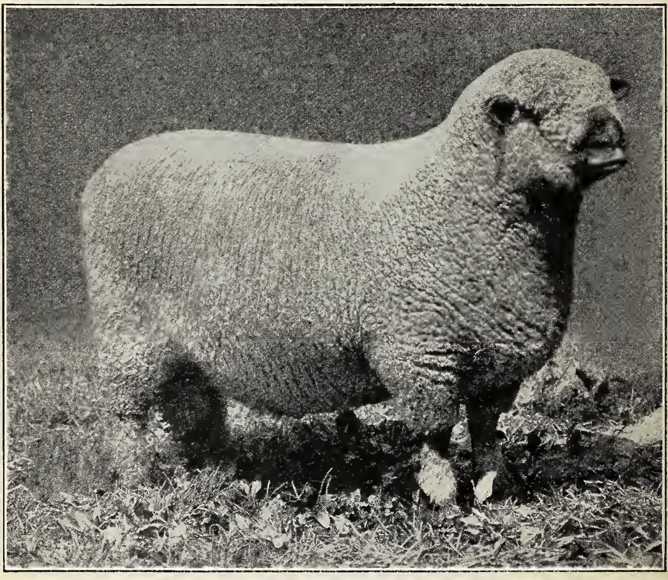


Fig. 118. Shropshire ram.

Shropshire.—This breed is of medium size. The colour of the hair on the ears, nose, and legs is a deep, soft brown. The ears are the smallest of all the breeds. They are short but not thick.

The wool extends over the face almost to the nose, and down the legs to the pasterns (the part of the leg between the joint next the hoof and the hoof). It covers the body to a greater extent than in any other breed. It grows to between 2½ inches and 3 inches in length and is slightly longer than the Hampshires, making up a fleece averaging between 8 and 10 pounds. The wool is finer in quality than the Hampshires but coarser than the Merinos.

In appearance this breed is inclined to be oval in shape. It is not as "Straight-sided" or as "flat-backed" as the Oxfords or Hampshires. It has shorter legs than the Oxford, Hampshires, Suffolks, or Merinos.

Fig 119. Suffolk sheep.

Suffolks.—This breed is of medium size. The hair on head and legs is black in colour. The wool is absent in front of the ears and below the knees and hocks. It grows to a length of from 2 to 2½ inches, the shortest of all the breeds, making up the fleece weighing only from 6 to 8 pounds. It is almost as fine in quality as the Shropshire.

In appearance this breed is not as rectangular as the Hampshire and Oxford breeds and not as oval as the Shropshire. It has longer legs. Improvement has been made in this respect so that now there are individuals that are fairly low set. It has a distinctly Roman-nosed profile.

Fig. 120. Merino ram. Class A.

Fine Wool Breeds

Merino.—There are three types of these—*A*, *B* and *C*. The differences in each type are noted below.

In size they are smaller than the other breeds mentioned so far. Type *A* is the smallest and *C* the largest. Type *C* is slightly smaller than the Shropshire. The colour of the hair on the nose, ears, and legs is white. The ewes have no horns; the rams have spiral horns. The skin in Type *A* occurs in folds over the whole body. In Type *B* it occurs in folds over the neck, shoulders and hind quarters. In Type *C* there is no folding over any part of the body except perhaps the neck.

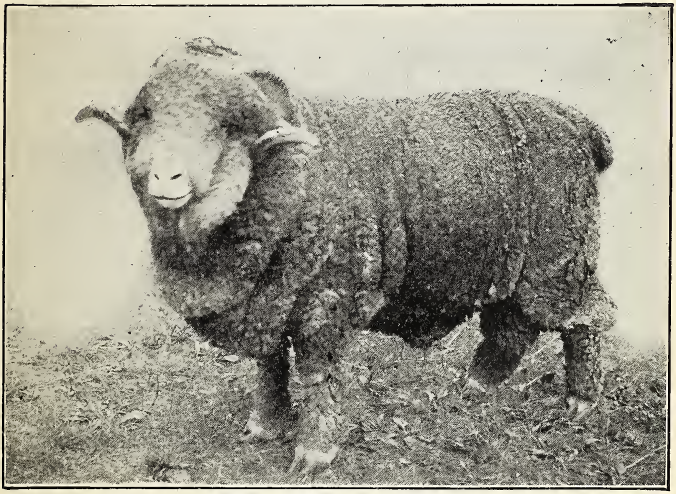


Fig. 121. Merino ram. Class B.

The wool covers the body completely as in the case of the Shropshires. The wool, however, is shorter at the extremities. It is short and grows from 1 to 2 inches in 12 months, making up the fleece which because of the folds that increase the wool

growing surface and because of the denseness of the wool, weighs in Type *A* from 15 to 20 pounds.
in Type *B* from 13 to 18 pounds.
in Type *C* from 10 to 13 pounds.

It has the finest quality of wool of all the breeds.

Fig. 122. Merino ram. Class C.

In appearance this breed does not resemble the other breeds because the body is not blocky nor does it carry a large quantity of flesh. Type *C* Merino resembles the ideal mutton type more closely than either Type *A* or *B*. Type *A* is not compact nor blocky and carries relatively very little flesh. This is because they have been bred for the wool they produce.

Rambouillet.—Because this breed was developed from the Merino breed it possesses many of the Merino characteristics. There are two types of Rambouillet—*B* and *C*. These are larger than the Merino and the Hampshires. The hair of the nose, ears, and legs is white in colour. The horns are the same as in the Merino. The skin and folds are the same as for Types *B* and *C* Merino. There is no *A* type in Rambouillet resembling the *A* type in Merinos.

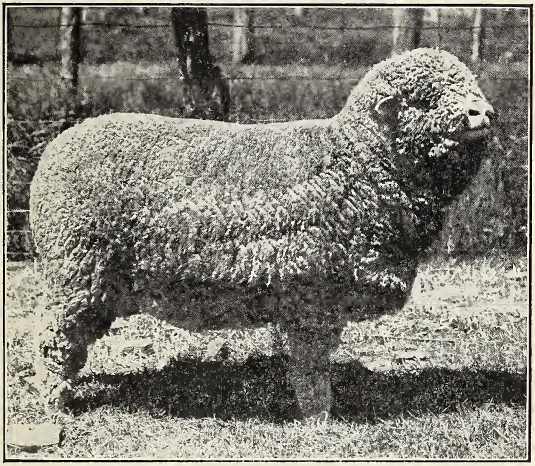


Fig. 123. Rambouillet ewe.

The wool covering is the same as for Merinos. It is longer than in the Merino and grows from 1½ to 3 inches in length and in some cases longer, making up a fleece weighing slightly more than in the same types of Merino. In appearance the Rambouillets are large rugged sheep, heavily-boned and somewhat upstanding. They are more inclined to resemble the ideal mutton type of sheep than the Merino because their bodies are blocky and compact in appearance and usually carry more flesh.

The student should examine the pictures of individuals of each of the above breeds to distinguish the differences in each breed as noted above.

Care of Sheep

On Ranges.—Sheep are pastured in the foothills during the summer and are generally wintered on the plains. Shepherds or herders tend the sheep throughout the year, moving the flock to better grazing lands and protecting it from wild animals and storms. No cured roughages or concentrates are fed to the range sheep except when conditions such as shortage of feed makes it necessary to do so. Lambs are usually sold off the grass and are not fattened in any other way. They are born on the range and no protection is given them except during severe weather or storms. In the spring the flock including ewes, lambs, and rams is corralled. The ewes and rams are sheared and the lambs are ear-tagged or notched for identification. In the fall the lambs are sorted from the ewes and the bulk of them are sold on the larger eastern markets. A small number of lambs are kept to replace the same number of ewes that are taken out and sold when too old to be of further service on the range.

On the Farm.—Sheep are pastured within fenced fields during the summer, and given shelter in barns in winter where they are fed cured roughage and sometimes concentrates. The lambing period is usually earlier than for range sheep and the lambs are generally born in barns. Lambs are fed liberally on grain or they are weaned and then fattened and sold on an earlier market than range lambs.

Suitability of Each Type to Alberta Conditions

Under Range Conditions.—The sheep have to forage for their feed throughout the entire year. No feed of any kind is fed except during storms or when the ground is covered with deep snow. They are given no shelter in addition to such natural shelters as ravines, clumps of bush, or wooded areas. Corrals are often built but only used as shelters in case of severe storms. The lambs are born on the open range. The flocks are large and are allowed wide pastures over which they may forage for food.

The requirements of sheep for range conditions are: (1) hardiness, which means ability to stand severe weather conditions and long periods of food shortage, and (2), gregariousness or the habit of remaining in flocks.

Merino and Rambouillet sheep have all the requirements of sheep suitable for range conditions. They are extremely hardy and have the gregarious instinct developed to a high degree. The smaller Merinos are the hardier; they can withstand more severe weather conditions and longer periods of food shortage than the other breeds.

Rams of all the other breeds of sheep mentioned in this chapter are used on ranges for breeding purposes only. Nearly all of the range sheep are not purebreds, but all possess a large percentage of Merino blood, for the gregariousness and hardiness which it carries. The use of rams of other breeds is to develop in range sheep better mutton qualities than are found in the Merino breed.

Under Ordinary Farm Conditions.—The sheep are kept in shelters during the winter and are fed roughages and concentrates. They are not allowed large pastures, and the flocks are usually not large. Lambing time occurs usually early in the spring at which time shelters are provided for the ewe and lamb. Gregariousness or extreme hardiness is not necessary because of the feeding and management.

Purebreds of the other breeds are more suitable for ordinary farm conditions because they lack the extreme hardiness and gregariousness possessed by the Merinos and Rambouillets. Among the purebreds there are differences in hardiness and earliness of maturity. As regards hardiness they may be ranked as follows: Oxfords, Hampshire, Shropshire, Suffolk. The Suffolk has not much wool on the under side of the body and so cannot stand very cold weather. As regards earliness of maturity they may be ranked as follows: Hampshire, Suffolk, Shropshire and Oxford. Suffolks are somewhat more active than the other breeds and for that reason are more difficult to handle.

The different breeds rank in mutton and wool production as follows:

	For quality of mutton	For quality of wool	For amount of wool	For length of wool
1st	Suffolk	Merino	Rambouillet	Oxford
2nd	Shropshire	Rambouillet	Merino	Shropshire
3rd	Hampshire	Shropshire	Oxford	Rambouillet
4th	Oxford	Suffolk	Shropshire	Hampshire
5th	Merino	Hampshire	Hampshire	Suffolk
6th	Rambouillet	Oxford	Suffolk	Merino

Co-operative Grading and Marketing of Wool.—A co-operative organization known as the Canadian Co-operative Wool Growers' Association, owned and operated by most of the persons who sell wool through it marketed over 3,000,000 pounds of Canada's wool crop in 1925, and one-third or more of this amount came from Alberta. Wool is assembled at various points in each province and shipped in carloads east to the warehouses of the organization where it is graded and sold. Dominion Government wool graders are employed to grade every fleece. The fleeces of each grade are assembled and sold in bulk to large woollen mills in Canada, United States, and England. At the end of the selling season each year the organization pays to the farmer the average price received for each grade less a small charge for handling the wool.

By selling through this organization the farmer has received a better price for his wool than if he sold to a local buyer.

Exercises.—(1) Classify the various breeds of sheep and describe in detail the characteristics of each breed.

(2) Write a note on the care of sheep on ranch and farm.

(3) Under what conditions are sheep raised in Alberta and what breeds are most suited to each?

(4) Discuss fully the value of each breed with respect to each of the following: (a) Quality of Mutton; (b) Quality of Wool; (c) Amount of Wool; (d) Length of Wool.

(5) Prepare a essay on the co-operative grading and marketing of wool in Canada.

CHAPTER LIII

Swine

Because pigs can consume feed which might otherwise be wasted, reproduce abundantly, mature rapidly, and usually sell at a reasonable figure, they are a very profitable type of live stock to keep on any farm. On the Wheat farms of Western Canada, the screenings, after the chaff has been removed, makes excellent feed for hogs. Shrunken and broken kernels of other grains may be included. On dairy farms hogs may be fed such dairy by-products as skim-milk, buttermilk, and whey. By feeding by-products which would otherwise be wasted, the farmer indirectly sells these by-products through the sale of the hogs. It is even claimed that in some sparsely settled districts a great distance from an outlet, the farmer may more profitably feed the grain to his hogs than attempt to ship it out.

Pronounced efforts to sell Canadian bacon on the British market has stimulated the raising of the bacon type of hog in Canada. A system of hog grading has been instituted and specific standards set for hogs suitable for export trade. Hogs that conform to this standard are known as "selects," and a 50-cent per hundredweight premium is paid for them. They should weight from 120 to 230 pounds at the stock-yards or local shipping points. They must be of a type and finish indicating their suitability: jowl and shoulder must be light and smooth; the back from neck to tail evenly fleshed; the side long, of medium depth, and dropping reasonably straight from the back; hams must be full without any excess fat.

STUDENT'S SCORE CARD

BACON HOGS

Scale of Points	Perfect Score	Student's Score	Corrected Score
GENERAL APPEARANCE—36 points:			
1 WEIGHT, 180-230 pounds (farm weight) the result of thick cover of firm flesh...	6	....	....
2 FORM, long, level, smooth, deep......	10	....	....
3 QUALITY, hair fine; skin thin; bone fine; firm covering of flesh without any soft bunches of fat or wrinkles.........	10	....	....
4 CONDITION, deep, uniform covering of flesh, especially in region of valuable cuts..............................	10	....	....
HEAD AND NECK—6 points:			
5 SNOUT, fine......................	1	....	....
6 EYES, full, mild, bright..............	1	....	....
7 FACE, slim......................	1	....	....
8 EARS, trim, medium size.............	1	....	....
9 JOWL, light, trim..................	1	....	....
10 NECK, medium length, light..........	1	....	....
FOREQUARTERS—10 points:			
11 SHOULDERS, free from roughness, smooth, compact and same width as back hindquarters......................	6	....	....
12 BREAST, moderately wide, full.......	2	....	....
13 LEGS, straight, short, strong; bone clean, pasterns upright; feet medium size	2	....	....
BODY—34 points:			
14 CHEST, deep; full girth..............	4	....	....
15 BACK, medium and uniform in width..	8	....	....
16 SIDES, long, smooth, level from beginning of shoulders to end of hindquarters. The side at all points should touch a straight edge running from fore to hindquarter...........................	10	....	....
17 RIBS, deep, uniformly sprung.........	2	....	....
18 BELLY, trim, firm, thick without any flabbiness or shrinkage at flank........	10	....	....
HINDQUARTERS—14 points:			
19 HIPS, smooth, wide; proportionate to rest of body......................	2	....	....
20 RUMP, long, even, straight, rounded toward tail......................	2	....	....
21 GAMMON, firm, rounded, tapering, fleshed deep and low toward hocks.....	8	....	....
22 LEGS, straight, short, strong; feet medium size; bone clean; pasterns upright...........................	2	....	....
TOTAL......................	100	....	....

STUDENT'S NAME..................................

ANIMAL SCORED..................................

DATE..

Characteristics of the Common Breeds

Yorkshire.—The improved Yorkshire is one of the largest breeds of swine. It is white in colour. Its body is longer and also narrower in proportion to its size than any other breed. Its body is deep and well proportioned and conforms closely to the ideal bacon type. Typical Yorkshire

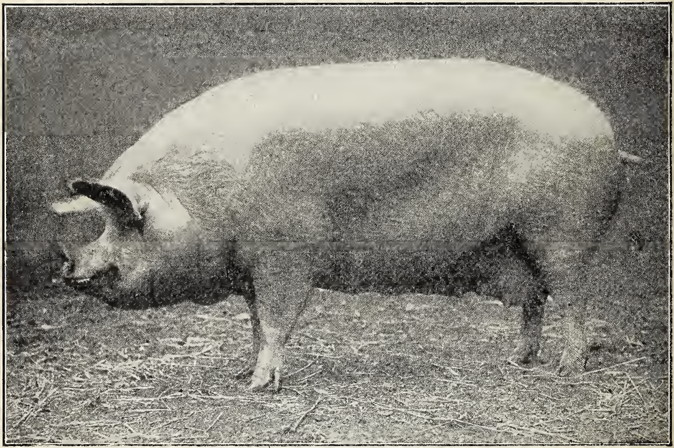


Fig. 124. Large Yorkshire hog.

hogs, when properly fed and finished for market, produce a carcass which carries the desired length, an even distribution of fat, and a wealth of lean meat.

Tamworths.—In size this is one of the largest breeds but it is slightly smaller than the Yorkshires. In colour it is golden red. The snout is longer than the other breeds.

Breeders of Tamworths are endeavouring to improve the length and depth of body. There are in Canada some strains of Tamworth that are equal to the Yorkshire in conforming to the ideal bacon type, but at the present time a large number of hogs in this breed are not equal in length and depth of body. They are fairly narrow and well pro-

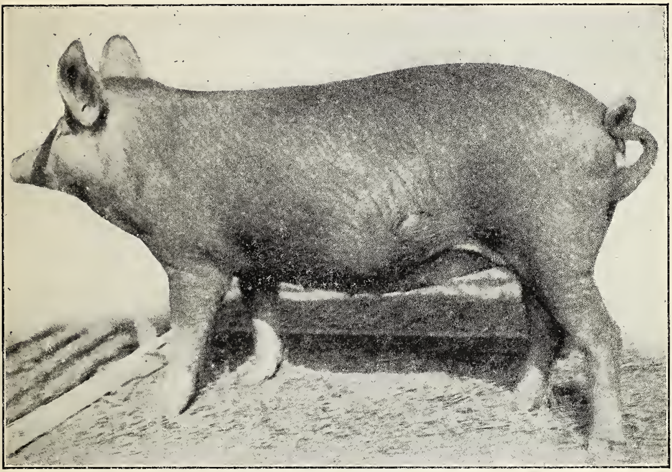


Fig. 125. Tamworth hog.

portioned. The carcass has not quite so much lean in proportion to fat as in the Yorkshire, but this fault is being improved.

Berkshires.—This breed of swine is medium in size. Their colour is black with white markings on the face and feet. The snout is short or medium. In body characteristics two types prevail:

(a) The Canadian Type Berkshire—an improved type—has been developed in Canada to conform more closely to the bacon type standards. Only a few strains of this breed have reached and developed that grade as "selects" on the market. The majority of the Berkshires are shorter, broader, coarser in shoulder and carrying a larger proportion of fat to lean, than the Yorkshire or Tamworth.

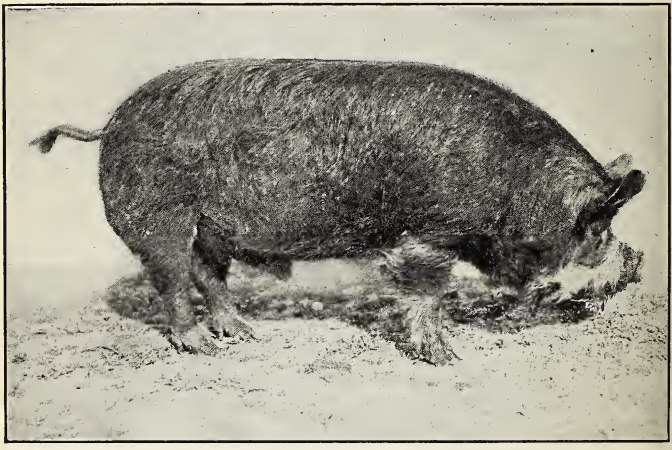


Fig. 126. Berkshire hog.

(b) The American Type Berkshire conforms more closely to the lard type, but in Canada this type is gradually being changed over to the Canadian type through selection and breeding. Berkshires of this type are broad, short, compact, of medium size, carrying large amounts of fat in proportion to lean.

Duroc-Jersey.—These are hogs of medium size and with a colouring of cherry red, sometimes with a yellow tinge.

The ears droop, and this is a distinguishing feature. The Duroc-Jerseys are being improved and are changing from the extreme lard type to the bacon type of hog. This process of improvement is slow, and as yet very few Durocs can be regarded as conforming to the bacon type standard. They are shorter, broader, coarser in the shoulder and carry much more fat in proportion to lean than the Yorkshires or Tamworths.

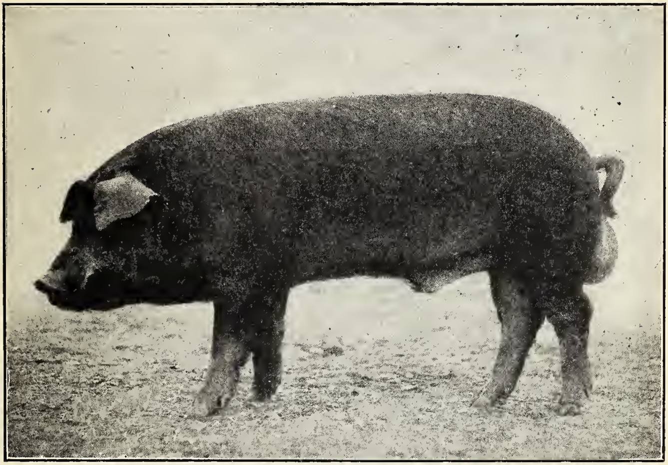


Fig. 127. Duroc-Jersey hog.

Feeding Swine

The pigs are wholly dependent upon their mother for the first two or three weeks. After this time they will begin to hunt for feed on their own account. At first it will be noticed that they will eat from the sow's trough and pick up scattered food. A pig creep should be provided in one corner of the pen in which they may go and eat by themselves. At first they can be fed a thin mixture of skim-milk and middlings. Little by little other grains can be added to the mixture so that when the pigs are weaned they have learned to eat and have become accustomed to the grain and skim-milk ration.

The raising of hogs is adaptable to almost every system of farming. This is because hogs will eat and turn into pork a large amount of feed generally wasted and consume by-products which other stock cannot utilize. They convert feed into meat more efficiently than any other class of live stock. On any farm there is always a large amount of household waste or garbage which can form all or part of their ration. Certain men near large cities gather the waste from restaurants and hotels and raise their hogs almost entirely on garbage.

On the Wheat farms of Western Canada, the screenings, after the chaff has been removed, can be ground and fed to hogs. Shrunken and broken kernels of other grains can also be fed to advantage. Hogs are especially adapted to dairy farming. The dairy by-products such as skim-milk, buttermilk, and whey cannot be surpassed as a feed for hogs. In other words, by feeding garbage, household refuse, grain by-products, and dairy by-products to hogs the farmer indirectly sells these feeds through the hogs. These feeds therefore that generally have only a small cash value or no cash value at all can be sold.

In sparsely settled districts that are a long way from the big markets, the cost of shipping grain is so high that the farmer receives a great deal less than what his grain actually sold for in the distant market. In the same districts when the grain, instead of being shipped, is fed to pigs and the pigs shipped to the same market, the farmer will generally receive more money for his grain that he fed his hogs than he could by shipping his grain.

Because pigs consume feed which otherwise might be wasted, reproduce abundantly, mature rapidly, and usually return a substantial profit, hogs are exceedingly useful and profitable animals for most farms.

The fundamental principle in feeding weaned pigs is to keep their appetites keen. Feed just as much as they will clean up readily, and keep increasing the amounts gradually as the pigs grow. Feed three times a day, and feed regularly—these are the two essentials. Abrupt changes in feed should be avoided, as digestive troubles may result.

A word of caution is necessary. The pigs at this age have very greedy appetites, and they are very apt to gorge themselves. Feed often, but never all that they would like to eat. Green feed such as Rape, Alfalfa, Oat, Rye, Clover, or native pastures is needed and is of great value.

The ration fed after weaning should contain a variety of feeds. Oats, middlings, Barley, Corn, Linseed oilmeal, tankage, and skim-milk or buttermilk can be fed. About one-tenth of their ration should consist of oilmeal and tankage or they can be fed a liberal amount of skim-milk or buttermilk instead of the oilmeal and tankage. Skim-milk and buttermilk are ideal foods for growing pigs and wherever they are available, one of them should be fed.

When the pigs have reached fifty to seventy pounds in weight, they should be changed to a fattening ration. This ration is composed chiefly of Barley or Corn, or both, together with other grains or by-products and from five to ten per cent. of oilmeal and tankage, or if skim-milk or buttermilk is liberally fed no tankage and oilmeal is needed. If the pigs are fattened on pasture, the heavy grain feeding is continued but the amounts of tankage, oilmeal, skim-milk or buttermilk can be reduced to one-half the amount mentioned.

Pigs are generally fattened on self-feeders. By this system they have access to their grain mixture at all times. Water, skim-milk or buttermilk is fed twice daily by this system. The pigs fed with a self-feeder do not make much greater gains than when hand fed, but there is a great saving in the labour required.

Pigs that are to be saved for breeding purposes should not be fed till they are too fat. These should be fed by hand and kept in a thrifty condition and a normal amount of flesh. A sow that is too fat or too thin will not raise strong and healthy pigs.

Pigs that are growing need more food for their size than pigs that have become full grown. They need extra feed to build the muscle and bone.

Sows with newborn pigs require more food than at normal times because they need food to produce milk.

Care and Management of Swine

Proper care and management is essential for profitable swine-raising. By proper care and management is meant the proper selection and mating of breeding stock, giving them plenty of exercise, comfortable quarters, and keeping them free from worms and lice.

Only the best type should be used for breeding purposes. Weak, unthrifty sows or sows having many undesirable characteristics will produce pigs like themselves, which are not profitable to raise. Brood sows must be comfortably housed and fed. They must have plenty of exercise. Weak pigs are probably more often due to lack of exercise than for any other reason. Sows should be allowed on the stubble, or they should be fed grain at a distance from the sleeping quarters to force them to exercise. Feeding Alfalfa hay tends to keep the sows on their feet and moving around. Several times during the winter the brood sows should be examined to make sure they are free from lice. By applying crude oil with a stiff brush especially between the shoulder and jowl the sows will be kept free from lice.

At the time the sow is expected to farrow she should be placed in a warm shelter, with lots of bedding, so that the newborn pigs will not be chilled. A fender placed about ten inches above the floor and eight inches away from the side walls saves many pigs from being crushed by the heavy sows.

After the pigs are born the farmer should see that they all get some nourishment from the sow. The pigs should be allowed plenty of room for exercise. Pigs that are not allowed to exercise become fat and are subject to thumps.

The pigs should be kept free from scours and worms. This can be done by keeping them in dry, clean, warm, shelters with plenty of sunshine. In the spring a sow and her litter should be placed in a small pasture with a colony house as shelter. These pastures provide a part of their food, allow them plenty of exercise and keep them in a healthy growing condition.

Exercises.—(1) What are the advantages of swine-raising?
(2) Name four breeds of hogs and state the characteristics of each.
(3) State the characteristics of the bacon type.
(4) Write a note on the feeding of pigs.
(5) What care should be given to hogs at the different stages of their development?

CHAPTER LIV

Poultry

Breeds of Poultry.—Poultry is the name applied to all birds that have been tamed and are used for food. It includes Chickens, Turkeys, Ducks, and Geese.

This chapter will deal with Chickens and aims to acquaint the student with the more important phases of Chicken-raising.

Chickens are divided into classes, breeds, varieties, and strains. Class is the name applied to groups of Chickens of common ancestry, common characteristics, and common purpose or use. In poultry the shape of the Chickens within a class determines the breed. One should become as familiar as possible with the shapes of the various breeds. This can be done by observing closely the pictures of prize winners. The varieties of Chickens within each breed are determined by the colour of the feathers and the kind of comb.

There are four classes of Chickens that have found favour on farms: American, English, Mediterranean, and Asiatic.

American.—Breeds included in this class are medium in size; have yellow skin and legs, red ear lobes, and legs free from feathers.

Rhode Island Red. All Chickens of this breed are red. There are both single and rose comb varieties.

The shape of the Rhode Island Red is rectangular. It has a straight, horizontal back with a slight rise to the tail. Its breast is carried well down very nearly perpendicular to the back line. The bottom line is always parallel to the top line, giving a side view similar to a rectangle. The neck is of medium length and the tail rather short.

Wyandotte. There are eight different coloured varieties but the most common are White Wyandottes. All Wyandottes carry a rose comb.

The Wyandotte is ball-shaped and is a bird of graceful curves. Unlike the Rhode Island Red, the Wyandotte

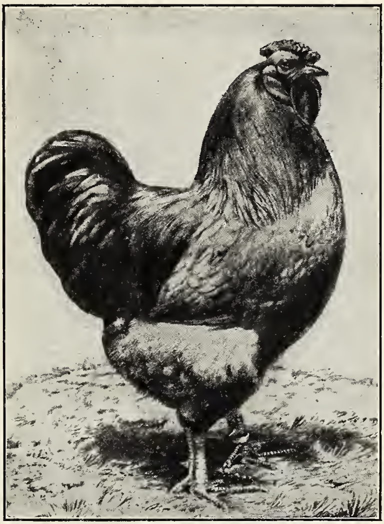


Fig. 128. Buff-Wyandotte (male).

has no straight lines. It is shorter in every section than the Rhode Island Red. The neck is short and the head is carried back. The tail is short, breast broad, and body short and round. From the side the body is circular or nearly so.

Plymouth Rock. There are seven different coloured varieties all carrying the single comb. The most common varieties are Barred, White, and Buff.

The Plymouth Rock is neither rectangular nor ball-shaped, but half way between the rectangular shape of Rhode Island Reds and the ball-shape of Wyandottes.

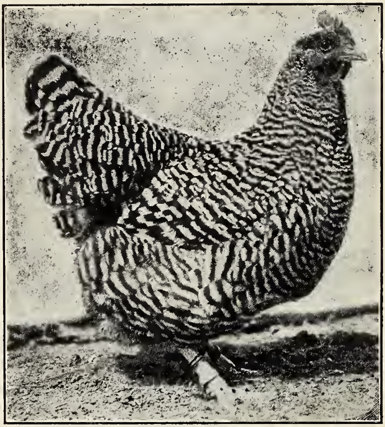


Fig. 129. Barred Plymouth Rock (female).

English.—The breeds included in this class are medium in size, have red ear lobes, and clean legs. They are somewhat similar to the American class. The Orpington is the only breed in this class which is extensively raised on the farm.

Orpington. There are three varieties in this breed, White, Buff, and Black, all carrying the single comb.

The Orpington has a distinctive shape. The legs are short and set well apart; the body is ball-shaped with the exception of the back which resembles that of the Plymouth Rock. Its head is carried similar to the Wyandotte. It has the appearance of being more massive than its weight indicates. This is due to the length of feathers upon the body.

Mediterranean.—The breeds included in this class are smaller than those in the American, English, and Asiatic classes. They are nervous in disposition, very active, compactly built, have *white* ear lobes, yellow skin and clean legs.

Leghorns. There are four different varieties, White, Brown, Buff, and Black. The White and the Brown varieties are the most common. Both single and rose combs are carried by Leghorns.

Fig. 130. White Leghorn (female).

The Leghorn has characteristics which differ from the other breeds previously studied. It belongs to a class of fowl which has been bred exclusively for egg production. It does not have the size found in Plymouth Rocks and Wyandottes. The feathers are closer to the body; the bird is trim and active and has a proud, energetic carriage.

There is no sharp line between tail and body; one is unable to tell where the tail begins and the body ends.

Minorcas. There are two varieties—the Black and the White, each carrying either a single or a rose comb.

The Minorcas is the largest breed of Chickens in the Mediterranean class. They have long legs and a rectangular body. The back is long and straight. The

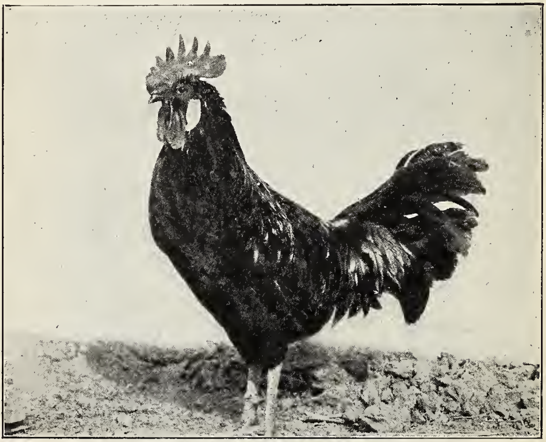


Fig. 131. Black Minorca (male).

bottom line is parallel to the top line. They have an erect carriage. The comb has six points instead of five. They are closely feathered, muscular and energetic.

Andalusion, *Anconas*, and *Spanish* breeds are included in this class.

Asiatic.—Breeds included in this class are large and clumsy, having red ear lobes and feathers on their legs.

Cochins. The Cochins are very large birds. They are low set and heavily feathered. On account of the long feathers they appear to have short backs, necks, and legs. There are four different coloured varieties.

The *Brahmas* are very large birds, but are less heavily feathered than the Cochins. They possess a stately appearance. There are only two varieties, the "light" and the "dark".

The *Langshan* breed is included in this class.

In addition to the above four classes there are *Polish*, *Dutch*, *French*, and *Ornamental* classes.

The different breeds of Chickens can also be grouped according to their egg or meat producing characteristics. Leghorns and Minorcas are famous for their ability to produce large numbers of eggs. The breeds which produce a fairly large number of eggs and also are good meat breeds are: Plymouth Rocks, Wyandottes, Rhode Island Reds, and Orphingtons. The breeds which produce fewer eggs but are raised chiefly as meat producing birds are: Brahmas, Cochins and Langshans.

The fancy breeds—raised as a hobby, or for show purposes—include Bantams, Polish and several others not raised to any great extent in Canada.

Feeding, Care and Management of Poultry

From Birth to Maturity.—Young chicks keep warm during the night and the cool parts of the day by huddling under the wings and body of the hen. Chickens hatched in an incubator are kept warm in a brooder. This is a small, heated, well-ventilated box-like compartment into which the chicks may go to get warm. The brooder is generally heated in the same way as the incubator.

The brooder must be used until the weather becomes warm or the Chickens have grown so that they do not need any artificial heat. When chicks are hatched early the brooder may have to be used for six weeks. Chickens hatched in late spring or early summer weather may only require the brooder for three weeks. By watching the Chickens a good poultryman will know how long to use the brooder.

The brooder should be operated for a few days before the Chickens hatch. This will dry out the sand and litter under the cover. When the chicks are put in, the temperature should be 100 degrees Fahrenheit. This temperature should be gradually reduced as they grow.

If they chirp a lot and pile up under the hover the temperature is too low. If they stay away from the source of heat the temperature is too high. When chicks are comfortable they spread out on the floor under the edge of the hover and make no noise. Chicks should not be allowed to get cold for digestive troubles usually result.

Newborn chicks must be fed very carefully to keep them in good health and to make them grow rapidly. Just before hatching the chick eats the egg yolk. Nature has provided this nourishment in order that the chick may subsist for 48 hours after hatching. Newborn chicks should not be fed solid food until they are at least 48 hours old. After this time the food should be increased. Chickens should be fed liberally after the first week because they grow rapidly and need a large amount of food to be made into bone and muscle tissue. Chickens should be fed a great variety of foods. When the weather is mild and the brooder or small colony house is placed in a small lot they will pick up a large portion of their ration in the form of grass and other foods. At this stage it will be unnecessary to feed them such a variety of foods.

Sand or grit and water, skim-milk and buttermilk are the only things that should be fed during the first 48 hours. These should be kept before them throughout their growing period. These foods start the digestive organs functioning properly so that they can digest the food fed later. Bread crumbs, Johnny cake, hard-boiled eggs, oatmeal, and milk are good foods to give the Chickens until they are 10 days old.

Small amounts of Wheat, bran, middlings, Cornmeal, meat scrap and ground Oats could be added to the ration. When these foods are added the earlier foods should be reduced. Chicks should be allowed to eat all they want from a small hopper. If a hopper is not used chicks should be fed 4 or 5 times a day until they are 10 days old. Successful poultrymen feed a part of the ration in the form of a wet mash. Green feed, such as tender grass, clover, lettuce, etc., is relished by young chicks. As soon as they can handle the larger grain particles, cracked or whole grain can be fed.

Young Chickens need exercise. Part of the feed may be thrown into chaff or cut straw. This will force the chicks to scratch for their food. Exercise is important in developing strong bodies.

Mature Chickens—for Winter Egg Production.—Chickens must be properly fed and cared for if they are to lay a large number of eggs or if they are to become fleshy birds.

The feed from which the eggs or flesh is made should contain a large number of different materials. These food materials are:

1. Water.
2. Protein—skim-milk, meat scraps, sour milk, buttermilk.
3. Mineral matter—charcoal, shells, bonemeal.
4. Carbohydrates—cereals, grains, green feeds.

The feeding of one kind of grain to the exclusion of all others is one of the greatest faults in poultry-raising. If this is done, even though they are allowed to scratch for themselves, the Chickens cannot secure all the food substances needed for egg-production and for keeping the Chickens in good health. The food for laying hens must include fresh plants, food from animals and some minerals if all the different substances needed for egg-production are to be supplied. The following are some of the common foods:

(a) Plant Foods:
1. Grains or Grain products—Oats, Barley, Wheat, Corn, Wheat bran, Wheat middlings, screenings, Linseed oilmeal.
2. Green feed—Cabbages, Carrots, Beets, chopped Alfalfa, Potatoes.

(b) Animal Foods: meat scraps, milk, skim-milk, buttermilk.

(c) Mineral Foods: bonemeal, Oyster shells, ground egg shells, charcoal, salt.

A hen will eat from 3 to 4 ounces daily. When hens have a range with plenty of green feed, 100 hens should receive from 20 to 25 pounds of a dry mixture. It will save labour if the dry mixture is fed in a self-feeder.

Hens should have exercise. It keeps the organs of the body in good condition, permits normal growth, and encourages egg-production. The hen may be forced to exercise in the following ways:

(a) Throwing feed in straw, where the hen will have to scratch for it.
(b) Hanging green feed above the floor where the hen will have to jump for it.
(c) Feeding green feed whole thus making the hen tear it up herself.

Poultry should be fed regularly; they should have clean, fresh water handy at all times; they should be kept free from lice and mice; and they should have a clean, dry, comfortable place to live in. If all these things are provided, poultry-raising will be profitable.

Crate Fattening.—The most rapid method of fattening Chickens for market is to feed them in crates. This system of feeding is usually practiced by all packing houses handling market poultry, and by farmers who have special markets for their well-finished poultry. The crates in which the Chickens are fed have upright slats on all sides so placed that the

Chickens can feed from a trough which encircles the crate. They are fed large amounts of sweet or sour milk and liberal amounts of ground grain mixtures in the form of wet mashes.

Crate fattening is only conducted through a period of from one to two weeks, since the Chickens cannot do so well under such feeding and confinement for a longer time without exercise. The purpose is not merely for rapid gains but to improve the quality of the meat.

Egg-Laying Competition.—The Dominion Government conducts at least one egg-laying competition in each province. The objects of these contests are to (1) encourage the breeding of poultry for higher egg-production, and to secure for poultry breeders information as to sources of such stock; (2) to provide a medium for Record of Performance and Registration; (3) to secure data of an investigational nature that will help to solve some of the important problems of poultry-raising.

Any breeder of purebred poultry may enter 10 birds in the contest. Application is made to the Poultry Division. An inspector visits the farm to make sure the birds are free from disease and meet the standards of the breed.

If the application is accepted the breeder sends in 12 birds, two of which are substitutes to be used in case one or two die or are taken out of the contest for other reasons. The birds are placed in suitable poultry houses equipped with trap nests and are fed and cared for in the best possible manner. Records are kept of the number of eggs produced by each bird, the dates of laying, and the weights of the individual eggs. The contest lasts 52 weeks. At the end of the contest the results are published.

Record of Performance (section AA) certificates are issued for each bird that has produced from 150 to 225 eggs. Advanced Record of Performance (section AA) certificates are issued for all birds producing 225 eggs or over.

Breeders of purebred poultry that care for, feed, and keep records of egg-production on their own farms according to rules laid down by the Poultry Division can receive Record of Performance (section A) certificates for birds that produce

150 to 225 eggs in 52 weeks or Advanced Record of Performance (section A) certificates for birds that produce 225 eggs or over.

Marketing of Eggs and Poultry.—The Dominion Government has ordered that all eggs offered for sale must be graded. This law was passed to ensure the customer good eggs and the farmer a reasonable price.

Eggs are graded into three groups known as: Extras, Number Ones (Firsts), Number Two's (Seconds). Eggs graded as "Extras" must all be of fair size and weigh at least 24 ounces to the dozen. They must be clean, sound in shell and the air space must not exceed a quarter of an inch. When looked at through the candler the white of the egg should show firmness and the yolk should be only faintly visible.

Eggs graded as "Firsts" should be clean, sound in shell and with an air space not exceeding three-eighths of an inch in depth. The white of the egg is not so firm as those grading as "Extras." The yolk in this case may be distinctly visible.

Eggs graded as "Seconds" contain larger air spaces, the whites are more watery and the yolk heavier. Small eggs are included in this group.

All the eggs in these groups are fit for food. Eggs that are stale or not fit for food cannot be sold.

Methods of Selling Eggs and Poultry.—Many farmers with small flocks sell their eggs to their storekeeper, in exchange for groceries and other merchandise. The storekeeper, in turn sells them to some egg-buying house for whatever price he can get. Farmers who keep poultry in large numbers usually sell to some special market and are able to get better prices for their eggs and poultry in this way. Eggs and poultry that are collected by the Alberta Poultry Producers' Association are marketed by the Egg and Poultry Marketing Service of the Provincial Government.

In almost every town there are men who will buy live or dressed poultry in turn selling to packers or other firms. Some farmers who are experienced in fattening poultry can sell their poultry on some special market and thus get higher prices than farmers who sell to the town buyer. If poultry (either alive or dressed) is sold in large numbers they must be graded according to standards adopted by the Canadian Produce Association.

Live poultry offered for sale is grouped according to class, sub-class, grade and sub-grade, and sold according to the group into which it has been graded.

Classes	Sub-Classes
Chickens	Broilers — under 2½ lbs. Roasters—under 4½ " " over 4½ " Capons — under 6 " " over 6 "
Fowl	Light—under 3½ lbs. Medium—under 3½ to 5 lbs. Heavy—over 5 lbs
Cocks	Heavy—over 4½ lbs. Light.—under 4½ "

Poultry in each sub-class is grouped according to the following grades and sub-grades, except broilers:

Grades	Sub-Grades
Milk-fed	1st Quality (well-finished birds). 2nd " (all others fit for food except culls)
Range-fed	1st Quality (well-finished birds) 2nd " (all others fit for food except culls)

Milk-fed birds are those which have been systematically finished for market in crates and with which milk has been a portion of the ration.

Range-fed birds are those which have been allowed the full run of the farm and have received no special attention as to finishing.

Dressed poultry offered for sale are also grouped according to class, sub-class, grade and sub-grade to conform to the market standards for dressed poultry as adopted by the Canadian Produce Association in 1925.

CLASS	SUB-CLASS	WEIGHTS
Chickens	Broilers, small	Under 20 lbs. per 12 birds
	Broilers, light	20 to 25 " " 12 "
	Broilers, heavy	26 to 30 " " 12 "
	Fryers	31 to 36 " " 12 "
	Roasters	37 to 42 " " 12 "
	Roasters	43 to 48 " " 12 "
	Roasters	49 to 54 " " 12 "
	Roasters	55 to 64 " " 12 "
	Roasters	65 " and up per 12 birds
Fowl	Small	Under 30 lbs. per 12 birds
	Light	31 to 36 " " 12 "
	Medium	37 to 42 " " 12 "
	Heavy	43 to 48 " " 12 "
	Heavy	49 to 54 " " 12 "
	Heavy	55 to 64 " " 12 "
	Heavy	65 " and up per 12 birds
Cocks	Light	Under 4 lbs.
	Heavy	4 lbs. and over.

In the Chicken class all birds are grouped in three grades and 5 sub-grades as follows:

GRADE	SUB-GRADE
Milk-fed	Milk-fed
	Milk-fed A
Selected	Selected A
	Selected B
Culls	

Fowl and Cocks are grouped the same as Chickens except that the "milk-fed" grade is omitted.

The grades and sub-grades indicate the degree of finish and the freedom from blem ishes

In Alberta the Provincial Department of Agriculture assists the farmer in selling eggs and poultry by chiefly acting as the selling agency for the Alberta Poultry Producers' Association. Better prices can be secured when eggs and poultry are sold through the Government marketing branches than when sold to local buyers.

Under this system eggs are shipped to the Government warehouse at Edmonton or Calgary where the eggs are candled and graded according to the Dominion regulations. Farmers are paid for the eggs according to grade at the price which the Government is securing at the time the eggs are received, minus a small charge for the service rendered. Eggs of each grade are assembled together and sold by the Government on the best markets and at the best possible price.

The Provincial Government buys live or dressed poultry. Live poultry is bought by the Government generally at a higher price than is being paid by the local buyers. The poultry is shipped to Edmonton or Calgary and there fattened in crates, dressed, graded, and sold on a suitable market. Sometimes the fattened live poultry is sold, depending upon market conditions. Poultry dressed by farmers are shipped to the Government warehouse where they are graded and paid for at the market price of the grade minus a small charge for the service rendered.

Comparison of Breeds from Various Market Standpoints.—Those smaller breeds of poultry that are included in the Mediterranean class, Leghorns, Minorcas, etc., are more suitable for broilers than any of the heavier breeds. Cockerels if separated and crate fed can usually be sold in an early market. Most of the birds are sold in the lightweight sub-classes. The American and English breeds that are raised in large numbers in Western Canada make suitable birds for all medium weight sub-classes and grades. They mature rapidly, can be fattened quickly, and the larger proportion of them are sold as medium weight roasters and fowl. A small proportion can be fattened as fryers—and a small proportion as heavier roasters, fowl, and cocks. Those breeds that are included in the Asiatic class are large, slow-maturing breeds that make suitable birds for the heavier sub-classes. Their heaviness of bone and slowness fattening when extremely young make them unsuitable for broilers, fryers, or the light classes of fowl and cocks.

Exercises.—(1) Distinguish the terms "class," "breed," and "variety" as applied to Chickens.

(2) Classify Chickens according to classes and breeds and enumerate the varieties and characteristics of each breed.

(3) Classify Chickens according to their egg-laying and meat-producing ability.

(4) Describe fully the care, feeding and management of Chickens under the following heads: (a) From birth to maturity; (b) Mature Chickens for winter egg-production.

(5) Write a note on crate-fattening.

(6) Under whose auspices are egg-laying competitions conducted? Describe fully the method of conducting them.

(7) Write a note on the marketing of eggs and poultry under these heads:

- (a) Eggs.
- (b) Poultry.
- (c) Canadian Produce Association Standards.
- (d) Assistance rendered by the Provincial Department of Agriculture.

(8) Make a comparison of the breeds of Chickens from various market standpoints.

PART 10

FARM MANAGEMENT

CHAPTER LV

Farm Homes

Improvement in farm homes has necessarily lagged behind improvements in barns, machinery, and equipment. With increased prosperity, however, farmers are seeking ways and means to increase the comforts of living, and their houses reflect this tendency in the design and in the installation of many household conveniences. It is now understood, as never before, that the farmer's wife and family must have sufficient time for recreation, and for participation in the activities of the community.

For example, the farmer must consider whether it is cheaper to install electric power and light, or to hire efficient domestic help. On the side of added comforts weighs the additional consideration, namely, that his family will be more likely to remain on the farm if city comforts are provided.

The well-planned rural residence should not be a copy of some town house: it must serve a different purpose, and it is essential when planning the house, that the particular needs of the individual family should be given full consideration.

The modern farm home is equipped with a basement, the walls and floor of which are either stone and concrete respectively, or both concrete. Besides providing excellent storage space, it is the logical place for furnace and soft water tank.

The kitchen should be compact, not designed to provide ample room for the men and hired help to wash and lounge. In some homes space may be provided in the kitchen for serving breakfast. The up-to-date kitchen should be spick and span with white and blue enamel and paint, curtains and linoleum in a matching colour, built-in cupboards, and furniture painted to harmonize.

The dining-room should be separate from the kitchen, but should be handy to it. This room should be roomy in order to accommodate increased help at certain seasons of the year.

The other rooms of the house should be designed to meet the particular needs of the family. Bathroom facilities of the farm are often inadequate. Only a house provided with modern facilities will be on a par with what is required by law in the cities.

In earlier chapters on Gardening and Floriculture attention has been drawn to the place that should rightfully be given to the beautification of the surroundings of the farm home.

Mention has also been made as to the desirability of a shelterbelt on the north and west sides. In addition to the trees included in the shelterbelt, others should be planted in groups about the buildings, Spruce and Pine, Cotton-wood, Birch, and Manitoba Maple are best.

Flowering shrubs should be set out in beds in front of the house, and beside the walks, Lawns and grass stretches may be had with very little effort. It is important that the soil should be of good loam, levelled or terraced. Grass-cutting may be saved by pasturing sheep on the lawns.

The two arrangements generally adopted are, namely, the conventional or geometric arrangement and the natural arrangement. In the former, shrubs, walks and beds are set out to form regular geometric shapes; in the latter the attempt is made to imitate ideal natural surroundings. In either arrangement the house is the centre of interest, but not necessarily the centre of the group. The groups of trees serve to round off the angular and straight-line effects of the buildings. They should be planted therefore, at such places as to give this effect. Walks should be set out to serve the purpose of utility, giving direct access from the house to the road, and from the house to the other farm buildings.

Exercises.—(1) Discuss the effect of the installation of city conveniences in the farm house.

(2) Draw a plan of a well-arranged farm kitchen. Discuss one or two colour schemes.

(3) Draw two plans of the lawns, flower garden, shrubs, trees, etc., surrounding the farm house, making one of them in geometric arrangement, and the other in natural arrangement. Write a short note telling which you prefer and why.

CHAPTER LVI

Farm and Farmstead

The term "farmstead" is used to include all the buildings required for the housing of everything employed in farm operations, including the farm house, garden, corrals, paddocks, and yards in conjunction with farm buildings.

Great care must be exercised in the planning of the farmstead, because once established it will continue to be used very much in its original form over a period of years.

Location.—Points to be considered in placing a farmstead on the farm are:

(1) Shape of the farm and how near the centre of the farm it is possible or desirable to have the farmstead.
(2) The proximity of public roads leading to the nearby towns or railways.
(3) The contour of the ground and whether it is possible to place the farmstead on high enough ground to give a clear view of a large portion of the farm. It should also be noted that high ground is valuable as providing excellent drainage.

Size of the farmstead.—This will depend on the size of the farm and upon the amount of livestock and machinery. The space between the buildings should neither be too great nor too small. The usual area of a farmstead is about six acres, if the farm is a quarter section. Less than six acres will be necessary if only grain-farming is practised. It should be remembered that the land occupied by yards, driveway, etc., is comparatively unproductive, and therefore should be confined in area to the barest necessity.

Ordinarily the shape of the farmstead is rectangular with the largest dimension at right angles to the highway.

Planning the farmstead.—The arrangement of lawns as discussed in the last chapter is, of course, to be included in the plan of the farmstead. In addition to the garden and other yards, the farm buildings apart from the house must be considered.

The dairy, garden, and poultry yard should be placed near the house. The calf-lot usually adjourns the dairy. Next to the poultry yard is the granary and beside it in a row at equal distances from the house are the cattle and horse-barns and the yards adjoining them. The hog-barns are usually placed farthest from the house.

Unwise expenditure in farm buildings should be avoided. Shelters for cattle and hogs may be constructed of poles and straw. The result may be quite as satisfactory as more expensive buildings. Milch-cows and working horses should be comfortably housed.

In the arrangement of farm buildings, it is desirable that the house should overlook the farmstead; anything in the nature of fire or accident may then be seen from the house.

A very important consideration in planning the farmstead must be the water supply. Possibly the greatest danger to health on the farm is typhoid fever. It is almost invariably due to contamination of drinking water.

The wells should be located where seepage from the barnyard and any other source of contamination may be eliminated. The top of the well should be above the level of the ground. It should be constructed of concrete and provided with a ventilating pipe.

Wherever there is reason to doubt the quality of the water, the supply intended for drinking purposes should be boiled.

Water taken from ditches or creeks in settled districts is very dangerous, even the water of larger lakes or rivers is not free of suspicion, unless there is no contamination near the place where the water is being taken out.

Exercises.—(1) Draw a plan of the farmstead, scale 100 feet to the inch, given the following dimensions: farmstead 400 feet by 600 feet, highway 66 feet wide, driveway 30 feet wide and 150 feet from one side, house 150 feet back to one side of the driveway. At the end of the driveway facing the highway is a row of buildings, including cattle-barn, horse-barn, implement shed, granary, and hog-barn. Place the poultry yard and dairy in suitable positions. Draw them to scale.

(2) Draw a plan to scale of a farmhouse, two stories, name and give the dimensions of each room.

(3) What should be taken into consideration in the location of the farmstead?

(4) Why should the farmstead be planned before any permanent buildings are erected?

(5) What are the advantages and disadvantages of open spaces between farm buildings?

(6) Where should the shelterbelt be placed in the plan required in Question 1, if the driveway runs north and south? Two answers are required.

(7) Where may a turnstile serve better than a gate? Why? What is the most suitable fence for a garden? For a horse paddock? For a hog run?

CHAPTER LVII

The Marketing of Farm Products

Long ago Man was self-sufficing. All his needs were satisfied by the raising of field crops and livestock and manufacturing from these, food and clothing. As population increased and communities and towns began to be formed, great changes came. The people within a community came to depend upon one person to grind their Wheat into flour, upon another to weave the wool they produced. The miller and the weaver in turn depended upon the farmers for food and other necessities. On the farms the people specialized until Dairy farming, Wheat farming, Sheep farming, Cotton farming, Tobacco farming, and many other kinds of farming were evolved.

Farmers who specialize depend upon other people to supply their needs. The people in the cities who manufacture the necessities for the specialized farmers depend upon these farmers for supplying their other needs.

This change from the self-sufficiency to specialization, created trade between people. Producers and manufacturers produced more than they required for themselves and sold the surplus to purchase these other necessities. The producers and consumers are sometimes long distances from each other. For example, most of the Wheat raised in Western Canada is sold in Eastern Canada, and people of Western Canada use such foreign products as silk from Japan, fruit from Ontario, British Columbia, and the United States, cloth manufactured in Eastern Canada, and the British Isles. Some of the raw products produced on farms must be processed, changed, modified, altered, before they can be used by the consumers. Wheat must be made into flour.

The raw products produced on the farms must be graded before they can be readily sold. Eggs must be graded so that people will know how fresh the eggs are which they are buying. Oats, Barley, Hay, Potatoes, and other farm products can more easily be sold on a quality basis after they have been sorted or graded according to established standards. The raw farm products also must be placed in boxes, barrels, bales, sacks or other containers to be more easily sold. Moreover, commodities must be stored in order that consumers can purchase them during all seasons of the year.

It is necessary therefore, that many things be done before the raw products of the farms can be utilized by the ultimate consumer. The services rendered are called essential marketing services. The producers of these raw products cannot do all these necessary things and they depend, therefore, on many persons or corporations—railroads and truck owners, manufacturers (millers, buttermakers, cheesemakers, canners, etc.), elevator and warehouse owners. Grading is done by the government, manufacturers, or by the elevator or warehouse owners.

By marketing is meant everything that is necessary to transfer commodities from producer to consumer; it includes all the essential marketing services.

They are:

(1) **Assembling:**

(a) Milk produced by many farmers is assembled at the cheese factory or creamery.
(b) Wheat from many farms is assembled at the grain elevators.
(c) When farmers in a community have a few hogs each for sale, they can assemble them and ship a carload to the packer or stockyard more easily and cheaply than each farmer could market his hogs separately.

(2) **Grading:** Farm products vary greatly in quality, shape, and size. Buyers of farm products want only a certain quality, shape or size of any product. In

order that the consumer may purchase just the kind of product he wants, farm products are graded.

(3) **Packaging.** Farm products differ in size and shape, in perishability and bulkiness. In order that products may be readily handled, shipped, and damage prevented, packaging in one form or other is required.
  (a) Eggs must be crated to prevent damage.
  (b) Hay and wool must be baled in order to reduce space required when stored or shipped.
  (c) Live poultry must be crated.
  (d) Cheese must be paragined to prevent evaporation.
  (e) Canned vegetables and fruits must be put in cans or jars to prevent spoiling.

(4) **Processing.** Some raw farm products are not in a form in which they can be utilized by the consumer. When products are changed in form or manufactured into some new product they are said to be processed.

(5) **Transporting:** When the consumer lives a long distance from the producer the products have to be transported.

(6) **Storing.** Since most farm products are produced in certain seasons of the year some must be stored in elevators or warehouses, so that they will be available to the consumer at all times.

(7) **Financing.** Money is required to do business. Financing as a marketing service is just as important as any other essential service.
  (a) In order that the essential marketing services can be performed, money must be invested in the equipment necessary to render the essential services above mentioned. Such money is called *fixed capital.*
  (b) Additional money is required to pay for goods that are to be held for a shorter or longer time, depending upon the services that are being rendered. Money

used for the purchase of farm products to be sold later is called *circulating capital.*

(8) **Distributing.** There must be some organization which is able to distribute farm products throughout the cities so that the consumers will be able to purchase them.

(a) After farm products have been assembled for storage, processing, and transportation, they must be divided into smaller and smaller amounts until that amount is reached which the consumer wishes to buy.

(b) Each wholesaler will distribute a commodity to many retailers and each retailer will distribute the commodity to many consumers.

The Cost of Marketing

Why there are Marketing Costs.—As mentioned above the expenditure of the essential marketing services involve labour and money. Any business organization expects to sell its goods at a high enough price to earn sufficient money to pay for the labour involved, interest on the money invested, and to yield a fair profit. The same is true for all persons or organizations rendering any of the marketing services. Each time a farm product changes ownership, after a marketing service has been rendered, the original value of the farm product is increased because of:

1. The cost of labour.
2. The cost of material used in rendering the services.
3. The interest on the capital invested.
4. The profit secured by each middleman.

Why the Costs of Marketing vary.—On account of the many kinds of farm products and the different marketing services that are necessary for each kind the costs of marketing vary greatly. In many cases the cost of marketing is several times greater than the original value of the raw product.

The costs in marketing canned vegetables and fruits are examples. The cost of processing, value of cans, boxes and materials used are extremely high when compared to the small value of the raw vegetable or fruit. Besides this there are other costs of assembling, distributing, financing, transporting, and grading.

The cost of marketing butter is relatively much smaller, the processing and packaging costs being much less.

Efficiency in the performance of the essential services by the producers and middlemen results in lower marketing costs. The producer receives more money for his products and the consumer better value for his money.

Grading and Standardization of Farm Products.—Grading is the sorting of products into groups of uniform kind, quality, and size, as for example, separating small Potatoes from large Potatoes, separating new laid eggs from those not so fresh. Standardization means the establishment of permanent grades. Standardization makes it possible for people to know what each grade of a product is and that each grade is the same to-day as it will be next week, month, or year.

Grading and Standardization benefit producer and consumer.—Standardization speeds up the marketing processes, lessens the cost of marketing, makes farm produce sell for higher prices and brings added return to the farmer.

Grading is economical to the consumer.—Ungraded products contain material of both good and poor quality and as a consequence there is a certain amount of waste in time and labour in order to prepare them for use. For example, if unsorted Potatoes were purchased, they would probably contain very small ones, large and hollow ones, bruised, broken, sunburned or frozen potatoes, and time would be taken in preparing them for consumption. Trading and standardizing benefit the consumer by enabling him to secure just what he wants more easily and economically than when products come to him ungraded.

Grading reduces the cost of marketing.—Transporting and storage charges are reduced by grading since all of the waste portions are sorted out, the remaining portion weighs less and takes up less space. For example, Wheat screenings which include chaff, weed, seeds, and other grains and foreign material are not used in the manufacture of flours. The expense of hauling the Wheat screenings in uncleaned Wheat to the elevator and shipping to the mill is the same as well-cleaned Wheat. By reducing the cost of marketing through grading the money returned to the farmer for his products is usually increased.

Grading and Standardizing reduces selling costs.—When farm products have been graded and standardized it is not necessary to inspect them before purchasing. Sales can be made at a distance; the purchaser knowing exactly the quality each grade represents.

Because grading and standardizing of farm products have proven a benefit to the producer as well as the consumer and because the marketing processes are more rapid and thus cheaper, the Government and business corporations have set grades for most of the common farm products. The Dominion Government employs inspectors whose duty it is to classify certain commodities that are being offered for sale, according to grade standards:

(1) Cereal grains are bought and sold according to grade standards. The following grades are given; according to quality of grain and contamination with foreign grains and weed seeds.

Wheat:	Number 1 northern		**Oats:**	Number 2 C.W.
	" 2 "			" 3 C.W.
	" 3 "			Extra 1 Feed
	" 4 "			Number 1 "
	" 5 "			" 2 "
	Feed			Rejected

Barley:	Number 3 C.W.	**Flax:**	Number 1 N.W.C.
	" 4 C.W.		" 2 C.W.
	Rejected		" 3 C.W.
	Feed		Rejected

(2) Hays such as Alfalfa and Prairie Hay are also graded; "Choice" hay is the best grade.
Numbers 1 and 2 are hays of an inferior quality.

(3) The government does not allow eggs to be offered for sale, unless they are graded as follows:

Fresh Extras	Storage Extras
" Firsts	" Firsts
" Seconds	" Seconds

(4) Poultry both live and dressed are sold according to grade. (See chapter on Poultry.)

(5) Pigs are being graded by the Government at the large stockyards and packing houses in Canada.

The student should visit a grocery store and find out how many things are being sold that have been graded: oranges, apples, canned goods, raisins, eggs, etc. Try to see how the consumer as well as the producer is benefitted and how it is possible to reduce the cost of marketing by grading.

Co-operative Marketing

The Pool is a system of co-operation among producers for the marketing of their products so as to secure for themselves as large a share as possible of the ultimate price paid by the consumer. The Pool differs from other systems of co-operative marketing in that all who participate get equal prices for the same grade of product, this price being the average for the year. The central idea of the pooling system is that all put in their products together, and then all share alike according to the amount of produce they put into the pool.

The organization of the farmers of Western Canada for the purpose of marketing their own products has come about as the result of certain conditions which have prevailed in the Wheat trade and which seemed to the Wheat growers to be abuses requiring correction. Many farmers were convinced that they were the victims of the organized interests who were in control of the grain trade. Some of the more serious abuses complained of were:

1. In the speculation on the Grain Exchanges, the Canadian crop was sold from ten to twenty times over in the course of the year. The profits of the traders on the exchange were at the expense of the grower or consumer, or both.

2. Speculation of this kind in such a necessary article of food has the appearance of gambling in the most necessary food of millions of people.

3. Pooling the Wheat crop seemed to be remedy for the "glutting" of the market when the Canadian crop is thrown on the market in the autumn. For a succession of years about 70 per cent. of the crop had been sold at the lowest prices of the year. This is the case still with the sales of those outside the Pool.

4. Mixing with foreign grain which has lowered the price of Canadian Wheat, it is expected, will cease when the farmers market their own. The effect should be to increase the value of Canadian Wheat. Chicago prices have ruled 8 to 10 cents below Winnipeg since the organization of the Canadian Wheat Pool, and this seems to bear out the contention above stated.

5. In 1913 the farmer's share in the cost of a loaf of bread was 21.4 per cent., in 1923 it was only 16.3 per cent. (See Report, Department of Agriculture, Washington.) The shares of all the other interests concerned were increased while that of the farmer was greatly decreased. Thus there seems to have been an increasing tendency to "bleed" the farmer.

6. There was good reason for believing that if the excessive charges of middlemen could be eliminated the sale of Wheat would be extended among many people who are not consumers

on a large scale at present, such as the people of the Orient, and of Southern Europe.

7. The farmers have complained for years of "overages" and "low grades." From "overages" alone there were profits of over a million dollars a year for the elevators as a result of giving light weight. The competition of the Pool has remedied this condition, and has also led to an improvement in the matter of grading, and the elimination of mixing grades whereby in the past the dealers have made profits.

The Alberta Wheat Pool was organized in 1923 and the Pools in Saskatchewan in 1924. These have united to form a marketing agency known as the Canadian Co-operative Wheat Producers, Limited, with headquarters in Winnipeg. This is commonly known as the Canadian Wheat Pool. Under this system the farmer signs a contract to deliver his Wheat to the Pool for five years. Over 36,000 farmers have signed these contracts in Alberta, and over 138,000 in the three Western provinces. The Canadian Pool has marketed over 200,000,000 bushels of Wheat in each of the last two years. The organization of the Pool in each of the provinces is simple and democratic. The Province is divided into seven large districts and each of these into ten smaller districts. Each of the smaller districts elects a delegate to the annual convention. The delegates of each of the seven districts elect a director to the Central Board, which controls the organization. Small committees of members in the districts and sub-districts watch the interests of the Pool, canvass for new members, and keep the central executive informed of local affairs.

The Pools in the three provinces are acquiring elevator facilities at different shipping points in the interior and also at the terminal points such as Vancouver, Fort William and Prince Rupert. An elevator fund is being created by the holding back of two cents a bushel on all grain sold to the Pool. Already the fund amounts to over $5,000,000. On this the Pools pay 6 per cent. interest to the farmers. In twenty years at this rate the investment of the farmers in elevators will be enormous, and besides being a profitable investment for the members it promises financial security for the Pool.

Advantages of Co-operation.—Producers of farm products organize co-operative companies in order to derive certain financial benefits. Since the co-operative organization takes the place of the middleman, the profits which usually are secured by the latter revert to the producer in the form of higher prices for his products. Co-operative organizations in some cases improve marketing methods and are able to lower the cost of marketing. Co-operative organizations strive to produce the products that the consumers demand. They strive to control the flow of products in the market. Co-operative organizations try to sell farm products when the prices are high. They also try to prevent lowering of prices due to flooded markets.

Conditions for Success in Co-operative Enterprises.—A co-operative organization to be successful must have sufficient turnover to conduct the business efficiently, and the persons placed in charge of the business must be well-trained. Every member must have confidence in the principle of co-operation and be willing to lend his aid in making his co-operative organization a success.

Kinds of Co-operative Organizations.—Some co-operatives are formed by farmers in a community, while others are more extensive and may include farmers of many provinces. Co-operative organizations which include farmers of a single community are known as local co-operative associations. Co-operative creameries, co-operative cheese factories, co-operative livestock shipping associations are examples of local co-operative organizations. The Alberta Co-operative Wheat Producers, Ltd., that conducts the Wheat Pool; the Alberta Co-operative Dairy Producers, Ltd., that conducts the Dairy Pool; and the Alberta Poultry Producers, Ltd., are examples of the more extensive co-operative organizations. Their activities cover the whole Province and they work in conjunction with similar organizations in the other provinces.

Certain co-operative organizations only render parts of the marketing services before the product is sold to private middlemen.

The co-operative creameries assemble the cream from the farmers in the community and make it into butter. They then sell it to private butter buying organizations.

The Alberta Co-operative Wheat Producers, Ltd., assembles the Wheat from the farmers, stores it in elevators, grades it and sells it to the millers who manufacture it into flour. The Canadian Co-operative Wool Growers, Ltd., assembles wool from all over Canada, grades every fleece, stores the wool in their warehouses in Eastern Canada and sell it to woollen mills.

Certain co-operatives render all the marketing services until the goods are sold to the wholesaler. The Sun-Maid Raisin Growers of California, an organization of this type, even advertises its products in papers and retail stores.

In addition to the Wheat Pool, which owing to its size, has attracted universal notice, there have been formed in the Province similar associations for the purpose of selling such products as livestock, poultry produce, and wool.

Exercises.—(1) "Man is no longer self-sufficing." Discuss.

(2) Define: "Essential marketing services," "Middlemen," and "Marketing."

(3) Name and describe fully each of the marketing services.

(4) Explain fully why there are marketing costs.

(5) Give reasons why the costs of marketing vary.

(6) Define the terms: Grading, Standardization.

(7) Explain how grading and standardization benefit producer and consumer.

(8) Show how grading reduces the cost of marketing.

(9) Why have Governments and business corporations set grades for most of the common farm products?

(10) What are the standard grades set in: Wheat, Oats, Barley, Flax, Hay, Eggs, Poultry, Hogs?

(11) Give reasons why producers of farm products should organize co-operative companies.

(12) What are the essentials of success in any co-operative enterprise?

(13) Name and describe fully the various kinds of co-operative organizations.

CHAPTER LVIII

Implements and Machinery

> "As I was walking about three years ago (1806) . . . I saw in a pasture . . . an immensely powerful team of not less than eleven horses, straining to the utmost to drag a pair of cart-wheels to which the beam of a mole-plough was attached. At least a dozen men were likewise employed; some whipping, some pushing and some hauling. All appeared to work desperately hard."

But a little over one hundred years ago, and what a change there is in farm methods. Everywhere the drone of the tractor is heard to-day; with what ease does Man control and direct his machines and tools. The most wonderful of our modern implements, however, are either adaptations, or combinations, or both, of the earliest implements with which Primitive Man wrung his livelihood from the soil. It is quite natural that our fundamental implements in tillage, seeding, and harvesting should boast the longest history of usefulness. Had the plough not been our most important implement it would not have had such an unending existence, nor would it contest ancestral honours with the spike-tooth harrow.

We shall divide our study of implements into the three divisions as suggested above—implements for tillage, for seeding, and for harvesting.

Implements for Tillage

Plough.—The earliest agriculturist had scarcely commenced seeding before he realized that by breaking up the top layer of soil a great saving could be effected in the quantity of seed required: his first harvest after this realization showed him that tillage had a marked effect on the productiveness of the soil. It may have been by accident that a broken and pointed crotch of a tree was first drawn over the surface of the ground in such a way as to scratch a furrow, but at any ate, for centuries after, the makers of implements were employed in adapting, modifying, and perfecting wooden ploughs with the crotch as a model. Although for the most part metals have replaced wood in modern ploughs, the changes in proportion and shape are very slight. Now we know why this model has been retained: without knowing why, earlier generations persisted in its use because of the results they achieved.

Three operations are accomplished by the use of the plough:

(1) Cutting in a vertical plane and in a horizontal plane.
(2) Lifting and turning the slice using the uncut edge as a hinge.
(3) Pulverizing the slice, or at least that portion of it in direct contact with the cutting and turning surfaces of the plough.

Construction. In its simplest form a plough consists of:

(1) a share or cutting edge,
(2) a moldboard or lifting and turning surface,
(3) a landside or vertical surface by which the implement is braced and maintained in an upright position,
(4) a frog, or horizontal base, upon which the other parts are mounted.

The share is usually made of steel or chilled iron. Examine a plough to determine the cutting edges for the vertical and horizontal cuts. Steel shares are more expensive but they can be given much sharper edges and are therefore to be preferred in all ploughing where one is likely to meet tough roots.

The moldboard requires greater care in its construction than one would suppose. It must be rigid and strong, yet curved and sloped very accurately. As we learned above, its function is to lift and turn over the slice. It must be shaped to do this gently and without buckling or kinking as it might by turning the slice too suddenly. Moldboards are shaped in a variety of ways for special purposes. For ploughing sod, a long, gently sloping moldboard is necessary; for ploughing stubble, where pulverization is the important consideration, a steep, short, and sharply-turned moldboard is used; for very sticky soil, the board is sometimes replaced by rods or flat pieces of steel.

The landside is the upright wall through which pressure is exerted by the moldboard against the side of the furrow. It has a tendency to maintain the plough in an upright position. Its height should be approximately the same as the depth of the furrow, and may vary from four to eight inches. The greatest wear comes on the sole of the landside, or the edge in contact with the bottom of the furrow. Many ploughs are equipped with detachable soles and some with detachable heels to be replaced when worn.

With the frog, these parts constitute what is usually called the bottom of the plough. Power is transmitted from the team or tractor through what is called the beam. The beam was formerly constructed of wood, but this has been replaced very generally by steel. Steel is not easily bent, and gives the bottom plenty of clearance. In recent years a special device has been perfected by which the steel beam may be "landed," that is, swung in a horizontal direction either towards or away from the land. This adjustment permits a shifting in direction of the force applied to the bottom and it is of great importance where teams are used.

For example, where three horses are used, the beam is usually adjusted so that it is in direct line with the landside; where two horses are used, the beam is adjusted so that the landside of the beam is almost directly above the point of the share; where four horses are used, the beam is shifted to make with the landside the same angle towards the land as away from the land in the adjustment for two horses. If the line of draft, that is, the direction in which force is applied to the bottom, is correct, the lines drawn from the collars of the horses (or in the case of tractors, from the drawing-bar) to a point just above the junction of the share and moldboard and two inches towards the moldboard side of the shin, should pass through the hitching point at the end of the beam.

This adjustment is also important as by it varying widths of furrows may be cut. If the beam is moved towards the land, a narrow furrow is cut; a wider furrow is cut by swinging it in the opposite direction.

The set of the plough refers to the relation to each other of the three lowest points when the plough is in use. They are the point of the share, the wing of the share, and the heel of the landside, and in some degree, with the relation of these three points to the hitch at the end of the beam.

Suction, or that force maintaining the share at a uniform depth, is obtained by curving the point of the share downwards below the lower edge of the landside. This curve varies from one-eighth of an inch to three-eighths of an inch. As this point of the share dulls, suction is destroyed. This cannot be righted by altering the hitch. Obviously, an alteration in the hitch may help to secure penetration, but this must not be confused with suction.

Horizontal suction is secured by turning the point of the share one-quarter to one-eighth of an inch towards the land. This "landsiding the point of the share," as it is called, has the effect of drawing the point of the share in toward the land. Penetration may be secured by altering the hitch in a horizontal direction, but again we must distinguish between penetration and horizontal suction.

Attachments. The two most important devices for use with the plough are jointers and coulters or cutters. The jointer is, in principle, a miniature plough. It is attached to the beam so that the point of the jointer is above and just back of the point of the share, and when the plough is in use should run at a depth of about an inch and a half in the soil. It is usually set about half an inch to the landside of the shin. The jointer is shaped so as to cut a very small furrow about an inch and a half deep and about three-quarters of an inch wide. The slice turned over by the jointer forms the outside edge of the slice turned over by the moldboard of the plough.

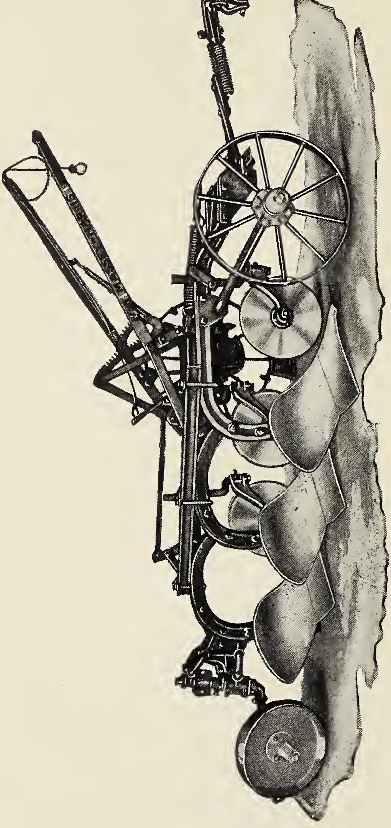


Fig. 132. Three-Bottom Gang Plough for use with tractor. Notice the coulters. (*Courtesy of Massey-Harris.*)

The result is a double turn which entirely prevents the sod growing up between the furrow slices on ploughed land.

The main function of the coulter or cutter is to produce a clear-cut furrow bank. Without the coulter the shin of the plough makes the vertical cut, but it has been found possible to produce a much neater furrow if the vertical cut is made before the shin comes in contact with the soil. There are various forms of coulters, all of which are attached to the beam just in front of the shin. They are never lowered to more than half the depth of the furrow.

Mechanical Devices for Reducing Draft, Increasing Number of Ploughs, and Facilitating Carrying.—Possibly the forerunner of all mechanical devices was the beam wheel by which the end of the beam was mounted on a wheel large enough to press firmly on the land. This was devised for the purpose of facilitating the handling of the plough.

We have to-day sulky ploughs, gang ploughs, and a modification of the gang plough for use with the tractor. The sulky plough is a plough bottom mounted on three wheels. The beam is retained and serves as a frame for the wheels. To the front of the beam is attached one wheel set at an incline away from the land, a second wheel supports the middle of the beam, and usually extends well out on the land to be ploughed, and a third wheel runs in the furrow just behind the landside. It also is set at an angle, the purpose being to reduce the friction on the landside and thereby decrease the draft. Levers operating on the axles of one or more of the wheels lift either the whole plough bottom or just the point of the plough clear of the land.

Gang ploughs are distinguished in this country from sulky ploughs solely by the number of plough bottoms. Where two or more plough bottoms are combined with the object of ploughing two or more furrows at once, the implement is called a "gang" plough. The greatest objection to be urged against gang ploughs is that of side draft. As the number of horses is increased, one must decide whether or not these shall be hitched in tandem or abreast. It may be taken as a rule that four horses cannot be hitched abreast without considerable waste of energy. There are so many devices on the market under the name of "eveners" that the problem of the ploughman has been much simplified. In some gang ploughs a steel wheel is substituted for the landside in order to reduce the draft. Where this is done, the frame is not mounted on a wheel at the rear.

Gang ploughs designed to be used with a tractor have a special extension on the front of the beam which lowers it to

Fig. 133. Three-Bottom Gang Plough in use in Alberta.
(Courtesy of McCormick-Deering.)

suit the new line of draft, and the levers are set forward in order that they may be operated from the tractor. The axle or axles of the two front wheels are horizontal.

Disc Ploughs.—The disc plough in its many modifications consists of several concave steel discs mounted on a frame in such a way as to act as moldboards as this frame is drawn over the ground. It is not desired to turn a complete furrow slice with each disc, therefore we notice the absence of land-sides in all disc ploughs. The purpose is simply to change the sliding friction of the moldboard into the rolling friction of the disc: the soil is not pulverized as well. Disc ploughs are recommended for use on heavy or sticky soils. Wherever very deep tillage is necessary the plough designed for this particular purpose is indispensable. To increase the depth

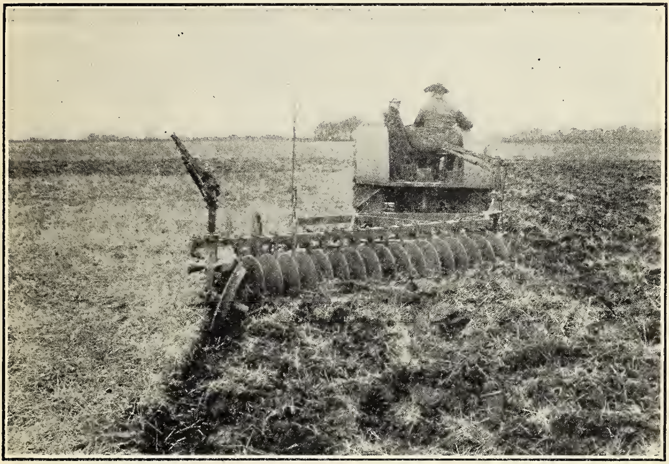


Fig. 134. Disc Plough turning Stubble.

of the furrow two discs revolve one behind the other in the same furrow. The front disc is set at a depth of from six to ten inches; the rear disc runs from five to twelve inches deeper. Thus, the combined depth varies from eleven to twenty inches or even twenty-four inches.

Stiff prairie sod is usually too heavy for deep-tilling disc ploughs; several types of moldboard ploughs have been designed which are quite satisfactory. In the latter, the draft is increased appreciably.

Harrows.—Recent investigations seem to show that the harrow predates the plough. The earliest harrow so far as we know consisted of a single pointed stick about three feet long with a rope attached eight inches from the pointed end. The primitive farmer held the stick in an upright position while his helper pulled the rope. It is not surprising that after a few centuries some one devised a means of using several pointed sticks at a time. Although it required more power to pull this new-fangled implement, the decrease in the time

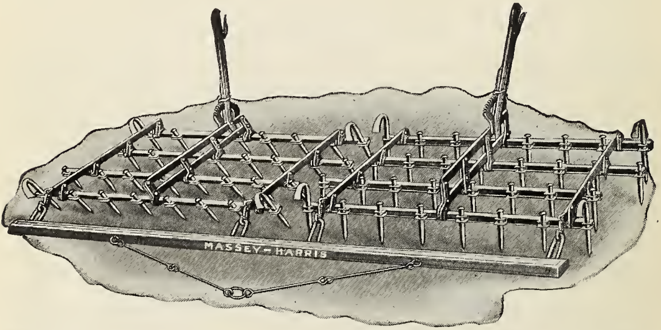


Fig. 135. Spike-Tooth Harrow. Notice the adjustment in the setting of the teeth (*Courtesy of Massey-Harris.*)

required to cultivate a field insured an instant popularity. Presently there appeared many forms of the same device: several of them have persisted to our own day. There are the spike-tooth harrows, with steel bars to which spikes are attached by clamps and with wooden bars through which steel spikes are driven and wedged on both sides. Levers by which the teeth may be set at various angles from the horizontal forward back to the vertical, runners, and guard rails, are the most common attachments.

In modern agriculture, the spike-tooth harrow is used as a leveller and pulverizer in the preparation of the seed-bed and where it is necessary to break up the surface of the soil to prevent loss of moisture.

Fig. 136. Spring-Tooth Harrow.
(*Courtesy of Case.*)

Spring-tooth harrows have long, curved, flexible teeth mounted on bars. When roots or other obstructions are met with the teeth bend back and the depth at which they are running is thereby lessened. This type of harrow is useful in the eradication of weeds. As explained in an earlier chapter, it pulls root-stocks to the surface in large sections. Other harrows and weeders are more apt to break the root-stocks, which may result even in giving the weed a wider distribution.

Disc Harrows.—The greatly increased popularity of the disc harrow is probably due to the recent changes made in the size of the discs. Only a few years ago, the disc rarely exceeded ten inches in diameter. A small disc penetrates further and the draft is increased considerably. With the introduction of discs sixteen to eighteen inches in diameter, a splendid all-round harrow has been perfected, useful on ploughed land and on stubble before breaking.

Six to eight discs, their concave surfaces all one way, are mounted on an axle and turn with it but not otherwise. The draft is applied either at the centre or at both ends of this axle. Two to four of these "gangs," as they are called, are combined to form one implement. The usual combination consists of two gangs attached to a frame. By means of levers the gangs may be shifted in two directions—the ends may be swung forward or back and lifted or lowered.

In the Out-Throw harrow, the discs of each of the two gangs are turned with the concave surfaces outward. In order to double the speed with which the land may be covered and to eliminate the necessity of reharrowing half of each strip, second frame is attached behind the first frame. Where the gangs are combined, the two front gangs turn the earth outward and the rear gangs turn it inward. The rear gangs are so attached as to cause the discs to follow the path of the front ones precisely. The field is thereby left even. When the two rear gangs are hitched to the front ones the power required is not doubled as is commonly supposed. There is a saving, therefore, not only of time but of energy as well.

The discs should be sharpened every two or three years, and proper attention should be given to lubrication.

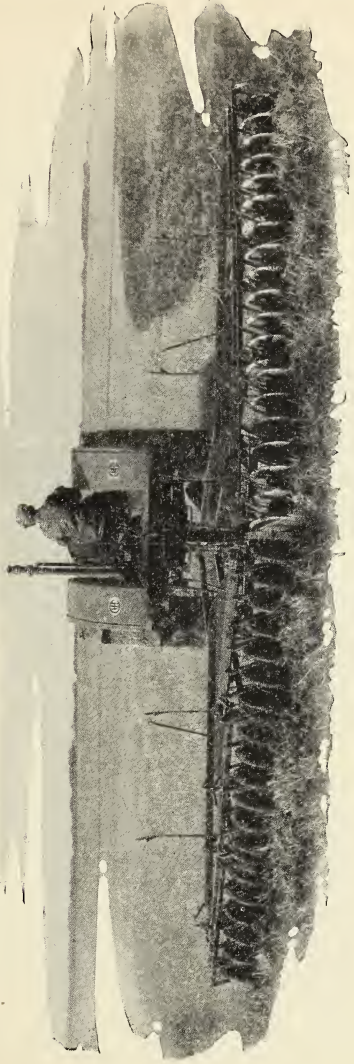


Fig. 137 Disc Harrow

Cultivators.—It is not difficult to trace the origin of the cultivator. The close relationship to the harrow is readily seen. Like harrows, cultivators are divided into stiff-tooth and spring-tooth types. The same differentiation in use applies. That is, where one would use a spring-tooth harrow one would recommend the spring-tooth cultivator. Surface

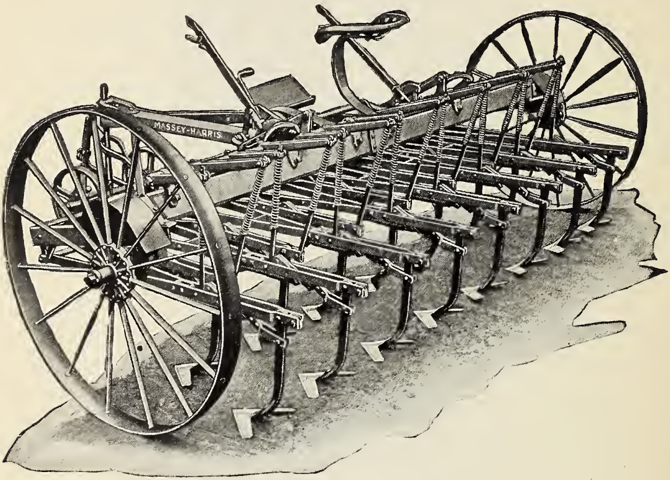


Fig. 138. Stiff-Tooth Cultivator.
(Courtesy of Massey-Harris.)

weeds are eradicated more readily by the use of the stiff-tooth or duck-foot cultivator as it has been called earlier in this book. Weeds with long root-stocks demand the use of a spring-tooth implement. The cultivator is essentially an implement for deeper cultivation than the harrow. It cannot be said to work the surface layer as thoroughly but its fewer, longer teeth run deeper; the cultivation of at least four inches of soil is the minimum required.

Implements for Seeding

Seeders.—Although implements for seeding include seeders for many crops, we shall confine our attention to grain seeders, or, as they are commonly called, "Grain-Drills".

In any mechanical seeding device two operations must be accomplished: (1) a furrow must be prepared to receive the seed and closed after the seed is dropped in order to cover the seed. (2) The seed must be distributed evenly over the acreage to be sown.

Various methods of producing a furrow are now incorporated in grain-drills. They may be grouped in two classes, hoe furrow-openers and disc furrow-openers. The principle behind each is to turn a small amount of earth outward for just long enough to allow the seed to be dropped when the earth will roll back again covering the seed. Chains or press-wheels are frequently attached behind the drills to facilitate covering the seed.

The accomplishment of the second essential operation necessitates the provision of a hopper for carrying sufficient quantity for a reasonable period, and conveyors through which the seed is allowed to pass in regulated amounts from this hopper to the drills. To regulate the amount of grain sown, gears on the axle of the implement drive force feed attachments which remove the grain from the hopper in regular amounts with each cog. Thus a steady volume is insured. By altering the speed with which the force feed gears revolve in proportion to the speed with which the main axle revolves it is possible to regulate the amount of seed sown.

Many grain-drills are manufactured with a second hopper, designed to distribute fertilizer with the grain. It is also possible to regulate the amount of the fertilizer per acre independently of the adjustment for the grain.

It is impossible to over-emphasize the need for the greatest care in the maintenance of all seeding machinery. If the implement is not kept scrupulously clean and well oiled, much wastage of valuable seed and fertilizer will result. If the gears are permitted to become worn or the chains to slacken, "blank spots" will occur, the seeding will be irregular and the whole crop suffer.

Implements for Harvesting

Mowers.—The principle back of all mowers and other harvesting implements of which the mower forms a part, as, for example, binders, combines, etc., is the same as that of the

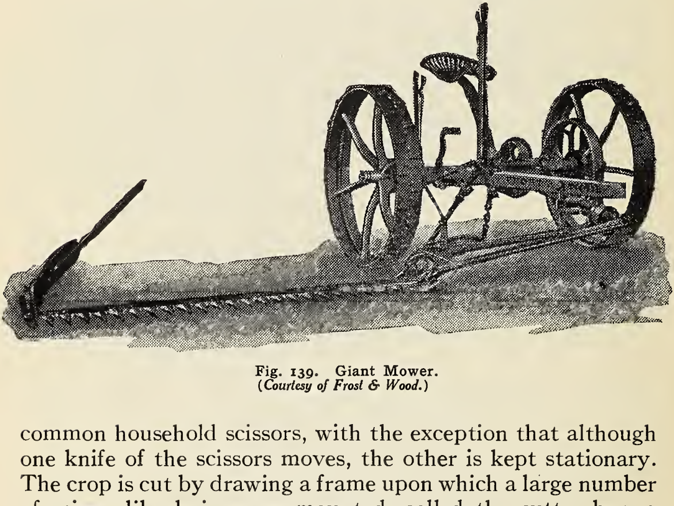


Fig. 139. Giant Mower.
(*Courtesy of Frost & Wood.*)

common household scissors, with the exception that although one knife of the scissors moves, the other is kept stationary. The crop is cut by drawing a frame upon which a large number of scissor-like knives are mounted, called the cutter bar, a few inches above the surface of the ground. As the stems come between the blades, they are cut and fall backward over the frame. The scissor-like motion of the cutting knife is taken directly from the wheels, either by gears alone or by chains and gears. A wheel is set to revolve about twenty-five times to each revolution of the ground wheel. To this wheel a rod is connected at some point other than its centre by a crankpin. The other end of this rod is attached to the moveable knives of the mower. The rotary motion of the wheel is thus converted into a rectilinear motion. Thus, for every revolution of the ground wheel, the knives open and close about twenty-five times.

In order to open completely and close, the moveable knives must move through a distance equal to the distance between the points of the stationary knives. If the rod connecting them to the gears is bent or loose, satisfactory cutting cannot be achieved. Also, the knives must be kept in true line.

The knives should be ground frequently and should be filed whenever necessary. Levers permit the raising of the cutter bar through an angle of 90° from the horizontal in some makes. A foot lever is provided to raise the bar high enough for turning in the field. Before the implement is used, it should be tested out to see whether or not the knives move as soon as the wheels begin to revolve. If not, the bearings are either worn or the chains need tightening. If not attended to, the mower will be drawn into the crop before the knives commence to operate with the result that the cutter bar will become choked.

In recent years the width of swath has been increased from four feet to eight feet in many instances. A very long cutter bar should be well supported or it will have a tendency, after extensive use, to lag behind at its outward extremity.

Binder.—The essential principles of the mower are retained in the binder. Because a binder must tie the cut grain in uniform bundles, many parts must be added. Revolving above and slightly in front of the cutter bar is the reel which places the grain after it is cut on a continuous platform just back of the cutter bar. The heads are all placed one way. The platform revolves inward carrying the grain. As the grain reaches the inner end of the platform, it comes in contact with the elevator canvases which lift it over the main wheel. From this elevated position it drops into the packing and binding attachment. Here it is essential that a fine degree of accuracy and neatness prevail. The grain is arranged by a series of vibrating packers; a butter-board squares the cut ends so that the sheaf will have an even base; while it is still held securely the twine is knotted about it holding the sheaf together. When this operation is completed the sheaf is released. It either drops to the ground or to a sheaf carrier. The latter may be tripped by a foot lever.

With the introduction of tractors it is now possible to utilize the tractor's power in two ways at the same time. In

Fig. 140. Tractor-Binder. The power take-off is right behind, and underneath, the driver.
(Courtesy of McCormick-Deering.)

addition to providing the locomotive power it has been found that there is a saving of power if the main gears of the binder be connected through a power take-off to the tractor instead of to the main or "bull" wheel of the binder. Certainly this is true wherever soil conditions are such that the main wheel would have a tendency to drag rather than revolve, turning the gears as it does so. The greatest advantage of the power take-off, however, lies in the fact that the regular speed of the working parts of the binder is not influenced by the speed at which the implement is drawn forward. There is a possibility here of increasing the rate at which a swath may be cut above that of the ordinary binder drawn by either horses or tractor.

The tractor is, in large measure, responsible also for the later developments, the reaper-thresher or "combine" and windrow-harvester with which the former is more successfully used.

The harvester-thresher or reaper-thresher is an attempt to combine the two essential operations indicated in its name.

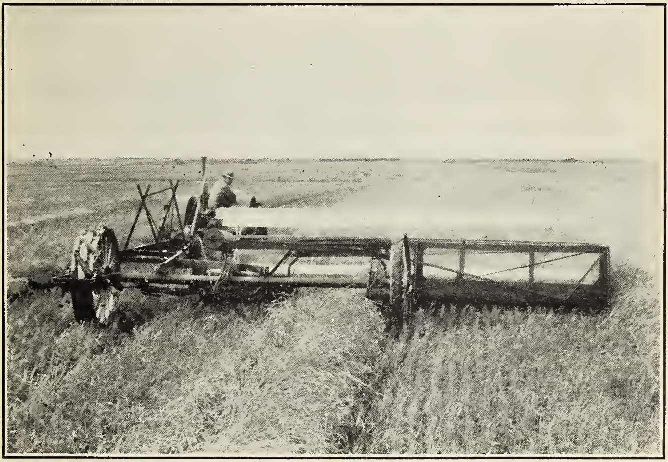


Fig. 141. Windrow Harvester.
(Courtesy of McCormick-Deering.)

Part of the power is supplied by the tractor and part by a subsidiary gasoline engine mounted on the implement. The mower and reel work in much the same way as in the binder with the exception that the grain is cut within a few inches of the heads. These heads are carried on a continuous platform to a threasher attachment which completes the process.

When used in combination with the windrow-harvester the reel and cutter bar are removed and a pickup attachment replaces the cutter bar in front of the platform. The windrow-harvester is a type of mower. The grain is cut and passed back on a platform which collects the cut grain and drops it in a continuous windrow. The grain lies lightly on the top of the long stubble, has a freer circulation of air to cure it, and dries more quickly after rain. It is later picked up by the harvester-thresher. This combination permits the use of the harvester-thresher in fields where the grain has not grown to a uniform height before ripening.

Threshers.—In the thresher the cut grain is fed on a continuous platform under a series of serrated band-cutting knives which cut each stem into several lengths. These lengths are then pushed by a mechanical combing device into what is known as the cylinder. The cylinder is really a steel reel, the bars of which may be either corrugated or set with teeth or pegs. The enormous friction when the grain passes between the bars of the cylinder and the concave surface of the grate under it, separates a very large proportion of the grain from the straw. The grain drops through the grate to the grain pan. The small proportion left must be removed, however, so a mechanical beater passes the straw back to the straw racks, a series of corrugated arms which toss the straw up and down a number of times as it moves across them. When the last of the series is reached practically all the grain has been separated and the straw is then blown by means of a fan to the stack. With the grain there is, of course, a large amount of chaff and other foreign material. The grain is collected at the back of the thresher and subjected to a powerful fan which effectually removes the undesirable portion.

Fig. 142. Harvester-Thresher showing pick-up attachment in use.
(*Courtesy of McCormick-Deering.*)

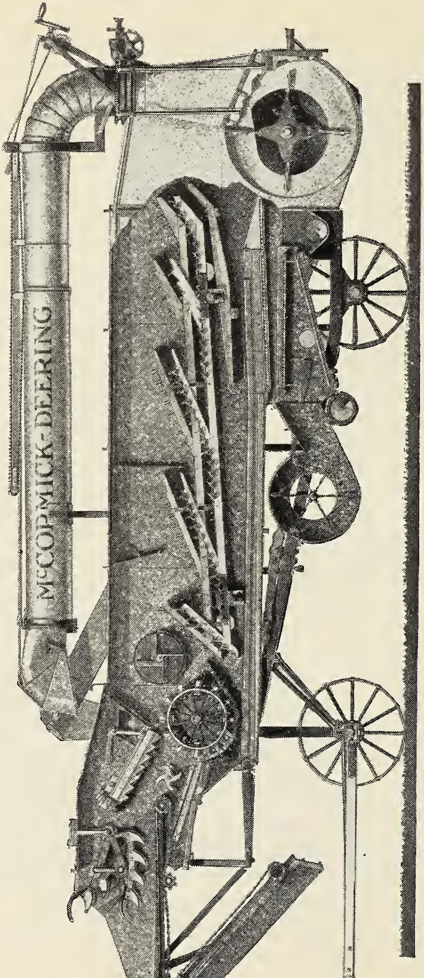


Fig. 143. A Thresher with the side removed to show the internal mechanism.
(*Courtesy of McCormick-Deering.*)

A weed screen is usually provided to give the grain a final cleaning before it is permitted to pass in to the auger by which it is delivered to the granary. A tailings auger catches the unthreshed heads and conveys them back to the cylinder for a second treatment. Every effort is made to prevent all wastage of the grain.

Exercises—(1) Trace the development of plough and spike-tooth harrow.

(2) Draw a plough-bottom and label all the parts.

(3) Explain the action of a Grain Drill. How is the amount of grain per acre regulated?

(4) Why is it particularly necessary to lubricate a disc harrow?

(5) Are more horses required to pull a disc plough than a gang plough? Explain.

(6) Discuss implements for harvesting. Trace the path of a stalk of Wheat from the ground through the windrow-harvester and harvester-thresher to the granary.

Date Due
