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Scope of Study: A purpose of present day biology is to help the student apply biological concepts to practical situations. The student is concerned with scientific knowledge about bacteria, insects, birds, trees and other forms of life because of their effect upon man. This report has been prepared for the purpose of bringing together and condensing into compact form as much as possible of the information concerning the economic relations of plants and animals; their bearing upon the welfare of the human race; their food habits; and methods of controlling the more harmful ones.

Findings and Conclusions: Man's dependence on other organisms for the essentials of his existence has been of paramount importance in his life since the human race began. Not only have they played an important part in the everyday life of mankind, but also they have had a profound influence on the course of history and civilization. A knowledge of the industrial, medicinal and edible plants and animals cannot fail to broaden one's outlook.

ADVISER'S APPROVAL James H. Zant

ECONOMIC ASPECTS OF HIGH SCHOOL BIOLOGY

By

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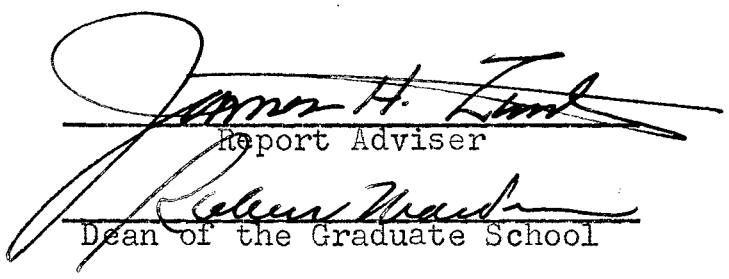

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M. M. H.

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CHAPTER I

INTRODUCTION

For some years past there has been an ever-increasing feeling among educators that the average courses in elementary biology have fallen far short of meeting the needs of the average student. For the most part, such courses have been conducted on the supposition that their sole purpose was to lay the foundation for further advanced work in this field. An elementary course should be so constituted as to be interesting and profitable to the extent of adding to the students' general fund of knowledge even if he does not continue in the field.

The context of this report is intended to be used as supplementary material to broaden the outlook of those students who do not go on to college and to give him something more tangible and with more carry-over value than the usual elementary course in biology. The material in this report is not intended to be used as a substitute for the usual course of high school biology nor is it a guide to follow in lieu of a textbook; it is as stated above only supplementary material, written in non-technical language that will be easy and fast to read.

From earliest times plants and animals have been intimately tied up with human existence. Not only have they

played an important part in the everyday life of mankind, but also they have had a profound influence on the course of history and civilization. A knowledge of the industrial, medicinal and edible plants and animals cannot fail to broaden one's outlook.

This report will not cover all organisms and their products or all the sources of any product; only those organisms which have been successful as typifying plant and animal products of a particular category are presented. Elaborations upon relatively few organisms of greatest economic importance should readily indicate to the student the chief ways in which these organisms are useful or harmful to man. It is hoped that such a presentation will provide a more interesting and clearer view of the whole than would a mere recitation of the multitude of economic plants and animals and their many uses.

CHAPTER II

ALGAE

Some twenty-five or thirty species are eaten by man. He obtains carbohydrates, vitamins (especially rich in A, E, C and D), inorganic substances; e.g., iodine (goiter is unknown among the people who eat seaweeds).[1] Certain algae are used as cattle feed. Perhaps the most economic aspect of the algae is that they constitute the chief source of food for fish and other aquatic animals. Algae are the basal units in food chains of both marine and fresh-water habitats. It has been established that the quantity of algae present in a body of water has a direct bearing on the size of the fish population of that body, and hence upon the fisherman's catch. It has been observed that the most productive fishing grounds are seldom very far from fields of algae. For these reasons, research on algae is an important phase of the work of marine biological stations and government fisheries

The presence of algae has another bearing on the welfare of fish in that the former, in the process of photosynthesis, uses up the carbon dioxide exhaled by the fish

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[1] Albert F. Hill, Economic Botany, (New York, 1937), McGraw-Hill Book Company, Inc., p. 28.

and releases oxygen, which may then be used by the fish and other aquatic organisms in respiration. Also, the oxygen given off promotes the activities of aerobic bacteria which bring about the decomposition of organic material in water and so aids in the purification of sewage in streams.

Certain algae, namely the blue-green, the golden-browns and the diatoms, contaminate water supplies, such as reservoirs and swimming pools. These algae produce oils which give the water a foul odor and a fishy taste. These are usually treated with copper sulfate in concentrations that will kill the algae but will not harm man or higher plants and animals.

Many marine algae are important sources of iodine, of potassium and of other minerals. Farmers along sea coasts have long collected algae with which to fertilize their fields. Algae, together with barnacles, oysters, bryozoans and similar organisms, attach themselves to ships and marine construction and produce a condition known as "fouling". At the end of the first year, a large vessel may have a three to four inch coating, weighing one hundred or more tons.[2] These fouling organisms constitute a serious problem for they may retard the speed of a ship as much as fifty per cent, and they cause wastage of fuel because of the resistance which must be overcome. As a result, vessels must be periodically drydocked, cleaned and painted. It is estimated that fouling

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[2] Harry J. Fuller and Oswald Tippo, College Botany, (New York, 1955), Henry Holt and Co., p. 36.

costs $100,000 a year for a vessel of the Normandie or Queen Mary class.

Economic Importance of the Blue-Green Algae

Like the other algae, the blue-greens are eaten by fish and by other aquatic organisms, which in turn may be eaten by man. They are a nuisance in that they may render water in reservoirs unfit to drink because they implant a foul odor and a fishy taste to the water. Copper sulfate is used to poison the algae. Sometimes they form a dense growth on the surfaces of pools, discoloring the water and producing the phenomenon known as water bloom. It has been reported that cattle have been poisoned by drinking this water. Blue-green algae often grow in large colonies on soils and, as they die, contribute to the organic matter of soils; some species are eaten by soil animals.

Economic Importance of the Green Algae

Some green algae are eaten by man; for example, sea lettuce. In India, dried Spirogyra and Oedogonium are sold in the markets. The green algae play a part in the purification of water since they give off oxygen which is used by fish and other aquatic life in respiration, and then the carbon dioxide which is given off in this process is absorbed by the algae and used as a raw material in the process of photosynthesis. Also, the oxygen released by green algae promotes the growth and activity of aerobic bacteria and

probably oxidizes various impurities in the water. Marine green algae, together with red algae, secrete calcium salts which play an important role in the formation of oceanic reefs.

Economic Importance of the Yellow-Green Algae, Golden-Brown Algae and Diatoms

On the negative side, the golden-brown algae contaminate water supplies while other species of the same phylum, especially the diatoms, are important components of the diet of aquatic animal life, so much so that the diatoms are often referred to as the "grass of the sea". Diatoms constitute practically the only plants in the open sea and those that grow in shallow waters along the coasts are extremely valuable to fisheries. In shallow waters, diatoms grow well because the waters are well supplied with organic matter by the streams which have their mouths at these points. Fish breed in these shallow waters and so their young find the extensive diatom areas good pasturage.

Many other economic uses of diatoms are dependent upon the fact that when these organisms die their bodies drift to the bottom of the body of water in which they occur, and so there accumulate large deposits of these diatom shells known as diatomaceous earth. The diatomaceous earth industry is a sizeable one; it harvests approximately 240,000 tons each year. The product has many different uses. Polishes for silverware, for metals and for automobiles

are produced from diatomaceous earth. It is used in tooth powders, as insulation for steam pipes and blast furnaces, as well as for the insulation of pipes in refrigeration plants. It is also used to filter oils and syrup in sugar refineries. It is used in dynamite as an absorbent for the liquid nitroglycerine. It is used in concrete and in making light-weight bricks.[3]

Economic Importance of the Brown Algae

Some of these algae supply iodine and others are important sources of potassium. For these reasons during World War I and to some extent during World War II, barges were fitted out with special devices for the harvesting of kelps. Farmers along coasts, especially in Northern Europe, have long collected kelps to put on their fields to fertilize the soil. Brown algae are also fed to cattle and fish feed upon them, also. Many of the browns are eaten by the natives on oceanic islands, by the Chinese and by the Japanese.

Economic Importance of the Red Algae

Many of the reds are eaten by fish and several species are fed to cattle in various parts of the world. Some are eaten by man. Irish moss is made into a dessert, the well-known "sea moss farina", as well as other puddings. One of the reds is used by Europeans in making soup, while in Japan

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[3]Harry J. Fuller and Oswald Tippo, College Botany (New York, 1955), Henry Holt and Co., p. 536.

it is a valuable crop plant for the same reason. Dulse, or sea kale, is collected, dried and sold in the popcorn and peanut stands of coastal resorts. Certain of the reds are the source of agar-agar, which is used as a solidifying agent in desserts, as a laxative and as a sizing material for textiles. It is also used in biological laboratories in the preparation of media for the culture of bacteria and fungi.

Some of the red algae are important land formers; they actually contribute more to the building up of coral reefs than do the coral animals and for this reason, it has been suggested to change the name of coral reefs to "algae islands".[4] Other red algae are sources of gelatin or jellies which are used as bases for shoe polishes, cheap grades of ice cream, hair dressing, shaving creams, cosmetics, shampoos and various lubricating jellies.

To summarize, the following are the more important ways in which the algae are of economic importance: as human food; as fish food; as cattle food; as purifiers of water; as contaminators of water supplies; as sources of iodine; as sources of potash and other minerals; as fertilizers for the soil; as builders of oceanic reefs; as causal agents of fouling on ships and other marine construction; as sources of gelatinous substances for the culturing of bacteria and fungi; as sources of jellies, shoe polish, cosmetics, shaving cream, and shampoos; as lubricating jellies; as laxatives; and as

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[4]Ronald Good, Plants and Human Economics, (Cambridge, 1933), University Press, p. 96.

sizing material for textiles. Diatoms are important as bases for silver and other metal polishes and for tooth powder; as insulation for heating and cooling pipes; as a filtering material; as a construction material; and as a testing material for microscopic lenses.

CHAPTER III

BACTERIA

Harmful Activities of Bacteria in Human Life

Bacteria cause many serious diseases of man; for example, tuberculosis, meningitis, pneumonia, lockjaw, typhoid fever, gangrene, cholera, diptheria, leprosy, dysentery and streptococcus infections. Bacteria cause diseases of domesticated animals; for example, tuberculosis of cattle and hogs, anthrax of sheep, chicken cholera, pneumonia, glanders in horses, sheep and goats, and septicemia in cattle.

Bacteria cause many diseases of cultivated plants; for example, fire blight of pears, citrus canker, cotton root rot, potato black leg, soft rot of carrot, cabbage, celery, cucumber and eggplant, pineapple rot and wilt diseases of tomatoes, potatoes, cucumber, squash and cantaloupes.[1] These diseases can cause large crop losses, the value of which reaches many millions of dollars annually.

Bacteria cause the spoilage of large quantities of human foodstuffs -- the souring of milk, the rotting of meat, the spoilage of butter, wines, potatoes, vegetables and

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[1]Albert F. Hill, Economic Botany (New York, 1937), McGraw-Hill Book Co., Inc., p. 43.

fruits, both fresh and canned. In their growth in these foodstuffs, bacteria frequently excrete waste products which are toxic to human beings and frequently cause severe, even fatal, types of food poisoning in persons who eat such bacteria-contaminated foods.

Denitrifying bacteria, which are especially abundant and active under anaerobic conditions in wet soils and soils with high organic matter content, break down nitrates through intermediate compounds to free nitrogen gas which escapes into the air. There bacteria thus reduce soil fertility by depleting the nitrogen content of soils.

Of these harmful or disadvantageous relations of bacteria to human life, the bacterial diseases of human beings have the most direct effect upon our personal, individual lives and thus have commanded greater interest and effort than any other phase of bacterial activity. Tremendous sums of money and large numbers of bacteriologists have for many decades been concentrated upon the medical aspects of bacteriology -- the isolation and identification of pathogenic bacteria which cause human diseases, the development of techniques and substances for destroying such bacteria outside and inside the human body, the prevention of epidemics, the building of resistance to disease in human bodies and the ultimate eradication from the earth's surface of all forms of pathogenic bacteria.

A textbook in general biology can devote little space to these vital medical aspects of bacteriology. There are,

however, other phases of this subject which deserve brief mention in this report. An important objective of medical bacteriology is the destruction of pathogenic bacteria wherever they may occur -- inside the human body, on the surface of the body, in soiled clothing, in body wastes, in water and elsewhere. The destruction of such bacteria can be accomplished in several ways -- by heat; by radiant energy, such as sunlight, ultra-violet rays and x-rays; and by the use of chemical agents called antiseptics and disinfectants. An antiseptic is a substance which prevents or stops the growth and activities of bacteria; a disinfectant kills bacteria. Among common disinfectants are iodine, chlorene, formaldehyde, boric acid, camphor, cresote, carbolic acid, sulfaric acid, hydrogen peroxide, sodium perborate, mercuric chloride, silver nitrate and many others. Some of these disinfectants, such as formaldehyde and sulfuric acid, kill or destroy body tissues as well as bacteria and thus cannot be applied to animal bodies. Others, such as iodine and mercuric chloride, may be used externally but cannot be introduced into an animal body because of their poisonous effects upon animal cells. Still others, like camphor, hydrogen peroxide and sodium perborate, destroy bacteria without injuring animal tissues and may be used internally. Among newly discovered substances with germicidal action are the sulfa drugs and penicillin which are used both internally and externally in the treatment of bacterial diseases of man and domesticated animals.

The four methods of food preservation that are in common use -- the application of heat, storage at low temperatures, the use of preservative chemicals and the drying of foods -- should be discussed in class but will not be included in this report.

Beneficial Activities of Bacteria in Human Life

As the preceding section pointed out, bacteria exert many harmful or disadvantageous influences upon human life. This section describes the beneficial activities of bacteria which far outweigh their damaging effects upon mankind. Only the most valuable activities will be presented since the time factor prohibits too prolonged a treatis.

The metabolic processes and products of bacteria are important in many industries. The manufacture of vinegar, of butter, of certain kinds of cheese, of sauerkraut, of dill pickles, the tanning of leather, the curing of black tea, coffee and cocoa beans, the removal of flax fibers from the stems of flax plants, the curing of vanilla pods and the production of ensilage through the fermentation of fodder are examples of industrial and agricultural activities promoted by bacteria. Bacteria utilize in their metabolism various sugars, proteins and other kinds of organic compounds, and in their metabolic activities excrete waste products, some of which have exceedingly important commercial uses. Among these products are acetone, an ingredient used in the manufacture of explosives, photographic film and other products --

butyl alcohol, a commercial solvent especially valuable in the manufacture of synthetic lacquers -- lactic acid, of special usefulness in the tanning industry -- citric acid, employed as a flavoring in lemon-flavored confections, beverages and other foodstuffs -- vitamins, useful in medicinal preparations and food -- and numerous other organic products. Very recently vitamin B_2 has been discovered as a product of the fermentation of carbohydrates by a species of Clostridium. This vitamin, which has been one of the more expensive vitamins to obtain in quantity and which is valuable as a preventive of pellagra, certain nervous disorders and other diseases, is now another commercially important product of the fermentation of carbohydrates by bacteria of the genus Clostridium.

The manufacture of vinegar is one of the oldest processes in human history which involves bacterial metabolism. Vinegar production begins with the fermentation of carbohydrates, such as sugars in apple juice, to alcohol by yeast. In the presence of oxygen, the vinegar bacterium oxidizes alcohol to acetic acid which is responsible for the characteristic odor and flavor of vinegar. Wine, cider, beerwort, fermented juice of sugar beets and other types of materials are used in vinegar production.

Ensilage is an important product of bacterial metabolism. Green plant parts, such as chopped corn stems and leaves, are packed into a silo where they are fermented by certain bacteria. During this fermentation, organic acids,

especially lactic acid, are produced. These acids have a preservative action which prevents the spoiling of the ensilage.

Bacteria bring about the decomposition of proteins, fats, carbohydrates and other complex organic compounds in the bodies of plants and animals and in their waste products. Thus, they clear the earth of organic debris and return to the soil and air the simple substances which are necessary for the maintenance of soil fertility and for the continued food-making activities of green plants.

The decomposition of carbohydrates, fats and certain other organic substances by bacteria proceeds through various intermediate organic compounds until the final stages of decomposition are reached, when carbon dioxide and water are the final products. As a result of the activities of these microorganisms, the carbohydrate and fatty constituents of dead plants and animals are completely broken down and carbon dioxide is restored to the air.

The bacteria involved in the decomposition of nitrogenous organic compounds are so important in the maintenance of soil fertility that they deserve some description. The groups of bacteria involved in nitrogen transformations in the soil are the ammonifying bacteria, nitrifying bacteria, nitrogen-fixing bacteria and denitrifying bacteria. Ammonifying bacteria transform various protein substances into ammonia in the soil. The nitrifying bacteria of soils are of two kinds: nitrite bacteria, which convert ammonium

nitrogen into nitrites and nitrate bacteria, which convert nitrites into nitrates, the most readily utilized of all nitrogen compounds by green plants. Ammonifying and nitrifying bacteria are directly concerned in the transformation of protein compounds of dead bodies and their wastes into nitrates and thus are essential in maintaining a supply of nitrates in the soil.

Nitrogen-fixing bacteria take nitrogen gas from the air and convert it into organic nitrogen compounds, which are subsequently decomposed by other bacteria and transformed through a series of stages into nitrates. There are two types of nitrogen-fixing bacteria -- those which live in the soil and those which live in small swellings or nodules on the roots of various seed plants, chiefly legumes such as clovers, alfalfa, soybeans and garden beans. In order to insure the development of nodule bacteria, pure cultures of various strains of such bacteria are prepared commercially in laboratories and are mixed with the proper types of seeds before planting or are added to the soil in which the seeds are to be planted. These bacteria are widely found in soils and even in the absence of seed inoculation with these bacteria, the leguminous plant roots sooner or later become infected with them.

While on the subject of soil fertility, it seems a discussion of sulfur bacteria should be emphasized. These bacteria convert hydrogen sulfide, a product of protein decay, through intermediate compounds into sulfuric acid which

undergoes transformation into sulfates. Sulfates are the major source of sulfur, an essential element for the metabolism of green plants. Were it not for the sulfur bacteria, the supply of sulfates in soils would become exhausted and the growth of green plants might become impossible.

Bacteria promote digestive and other processes in the intestinal tracts of animals. The digestion of cellulose by such herbivorous animals as horses and cattle results in part from enzymes excreted by bacteria in their intestines. Bacteria also live in the human intestinal tract, particularly in the lower part of the small intestine and in the large intestine. Their activity in the human gut is not known for sure, but some physiologists believe that they carry on certain digestive activities of value to the body while others believe that lactic acid and other products of these normally occuring bacteria inhibit the growth of putrefactive and certain pathogenic bacteria. Whatever the significance, it is certain that the maintenance of a normal bacterial flora in the intestines is essential to the health of the individual and that any major disturbance in this flora results in derangements of health.

CHAPTER IV

YEASTS

Yeasts are among the economically most important fungi. They respire sugars by means of an enzyme system called zymase to alcohol and are the principal source of alcoholic beverages and industrial alcohol. In dough they release carbon dioxide in their respiration; the bubbles of carbon dioxide thus released cause the dough to "rise". Yeasts also manufacture vitamins and one species has been found which synthesizes proteins from molasses and ammonia; this latter activity may become very important in the production of protein foods.

A few species of yeasts are parasites of higher plants, occasionally causing diseases of tomato fruits and garden beans. Several species of yeasts are pathogenic in man causing a number of serious diseases, best known of which is blastomycosis which attacks the central nervous system and skin of man and often ends fatally. Thrush is a disease of the mucous membranes, found most often in sucking babies and is usually fatal. It is not very well-known in this country since most mothers bottle feed their babies with pasteurized milk.

Most fruit juices containing sugars will undergo spontaneous alcoholic fermentation if expressed and allowed to stand for a time. The microorganisms primarily responsible for the fermentation of these juices are yeasts, in most cases forms which occur upon the surface of the ripe fruits. These are present in sufficient quantities so that usually the addition of yeast is unnecessary for starting the fermentation. However, the kinds of yeasts naturally present may not always be those giving the best aroma, flavor and quality of product. In many cases pure cultures of yeasts are added to control the fermentation. The most important of the beverages produced in this way are wine, cider and perry from the juice of the grape, the apple and the pear respectively. The juices of many other fruits are occasionally used, such as those of raspberries, elderberries, blackberries, cherries as well as other sugary juices from plants such as the palm and the agave.

Alcoholic fermentation is usually carried out in four steps -- malting, mashing, fermenting and aging. The fermentation of the wort and its conversion into beer are initiated by the addition of yeasts. This is usually accomplished by the addition of a pure culture of desirable yeasts. Fermentation is carried out in vats. It proceeds with considerable rapidity for several days, then gradually subsides. The sugar and dextrins originally present in the wort are largely converted into carbon dioxide and alcohol. The beer is then placed in large casks where it slowly continues to

ferment, the yeasts settle out and the aging is complete in from a few weeks to a few months.[1]

Beverages of many types are produced by the distillation of fermented sugar solutions. Brandy is prepared by the distillation of fermented fruit juices, rum from fermented molasses or cane sugar syrups, whisky by the distillation of a fermented mash prepared from molted grain.

Commercial alcohol may be prepared by distillation from fermented sugar solutions of various kinds. The chief problem in its manufacture is to secure a satisfactory and cheap source of sugar. The most important raw materials for production of industrial alcohol in the United States is the molasses by-product from sugar manufacture and in recent years petroleum and natural gas.

The leavens used for breadmaking may be divided into three groups: the relatively pure yeasts secured in the form of brewers yeast, compressed yeasts or yeast cakes; the leavens propagated in the bakery or the home in solutions of various kinds; and the leaven that develops as a result of growth of organisms already present in the flour when mixed with water under appropriate conditions. The essential in the preparation of all bread is to secure sufficient production of gas to cause the dough to rise or become light. Generally, characteristic flavors and aromas develop also in consequence of this fermentation. The gas

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[1]Robert E. Buchanan and Estelle D. Buchanan, Bacteriology, (5d ed., New York, 1951) The Macmillan Co., p. 305.

is the result of alcoholic fermentation of sugars by the yeasts present.

To summarize, yeasts are associated with alcoholic fermentation in brewing, breadmaking, winemaking, in distilleries and in production of commercial alcohol.

CHAPTER V

MOLDS AND MILDEWS

Penicillium and a closely related genus, Aspergillus, comprise probably the most widely spread fungi. They are the common blue and green molds and occur on citrus fruits, jellies and preserves. Their conidia are everywhere in the air and soil, and in the biological laboratory they are frequent contaminations in culture media. Enzymes that they secrete are particularly active in digesting starch and other carbohydrates. When purified, these enzymes are used in preparation of rice wine, soybean sauces and cheese manufacture. A disease resembling tuberculosis is caused by Aspergillus fumigatus, and a number of other Aspergillus species cause diseases in plants. Most fruits, after falling to the ground and breaking their skin, will be readily attacked by molds and yeasts, thus making the fruit unfit to eat.

Species of Aspergillus cause rot of dates and other fruits, decay of tobaccos and cigars, the spoilage of bread, nuts and other foodstuffs, the deterioration of leather goods and fabrics and are responsible for several diseases of human beings such as ear and lung infections and of animals,

especially birds. Aspergillus species are used in the manufacture of alcohol from rice starch and in the commercial production of citric and other organic acids.

Species of Penicillium are responsible for the spoilage of tremendous quantities of foods, including apples, pears, grapes, citrus fruits, bread and for the discoloration and deterioration of paper, books, lumber, leather and other products. Penicillium notatum has achieved wide publicity in recent years as the source of a bacterial drug, penicillin.

The powdery appearance of the surface of leaves infected with many members of Erysiphe and related genera suggests the common name, powdery mildews. All the powdery mildews are obligate plant parasites.[1] Their food requirements are closely integrated with the metabolism of the host plants and so frequently the host plant is not killed. This relationship insures the fungus a continued food supply. Sulfur dusted on the host plants is an effective control. While the mildew may not kill their host, they weaken it and greatly reduce the crop yield. They cause diseases of apple, grasses, grains, grapes, cherry and many other plants.

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[1]Wilfred W. Robbins, T. Elliot Weier and C. Ralph Stocking, Botany, An Introduction to Plant Science, (2d ed., New York, 1957) John Wiley and Sons, Inc., p. 406.

CHAPTER VI

LICHENS

Lichens vary greatly in color -- some are grayish-green; others are white, orange, yellow, yellowish-green, brown or black. They are common on rocks, tree bark, certain types of soil, shingles, fence posts and other wooden objects. Some are able to withstand low temperatures and long periods of drought. Such species are abundant on high mountain elevations, in the arctic tundras, in desert regions and in many other environments where conditions are unfavorable for the growth of other types of plants.

Although they do not usually form a conspicuous part of the vegetation, except in such habitats as those just mentioned, lichens play important roles in nature and in human life. Some species are included in the diets of mites, caterpillars, earwigs, termites, snails and slugs. Tundra lichens are valuable sources of food for reindeer, caribou, musk ox and other wild animals. Lichens are also important in nature in that they excrete organic acids which disintegrates rocks, thus forming soil and preparing substrata in which other kinds of plants can subsequently become established.

In the arctic regions and in the orient, lichens are harvested and dried to be used as human food and sometimes as food for cattle, swine and horses. It is believed that the manna of the Bible was a lichen, which is still eaten by desert tribes of Asia Minor. Lichens have been used in the treatment of jaundice, diarrhea, fevers, epilepsy, hydrophobia and skin diseases.[1] Most of these supposed medicinal benefits are now known to be without scientific foundation; however, a lichen known as Iceland moss produces a substance which has some value as a laxative. This mucilaginous substance is also used in salves, puddings and culture media for bacteria, as well as in sizings for paper and calicoes and in isinglass. Some lichens produce dyes which have been used for centuries in coloring fabrics and paints -- among these dyes are orchill, a blue dye; cudbear, another blue dye; and various brown and yellow dyes. Litmus, the dye used in chemical work as an indicator of acidity and alkalinity, is obtained from certain lichens.

Some lichens contain tannins and are used for tanning animal hides in France and other European countries. In parts of Russia and Siberia, lichens are used in place of hops in the brewing of beer. Some species are ground to powder used in cosmetics and others are used in perfumes and soaps in Europe.

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[1]Harry J. Fuller and Oswald Tippo, College Botany, (New York, 1955), Henry Holt and Co., p. 614.

CHAPTER VII

MOSSES, LIVERWORTS AND HORNWORTS

In comparison with other groups of plants, their economic value is not immediately obvious, although indirectly the part they play in nature may lead to a loss or gain of millions of dollars. Bryophytes are important land formers in that they are among the first plants to colonize rocky ledges on hillsides and other exposed areas. Liverworts and mosses, together with lichens, establish themselves on these bare areas and partly by chemical and partly by mechanical action, they convert the top surface of the rocky ledge into soil. Upon dying, they build up the organic matter in this newly created soil. Soon there is sufficient soil that ferns and flowering herbs are able to grow and later, trees and shrubs may grow in these areas. As a result, a forest may grow in this once barren area.

Bryophytes are important in prevention of soil erosion. They hold the soil in place and keep it from washing away. They are important in flood control. They have tremendous absorptive capacity, and so they take in water and hold it, preventing excessive run-off in times of heavy rainfall.

Some of the larger mosses have been used for packing material in shipping fragile goods. The most important

product from mosses is peat, a valuable fuel product in some parts of the world.[1] Since mosses have the ability to store large amounts of water, they are used in shipping live plants and small animals.[2]

Certain mosses are also used for surgical dressing because of their absorptive properties and also antiseptic properties.

To summarize, Bryophytes are economically important in the following ways: build up land on rocks and cliffs; help prevent erosion; help prevent floods; packing material; furniture stuffing; forms fuel known as peat; fills in ponds and lakes; used to pack living plants and small animals; used as a surgical dressing; bedding for livestock; and by gardeners to increase the porosity of the soil and its water-holding capacity.

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[1]Harry J. Fuller and Oswald Tippo, College Botany, (New York, 1955) Henry Holt and Co., p. 622.

[2]Nelson Coon, Using Wayside Plants, (Watertown, 1957) Eaton Press, Watertown, Mass., p. 83.

CHAPTER VIII

CLUB MOSSES AND HORSETAILS

Very few of the members of the Lycopsida have any economic value. The spores of some are used by druggists in preparation of pills and ground pine is used in the making of Christmas wreaths. Some are grown for ornamental purposes. Corms are eaten by ducks, muskrats and other aquatic animals. The chief economic importance is that the dead bodies of some forms of Lycopsida were transformed into coal.[1]

Horsetails are of little economic importance. They were once used by our early settlers to clean and to polish pots, pans and floors. The chief economic significance of the horsetails is their contribution to the formation of coal deposits.[2]

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[1]Albert F. Hill, Economic Botany, (New York, 1937) McGraw-Hill Book Co., p. 133.

[2]Ibid, p. 156.

CHAPTER IX

FERNS

Ferns are extensively grown in greenhouses and gardens because of their endlessly diverse and beautiful foliage. It has been said that "God made ferns to show what He could do with leaves." Rhizomes of certain ferns are eaten by some persons who must have an aboriginal digestive system to handle them because of the large quantities of tannin in them. A drug is derived from the rhizomes of the male fern and this is used to expell parasites such as tapeworms, liverflukes and others. In the tropics, fern leaves are sometimes used as thatch and the stems of tree ferns may be used in building small houses. Fossil ferns also contributed heavily to coal formation.

To summarize, ferns are of economic use in the following ways: ornamental plants; edible rhizomes; stuffing fibers for pillows and mattresses; thatching; drugs from male fern; and fossil ferns in formation of coal.[1]

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[1]Ronald Good, Plants and Human Economics, (Cambridge, 1933), University Press, p. 164.

CHAPTER X

CONIFERS

Since the gymnosperms and angiosperms are the best known members of the plant kingdom and their economic values easily found in most school libraries, only their most important uses will be summarized in this report.

The conifers find their greatest use as sources of lumber, timbers, fuel and structural materials. One has only to list the important timber-producing trees to appreciate the tremendous value of this group -- pine, douglas fir, redwood, spruce, fir, cedar, hemlock, cypress and others. Turpentine, various oils, charcoal, tar, wood gas, resin and methyl alcohol are among the valuable products derived from conifers. Several of the conifers are important sources of pulpwood for the manufacture of paper. Hemlock bark supplies tannins for the tanning industry, for ink making and for the manufacture of drugs. The southern hemisphere kauri pine produces copal which is an important varnish resin. Amber, which is used in making ornaments, is fossil resin produced by an extinct pine which once grew on the shores of the Baltic Sea. Several pines bear edible nuts. Ephedrine, used in the treatment of colds and other respiratory disorders, is a derivative of the genus Ephedra. Fin-

ally, the use of spruce, fir and other conifers are used as Christmas trees.

CHAPTER XI

FLOWERING PLANTS

There is no question but that the flowering plants are economically the most important class of plants in the whole plant kingdom. It will suffice here to give a brief listing of many of the products of the flowering plants. The categories include: (1) food -- vegetables such as beets, carrots, cabbages and dozens of others; cereals such as rye, oats, wheat, corn, barley, etc.; fruits, nuts, sugarcane and others; (2) shelter -- structural timbers and other uses of woods such as oak, mahogany, walnut, maple, etc.; (3) clothing fibers -- cotton, flax and many others; (4) drugs - quinine, belladenna, cocaine, etc.; (5) rubber -- all natural rubber is derived from the flowering plants; (6) fuel -- oak, hickory, etc.; (7) spices -- ginger, cinnamon, cloves, etc.; (8) perfumes -- rose, geranium, jasmine; (9) dyes -- logwood, indigo, etc.; (1) gums; (11) resins -- for varnish, shellac and lacquer; (12) oils -- soybean, coconut, etc.; (13) tobacco; (14) beverages -- coffee, tea, cocoa, chocolate, etc.

It should be added that this is by no means an exhaustive list of the almost endless economic uses of the Angiosperms.

CHAPTER XII

PLANT DISEASES AND THEIR NATURE

Plants, like animals, are susceptible to attacks by other living organisms which may live inside them or upon them. The parasitic organisms which invade the tissues of plants and rob them of food or injure them in some other manner are called pathogens and the disturbance which they bring about are called diseases. A plant disease may be defined as any abnormal physiological or morphological condition which is of sufficient duration to cause a marked disturbance and which is induced by the attacks of pathogens or by unfavorable conditions, such as deficiencies in soils of essential nutritional elements or internal physiological abberrations.[1]

The plundering of food from the tissues of a host plant by the cells of a parasite decreases the stores of material which the host uses in its growth and thus leads to stunting and retardation of growth processes. Parasites frequently form metabolic waste products which are toxic to host tissues and cause their death. The mere presence of parasitic organisms within the tissues of a host often induces abnormalities through simple mechanical effects as, for example, in

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[1]Harry J. Fuller and Oswald Tippo, College Botany, (New York, 1955) Henry Holt and Co., p. 692.

certain wilt diseases in which the death of a host is in part a result of the stoppage of conducting cells by masses of bacteria. Parasites frequently secrete considerable quantities of growth substances which accelerate the growth of certain cells and produce various types of abnormal enlargements, such as galls. The diseases which result from a deficiency of essential chemical elements are attributable to abberrations in the normal physiological activities of the diseased plant; for instance, a deficiency of iron induces a condition in which chlorophyll fails to develop, a lack of sulfur, nitrogen, or phosphorus hinders the synthesis of proteins.

The effects which are produced in a diseased plant or part of a plant by such disturbances are called symptoms. These symptoms constitute the means by which plant pathologists are able to detect the presence of disease and to distinguish among various kinds of diseases. Among the common external symptoms of plant diseases are the following:

1. Wilts, in which the aerial portions of plants wilt and dry out. Example: Wilt diseases of cucumber, watermelon, tomato, potato, corn and carrots.

2. Scabs and blotches, which are lesions produced by the growth of a pathogen in surface tissues of the host. Examples are apple scab and potato scab.

3. Rots, soft, discolored masses of tissue, the cell walls of which are destroyed by a pathogen. Some examples are soft rot of peaches, bitter rot of apples and rot diseases of strawberries and sweet potatoes.

4. Galls, which are enlargements formed as a result of accelerated growth of the host tissues invaded by a pathogen. Some common galls are crown gall of alfalfa, clubroot of cabbage, insect galls on leaves and stems and

black knot of plum.

5. Leaf spots, usually brownish areas of dead tissue killed by parasites present in the leaves.

6. Cankers, depressed, dead areas of the surface tissues, resulting from infection by bacteria or higher fungi. Some well-known diseases showing this symptom are the fire-blight diseases of apples and pears and chestnut blight.

7. Blights, the sudden death of blossoms, young leaves and twigs, usually before they are fully developed. An example is the fire-blight of pears.

8. Hyphae, or fungus threads which frequently form whitish or grayish patches upon the surface of leaves and fruits. The powdery mildews cause this symptom.

9. Pustules, or blisters, formed by the rupture of the surface tissue of a host by spore masses or fruiting bodies of pathogenic fungi, such as wheat rust.

10. Chlorosis, failure of chlorophyll to develop, which is caused by mineral deficiencies or by viruses and certain fungi.

11. Mosaics, or unequal development of chlorophyll in different parts of a leaf, caused chiefly by viruses. Tobacco mosaic and tomato mosaic are two well-known examples.

12. Discolorations, or the development of unusual colors in the diseased tissues, such as in the black heart disease of potatoes.

The principal agents responsible for many diseases of seed plants are outlined as follows:

1. Bacteria, which cause the following important diseases: fire-blight of apples and pears; wilt diseases of corn, cucumbers, melons, potatoes, tomatoes and squash; crown galls of apple, alfalfa, raspberry and grape; blight of beans; soft rot of vegetables; citrus canker and several others.

2. Higher fungi, are responsible for the rusts and smuts of cereals; bitter rot of apples; apple scab; Dutch-elm disease; chestnut blight; potato blight; downy mildew of grape; brown rot of peaches and many others.

3. Parasitic flowering plants, such as mistletoes and dodders attack many other flowering plants including legumes, pines, oaks, hemlock, douglas fir, apple and many other host species.

4. Nematodes, or roundworms, attack the roots, stems, and leave of numerous host species, causing the nematode diseases of wheat, rye, clover, tomato, cotton, sugar beets, tobacco and many other kinds of flowering plants.

5. Insects, are important as carriers of disease and also responsible for diseases as a result of their chewing, boring, egg laying and sucking activities.

6. Viruses, are responsible for a large number of diseases, among which are tomato mosaic, potato mosaic, potato leaf roll, mosaic disease of cucumbers, muskmelons and other melons, curly top of beets, alfalfa, cabbage, turnips, radish and others.

7. Chemical deficiencies result in physiological derangements because of the lack of certain essential nutrient elements such as iron, magnesium, sulfur, etc. Deficiencies in essential elements may induce weakness in a host and thus allow pathogens to develop in the host tissues.

Environmental factors also frequently exert indirect influences upon plant diseases, chiefly through the effects of temperature and moisture conditions upon the host plants or upon the parasitic organism causing the disease. It has been often observed that the severity of various plant diseases fluctuates considerably from year to year, a fact which is explained mostly by seasonal variations in environmental conditions. For example, the bacterial wilt disease of sweet corn is usually much more severe in a summer which follows a mild winter than during a season following a very cold winter. Also, the potato scab disease is usually more severe when the host plants are growing in an alkaline rather than in an acid soil. Varying environmental factors thus influence the degree of disease resistance in host plants, the rate of growth and virulence of pathogenic organisms, the rate of spore production, the dispersal of spores and also the germination of spores.

One of the major objects of plant pathologists is to devise effective methods of combating plant diseases, either by holding them in check or by eradicating them completely. The principal methods employed in the control of plant diseases are:

1. Spraying and dusting, which is the application of liquid or powdered chemical preparations to the parts of plants which are diseased or likely to become diseased. Some of the sprays include copper and sulfur to combat fungi; lead, nicotine and arsenic to control insects; and other chemicals according to the pathogen.

2. Seed treatment, the soaking of seeds for brief periods of time in solutions of chemicals which kill the spores of higher fungi or bacteria which may adhere to the coats of seeds. Some of these solutions contain formaldehyde and mercury compounds, which kill spores and bacteria without injuring the seeds if they are not left too long in the solutions.

3. Eradication, the removal and destruction of infected plants to prevent the spread of diseases to healthy plants.

4. Checking insect carriers, the reduction in numbers or destruction of the insects which carry disease-producing agents, such as bacteria, fungus spores and viruses. This is the only effective method in checking virus diseases.

5. Quarantine, the regulation of traffic in plants between areas with certain diseases and other areas in which those diseases have not yet appeared.

6. Breeding of resistant varieties of crop plants, a method of eliminating the harmful effects of certain diseases by breeding new varieties of crop plants which are resistant to particular diseases. As resistance varies among host varieties, so virulence varies among pathogens; thus it is impossible to develop varieties of crop plants which remain permanently resistant to particular fungus diseases.

The actual kinds of injury caused by plant diseases and responsible for the undesirability of diseased plant produce are varied. Some disease cause flowers, fruits, and other parts to become stunted, malformed or discolored so that they

become unfit for commercial use. Other diseases render the products derived from the host plants distasteful or poisonous. Another of the effects of plant diseases is to reduce crop yield to such an extent that the cultivation of certain crops may become economically unprofitable.

CHAPTER XIII

SUMMATION OF ECONOMIC BOTANY

Throughout this part of the report, emphasis has been placed upon the importance of plants in human life as sources of food, of oxygen, of wood, of drugs and of other products. For the most part, these products have been mentioned briefly and no organized account of the principles underlying man's use of plant products and of the features of plant products exploited by man has been given. This part of the report presents such an account in a condensed form. The plant products which are most valuable are arranged for the sake of convenience into several groups which are discussed in succeeding paragraphs. A brief glance at these catagories indicates that most of these products are derived from the true flowering plants, the dominant plants of our earth at the present time.

1. Foods. The complete dependence of human beings and of all other animals upon the food synthesized by green plants has received such emphasis in earlier chapters that little additional comment is required. Our cereals are man's basic food crops. They, together with legumes, fruits, vegetables and nuts are all products of the flowering plants. In addition some foods are products of lower plants: mushrooms, truffles, morels and puffballs from the fungi; Irish moss and edible kelps from the algae; and pine seeds from gymnosperms. The flesh of animals is produced at the expense of plants.

2. Fibers. Fibers are used principally in the weaving of cloth fabrics and in the manufacture of rope, string, thread, nets and bags. Some kinds are used in the production of rayon, of paper, cellulose lacquers, cellophane and other industrial commodities. The most valuable plant fibers are cotton, linen, jute, Indian hemp, Manila hemp, sisal hemp and ramie.

3. Drugs. Although many of the plant drugs used by mankind in earlier periods of history have been supplanted by synthetic drugs, there are still many kinds of medicinal substances of plant origin which are extremely valuable in modern medicine. Among these are quinine, used in the treatment of malaria; digitalis, a valuable drug in certain types of heart disease; ephedrine, an important ingredient in nasal sprays; cascara and senna, gentle laxatives; morphine, effective in easing pain; cocaine, used in local anaesthesia; antibiotics, destructive foes of many kinds of pathogenic bacteria; balsams, used as soothing and healing agents and many others.

4. Beverages. The study of the history of beverage plants indicates that the human civilizations which arose in different parts of the world developed their own characteristic beverages. Tea was the beverage of eastern Asia, cocoa of the people of Mexico and Central America and coffee in northeastern Africa and Arabia. These beverages are used by man partly because they contain mild stimulating alkaloids, such as caffein, and partly because of their pleasing flavors and aromas.

   Alcoholic beverages are the products of the fermentation of sugars by yeasts. Fruits, grains and other plant products rich in sugars and starches are favorable food sources for yeasts.

5. Gums and related substances. These are substances which are natural derivatives of cellulose and other carbohydrates and which are sticky when they are wet. Gums, such as gum arabic from North Africa, swell and dissolve in water, forming viscous liquids used in the manufacture of mucilages and other adhesives, as binders in medicinal pills, as stabilizing agents which keep solid particles in suspension in liquids, as soothing agents in cough syrups and as stiffening agents in ice creams, meringues, candies and other confections.

6. Essential oils. They are odoriferous substances which are generally regarded as waste products of metabolism and which occur widely in plant tissues. Unlike true oils, they evaporate rapidly when exposed to air. They are extracted from the tissues in which they develop, and are used by man in many ways. Essential oils from

flowers of jasmine, carnation, lavender, roses and other plants give pleasing odors to perfumes, soap and other cosmetics. Oil of camphor is used in medicinal preparations, in cosmetics and in the manufacture of celluloid. The odors and flavors of such spices as cinnamon, nutmeg, ginger and cloves, used in flavoring foods, are attributable to essential oils. Oil of turpentine, from pines, is important as a paint solvent and many other types of essential oils are used in deodorants, in incense and other products.

7. Resins. Resins are substances which develop in some plant species as a result of the partial or complete oxidation of essential oils. Some are sticky, viscous liquids, while others are hard, brittle solids. Resins dissolved in organic solvents are called varnishes; when the solution is spread out in a thin film, the solvent evaporates, leaving a hard protective layer of resin. Many resins have medicinal properties and are used in soothing ointments, in cough medicines and in nasal preparations. Some are used in perfume to retard the rate of evaporation of the essential oils responsible for the perfume odors and thus prolong the fragrance. Rosin, a distillation residue of turpentine resin, is widely employed in the manufacture of linoleum, oil cloth, printers ink, roofing compounds, paper sizing and other industrial products.

8. Tannins. These are organic compounds which occur in many types of plant tissues and which are regarded as metabolic wastes since they tend to accumulate in dead or inactive tissues. They are extracted commercially from bark, from wood and from leaves. Tannins react with proteins of animal skins in such a manner that the skins become and remain soft and pliable. In the absence of this tanning treatment, skins soon become hard, brittle and unsuited to the manufacture of shoes, bags, belts and other leather products. They are also used in the manufacture of certain types of inks.

9. Dyes. Dyes extracted from the tissues of seed plants have been used by man for thousands of years for the coloring of fabrics and skins and for personal adornment. Within the past seventy-five years, many natural dyes have been supplanted by synthetic dyes prepared by organic chemists, so that the economic importance of plant dyes has been steadily diminishing. Nevertheless, a few plant dyes have persisted as important commodities in world trade, largely because they possess certain qualities not supplied by synthetic dyes. For example, the best and most nearly permanent black dye available is logwood (haematoxylon), derived from a tropical American tree, and used in dyeing fine fabrics and in the staining of biological tissues.

Indigo, a deep blue dye from plants, is unrivalled in the permanency of its color and is thus still an important natural dye. Fustic, from a tropical American tree, furnishes important yellow, olive and brown colors still widely used in the dyeing industry. Several plant dyes are commercially valuable in the coloring of foods and beverages, since they are odorless, tasteless and without adverse physiological effects upon human beings. Dyes of this type are saffron, a yellow dye used in coloring foods and medicines, annato, a yellowish-orange dye utilized in coloring butter, cheese and other food products and chlorophyll, the abundant green pigment of plants, used in coloring foods and beverages.

10. Fatty oils and related substances. These are true oils and fats, synthesized by plants and commonly stored in seeds, fruits and other parts as reserve foods. Many of these oils, for example, olive oil, soybean oil, corn oil, and cottonseed oil, are important foods in human diet; they are used as cooking oils, in the manufacture of oleomargarine, salad oils and vegetable shortenings and in the tinning of fish and meats. Some fatty oils, such as linseed oil and tung oil, dry rapidly upon exposure to air, hardening to form durable films; such drying oils are widely used in the manufacture of paints, linoleum and printer's ink. Coconut oil, olive oil, African palm oil and other oils are the major fatty substances used in the manufacture of soaps. Oil cloth, artifical leather, putty, glycerine, nitroglycerine and lubricants are other important products of fatty oils.

    Plant fats, which are chemically related to oils but which differ from them in their solidity at room temperatures, include cocoa butter, an important ingredient of cosmetics, confections and medicinal ointments, and nutmeg butter, used in medicines and candles.

    Plant waxes are chemically related to fats and are harvested chiefly from leaves and fruits, on the epidermal layers of which they sometimes occur in considerable quantities. Most valuable of the plant waxes is Carnauba wax, a product of the leaves of a Brazilian palm. This is widely employed in the manufacture of candles, wax varnishes and polishes and phonograph records. A wax which is well known in the United States, though of minor commercial value, is bayberry wax, derived from the fruits of a small shrub native to the northeastern states; bayberry wax is used in the manufacture of candles.

11. Latex products. Latex, a viscous, milky juice of unknown physiological significance, occurs in several hundred species of flowering plants. The latex of some species contains organic substances which harden upon exposure

> to air or chemical treatment and which form pliable or elastic solids. Most familiar and most valuable of these is rubber, which, because of its elasticity, pliability, and resilence, is used in hundreds of products of great economic importance: tires, inner tubes, hose, mattresses, shock absorbers, drug and surgical appliances, cements and many others. Most of the world's natural rubber is a product of the Para or Brazil rubber tree, which is a native of the Amazon basin and which is widely cultivated in the East Indies, Malaya and Africa. Another latex product of economic value is gutta-percha, from several species of Asiatic trees; gutta-percha differs from rubber in that it is only slightly elastic; it is resilient and pliable, however, and finds important uses in the insulation of submarine and other kinds of cables, in the manufacture of golf balls, telephone mouthpieces and receiver cases, surgical splints and apparatus and in dentistry for temporary fillings, dentures and molds. Similar to gutta-percha is balata, a product of a tree native in northern South America; balata is frequently used as a substitute for gutta-percha, and is a common ingredient of machine belting. Another latex product, chicle, comes chiefly from southern Mexico, Central America and Venezuela and is the principal constituent of chewing gum.

Any discussion of the effects of plants upon human life must include at least brief mention of some of the social consequences of plant exploitation. Addiction to opium, marijuana and other narcotics of plant origin is a grave social evil attributable to the exploitation of a few species of flowering plants. Another social evil, negro slavery, was a consequence of the desire of plantation owners to gain profits from the cultivation of cotton and sugar cane, crops which, until recently, required an abundance of cheap hand labor. Share croppers and migrant farm workers occasion many social problems which are among the major unsolved social difficulties of our contemporary life. Greedy and wasteful exploitation of grasslands and forests have again and again in human history yielded their tragic harvest: erosion, destruction of

topsoil, barrenness of the land, misery, starvation and weary migrations from the dustbowls of human history, those of Persia, China, Carthage, of parts of Oklahoma and Kansas. Lack of diversification in agriculture, with its too-frequent problem of over-production and ruinous prices, is another source of social and economic problems which are still unsolved in our civilization. The economic exploitation of plants in the future will increasingly involve in greater degree, for its guidance, scientists with training in economics, sociology, and other social sciences, and statesmen with an appreciation and knowledge of biological facts and principles.

CHAPTER XIV

PROTOZOA

Protozoa have had a profound influence on the progress of civilization and are still an important problem in the tropics. Human beings are parasitized by no less than twenty-six species of protozoa. Some of these are harmless or of very little importance, but others are responsible for diseases in millions and the deaths of hundreds of thousands of human beings every year. The large intestine is a regular menagerie of protozoa for five species of amebas live here. Amebic dysentery, a disease very common in the Orient due to the use of human feces to fertilize their vegetable crops, kills thousands of people a year in the Far East.

Sleeping sickness, a disease of Africa and the tropics, is caused by a protozoa carried by the tsetse fly. This little protozoan has kept parts of Africa from being developed or even explored to any extent. Malaria is another disease caused by a protozoan carried by a species of mosquito. Several species of protozoans sometime become very numerous in water confined in reservoirs and render it unfit for drinking purposes. When the skeleton-building protozoa that live in the sea die, their skeletons slowly sink to the bottom. The skeletons accumulate on the sea bottoms in such

incredible numbers as to form a great ooze. The greater part of the bottom of the Atlantic Ocean is covered with it, an area of about twenty million square miles. As the deposits increase, the ooze becomes compact and finally solidifies in the form of limestone called chalk. The pyramids of Egypt were built up of stone formed by the skeletons of these tiny animals.

Detailed information on the role of beneficial protozoans in the general scheme of things is sadly lacking, but we can make a few general statements.

They are probably of most importance in the so-called food chain that occurs in oceans, lakes and streams. Here the small animals eat smaller plants and animals, and they are in turn eaten by larger animals. This process continues up to the food and game fish important to human beings. These animals are also of tremendous value in helping to maintain bacterial efficiency by eating the excess population of bacteria. If sewage or similar materials are dumped into water, one big factor that determines when the water will be pure again is the efficiency of the bacteria which destroy the organic material. These bacteria work best if they are not overcrowded and here is where the protozoans come in.

CHAPTER XV

SPONGES

The sponges of commerce come from the eastern Mediterranean Sea, the West Indies and the coasts of Florida and Central America. The finest sponges are obtained in the Turkish waters. Florida is the only state in the Union which has a sponge fishery, and there it is confined to the southwestern part of the coast, along the reefs and between St. Mark's and Anclote Keys. The former is known as the Key ground, with its centre at Key West; the latter as the Bay ground, with its centre at Tampa Bay. Negatively, certain sponges are of economic importance because of their destructiveness to oyster beds, either by smothering the oysters or by boring through their shells and thus killing them.

There are a few sponges that live in fresh water, and all with commercial value are found in salt water. The living sponges, which somewhat resemble pieces of raw liver, are collected on fishing boats and prepared for market. Methods of treatment vary but the objective in all cases is to remove all the living material from the sponge, leaving the marketable spongy skeleton. Even animals find uses for the sponges. Many species, including fish, secrete themselves

among the channels and pores of living sponges and certain crabs attach small pieces of living sponges to their backs. These pieces grow and within a short time the crab is covered. This camouflages him so that he can hide from his enemies and sneak up on his food.

CHAPTER XVI

COELENTERATA

There is no simple common name for the group of animals that includes the jellyfish, corals, hydroids, sea anemones and many similar species. They are usually spoken of as coelenterates, a term derived from the scientific name of the group. These animals are all aquatic and most live in the ocean, although a few occur in fresh water. In structure coelenterates are among the simplest of animals, but some of them have considerable influence upon the life of people and other animals. Many of the species have tentacles covered with tiny stinging cells which are used for defense and for obtaining food. The Portuguese man-of-war, a jellyfish, has been known to kill and eat a full-grown mackerel. Despite their stinging cells, a jellyfish itself does not go unscathed. Various coelenterates are used as food by other marine animals and the ocean sunfish subsists almost entirely upon jellyfish and other coelenterates.[1] Some people, especially the Japanese and other orientals, use jellyfish for food. They are dried and treated with salt and alum. Before being eaten, the concoction is usually soaked, flavored and

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[1] Osmond P. Breland, Animal Friends and Foes, (New York, 1957) Harper and Brothers Publishers, p. 223.

cooked. Jellyfish are also pests along beaches because of their sting and a few deaths have been reported due to their sting.

Hydra and other species have been thought to help destroy organic waste particles in water and also mosquito larvae. Some species on the other hand eat oyster larvae and they cause large economic losses. Of this group, corals are probably the most important economically.

The skeletons of some coral are valuable for making trinkets and jewelry; this is especially true of the precious coral of commerce. These corals form upright branched colonies somewhat similar to small trees and shrubs. The central axis of the branches is a hard bright red core, and it is from this that beads and other jewelry are made. Precious corals occur only in parts of the Mediterranean Sea and in the Sea of Japan. Many Pacific islands are made almost entirely of coral rock and great reefs of one kind or another are known in various of the several oceans. Coral reefs have been built by millions of tiny animals, the reef-building corals, which live in enormous colonies. There reefs are formed by the skeletons of limestone which each of the little coral animals secretes about itself. The skeletons are cup-like in form and the soft-bodied corals can partly withdraw into them for protection. The cup of a colony are cemented together and, as the animals die, younger individuals become attached to the old skeletons and continue the formation of a reef.

CHAPTER XVII

ECHINODERMS

The echinoderms are the starfishes, brittlestars, sea-urchins, sea-cucumbers and sea-lillies. Few animals are more appropriately named than the echinoderms, a name meaning spiny-skin. All of these creatures are marine and can be seen only in the ocean. They are very complex and hence not studied intensively in a beginning course, but there are four reasons in particular that we study them and these are:

1. The change from a bilaterally symmetrical larvae to a radically symmetrical adult;
2. The resemblance of the larvae to the larvae of certain other phyla, a resemblance that has led some to believe that they represent a stage in the evolution of the vertebrates;
3. The powers of regeneration of many species;
4. The results of extensive experiments on artificial parthenogensis which have been carried on with echinoderm eggs.

The value of echinoderms in their relation to other animals is problematical. Many animals can open a clam or oyster by breaking its shell but a starfish pulls the shells apart. The animal wraps itself around an oyster, attaches its tubefeet to the shells and starts pulling. The starfish has hundreds of tubefeet and it can keep up a steady pull; it uses the feet in groups, thus allowing some to rest while

others are pulling. At last the oyster or clam is worn down and the shells fall apart. Oyster fishermen learned that starfish could be caught in large numbers by scraping mops over the sea bottom and over the oyster beds. The starfish catch the strands of the mop and are hauled out of the water.

Sea cucumbers are popular for food in some parts of the world. In the Phillipine Islands and parts of the Orient, sea cucumber fishing has become a large industry. The creatures are cleaned and dried, then sold as trepang which is used primarily in the making of soup.[1]

No animal is more aptly named "pin cushion" than the sea urchin, with its body covered by long spines. The spines are easily broken off, and woe betide the barefoot wader who accidentally steps on one of these animals. The spines can cause nasty wounds and they are reported to be poisonous in some species. Some years ago, a small industry based on sea urchin eggs was located on Barbados, an island of the West Indies. This industry was dependent upon the collection and sale of urchin eggs. In Italy today, the eggs of sea urchins are a popular food and is known as fruit of the sea. Near the turn of the century, when biologists were intensely studying the process of fertilization and development, it was found that sea urchins made excellent subjects. As a consequence, much of our knowledge of embryology was first

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[1]Robert W. Hegner, College Zoology, (5d ed., New York, 1947) The Macmillan Co., p. 362.

acquired from the study of sea urchin eggs.[1]

[1] Osmond P. Breland, Animal Friends and Foes, (New York, 1957) Harper and Brothers Publishers, p. 231.

CHAPTER XVIII

WORMS

Flatworms

There are three major kinds of large human tapeworms. These parasites are found in various parts of the world, including the United States. They are the pork tapeworm, the beef tapeworm and the fish tapeworm. A person gets the parasites by eating insufficiently cooked pork, beef and fish respectively. In each case, after the infective stage is taken into the mouth, it passes to the intestine, attaches to the intestinal wall and grows into an adult. Tapeworms may get to be quite large. The fish tapeworm is the longest and may reach a length of sixty feet.[1]

The life history of a typical tapeworm might be the best way to study their economic importance. The adult worm lives in the intestine of man; usually only one worm is found in an individual but as many as fifty-nine have been reported.[2] Following the head is a slender neck, the segments of which gradually enlarge toward the posterior end. There may be a thousand or more segments; each is a complete

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[1] Osmond P. Breland, Animal Friends and Foes, (New York, 1957) Harper and Brothers Publishers, p. 219.

[2] Albert M. Reese, Outlines of Economic Zoology, (4d ed., Philadelphia, 1942) The Blakiston Co., p. 34.

animal sexually and they are constantly breaking off and passing to the exterior with the feces. It is estimated that a single worm may produce 150,000,000 eggs per year. These, together with the entire segments, are passed to the exterior and may be taken into the digestive tract of a beef or hog with grass or in drinking water. While still in the segments, proglottids, the eggs are fertilized and develop into tiny embryos. These embryos, if taken into the intestine of an animal, burst out of their containing shells, burrow through the digestive walls of their second host and become encysted in the muscles. If, now, this muscular tissue be eaten, imperfectly cooked by man, the encysted worms will complete their development inside the victim. This worm may live inside man for years if not expelled by proper treatment.

The trematodes are represented by the liver, lung, intestinal and vernal flukes of man and other animals, the disease being known in a general way as distomiasis, from Distomata, the name of a group of common flukes. One of the commonest flukes is the one that lives in the bile ducts of sheep and other herbivorous animals. It is found the world over and sometimes causes severe loss among flocks from liver rot.

The tapeworms and flukes are all parasitic in habit and spend almost all of their lives in the body of other animals.

Roundworms

The number of worms in existence is almost incredible.

It has been estimated that more than 80,000 roundworm (nematodes) species infest the forty-odd thousand species of vertebrates. It has also been estimated that in the upper foot of an arable soil the number of nematodes runs to thousands of millions per acre. Until relatively recently, little attention was given to the possible effects upon plants of the soil inhabiting nematodes, but as information on these worms accumulate, there is increasing evidence that some of them are among the most important plant pests in existence. In late 1955 one writer estimated that these worms destroy one-tenth of the total crop production in the United States.

The most harmful species of nematodes attack the roots of plants; the resulting wilting or stunting was often thought to be caused by inferior soil, but it is now believed that the boring of the worms into the roots makes openings which allow fungi, bacteria and other harmful organisms to gain access to the plant tissues. Much land here and abroad which has been abandoned as worn out or exhausted may simply have had an oversupply of nematodes. There is also a possibility that the pests were an important factor in the fall of the Mayan civilization of Mexico.

One of the larger and more common of the roundworms is the genus Ascaris, found as a parasite in the intestine of man, horse and pigs. The species common to man is the human eel worm. It is one of the most common of the human worm parasites, found mostly in children from five to ten years of age and in women more often than men. It is also

more common in warm than in cold climates and is more frequently met with in the country than in cities. The eggs that are passed out of the body in the feces may be taken into the digestive tract of the same or of another person in drinking water, upon unwashed fruits, vegetables or salads, or by simply eating with dirty hands. It is thus easy to understand how young children may be infected and why women, who generally handle the raw fruits and vegetables, are more subject to the disease than men. It sometimes wanders about through the intestine and has even been known to enter the appendix and to cause death by boring through the intestinal wall.

Probably the most widespread and important worm parasite of man is the hookworm, of which there are two chief forms -- the European and the American. The disease caused by this worm is generally known as hookworm disease. Hookworms live in the human intestine where they attach themselves to the intestinal wall, bite through the skin and feed upon blood. If very many of them are present, the patient loses a large amount of blood. In cases of long standing, the patients are in such a weakened condition that they are subject to other diseases.

A person infected with hookworms passes the eggs from his body, and if they are deposited on the ground, they hatch into very small hookworms or larvae. If the bare skin of a person, such as hands or feet, comes in contact with the larvae, the parasites bore into the skin. They enter small

blood vessels and ultimately reach the intestine where they develop into adult hookworms. Complete elimination of hookworm disease could be accomplished within a relatively short time if all human beings could be taught proper sanitary habits.

Trichinosis is a disease caused by a small nematode sometimes called the trichinella worm. The adult worms get into the human intestine by eating uncooked pork in which there are cysts. The cysts dissolve in the intestine, thus liberating the worms which in five or six days or able to produce embryos, and this they may continue to do for a month if the adults are not gotten rid of by purgatives or by diarrhea. In any case, the adult worms usually disappear in five or six weeks. The embryos immediately begin to migrate into the surrounding tissues, finally finding their way to the muscles of their host where they grow until nearly one mm. in length. As it grows, the embryo coils itself into a spiral and forms an elliptical cyst around itself as it lies in the connective tissue between the voluntary muscle fibers. This cyst after seven or eight months begins to degenerate and becomes calcified, and the worm is destroyed though it may take from two to ten years. If the disease is recognized before the embryos have begun to migrate, it may be arrested by use of calamel and other purgatives but after the worms are in the muscles, there is no treatment that will affect them.

Many centuries ago when the Israelites were wandering in the wilderness, some of them were attacked by creatures

called fiery serpents. The Bible does not tell much about the nature of these creatures, but many biologists believe that they were a kind of parasitic worm called the guinea worm. The adult of this animal is only a fraction of an inch in diameter, but it may be three or four feet long. It lives in the tissues of a human being and, when ready to reproduce, it comes close to the surface of the skin where a blister is formed. The young worms must get into the water to live, and the adult worm usually moves to the surface of the body on an arm or a leg. The head punctures the skin, forming a small vesicle which ruptures and allows the embryos to escape. The worm may then leave the body or it may be carefully withdrawn, care being taken not to rupture it. It is sometimes the custom to wind the extruded end on a small stick to prevent the worm from withdrawing into the body; each day a little more of the worm is wound on the stick until it is all out of the skin. It may also be removed by surgery or may be killed by injections of bichloride of mercury.

Guinea worms are common in parts of Africa and Asia and a similar worm has been found in the United States. The American worm has been found only in animals and probably will not attack people. A person may pick up a guinea worm if he accidentally swallows an infected waterflea in drinking water.

Various minute nematodes are parasitic on beet roots, wheat, tomatoes, potatoes, cucumbers, turnips, lettuce,

trees, soybeans, etc., and hence are of great importance in agriculture.

Some nematodes are beneficial. Some kinds eat other nematodes, and many are parasites of harmful insects. Man has probably exploited the nematode parasite of the Japanese beetle more than any other species. The parasites have been cultivated in the laboratory and distributed over a large area in New Jersey in an attempt to control this important pest. Later examinations showed that in some regions as much as eighty per cent of the Japanese beetle grubs were attacked. The beetle population declined and the nematodes were a major factor in this reduction.

Segmented Worms

In a current issue of an American outdoor magazine, there are thirty-three advertisements dealing with earthworms. These advertisements stem from thirteen states, from New Jersey to Georgia and west to California. In many cases instructions for raising worms are available and all kinds are described. The prices are around a cent each and one dealer maintains he ships 500,000 daily. A majority of these worms are sold for fish bait, but earthworms are also in demand for other reasons. A few years ago after the well-remembered Netherlands floods, several million earthworms were sent to that country from farms in the United States. The burrowing activities of the worms are credited with contributing greatly to the speedy return to cultivation of many flooded

areas.

Charles Darwin was one of the first to point out the value of earthworms. They literally eat their way through the soil, and this helps to keep the soil loose and porous, allowing air and water to enter. At night the worms often come to the surface and deposit mounds of dirt pellets. Darwin estimated that the earthworm pellets on an average acre were sufficient to provide one-fifth of an inch of new soil per year to the surface.

It has recently been reported that certain hybrid earthworms are of tremendous value to fruit and berry growers. The animals are said to cause young trees to grow faster and if added to strawberry beds, the yield will be greatly increased. They are useful for study in biology classes. Birds and other animals use them for food and even human beings use them for food in some countries.

Nearly all ponds or streams have their quota of bloodsuckers which attach themselves to the bare skin of any human being who comes within their reach. These animals are leeches, a kind of worm related to the more familiar earthworm. Those that live in water feed upon small aquatic organisms or upon blood by attaching to man or an animal. The leech has two suckers with which they firmly attach themselves to surfaces and removing one of them from the skin is difficult. The bite of a leech is relatively painless. The animal will fill itself with blood and then drop off its victim; it will not need another meal for weeks or months.

For many years, letting blood from the body of a person was considered a standard medical practice and leeches have often been employed for this purpose. Leeches are not employed in modern medical practice, but even today some amateurs use them for treatment of bruises, such as black eyes.

CHAPTER XIX

MOLLUSKS

The name mollusk means soft. All of the mollusks have relatively soft bodies as compared with those of lobsters, crabs, shrimp and crawfish. Mollusks include snails, clams, oysters, squids, octopuses and similar species. Edible mollusks of this group are often called shell-fish. Some have no shell at all, or only remnants of one. Shell-less mollusks include the octopuses and slugs. The mollusks are the second largest animal group, exceeded in numbers only by the arthropods.

Some authorities consider the bivalves to be useful scavengers because they consume vast quantities of organisms that might otherwise pollute the water. A member of the United States Bureau of Fisheries has estimated that a single husky oyster can strain approximately eighteen gallons of water a day; thus, a single oyster may eat as many as seventy-two million organisms during each day that its straining mechanism operates for eighteen hours.[1]

Oysters are the most important food mollusks in the United States and probably in the world. In the United

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[1] Osmond P. Breland, Animal Friends and Foes, (New York, 1957), Harper and Brothers Publishers, p. 205.

States and Alaska alone, it has been estimated that the yearly catch of oysters amounts to more than seventy-five million pounds. Several kinds of fishery products exceed oysters in the amount that is caught, but only the salmon catch has a greater monetary value.

Most of the oysters caught in the United States are the so-called eastern oyster from the Atlantic Coast, but there is also a fair-sized oyster industry on the Pacific Coast.

Many years ago it was believed that the wild crop of oysters was inexhaustible and each year millions of bushels were taken from beds in the Chesapeake Bay and adjacent areas. Gradually, these natural oyster beds disappeared and the oyster seemed doomed to be eaten out of existence. Then someone thought of coming to the rescue by cultivating the shellfish. Now, thanks to this development, the oyster crop is relatively stable from year to year. Oysters are most valuable as food, but within recent years even the shells have been greatly in demand. They are used in building roads, and for the lime they contain, they are also ground to various sizes as poultry grit. Various types of oysters produce shells that are valuable in making buttons, knive handles, ornaments, etc.; some oysters are more valuable for the pearls they might contain and usually this same species produces a shell that is used in making ornaments.

The pearls, which may be attached to the inside of the shell or may be free between the shell and the mantle, are formed by the same glands of the mantle around some small

body or a nucleus. This foreign body may be a grain of sand, a dead egg, a dead parasite or a small shot or other object introduced by man between the shell and the mantle. The irritation of this foreign body probably causes an active secretion by the mantle glands of the macreous material in concentric layers over the offending object, the result being a pearl whose value depends upon its size, shape and color. Pearls of considerable size are often found in the edible oysters and other bivalves but have little value, as the glands of the mantle do not secrete the proper mucreous material. The true pearl oysters are found in the Indian Ocean, Red Sea, Gulf of California and elsewhere, though the value of the pearls and shells varies in different localities.

The soft or long-neck clam is famous in clam chowders and clambakes. It is essentially a northern form where it was formerly found in enormous numbers. It spends most of its time buried in the sand or mud, sometimes to a depth of a foot. Its long neck reaches to the surface of the sand and is withdrawn when the sand is left bare by the retreating tide, leaving a characteristic hole that reveals the presence of the hidden clam. Although the conditions suitable for the culture of soft clams are quite different from those of oysters, they are not unusual and are fairly well understood. It is estimated that four hundred bushels per acre, at a profit of seventy-five cents per bushel, could be raised.[2]

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[2]Albert M. Reese, Outlines of Economic Zoology, (4d ed., Philadelphia, 1942) The Blakiston Co., p. 68.

The hard or little-neck clam is common along the entire Atlantic Coast, but for some reason is seldom eaten in the South where it is more abundant. The smaller specimens may bring four dollars a bushel and are served in restaurants to be eaten raw from the half shell. They are sometimes found between tides, but usually are in greater numbers in deeper water and are collected from their beds with a large, long-handled rake. Enough work has been done to indicate that culture of this clam might be carried on at a good profit.

There are two species of scallops found along the Atlantic Coast from Cape Cod to Texas. One species likes shallow water and the other deeper water. The only part that is usually eaten is the small, cylindrical adductor muscle, although the rest is perfectly good food.

There are more different kinds of snails and their relatives than any other kind of mollusk. The coiled shell is one of the most characteristic features of snails with which many of us are familiar. Many a tidy housewife has been made unhappy by the sudden appearance of narrow glistening lines that crisscross over walls, sidewalks, porch or basement floors. These ribbons or lines are tracks made by snails and slugs. They crawl on their stomachs and a gland near the head continuously secretes a slimy mucous. This spreads into a moist, smooth surface over which the animal crawls in comfort. Many snails will eat dead plant and animal material. They are useful scavengers, therefore, in aquaria, ponds and streams.

There are various species of snails used for food. It is estimated in Paris alone 200,000,000 snails are consumed in a season, September to April.[3] Snail forms are common in southern France, in Italy and in Spain. Some snails can kill people. These poisonous snails are called cone shells because their shells are cone shaped. They are all marine forms and are found in waters about the Hawaiian Islands, New Guinea, Samoa and Australia.

Some snails that live in the ocean actually eat oysters on the "whole shell". The snail perches itself atop an oyster and starts boring through the shell to get inside. When a hole is completely through the shell, the snail proceeds to suck out the soft parts of the victim's body. There are several kinds of marine snails that attack clams and oysters in this way. Some are called oyster drills. These oyster drills are common along the Atlantic Coast and they sometimes cause considerable damage to commercial oyster beds. The annual loss has been estimated at several million dollars, but much of the damage can be prevented if the seed oysters are freed of the snails before they are put in commercial growing beds.

Some land snails are harmful because they have an appetite for flowers and other vegetation and in some places, they are major pests. The East African snail is one of the most important. In many cases it is almost impossible to grow

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[3]Ibid, p. 72.

crops successfully because of the depredations of these snails.

An octopus has a bulbous body with eight arms or tentacles which are all about the same length. A squid's body is much more elongated; the end opposite the arms has a couple of flattened fins and it is often somewhat pointed. In addition, a squid has ten tentacles, two of which are much longer than the other eight. Both are found only in salt water. There are many different kinds and sizes of squids, and even some of the smaller ones are of some economic importance to human beings. A rich brown pigment called sepia can be made from the ink of certain squids and, in the past at least, this material has been in considerable demand by artists. Some squids are called cuttlefish and from the shells of these come the cuttlebones commonly used in bird cages. Many small squids are used for fish bait, but the most interesting use for them is for human food. Large numbers are consumed even in the United States and in some years, more than a million pounds of squids are captured for food off the west coast of this country.

Even the less attractive octopus is used today for making soup and in ancient times, the Romans and Greeks considered it to be the finest seafood obtainable. In the Far East, both the squid and the octopus are an important source of food.

The sea mussels have for ages been an important article of diet in Europe but for some reason have never become popular in America although the natural beds would supply large quantities at a low cost. As a food material, it is superior

to many articles which are commonly eaten. The mussel breeds at a prolific rate, it develops rapidly, requires less special conditions for growth than the oyster, and therefore may be easily cultivated. They are also used as bait by fishermen and as a fertilizer. They are also being used to some extent in the manufacture of vitamin products.

CHAPTER XX

ARTHROPODS

There are more different kinds of animals among the arthropods than within any other group of the animal kingdom. It is impossible in a report of this kind to discuss the economic importance of such a diverse group of animals; hence, it would be folly to attempt such an undertaking. Since it is the author's aim to create more interest in a general biology course as well as to give the students something to carry with them throughout life, it might be more beneficial to discuss the more interesting, nor necessarily the most important, aspects of this great group of animals. Arthropods of one kind or another are found all over the world, from high mountains to the depths of the ocean, from the arctic to the Antarctic, and from tree tops to deep in the soil. Some can live under such adverse conditions that it has been predicted that they will be the eventual inheritors of the earth.

Insects have been described as man's chief competitors on earth and it is certain that from the human standpoint, they form one of the most important of animal groups. Many insects destroy crops and other products and many carry important diseases, both animal and human. The cost of harm-

ful insects in human misery and suffering is incalcuable, but in cold dollars and cents, it has been estimated that within the United States alone, they cause a direct loss of approximately three and a half billion dollars per year. Of the known insects, only a relatively few can be considered major pests. It has been estimated that there are 84,000 different kinds of insects in the United States, and of that number only six hundred caused enough damage to be considered important. On a worldwide basis it is believed that there are approximately 10,000 kinds of important harmful insects.[1] A biologist once estimated that if all the offspring of a single pair of houseflies lived and reproduced throughout the summer, within six months more than 191 quintillion flies would be produced, enough to cover the earth to a depth of forty-seven feet. Thanks to lack of food, natural enemies and other limiting factors, such a situation never arises. These figures help to explain why flies and certain other insects can appear suddenly in large numbers in the summer.

The rest of this section will deal with common questions and answers of interest as follows:

1. Are fruit flies of any value?

Some of them are harmful because they destroy edible fruits. One group of fruit flies, however, is among the most valuable insects of the world. They have been of tremendous importance in the science of genetics dealing with

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[1] Osmond P. Breland, Animal Friends and Foes, (New York, 1957), Harper and Brothers Publishers, p. 205.

the inheritance of the organism. Fruit flies were selected for several reasons. They are easy to rear in the laboratory, and their small size makes it possible for many colonies to be kept in a minimum of space. Also, equally important, the life cycle of the insect is so short that many generations can be completed within a relatively short time.

2. Will singing mosquitoes bite?

There is a common belief that mosquitoes that sing or buzz will not bite, but anyone who has had much experience with these pests knows that this is not entirely true. The mosquito's song is made primarily by the rapid movement of the wings. Some small gnats similar to mosquitoes do not bite, but will buzz around a person's ears; this is probably one reason for the mistaken belief. Another reason is the difference in the habits of male and female mosquitoes. Only females are the bloodthirsty sex; male mosquitoes do not bite. Male mosquitoes feed upon innocuous substances such as plant juices and nectar, never upon the blood as do the females.

3. What is the most dangerous animal in the world?

The house fly. In view of the number of diseases it carries, few people would argue with this description. Yet, the house fly does not bite. The mouth parts are formed in such a way that the creature could not bite even if it wanted to. The house fly and its relatives may serve in the transmission of approximately thirty diseases and parasites.[2]

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[2] Ibid, p. 143.

Some of these are the most serious diseases in the world and include typhoid fever, cholera, anthrax, tuberculosis, leprosy, plague and polio. In all fairness to flies, it must be said that people can get these diseases in ways other than from the insects.

4. What is the most feared animal of the jungle?

Many animals, such as lions, tigers, elephants, crocodiles and venomous snakes, are feared by a majority of jungle creatures. At one time or another, however, each of these dangerous animals contacts equally brave, stubborn or foolish individual of another species that contests its right of way. There is one group of animals which is feared by all species and when they appear, every living thing including human beings beats a hasty retreat. These most feared of jungle animals are ants.

The ants in question are the driver ants of Africa. These insects move in great armies containing millions or even billions of individuals and they literally drive everything before them. Driver ants are primarily meat eaters and everything in their paths from insects to elephants is likely to be overwhelmed and dismembered.

5. What insects are the most important scavengers?

Many different kinds of insects feed upon animal excrement and upon the bodies of dead animals. Their activities are of tremendous importance in the economy of nature since they speed up decomposition thereby enriching the soil. In some cases carcasses and other objectionable materials are

buried by the industrious insects.

Among the most important insect scavengers are the blow flies, flesh flies, dung flies, burying beetles and the tumblebugs. Burying beetles bury the carcasses of small animals. This they do by digging around and under the animal until it sinks into the loosened soil and eventually becomes covered. Eggs are then deposited on the body which serves as food for the beetle larvae that hatch.

6. What use is made of the lac?

Most commercial shellac comes from a species of insect known as the lac insect. The lac occurs in Burma, India, Formosa, the Phillipines and adjacent areas. As the insects feed upon various plants, they secrete a waxy substance about their bodies which forms encrustations on twigs as much as half an inch thick. The encrusted twigs are collected; the secretions are separated from other materials and refined into shellac. The yearly production of shellac is about four million pounds, of which the United States uses some twenty million dollars worth.[3]

7. Of what value are spiders?

Spiders are sometimes found in large numbers in certain areas and since they eat insects, the chances are that they do a considerable amount of good. Dr. Willis J. Gertsch of the American Museum of Natural History cites an instance of spiders' eliminating an infestation of bed bugs in Athens,

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[3]Ibid, p. 172.

Greece. Camps occupied by Greek refugees had supported thriving colonies of bed bugs for more than a year when there was a sudden and dramatic decrease of the blood thirsty pests. Investigation showed that there was a large number of little crab spiders in the barracks and that a single spider might kill thirty to forty bed bugs in a single day. Thanks to these spiders, the bed bugs were completely wiped out.

8. What insect is the world's worst crop destroyer?

Since early biblical times and probably for many ages before that, certain countries of Africa and Asia have been invaded by plagues of locusts. The insect often occurs in countless millions and when they have finished eating and moved on, not a green sprig remains in the fields on which they had settled. The name locust has been used for at least two distinctly different kinds of insects. One is the cicada, but most biologists limit the term to certain kinds of grasshoppers. There are the shorthorned grasshoppers with relatively short "feelers" or antennae. Those that are most destructive have tremendous appetites for crops of various kinds and most of them are strong fliers. The insects often migrate long distances in hordes and they may occur in such tremendous numbers that a flight literally darkens the sun.

Residents in the eastern United States sometimes experience a local outbreak of grasshoppers, but the damage in this part of the country is minor compared with that in

the states farther west. During a twenty-five year period, from 1925 to 1949, it was estimated that grasshoppers had caused more than half a billion dollars worth of damage in twenty-three states in the western United States.[4] Today, grasshoppers are still considered to be among our most important insect pests and millions of dollars are spent in their control. In some countries, especially the Middle East, millions of people have starved to death as a result of grasshoppers. Some of the swarms have covered as much as two thousand square miles; one in Brazil is said to have migrated on a sixty-mile front and to have taken four hours to pass a given point. During a campaign in Turkey, more than four hundred tons of eggs and twelve hundred tons of grasshoppers were collected within three months.[5]

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[4] Ibid, p. 169.

[5] Ibid, p. 170.

CHAPTER XXI

FISH

There are more different kinds among fish than in any other vertebrate group; one recent estimate places the number of species at 25,000. There are also more individuals of the fish clan than any other kind of vertebrate animal. Anyone who has ever cleaned a fish knows that many of them have an air or swim bladder just below the backbone. The swim bladders of sturgeons, carp, catfish, cod and several other fish are used in the manufacture of a substance called isinglass. In the past isinglass was employed in the bottling of jellies and preserves, but it has now largely been replaced by true gelatin, which is cheaper. Today, the primary use of isinglass is in the clarification of wine. A single ounce of isinglass added to several hundred gallons of freshly made turbid wine causes the liquid to become clear and sparkling within a few days.

On the basis of volume, probably more herring and related species are caught than any other kind of fish. All sardines are small fish that belong to the herring family. Herring are also used in the manufacture of certain kinds of anchovies but are mostly in demand as cured or processed fish -- salted, smoked or kippered -- rather than as fresh fish. Because of the tremendous numbers used, the herring

is considered to be the most important cured fish in the world.

Also of great commercial importance from the food angle are various kinds of flatfish such as flounders, halibuts and turbots. Although salmon rank far down the line in quantity of fish caught, it is believed from the monetary standpoint that salmon are the most valuable fish in existence.

Fish furnish us with a large number of valuable products in addition to food. According to a recent estimate, approximately one-third of the world's catch of commercial fish is used for the manufacture of products other than food. Fish meal and fish oil are the most important of these products. Fish meal was formerly used primarily for fertilizer, but it is now used as an important ingredient of various types of foods for animals such as hogs, cows and chickens. Fish oil is used in the manufacture of various types of soap, paints and varnishes. Other by-products include fish glue, used in the manufacture of stamps, books and in photoengraving work, and fish liver oils. Caviar is made from the eggs of several species of fish.

Both vitamins A and D were formerly obtained from fish liver and at first the principal source was the codfish. Today, many other fish are used, including sharks and dogfish; the livers are processed primarily for vitamin A. Vitamin D is now produced by easier and cheaper methods.

The dogfish, which is a small shark, is one of the principal animals studied in college courses of comparative

vertebrate anatomy and the successful completion of this course is required for entrance into many medical schools. In this course many pre-medical students get their first training in dissection. Dogfish are used in medical training for several reasons. They are numerous and relatively easy to obtain in large quantity. The organ systems are similar to those of man and their skeleton is composed of cartilage rather than bone. Cartilage, which is much softer than bone, allows a student to make successful dissections of complex structures such as the brain, the nerves connected to it, and the delicate tubes of the inner ear.

The accidental introduction of the sea lamprey into the Great Lakes is an excellent example of serious consequences that may result from introducing an alien animal into a new environment. At one time, Niagara Falls prevented ships from passing between Lake Ontario and the remainder of the Great Lakes. These falls were also an effective barrier to any marine animal that might want to take a fling in any of the lakes other than Ontario. Then came the Welland Canal which bypassed Niagara Falls, thus opening a free channel from the lakes to the sea. The reverse was also true and full advantage of the situation was taken by the sea lampreys.

The commercial fishermen soon felt the results of the sea lamprey's presence. At one time, lake trout was one of the most important of the food fishes in Lakes Huron, Michigan and Superior. In 1939 more than a million pounds were taken from Lake Huron; in 1951 the catch had dwindled to

twenty-five pounds. More than five million pounds of trout were caught in Lake Michigan in 1945; only four hundred pounds were taken in 1954.[1] Until these voracious parasites can be controlled, they will be responsible for the loss of millions of dollars to commercial fishermen.

Everyone is aware that fish exhibit an enormous variety of colors. Many years ago, it was found that if the shiny material from fish scales was applied to beads, it would give them a lustre quite similar to pearls. This was a big factor in establishing the costume jewelry industry. This shiny material used to make imitation pearls is called pearl essence. Pearl essence is also used to decorate many other articles such as jewelry boxes, toilet sets and even car fixtures.

The scales of some species of fish such as the tarpon are used in making trinkets and souvenirs. Biologists can tell the age of a fish by studying its scales. Knowledge of how long fish live, how large they are at a certain age and the rate of growth under various conditions is on importance to those interested in the problem of propagating and conserving food and game fish. The demand for shark leather products such as wallets, tobacco pouches, shoes and handbags now far exceeds the supply.

Despite the discovery of DDT and even more powerful insecticides, man still depends upon fish to help him in his fight against disease-carrying mosquitoes. Among the species

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[1] Osmond P. Breland, Animal Friends and Foes, (New York, 1957), Harper and Brothers Publishers, p. 127.

that are particularly effective in destroying mosquitoes are sunfish, goldfish and killfish. A little top minnow that occurs in the United States is probably the most famous of these mosquito killers. A single specimen may devour more than a hundred wigglers within eight hours. Many mosquito abatement districts have specialists who rear fish and distribute them to mosquito-infested areas.

The part fish play in man's recreation can be estimated by the millions of dollars spent annually on fishing licenses, boats, motors and various other equipment. It has been estimated that approximately three hundred million dollars or more is spent annually on this type of recreation.

CHAPTER XXII

AMPHIBIANS

Although not one of the more important groups economically, practically all of the amphibia are of some value to man, and few if any are more injurious than beneficial. Many species are of considerable value as destroyers of insects. Some of the larger forms, like the common mud-puppy and the hellbender, are also useful as scavengers in our streams. On a worldwide basis among amphibians, the large frogs are certainly the most popular as food. In spite of the many people who will not eat frog legs, they are so popular in the United States that the wild population of the country cannot supply the demand. Some years more than half a million pounds of frog legs are imported and frog farms have been established with varying degrees of success. The giant Japanese or oriental salamander has long been eaten in Japan and China and some zoologists state that mud-puppies and hellbenders make good food.

Almost any of the true frogs may be used as food, though many people think only the bull frogs are edible. A similar mistaken idea prevails in the belief that only the hind legs can be eaten; all of it can be eaten and many persons only throw away the head.

Several kinds of amphibians are regularly used for study in biology courses at colleges and universities. Most often used are frogs of various kinds and mud-puppies. The leopard frog is probably used more in elementary courses than any other single kind of amphibia. The retail price of a bullfrog prepared for dissection suggests that the supply houses have to compete with dealers buying bullfrog legs for food. They are listed from one dollar and fifty cents to three dollars and fifty cents each, depending upon size and type of care with which they have been subjected.

Some years ago, a government biologist estimated that toads were worth ninetten dollars and forty-four cents each as insect destroyers. It has also been found that the tadpoles of some species will feed greedily upon mosquito wigglers. Their use for mosquito control on a large scale has been recommended.

CHAPTER XXIII

REPTILES

Next to the amphibians, reptiles have the fewest known kinds among major vertebrate groups. Millions of years ago, however, reptiles were the dominant form of animal life in the sea, on land and even in the air. The reptiles still living today represent only a small remnant of the once mighty hosts which then ruled the earth. It is unfortunate that so many people are either afraid of reptiles or repulsed by them for within this group are to be found some of the most interesting of vertebrate animals. While it is true that some reptiles are dangerous, most of them do far more good than harm.

One kind of snake or another will eat almost anything from insects to people and so far as known, there are no snake vegetarians. Most of the snakes are not particular and their menus include a variety of food. A few are more limited in taste; for example, the egg-eating snake of Africa will eat only bird's eggs and some of the sea snakes seem to eat only fish. The benefits derived from snakes are due to their food habits. Water snakes, in addition to fish, eat turtles and large water insects, many of which destroy young game fish. Hog-nosed snakes and garter snakes consume grubs and

other harmful insects in addition to the beneficial amphibians that they eat. The bull snake feeds primarily upon mice, gophers, rats and other destructive rodents. One five-foot specimen was found to contain thirty-five field mice, which indicates how valuable these serpents may be.

Snakes are eaten in practically all countries where the reptiles are large enough and numerous enough to make collecting worthwhile. In the United States, canned rattlesnake meat has been on the market for years. Crocodilians are hunted regularly for food in many parts of the world, but they are seldom eaten in the United States. Various varieties of lizards are used for food in different parts of the world and turtles are eaten by people of every country in the world. The eggs of certain species of turtles and alligators are also used as food. Not only are turtle eggs good to eat, but in some areas the nests of the reptiles are so numerous that turtle eggs are a staple food for the natives. The eggs of some species are supposed to be more nutritious than hen's eggs. On a worldwide basis, the eggs of sea turtles, including those of the green turtle, the loggerhead, the hawksbill and the leathery turtle, are eaten more than those of any other group. Various kinds of concoctions may be made from the eggs, including fancy, pickled eggs and so-called egg butter.

Many animals plunder turtle nests for food and now man has discovered that the eggs make excellent fish bait. On Reelfoot Lake in Tennessee, the eggs are collected and sold

to fishermen for use on their trotlines.

Several groups of snakes include species capable of killing a human being. These are: the cobra group to which belong the cobras, mambas, kraits, coral snakes and their relatives; the pit vipers which include the rattlesnakes, the moccasins, copperheads, the bushmaster and the fer-de-lance; the true vipers, such as Russel's viper, the gaboon viper and the common viper of Europe; and the sea snakes which are considered to be related to the cobras. Probably more people are killed by snakes in India than in any other country. One reason is that a large part of the inhabitants go barefooted and barelegged.

Most snakes will avoid people if given the chance, and this is the principle that should be kept constantly in mind. In country where venomous snakes are known to occur, always look before you step. High top boots and loose trouser legs offer considerable protection against snake bite.

There are several kinds of crocodilians that occasionally attack people, but the African or Nile crocodile and the salt water species are by far the most notorious man-eaters. The African crocodile occurs in the Nile and many other large rivers over an extensive area of Africa. The salt water crocodile is widely distributed in India and other parts of Asia, Australia and many islands of the Pacific including the Philippines.

There is a common belief that many lizards have a venomous bite. Actually there are only two lizards in the world known to have a poisonous bite and the North American conti-

nent has the honor of harboring both of them. These two are the American Gila Monster and the Mexican Gila Monster. There has been considerable argument among biologists on just how venomous the Gila monster is. It is definitely known, however, that Gila monster venom kills small mammals if it is injected into them.

CHAPTER XXIV

BIRDS

With few exceptions, almost all kinds of birds that occur in relatively large numbers have been used for food at one time or another, and the availability of birds and their eggs has saved human lives on more than one occasion. Today, certain primitive people are largely dependent upon birds for their major food supply. It is said that the little auk makes it possible for the Eskimos to live in certain parts of Greenland. In more civilized countries duck, quail, pheasants and many other birds are important articles of food. Not so well known is the fact that many song birds including the robin, meadowlark, bobolink and flickers have been served in restaurants as "rice birds".

The hunting of birds and bird watching is a form of recreation that millions of people spend millions of dollars each year and is getting more popular each year. If it weren't for the hunting of birds and mammals, the firearms industry would be in sad shape. Some people get more fun out of shooting birds with film rather than bullets and now several thousands of dollars are spent annually on this form of recreation.

Birds are probably of most importance to human beings

because of their food habits. The value of birds as destroyers of harmful insects, rodents and other pests was recognized by biologists even before detailed studies had been made on the food preferences of the various species. Half of the approximately 8,600 different kinds of birds in the world eat a certain number of insects. Many species depend primarily upon insects for their food.[1] Birds certainly help to keep many harmful insects in check, and in some instances have actually averted disasters as can be attested by the Mormons of Utah. Some birds, such as warblers, swallows, flycatchers and nighthawks eat insects regularly, whereas others eat them when available in large numbers. During a plague of the Rocky Mountain locust in the Midwest some years ago, more than two hundred different kinds of birds were seen feeding on the insects. Meadowlarks were given primary credit for destroying an infestation of coulee cricket in the state of Washington, and woodpeckers cleared up a heavy concentration of spruce beetles in Idaho. Several species of birds subsist mainly on weed seeds, thus helping to keep weeds in check. Of course, they also eat food crops but the good they accomplish far outweigh the harmful effects.

Birds have always been used for food, but the products they have probably been most in demand over the years are the plumes and feathers which were used primarily for decoration of women's hats. Hummingbirds, egrets, heron, birds

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[1] Osmond P. Breland, Animal Friends and Foes, (New York, 1957), Harper and Brothers Publishers, p. 65.

of paradise, terns, swans, condors and even albatrosses were in demand for their plummage. The birds were hunted so enthusiastically for this purpose that several species were completely exterminated and several others were threatened with extinction. In one season, the skins and feathers of fifty-five million birds were purchased in the United States and England accounted for another eleven million.[2]

Ostrich farms have been flourishing in Africa for many years, and since the decline of the wild plumage trade, farms have been established in Europe, South America and parts of the United States where the feathers and plumes are the most valuable products produced. The skin, too, is sometimes used for the manufacture of articles such as belts, wallets and purses.

The nests of certain kinds of swifts are used for soup in China. A more important natural product is accumulated droppings or guano which is of great value as fertilizer. The down and soft feathers of many ducks, geese, swans and chickens have been used for centuries for making pillows and featherbeds, also for the insulation of sleeping bags and cold-climate clothing. The most valuable down is that of the eider duck that nests in the far north. Much of the commercial down now comes from Norway and Iceland where the ducks are rigidly protected. The eiders, like most ducks and geese, line their nests with down they pluck from their breasts. In Norway and

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[2]Ibid, p. 69.

Iceland the down is collected from the nests.

There are a few birds which do more harm than good. The English sparrow is an example. It eats valuable grains and vegetable crops. It also damages fruits and young flower beds. It is pugnacious and quarrelsome and by occupying the available nesting places, tends to drive away other small, valuable birds. It has a tendency to live about houses, which it soils in a very annoying way. It is also a carrier of certain poultry diseases.

The American crow is very generally considered by farmers to be a pest because of its habit of eating newly planted corn and other grain, not to mention eggs and small chickens. In the South, pecan growers maintain a constant war on crows and bluejays. In some sections blackbirds and ricebirds congregate in such numbers that they are considered major pests to rice farmers and corn farmers.

Some hawks do more harm than good. The cooper's hawk feeds mainly on song birds, game birds and chickens while the sharp-skinned hawk feeds mainly on songbirds.

There are few diseases that are directly transmitted from birds to man, but a couple of these can be serious. The best known is psittacosis or parrot's disease; it is a virus disease that has been classified as a type of pneumonia. This disease has been found in parrots, pigeons, parakeets, canaries and certain other birds. Man apparently gets the disease in most cases when he breathes in dust or other material with the virus on it.

Birds such as quail and grouce sometimes catch tularemia or rabbit fever, and an occasional person has become infected with the disease while cleaning such a bird. Birds are hosts to mites, ticks, fleas and many other parasites and some of these pests will occasionally attack poultry and human beings.

CHAPTER XXV

MAMMALS

First and foremost should be considered mammals as a source of the meat supply. Taking the people of the whole world into consideration, the flesh of mammals probably occupies a more commending position in the food supply than all other meat. The average American eats the equivalent of his own weight in meat annually with most of it coming from beef and pork, but other countries consume great quantities of mutton, goat meat, horseflesh, camels, llamas and even dog meat.

Domesticated mammals supply not only the greater part of the world's meat supply, but also the almost indispensable dairy products such as milk, butter and cheese.

Turning to wild mammals, it is impossible to make a satisfactory guess at the number available for food or the amount of meat consumed annually. In North America the members of the deer family are far the most important large game mammals. The bison is no longer available in the wild state; bears, mountain sheep and goats are not abundant or easy to obtain and moose and elk are confined to a few localities. In British America and Alaska, caribou is still found in great numbers. This mammal is a very important source of

food for prospectors, miners, trappers and others over a vast area of the northern country. The reindeer has for many years been a domesticated animal in Northern Europe where it is used for food and also dairy products. During this century, it has been introduced into Alaska and Labrador as a source of food for the natives. In Africa buffaloes, many species of antelopes and other large mammals have always furnished meat in abundance to the natives.

Of the smaller mammals, rabbits are far the most important as a food supply for the human race. Muskrats are now sold regularly in the markets of several eastern American cities where it appears under the trade name "marsh rabbit".

Other mammals that have been eaten and are still eaten by many are squirrels, raccoons, opossums, prairie dogs, beavers, skunk, wildcats, badgers, porcupines, woodchucks, gophers, and many other mammals. Marine mammals that are eaten are seals, porpoises, walrus and whales.

In addition to meat, milk, leather, furs and skins, there is a long list of other useful products obtained from mammals, only a few of which will be mentioned. Wool immediately suggests itself as a likely candidate for a position at the head of the list because of its importance to the human race. Other mammals besides sheep are important sources of wool. The angora goat, from which mohair is obtained, is becoming very important in the United States and other countries. In South America the vicuna, alpaca and llama yield wool and wooly hair of importance and camel's hair from Asia

is used for many purposes.

It is impossible for the present generation to form an adequate idea of the importance to former generations of whalebone, whale oil, sperm oil, sperm candles and other commodities brought to market by the whalers. Whaling and sealing was once among the most important industries of the world, but have now dwindled to relative insignificance although whale oil is yet an important item in the manufacture of soap.

Animal compost from the barnyard, used as a fertilizer, returns to the soil considerable plant food. The waste of whales at whaling stations is also converted into fertilizer. Bat guano filled some of the rooms in the great Carlsbad Caverns in New Mexico to a depth of one hundred feet, and it is estimated that 100,000 tons of it valued at several million dollars was removed and marketed.[1] Deer antlers are very extensively used in the manufacture of handles for knives and forks. Elephants yield most of the commercial ivory used in the manufacture of billard balls and other articles.

We have briefly covered the bright side of the relations of mammals to our food supply. The dark side is the destructiveness of certain species. Rodents, because of their great numbers, are the chief offenders. According to some estimates, house rats and mice annually do damage to the extent of $200,000,000 in warehouses in the United States, while other

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[1] Funius Henderson, and Albert L. Craig, Economic Mammalogy, (Baltimore, 1932), Charles C. Thomas, p. 34.

rodents to damage amounting to $300,000,000 to agriculture in the western states annually.[2] Some authorities assert that the damage done to food supplies in homes, stores and warehouses by rats and mice tracking in filth from the stables, etc. and mussing over the food making it unfit to eat, is as great or greater than that caused by the actual destruction of food. The brown rat of Europe, now of the whole world, is characterized as the most destructive animal in the world. To this must be added an unknown amount of intangible damage such as loss of rent of rat-infested buildings, the cost of trapping, poisoning and otherwise destroying rats, fumigating ships, rat-proofing buildingsand in various other ways seeking to prevent damage by rats.

Where they occur in immense colonies over a vast area in the western United States, prairie dogs do great damage to fields in the vicinity of their colonies and especially to grasslands, thus reducing the number of cattle and sheep the plains are capable of supporting. Rabbits are more or less injurious wherever they occur about orchards, fields and gardens. The cottontails gnaw the bark of orchard trees during the northern winters and in the summer raid the gardens and fields.

Some mammals such as wolves, coyotes, mountain lions, bobcats and lynxes affect our food supply by raiding our pastures for cattle and other domesticated animals.

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[2]Ibid, p. 37.

It has long been known that certain species of mammals are active agents in the dissemination of serious diseases which affect the human race. The various diseases are transmitted in several ways, such as by contact, by biting, through meat and milk. The opportunities for pet dogs and cats to carry diseases are particularly numerous since they are often permitted to enter and leave sickrooms. Cats are one of the chief carriers of ringworms, transmits various internal and external parasites and often transmits various infections by its teeth and claws, including tetanus. Dogs and cats have both been recognized as carriers of creeping eruptions.

Rabies not only affects dogs and cats but also affects wolves, foxes, mountain lions and other members of the dog and cat families and they in turn can transmit the disease to man and his domestic animals. Tularemia is carried by rabbits and other rodents and is transmitted to man while he is cleaning them. Bubonic plague is transmitted by the bite of a flea which is carried around by rodents, but chiefly by the brown house rat. The Rocky Mountain spotted fever is transmitted to human beings by the bites of wood ticks which have become infected through first biting infected mammals of some sort.

Many mammals live to some extent upon carrion and other waste and decomposing material and are therefore somewhat beneficial because of that repulsive habit, but it is doubtful whether the total result of their activities in that line is of much consequence though the aggregate amount of

refuse consumed by all species must be large.

Every western rancher is well aware that coyotes consume great quantities of carrion, and they take advantage of this knowledge by inserting poison into the carcasses of cattle, horses and sheep in order to destroy the coyotes. The scarcity of buzzards in many localities where they were once abundant is due to the eating of poisoned meat prepared for coyotes. Bears are sometimes found eating carcasses of deer or livestock killed by mountain lions or wolves and wrongfully accused of having themselves killed the victims. The house rats and mice and other species of rodents feed to a considerable extent upon refuse and garbage. Hyaenas are notorious scavengers, even entering villages in search of garbage though they also kill other animals. The wolverine is both hunter and scavenger, a great scourge to the trapper, following the trap lines and devouring the animals caught therein for which reason it is often called the glutton.

Some groups of mammals almost deserve to rank with insectivorous birds as insect destroyers, helping to keep the insect hordes within reasonable bounds. This is particularly true of the moles, shrews, anteaters, armadillos and bats which feed on flying insects, though many other mammals are also highly insectivorous. The food of the bats of the United States and England consists almost exclusively of nocturnal flying insects of many kinds, thus supplementing the work of insectivorous birds which live chiefly upon diurnal insects. The total amount of insect life annually destroyed by these

flying mammals is enormous. Stomachs of bats shot in the early evening after only twenty minutes of flight, have been found packed with insects.[3]

While the bats are busy ridding the air of insects, most species of moles and shrews are battling the insects that swarm upon and beneath the ground. They get a great many ants, wireworms, cutworms, white grubs and other destructive insects. The armadillo is a consumer of insects, especially white grubs and their adults, caterpillars and ants. The largest part of the food of skunks consists of grasshoppers, beetles, crickets and other insect larvae. Squirrels sometimes feed freely on scale insects and other tree pests; the western ground squirrels eat quantities of injurious insects such as cutworms, wireworms and grasshoppers. The badger occasionally makes a hearty meal of grasshoppers, cicadas and beetles.

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[3] Ibid, p. 129.

CHAPTER XXVI

CONCLUSION

As was stated in the introduction, the average courses in elementary biology have fallen far short of meeting the needs of the average student. The purposes of the present day biology course should emanate from the principle that education is concerned with the needs and interests of the learner and not subject matter to be learned for its own sake. The student is concerned with scientific knowledge about bacteria, insects, birds, trees and other forms of life because of their effect upon man. How these forms of life affect man or handicap him and what man should do about them are as fundamental to the student as the scientific knowledge itself.

This report has been prepared for the purpose of bringing together and condensing into compact form as much as possible of the information concerning the economic relations of both plants and animals; their bearing upon the welfare of the human race; their food habits; methods of preserving the more useful species and controlling the more harmful ones.

Even though the value of including a considerable amount of economic material in a beginning course in biology may be recognized, the limitations of time usually render

such a procedure impracticable. It is possible, though, to bring an economic discussion into the usual treatis of the various plant and animal phyla. The amount and procedure would vary with the type of students, their environment and the teacher. Such a course should have value to students planning on careers in fields other than biology.

It should be stated that the subject is so broad and has so many ramifications that it can scarcely be hoped that this report is either complete or perfect.

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