Biology: The Science of Life

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UNIT I

Question: Why is biology offered in a high school course of study?

You may or may not be one of those fortunate few who have known the joy of finding wild columbine in full bloom, perched gracefully on top of a huge rock, with the sunshine streaming through upon it, intensifying its georgeous color. You may have seen it without knowing its name. Indeed, you may have seen dozens of kinds of beautiful wild flowers, only to wish you knew what they were. Worse yet, you may have missed altogether the delight to be found in tramping through fields and woods, or following a stream along its course, with your eyes and ears open to the abundance of living things about you. Whatever your opportunities have been in the past for becoming acquainted with your native wild flowers, birds, trees, insects, or animals, you are now entering upon a course in biology, in which one of the major aims is to give you just such opportunities. You will now have a chance to discover whether you have any interest in knowing wild plants and animals. If you do discover and develop such an interest within yourself, it will be a great source of happiness throughout your life. This course in biology is offered to you with this purpose in view.

Have you ever watched a tadpole change into a frog, or a "tomato worm" spin a cocoon and emerge a beautiful moth? Try feeding some thyroid extract to some tiny tadpoles. If their sudden sprouting of legs and acquisition of a frog's appearance, even while still as small as flies, arouses your wondering interest, you should look forward eagerly to your course in biology. Another reason for offering this course is to give you a scientific understanding of the growth of living things. There is no more amazing story in the world than that of the reproduction of a new plant or animal. No machine or artificial device has the power to reproduce itself, nor can a stone or drop of water or any other inorganic (not-living) thing do so. And yet every organic (living) being has this ability and it is your privilege in this course to study this life function (power) in great detail.

Have you ever stopped to wonder what would happen if all of the green plants were to disappear? Animals cannot take in dirt, water, and air, and change them into foods and tissues as green leaves can. Still another reason for offering this course in biology is to give you a better understanding of the interdependence of all living things and of the whole range of life processes.

Have you ever read the story of Louis Pasteur's discovery of a treatment to prevent a person's dying from rabies, when bitten by a mad dog? Until some fifty years ago, rabies was a fairly common disease and it was one of the most horrible. The person afflicted showed the same symptoms as a mad dog and always died, after an illness involving the most agonizing suffering imaginable. When still a child, Louis Pasteur saw a blacksmith burn the bite of a mad dog out of human flesh with a red hot iron. The memory of this event never left him. Eventually, in his later years, he was able to prove that the cause of rabies in dogs was a virus, but it still took many years of patient research before he finally developed a serum which made dogs immune to rabies. Even after he knew how to prevent rabies in dogs, he was afraid to try his treatment on human beings. One day a little boy was bitten in many places by a mad dog. His mother knew that he must die a horrible death, but she had heard of Pasteur's success in treating dogs to prevent rabies. She took her son to Paris and begged Pasteur to try his treatment on the lad, pleading that it would be his great chance to see whether it would solve this age-old human disease. Very unwillingly, Pasteur agreed and after many sleepless nights, he achieved success, for the boy did not develop rabies, but remained perfectly well. Today it is still the Pasteur treatment which doctors give anyone who has been bitten by a dog suspected of having rabies.

This story suggests another reason for offering a course in biology. In the last one hundred years man has learned more about the cause, treatment, and prevention of disease than in all of the previous half million years of his life on this planet. If the general public could only know the major facts concerning such diseases as appendicitis, tuberculosis, diabetes, and diphtheria, and would act upon this knowledge, a very large proportion of the illnesses and deaths of the nation could be prevented. For instance, a child is rushed to the hospital with a ruptured appendix. In most cases the story is the same. He began with a pain in the abdomen, so the mother gave him castor oil, in all good faith. Of course modern medicine knows that either castor oil or salts is the very worst possible treatment for a pain in the abdomen, since any such pain means a possible appendicitis and a laxative is almost sure to rupture an appendix with an acute infection. The anxiety of the mother during the uncertain days, or even weeks, while her child hovers between life and death makes the doctor wish he had it in his power to teach all of the boys and girls of this land even this one simple fact about appendicitis, so that he might never again have to face a mother's tragic "I did not know." You are going to have the opportunity in this course to learn a great many facts which modern medicine has made available to you. You should appreciate the opportunity and use the information for your own health's sake.

Did the story of Pasteur interest you? Perhaps you may have the ability and interest to do something of the same sort, for there are still many problems to be solved. Or perhaps you may have the talent and latent dexterity and intelligence to become a surgeon, or to enter some field of medicine. Or, again, you may have the wise sympathy and self-forgetfulness to become a good nurse. Or you may like the woods and have a desire to become a forest ranger, or perhaps you may even like to write as a naturalist. Then, there are also pharmacy, scientific agriculture, insect-pest control, work of the hospital laboratory technician, bacteriology, and other fields in which there are occupations and professions for which a course in biological science will lay a foundation. You will have the chance to find out this year whether you have any inclination or ability in some of these fields. There will be presented later a full unit on the related occupations and professions with details as to training, opportunity, rank, income, responsibility, and demand for ability. This is still another reason for offering you this course, that you may have this opportunity to discover your own interests in relation to biological science and to glimpse the way to follow up your interests during your lifetime, if you discover that you are so inclined.

Make a list of reasons why biology is included in a high school course of study, as suggested above.

1. To learn about plant and animal life.
2. It gives you a scientific understanding [illegible] of living things.
3. To give a better understanding of the interdependence of all living things and of whole range of life problems.
4. It teaches the cause, treatment and prevention of disease.
5. It teaches the facts of modern medicine.

Can you add some further reasons?

You may have this opportunity to discover your own interests in relation to biological science and to glimpse the way to follow up your interests during your lifetime.

UNIT II

A. Question: What is biology?

Probably your first impression of a biologist is the popular one such as the movies present. You think of a queer-looking person who goes dashing around with an insect net hunting bugs and butterflies. For many persons there is a fascination about collecting insects, though this picture is really very far from representing the real biologist. The entomologist (student of insects) is interested in a very small part of the whole subject of biology, which is as broad in its interests as life itself. The term "biology" is of comparatively recent origin, having been coined in the year 1802. Previous to that time plants had been gathered, pressed, named, and classified, and this subject was taught as botany. Animal life was studied as zoology. But the idea that all life is unified and may be studied together is a development of the early part of the nineteenth century.

Biology means simply the study of life, or the science of life. Consequently it includes not only the study of insects, but also the study of all living things on this earth, from the simplest ameba to the most complex of all organisms, man himself. The real biologist is simply the student of living things. To be sure, he usually has specialized in some particular field of the science, for the subject includes far too much to be learned entirely by any man in his whole lifetime. Therefore, you should learn to think of a doctor, or a research worker on crop production, as being just as truly biologists as is the insect collector.

Biology is the science of life. No person knows what life is, any more than any one knows what electricity is. But modern biology has accumulated much knowledge about how life expresses and maintains itself. During the study of the science of life, you are to receive a glimpse of this accumulated knowledge.

UNIT II

B. Question: What is science?

Biology is the science of life. No one knows what life really is, but you can be given a very accurate idea of what science is. The word "science", in its origin from the Latin, merely means knowing. There are certain things which man may know, and other things which he may believe. For instance, you know that a pencil will fall if dropped in mid-air. You do not have an opinion on the subject. You know. This is an example of an observed fact and science is the accumulated knowledge of observed facts. On the other hand, you may believe that a sick child has no temperature when you feel his forehead, but this is only an opinion or belief and has no place in science, unless it is definitely tested with an accurate thermometer. Or again, you may believe that early rising and retiring will bring you health, wealth and happiness, but this, too, is a mere opinion, entirely unscientific, since there is no experimental evidence at hand to prove it.

The scientific way of looking at the universe is a new way, having reached its first complete development in the sixteenth century A.D. The scientist looks at his universe in a way totally different from the average man. When he attacks a problem, he simply observes and records facts. The essential point is that he comes to the problem with an open mind, free from any preconceived opinions, ready to accept any solution which the facts prove to be true. After the facts have been observed and recorded, he then analyzes his data to see what conclusions necessarily follow from them. He calls such a possible conclusion a hypothesis. Then he tests his conclusion by further observation of facts and by experimentation. Only after <u>all the facts</u> and experimental evidence have been found to agree with his hypothesis does he announce the discovery of a new truth, and even then he still refuses to call it an absolute law because he knows that new facts may come to light which will make it necessary to revise his discovered truth. The history of Newton's law of gravity offers a splendid example of this very thing. For many years, Newton's law was considered absolute and final, until Einstein's recent work produced new evidence which led to its revision. Does the modern physicist refuse to accept Einstein's discovered facts because they force him to revise his previous conclusions? Absolutely not. The scientist is, above all else, open-minded. He holds all his accumulated knowledge as being forever subject to revision in the light of new facts. This is in absolute contrast with the masses of mankind, who cling to their opinions and beliefs in spite of well-proved evidence to the contrary.

For example, during the years 1564-1642, there lived in Italy, a man named Galileo, who possessed the scientific attitude in completeness. It was he who established the fact that the earth and planets go around the sun, much to the disapproval of the authorities of his day. In fact, the learned fathers disapproved so completely of Galileo, because his science disproved their opinions, that they forced him to deny his proved laws in order to save his own life. You will find a full story of how the Inquisition treated Galileo in an interesting book called "The Scientific Outlook" by Bertrand Russell. One example of Galileo's use of the scientific method will serve our purpose here. The scholars of Galileo's day claimed that an object which weighed ten pounds would fall from a given height in one-tenth the time that would be taken by an object weighing one pound. They held this as an opinion because Aristotle said so, not as an observed or tested fact. In fact, no one even thought of testing it to see if it were true until the young Galileo became interested. Now this Galileo was open-minded on the subject of falling objects, so that he began to wonder if a heavy object really did fall faster than a light object. He showed his scientific spirit in being open-minded about a supposed "law" which all of his contemporaries believed, and also by deciding to test this "law" by an actual experiment to see if the heavier object fell faster than the lighter. One day he climbed to the top of the Leaning Tower of Pisa with a ten-pound shot and a one-pound shot. He waited until the professors were passing on their way to their classrooms. Then he attracted their attention and proceeded to drop the two weights. Of course they reached the ground approximately together, much to the amazement and disgust of the observers. Galileo had demonstrated a fact to them but they were unable to accept a fact which contradicted their opinions, so that they still clung to their belief, in spite of the evidence of their own eyes. Galileo was scientific and they were not. His work was the beginning of a great and important change in the thinking of mankind.

The scientific method began to produce results as early as the sixteenth century. During the first period of scientific investigation, man naturally turned his attention toward the control of his surroundings. Discoveries in physics and chemistry, the physical sciences, came so rapidly that they soon revolutionized human industry, finally giving us the machine age. Your whole life is filled with examples of man's increased control of the things around him, which came to him when he began to apply the scientific method to the problem.

The last few centuries have produced more discoveries and inventions than all of the thousands of years preceding, simply because man began to demand the evidence of facts and to base his conclusions upon them. At once he began discovering universal laws and this led to practical discoveries. Steam engines, gasoline-driven cars, radio, telephones, electric lights, aeroplanes, telegraphy, all of the remarkable series of discoveries of the past few centuries were the inevitable result of man's learning to recognize and relate facts.

This is an age of science and, if you would be in step with your age, it should be your highest ambition this year to develop something of the scientific attitude. That means you should try to be open-minded on every subject until you know the facts. Make it your aim to learn to seek the facts before you come to any conclusion. There is no attitude which you can acquire in the course of your education which can do as much to make you a real part of this age as the scientific attitude of open-mindedness, because the scientific attitude is the foundation of all discovery, the very basis of all advancement. Surely it is well worthy of your cultivation.

At the present time man has mastered his major problems in the control of his environment. He can fly in the air, or dive to the bottom of the sea. He can travel at extreme speed, or talk to the ends of his earth. He is now turning his attention upon himself; he is studying life in all its forms, his own life most of all. If you would be in touch with the biggest discoveries of the next few decades, keep in touch with biological science. Lay your foundation in this course for at least some understanding and appreciation of the changes which biological research will bring into human life. What discoveries are being sought? Probably the search for a cure for cancer is as urgent as any problem at present. What may be done to control or even banish disease, we may only guess. But the light of progress is certainly focused on the research being done in biology as the most promising field of advancement for the human race.

If you find that you are interested, read Paul DeKruif's "Microbe Hunters". It is a series of fascinating stories of men who sought and found the causes and cures of many diseases by applying the scientific method to the problem. Other recommended books are:

"The Story of San Michele" Axel Munthe
"Arrowsmith" Sinclair Lewis
"Science of Life" Wells, Huxley, and Wells
"Scientific Outlook" Bertrand Russell
"Science and Modern Civilization" Millikan

Review of Unit II - A

1. What is biology? Biology is the science of life.

2. Name as many different things included in the subject as you can.
Biology does not include only the study of insects but also the study of all living things, from the simple ameba to the most complex organisms.

3. When was the term "biology" coined? 1802

4. What is life? No one knows what life is anymore than anyone knows what electricity is

Review of Unit II - B

1. What are the three steps in the scientific method?

(a) Observes and records facts
(b) Open mindedness
(c) Conclusion

2. What is the essential part of the scientific attitude?

(a) Open mindedness

3. How many centuries has man been using the scientific method?

(a) Since the sixteenth century.

4. What man first demonstrated the scientific method in its completeness?

Galileo Why? He carried out his facts by experimentation

5. What sciences developed most rapidly when man first began to use the scientific method?

(a) Physics
(b) Chemistry

What science is developing most rapidly at present? biology

UNIT III
Cells

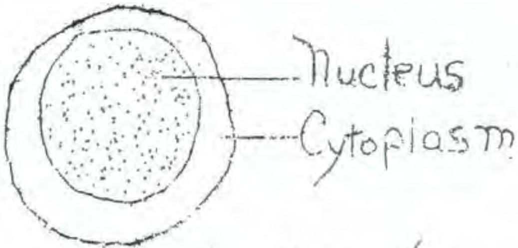
A. Question: Of what material are living things made? Has this material any particular structure? What are some common examples of cells?

Before the seventeenth century no one had any idea what composed the flesh and blood of the human body or the woody trunk of the tree. During the seventeenth century a microscope was invented, and with it curious men began peering at shreds of living things. Robert Hooke, in 1667, looked at a thin slice of cork under a microscope. He found that it consisted of rows of empty squares which reminded him of monks' cells in a monastery. So he named these little units in the cork "cells", and the name still is the accepted term, although biologists have known for a long time that it is a poor one. Cork happens to be dead, so that the cell contents have disappeared. But increasing observations with microscopes soon proved that cells are not empty when alive, but are really filled with a mass of slimy, jelly-like substance which is called protoplasm.

By 1838, microscopic study had convinced two Germans, named Schleiden and Schwann, that all living things are made up of cells. Biologists now know that this is a fact, and that all cells, when alive, consist of a tiny bit of protoplasm. In the center of the protoplasm of a cell, there is found a denser mass, called a nucleus. And most plant cells have a kind of box around them which is called the cell wall.

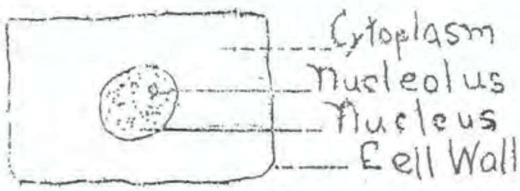
Chemistry has revealed that protoplasm is composed of elements. An element is a simple substance which cannot be decomposed by any known chemical means. There are just ninety-two of these elements in the whole universe, so everything in it is composed of these elements alone or in combination. Just as the twenty-six letters of the alphabet compose all the words of the English language, so the ninety-two elements compose everything in the universe. Only six of these elements are necessary to form protoplasm. They are carbon, hydrogen, oxygen, nitrogen, sulphur, and sometimes phosphorus. These six elements, when properly united, form living protoplasm. But no one has yet learned how to cause them to unite artificially, so that at present all new protoplasm grows from protoplasm already in existence. Where the first protoplasm came from, or how the six elements happened to combine to form it, biologists do not know. There are indications in present day research that they may soon discover how to produce living protoplasm from these elements.

At any rate, all living things are made of protoplasm, which is organized into cells. Most of these cells can only be seen with a microscope. Their shape and size vary as much as life itself. The cells which line the mouth are flat, irregular cells. The nerve cells have long projections on them to carry nervous impulses. Every human tissue such as bone, muscle, or gland, is composed of its own type of cell. Not only human bodies, but those of all plants and all animals, are made of the same stuff, called protoplasm, organized into the same units, called cells.

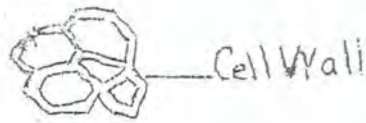


White Blood Cell (Human)

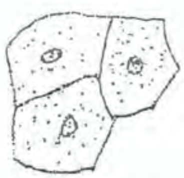
Red Blood Cells



Cell in Onion Root



Wood Cells



Cells from Lining of Mouth

Muscle Cell (Smooth Muscle)

Nerve Cell

Moss Sperm

Recently, biologists (particularly Dr. Canti and the late Dr. Strangeways) have developed a fascinating new field of investigation. They have been able to prove conclusively that the cell units of an animal are alive individually as well as collectively. In other words, an animal may be compared to a community of living individual cells. Those men have been able to isolate single cells from the rest of the body and keep them alive indefinitely.

The story of how such an experiment was carried out may prove interesting. The experiment was started by taking a tiny bit of living tissue from an animal and placing it in the serum obtained by letting blood clot. This culture had to be kept just as warm as the body of the animal from which it was taken. It was arranged to place this culture under a microscope where it could be watched.

After several hours, a few of the cells were seen to move out of the tissue into the serum. There each cell roamed about, took in food, breathed, and threw off waste materials as a living individual. A few hours later, the observer saw a single cell pinch into two parts. Each part had a nucleus in the center and resembled the original mother cell. The two daughter cells moved around, took in food, breathed, and threw off waste material just like any living thing. In time each daughter cell again pinched into two parts and thus reproduction was carried out.

You see that it has been established as a fact by such experiments that an individual cell of an animal's body can be made to live its own life and do everything which any living thing can do.

You will find a full account of these experiments, beginning on page forty of Wells, Huxley, and Wells' "Science of Life".

Laboratory Suggestions

A large part of your work in this course will be done in the laboratory. The following quotation from Twiss' "Science Teaching" will give you some idea of the reason for laboratory work.

"The student should go to the laboratory, just as the scientist does, to find out at first hand ---- certain essential facts of observation which he needs in the investigation of a scientific problem."

The laboratory is a work room. You are to direct your own work with entire freedom, as long as you so direct it that everyone present may carry out his investigations without hindrance from you. Feel free to ask for help whenever you are unable to proceed without it. But learn to depend upon yourself as fully as possible.

Your attitude will be judged directly by the way you go about your job. Learn to be business-like. Use every minute to the best of your ability. There is every reason for you to enjoy the work you are starting. It may seem very different from classroom work, as it is meant that it should be. In the laboratory you are working as an individual, or with a partner, rather than with a whole class. This very fact should give you more satisfaction than group study can give. Do your work thoroughly and earnestly and you cannot help doing it happily.

Laboratory Study I

Human Blood Cells

Under the microscope, look at a slide of human blood which has been stained blue with Wright's stain. You will find two kinds of cells, white blood corpuscles and red blood corpuscles. The white corpuscle is larger than the red and contains a denser area in the center, which is the nucleus. Red blood corpuscles of human beings have no nucleus when full grown. But when they are still young, while they are being formed in the marrow of the bones, they also contain a nucleus. Are the red blood cells on the slide young or full grown? Yes. How do you know? Because each one was seperate

Make a careful drawing of a white blood corpuscle and three or four red blood corpuscles. Label the denser portion in the center of the white cell the nucleus. Label the cytoplasm of the red blood corpuscle and label the white and red corpuscle as such. Mark the magnification of the microscope beside your drawing.

Laboratory Study II

Cells of the Onion Root Tip

Look at a thin slice of an onion root tip under the microscope. It will appear to be composed of rows of oblong spaces like rows of bricks. What do you suppose each oblong space is? a cell. Can you see any denser area in the cent of each cell? yes. What is its name? nucleus Can you see a sort of box around each cell? Yes. What is its name? cell wall What is the name of th substance between the denser center and the surrounding box? cytoplasm

(See your drawing of the white blood corpuscle.)

Draw carefully one cell of the onion root tip, and label the three parts named above.

You have now seen two kinds of cells, the human blood cells and the cells of the onion root tip. There are other single cells which make up whole plants, such as the Pleurococcus, or whole animals, such as the Ameba and the Paramecium.

Pleurococcus is a splendid example of a plant which consists of only one cell. It forms a rich growth of these cells on the bark on the north (shady) side of trees, so that it makes the bark a dull green. The American Indian was familiar with this greenness on the north side of tree trunks and used the fact to help determine directions. But he did not know that the greenness was simply due to millions of tiny one-celled plants, which botanists have named Pleurococcus.

Amebae and Paramecia may be grown in the laboratory by allowing pond scum or hay to stand in a glass of water until decay takes place. An Ameba is a tiny mass of protoplasm with a nucleus; in other words, an Ameba is a real cell. It has no cell wall, but it does contain cytoplasm. Scattered in the cytoplasm are bits of food and vacuoles for throwing off waste material. The Ameba moves along by projecting a bit of its cytoplasm in one direction and then flowing into that bit of cytoplasm. This projection of cytoplasm is called a pseudopodium or "false foot". These pseudopodia change the shape of the animal constantly.

The Ameba ingests (takes in) food by moving up to a particle of food material by means of its pseudopodia and then flowing around it. After it has digested the food and absorbed what has been digested, it simply flows away from the bit of waste material, leaving it behind. Here you have a whole individual life within the compass of a single cell.

In the Paramecium you have another cell which makes up a whole animal. In this case, the single cell has become much more complex. The Paramecium has a cell wall, which gives it definite shape. The surface is covered with little hair-like projections, called cilia, with which it swims. It contains both a large and small nucleus, contracting vacuoles, digestive vacuoles, a mouth and a gullet. In other words, it has several special parts to do special things, all within a single cell.

Laboratory Study III

Pleurococcus

Bring into the laboratory a piece of bark which is covered with a dull green material, something like green paint. On a microscopic slide, place a small drop of water. Then scrape a little of the green dust off the bark into the drop of water and place a cover slip over it. Then examine under the microscope.

Each little green circle is one cell, and represents a whole plant of Pleuro-coccus. What is the shape of the cell? Round. What surrounds each cell? cell wall. Look for the denser area in the center. What is its name? nucleus. What color is present in the cytoplasm? green. This green color in plants is called chlorophyll.

When a single cell of Pleurococcus divides, the two cells may cling together. Do you see any two-celled groups? Yes. When the two cells divide, four cells may cling together, and so on. These groups of cells are called colonies.

Sketch some Pleurococcus cells alone and in colonies. Label the nucleus, cell wall, cytoplasm, chlorophyll, and colony.

Laboratory Study IV

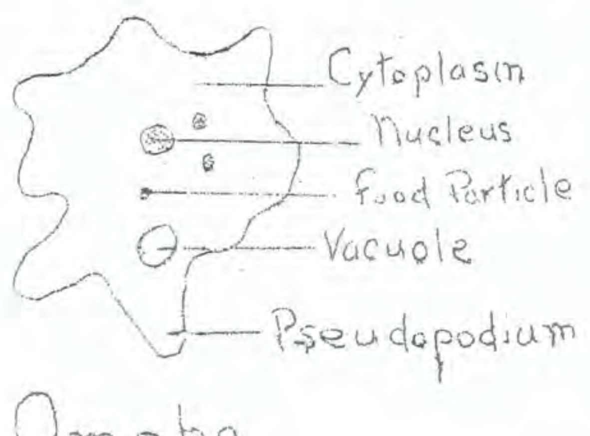
The Ameba and the Paramecium

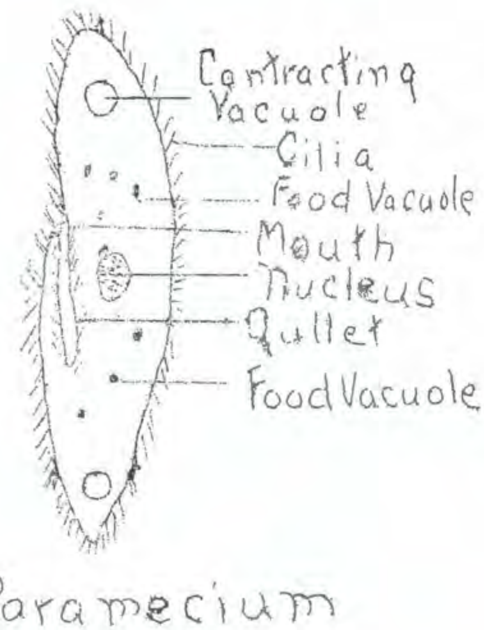
Look at a drop of water from the decayed hay in water under the microscope. What do you see? Paramecium. These moving cells darting around are one-celled animals, correctly called protozoa. There are several kinds present. The long slipper-shaped forms are Paramecia. Watch them for a while. Do they always swim in the same direction? No. What do they do when they run into something? backups. Can you see a groove in one side of the Paramecium? Yes. This is the mouth and gullet. What is their function (use) to the animal? food taking. What can you see inside the Paramecium? [illegible] to take in food. Look at a slide of dead Paramecia which have been stained. What is the name of the denser area near the center? nucleus; the groove? gullet. The other dark areas within the cytoplasm are food particles or digestive vacuoles. The two clear circles at either end are excretory vacuoles, to throw off waste material.

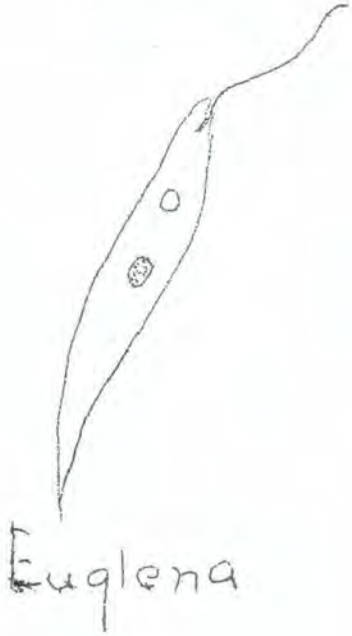
Make a diagrammatic sketch of a Paramecium, reconstructing it from the living and stained animals. Label the nucleus, mouth, gullet, cilia, cell wall, cytoplasm, digestive vacuoles, and contracting vacuoles.

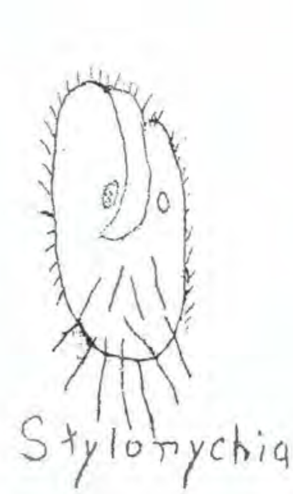
If living Amebae are available, watch one under the microscope for some time. Does it keep the same shape? No. What is the name of the projection of cytoplasm into which it flows, in order to move from place to place? Pseudopodium Does it move very rapidly? yes. Does it have a definite mouth? No. The Ameba has only one definite part and that is the denser area in the center. What is its name? Nucleus.

Look at a slide of dead Amebae which have been stained. From your impressions of the living and stained specimens, make a diagrammatic sketch of an Ameba, labeling the nucleus, cytoplasm, food particles, and a pseudopodium.









Betty H[illegible]

13. The cell of the onion root tip consists of ~~three~~ four parts, namely: nucleus, cytoplasm and cell wall and cell membrane.

14. The cell of Pleurococcus consists of cell wall, nucleus, cytoplasm and chlorophyll.

15. When several cells of pleurococcus cling together, we call it a colony.

16. The only definite part of the Ameba is the nucleus. It moves by means of [illegible] flowing around it ingests food by [illegible], and excretes waste material by leaving [illegible] behind [illegible].

17. The Paramecium has a mouth and gullet for taking in food, cilia for swimming, digestive vacuoles for digesting food, contractile vacuole for throwing off waste, and a denser area in the center called the nucleus. It is also enclosed by a definite cell wall, which gives it the shape of a slipper.

18. How many cells make up a whole animal in the Ameba and Paramecia? one.
What do we call animals which consist of only one cell? protozoa.

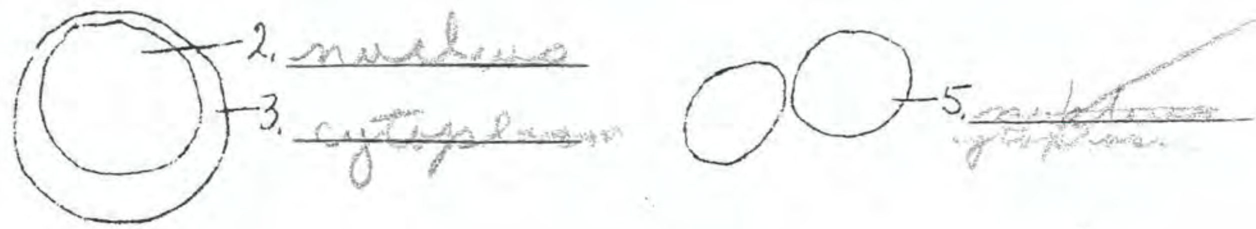
19. Where would you look for Pleurococcus? tree bark; for Amebas? stagnant water; and Paramecia? in stagnant water.

20. Are there any other kinds of one-celled animals? yes. How do we know? by observation.

Brief Summary of Essentials

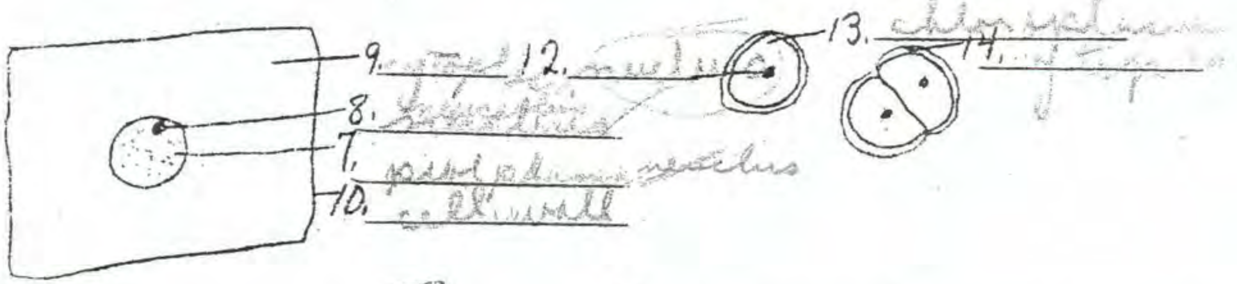
1. What is protoplasm? [illegible] the stuff [illegible].
2. What is a cell? A living unit of life.
3. What elements compose protoplasm? carbon, hydrogen, [illegible] nitrogen, oxygen, sulphur, [illegible].
4. What five kinds of cells have you seen? onion root tip, red blood, cell [illegible] cell, pleurococcus and ameba.
5. Of what units are all living things in the world composed? cells.
Of what material are these units composed? protoplasm.

Billy Hofmann



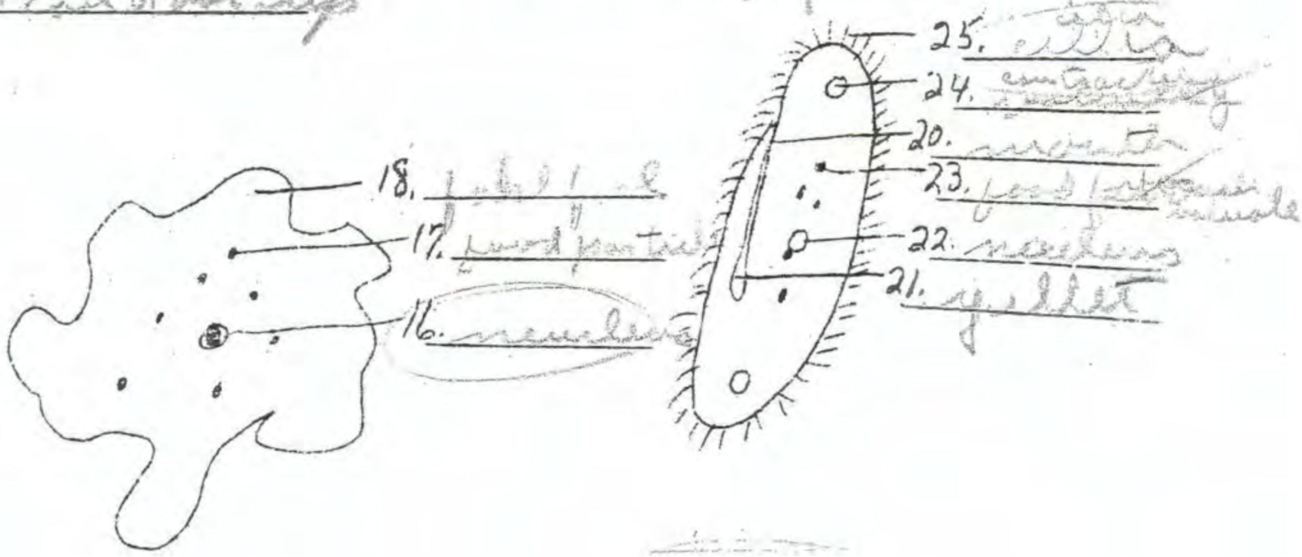
1. white blood cell

4. Red Blood cell



6. Onion Root tip

11. colony of Pleurococcus



UNIT IV
Life Functions

Question: What are living things able to do which inorganic things cannot?

Living protoplasm, organized as it is into cells, is able to do certain things which are characteristic of it and no other substance in the world. You may speak of these activities as the functions of protoplasm, or the functions of living things.

All organisms (living things), whether a single cell, or a complex plant or animal, are able to take in and use food to give them heat and energy, or to build and repair their own substance. They also throw off or excrete the waste materials which are left over. This process is called metabolism and may be subdivided into the functions of food-getting, digestion, absorption, circulation, assimilation, respiration and excretion.

Besides the functions involved in metabolism, an organism is also able to do certain other things. As you saw under the microscope, when a Paramecium swims against an obstacle it feels something in its way and backs up to get away from it. Even a green plant feels the light, for it turns its leaves toward the window. Biologists speak of this ability of living things to fell, as the function of sensation, or irritability, and it is inherent in all protoplasm.

You saw, too, how even the tiny Ameba is able to move. Observation of living plant cells under the microscope shows a streaming of the protoplasm within the cell. The sensitive plant folds its leaves when touched. Plant roots turn toward gravity and water, and the leaves toward sunlight. In fact, all living things possess some power to move, and this is called the function of motion.

Last of all, living things are always able to reproduce offspring like themselves. In the single cells, the function is carried out by the dividing of one cell into two daughter cells and is controlled by the nucleus. Each daughter cell always receives just half of the nucleus of the mother cell. In the more complex plants and animals the process becomes very complicated, as you shall learn, but note the point here that all organisms have the function of reproduction.

To summarize, all organisms have the functions of metabolism, motion, irritability, and reproduction. Metabolism involves food-getting, digestion, absorption, circulation, assimilation, respiration and excretion.

List four common functions of all living things.

1. Motion
2. irritability
3. reproduction
4. excretion.

List six processes involved in metabolism.

1. Food getting
2. digestion
3. absorption
4. circulation
5. assimilation
6. respiration

UNIT V
Reproduction

A. Flowers

Question: Why do plants have flowers? What are the parts of a typical flower? What are the functions of these parts?

You have seen flowers all your life but probably you do not understand their importance at all. By flowers, we mean the blossoms on certain kinds of plants which produce seeds. Botanists call all plants which form seeds Spermatophytes. There are just four large groups or phyla in the whole plant kingdom and the Spermatophytes are the highest group of the four. The Spermatophytes are divided into two classes: the Gymnosperms or cone-bearing seed plants, and the Angiosperms or flowering plants.

Plants do not produce flowers to beautify the earth, although many persons believe that they do. The flower has only one function to perform for the plant, and any beauty or sweetness of scent which may occur in the blossom is only secondary to the real purpose of the flower.

If you will stop to consider that a flower is followed by seed, and that seeds, when planted, grow again into new plants like the parent, you will realize that the purpose of a flower is simply to reproduce the plant. Flowers exist for no other reason. How they carry out the function of reproduction will be presented in this unit.

If you will look at any flower, such as the lily, you will find that it consists of four main parts. Underneath you will find green leaves which enclosed the flower in the bud, They are called sepals and together they make up the calyx. (The colored parts of the lily are called petals, which together make up the corolla.) Inside the petals you will find long projections with yellow pollen on top of them. They are the stamens. In the very center of the flower you will find a pistil.

A stamen usually consists of two parts, called the filament and the anther. A pistil usually consists of three parts, called the ovary, style, and stigma. Be sure that you have learned all of these parts as represented in the diagram of a typical flower.

Since the sepals enclose the bud, it is evident that they protect the flower. The petals are usually beautifully colored, but the plant cares nothing about beauty. Let us seek further the reason for the color.

On the anther of the stamen is found a yellow dust called pollen. Under the microscope pollen is found to consist of grains, each of which appears to be a cell. Inside of the mature pollen grain or cell are found two nuclei. The stigma is usually sticky so that pollen which falls upon it will stick fast. After the pollen grain reaches the stigma, it begins to grow a little tube, like a little root, down through the style. This tube is called the pollen-tube and it continues to grow down through the style until it reaches the ovary. The pollen grain itself remains on the stigma. See diagram.

Inside the ovary are found tiny ovules, each of which contains an egg nucleus, an endosperm nucleus, and some other less important nuclei. The pollen tube grows down into the ovary and into one of the ovules. One of the two nuclei found in the original pollen grain is used up by the growth of the pollen tube, so it is called the tube nucleus. The other nucleus found in the original pollen grain divides into two parts, which are called male nuclei. These two male nuclei leave the pollen

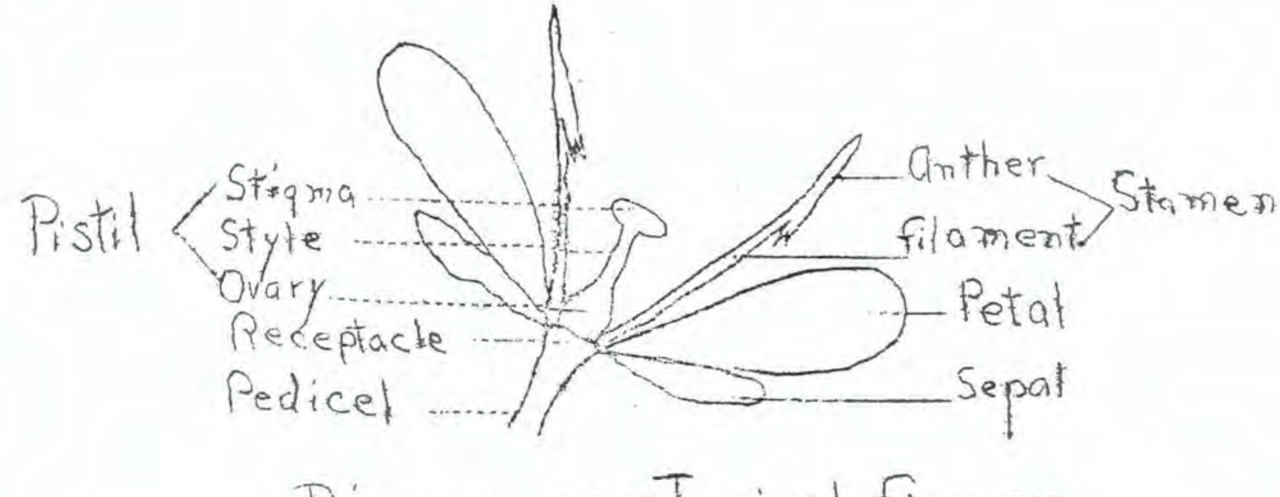


Diagram of a Typical flower

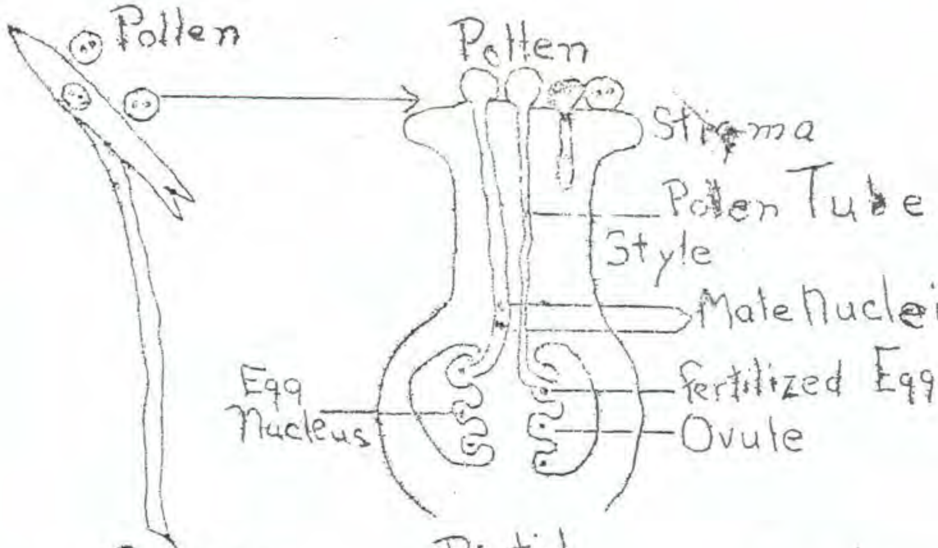


Diagram of Pollination and fertilization grain on the stigma and go down through the hollow pollen-tube into the ovule. One of these male nuclei unites with an endosperm nucleus in the ovule and together they form a tissue, called endosperm, which will serve as food later for the baby plant in the seed.

The other male nucleus unites with the egg nucleus. They simply come together and fuse into one cell, something the way two small drops of water on a window pane can be made to run together to form only one drop. The uniting of the male cell (sperm) with the female cell (egg or ovum) is called fertilization and the resulting cell is called the fertilized egg.

Following fertilization, the fertilized egg at once begins to grow into a tiny plant inside the seed. The new baby plant is called an embryo. In a peanut it is the embryo plant which you eat. You may easily see the two seed leaves (two halves of the peanut), and the first tiny root and pair of leaves between them.

All seeds are formed by this process of fertilization. In fact, unless a male cell reaches and unites with the egg, no seed will grow, for an egg alone cannot grow into an embryo plant. (Note: There are a few known exceptions. For instance, dandelion ovules are able to form seeds without receiving any pollen or sperms. Likewise, in the laboratory, frog eggs have been made to grow into tadpoles by pricking them with an electric needle, instead of letting them be fertilized by sperms from the male frog. But these are very rare exceptions, which need not prevent your learning that all eggs must be fertilized by sperms before they can grow into offspring.)

Thus the real function of the flower is completed with the formation of seed, for the seed will reproduce the plant if placed in the soil.

You are familiar with the word sex, and you undoubtedly know that sex is related in some way to reproduction. But probably the scientific fact that sexual reproduction is simply the starting of a new plant or animal by the uniting of a sperm with an egg is new to you. Flowers have sex, just as truly as any of the animals. There is nothing mysterious at all about the process if you understand it in the light of biology. In the next problem the origin and early development of sex in the lowest plants will be discussed.

As you have just learned, it is necessary for the pollen to reach the stigma if seeds are to be formed. Consequently, flowers have developed all kinds of devices to insure the carrying of pollen. The transfer of pollen from the anther to the stigma is called pollination. There are two kinds: self and cross. In self-pollination the pollen is carried from the anther to the stigma of the same flower. In cross-pollination the pollen is carried from the anther of one flower to the stigma of another flower. This is the more common method.

Pollen may be carried from one flower to another by the wind. Flowers of this type are usually inconspicuous and the stigmas are long and feathery. Corn is an excellent example of this type of flower. The tassel on top of the corn stalk is a cluster of stamens. The silk on the ear of corn is the style and stigma of the pistil and the grain of corn is the ovary. There are no true sepals or petals in corn flowers. The wind blows pollen from the tassels to the silks. The pollen tubes grow down through the silks to the small grains of corn, where fertilization occurs, causing the grains to grow into seeds. There is no need in the corn flower for beautiful petals or nectar or sweet odor, since they are pollinated by the wind.

In a flower with color, or odor, or nectar, pollen is carried by a different means entirely. Insects, such as bees, are attracted to a brightly colored flower, where they gather nectar. As they dip down into the flower for nectar, pollen adheres to them. When they fly to another flower, naturally some of this pollen will be deposited on the stigma, thus accomplishing cross-pollination. Cross-pollination seems to produce more vigorous seeds and greater variety in the offspring than self-pollination, so that it is very advantageous to the plant. The beauty and fragrance of flowers are thus seen to be merely the means of bringing about cross-pollination and seed formation, and they serve the purpose very well indeed.

There is an interesting story told of a wild orchid found in Madagascar, which has its nectar at the bottom of a small tube eleven inches long. When the process of cross-pollination was first being discovered, there were botanists who laughed at the idea and they offered this Madagascar orchid as proof that the insect theory was impossible, since no insect could possibly reach down eleven inches for nectar. Eventually, a young student went out to Madagascar to study the pollination of the strange flower with such a long nectar tube. For a long time he was unable to find any insects visiting the blossom and was about to give up the task in despair when, one night, he caught a moth hovering over the orchid. With real excitement he uncoiled the moth's proboscis (sucking tongue) and found that it also measured eleven inches. As a result of this and similar research, modern botanists all agree that nectar, color, and odor are always devices to attract insects or humming birds, which will carry the pollen from flower to flower.

Laboratory Study V

The Gladiolus

Obtain a gladiolus blossom at the desk. It is a typical flower except for one thing. The sepals are colored like petals instead of being green. The green leaves at the base of the flower are bracts.

Look at your specimen carefully. The three outside colored parts are the sepals and the other three are the petals. Remove the green bracts from the base of the flower, being careful not to break off the ovary which is below the vlower and inside of the bracts. What color are the stamens? white. What color is the pollen? Yellow. What color is the pistil? white. How many parts has the stigma? Three.

Sketch the gladiolus, normal size. Label the ovary, sepal, petal, stamen and pistil.

Remove the sepals and petals, being careful not to break the style from the top of the ovary. Sketch a stamen, labeling the filament, anther, and pollen. Sketch the pistil beside the stamen, labeling the ovary, style and stigma.

Look at a few of the pollen grains under the microscope and sketch them. Can you see any nuclei in them? _______. If so, label them.

Cut the ovary lengthwise into two parts. What do you find inside of it? ____________. Select an old flower in which the sepals and petals have withered and cut the ovary in the same way. What change do you notice in the ovules? ______________________________. What caused them to begin to change? ______________________________.

Does the gladiolus have sex? _______. What is sexual reproduction? ________ ____ ____.

Which part of a flower is male? ______________________________. Which part is female? ______________________________.

Study any other four flowers as you have studied the gladiolus. Make the same drawings with the same parts labeled.

Laboratory Study VI

(Optional)

Germination of Pollen

Dust some pollen of various flowers into a Minot dish containing a dilute sugar solution. Keep in a warm place for several hours. Then examine a drop of the culture under the microscope. Have the pollen grains begun to grow? _______. If so, what are the elongations which you see coming out of the pollen grain? _______. Can you see any nuclei? _______. If so, how many? _______. What is the name of each nucleus? ____________. If the pollen had fallen on the stigma, where would this projection be growing? __________________. What purpose does the pollen tube serve in the flower? ______________________________ ____.

Sketch a pollen grain, showing the pollen tube, labeling the tube nucleus and the two male nuclei.

Betty Hof[illegible]

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C+

Review of Unit V, Subtopic A

1. What is the name of the parts of the flower which enclose the bud? calyx. What is their function? to protect the bud.

2. What is the name of the colored parts of the flower? petal. Why are they colored? to draw insects.

3. What is the name of the part of the flower which produces the pollen? stamen What are the two parts of this structure? anther and filament

4. What is the name of the part of the flower found in the very center of it? pistil. What are the three parts of this structure? ovary style and stigma

5. Where must the pollen be placed if seeds are to be formed? on the stigma What is pollination? It is the uniting of the egg and the sperm to form the embryo. it is the placing of the pollen from the anther to the stig.

6. What are two kinds of pollination? cross and self.

7. Pollen may be carried from one flower to another by water, wind or insects

8. Flowers have brightly colored petals in order to attract insects. Other means of attracting them are nectar and odor.

9. What purpose of the flowers does a bee serve while visiting them? It serves as a cross pollination.

10. How many nuclei has a mature pollen grain? two.

11. After a pollen grain has reached the stigma of the pistil, a pollen tube begins to grow down toward the ovary. One of the nuclei, called the tube nucleus, is used up during the growth of this structure. The other nucleus divides to form two nuclei which go down through the pollen tube into the ovule. Within the ovule is an egg nucleus. One of the male nuclei from the pollen grain unites with the egg nucleus of the ovule to form the fertilized egg. which grows into the embryo within the seed.

Betty Idof[illegible]

12. The uniting of these two nuclei to begin the new plant is called fertilization

13. What is sexual reproduction? It was when an egg and sperm unite to form a new plant.

14. Do flowers have sex? no. Prove that your answer is correct. It may be proven by the appearance of seed.

15. When plants or animals reproduce in any other way except by the uniting of two cells, we call it asexual reproduction. Give an example. [illegible] plant [illegible] with [illegible] to form[illegible]

16. To what phylum of the plant kingdom do the seed-producing plants belong? the highest. spermatophyte

17. What is the function of a flower? reproduction

18. What parts are essential to this function? pistil and stamen

19. What part of the corn plant represents the stamens? the tassel The pistils? the silk. How is the pollen carried in corn? by wind

20. On the end of an ear of corn, there are usually small undeveloped grains. How do you account for their failure to grow into seeds? they were not fertilized.

21. Sweet corn and pop corn planted near each other will often produce seed which will grow into a mixture of the two kinds of corn the following year. How do you explain this fact? The pollen of the one blows on the stigma of the other.

22. In an apple core there are usually small black specks, like tiny seeds. Why did they fail to grow into seeds? were not fertilized

23. How could you tell by looking at a flower whether it is insect or wind pollinated? By its color.

By [illegible]

UNIT V
Reproduction

B. Algae

Question: What kind of plant is an Alga? What methods of reproduction are found among the Algae?

The nasty green scum you have seen on ponds and stagnant pools is really a mass of very simple plants which belong to the lowest group or phylum of the plant kingdom. The color of the Red Sea is due to masses of free-floating plants of this group. Likewise the waters in the hot springs of the Yellowstone National Park owe their color to Algae. You already know that the plant kingdom has been divided into four large groups or phyla. The lowest group has been named Thallophytes. The Thallophytes have been divided into two classes, the Algae and the Fungi. The Algae are green; the Fungi are not green. The Thallophytes are very simple plants, such as the Pleurococcus, pond scums, and sea weeds of the ocean.

There are four sub-classes of Algae, as follows:

1. Blue-greens: Gleocapsa.
2. Greens: Pleurococcus, Ulothrix, Spirogyra, Zygnema and Vaucheria.
3. Reds: Salt water sea weeds.
4. Browns: Salt water sea weeds.

They increase in complexity from the blue-greens to the ocean forms.

It is easier to study the earliest and simplest forms of reproduction amongst the blue-green and green Algae than in any other group of plants or animals, for here we find the very beginnings of the process. In some of the green Algae fairly complex methods of sexual reproduction have already developed, so that you have a good opportunity for the study of the evolution of sex in plants.

Gleocapsa is a simple, one-celled plant, belonging to the blue-greens. It has a denser area in the center, which is called the nucleus, although it is not very definite. The cell has a cell wall and a sheath around it. The cytoplasm is blue-green in color in the living plant. It may be found in quiet water or on moist surfaces near water.

Gleocapsa reproduces by simple division. The nucleus of the mother cell divides in half. Then the cytoplasm pinches into two halves, either half containing one piece of the original nucleus. These two daughter cells may be held together by the sheath and the cells may continue to divide until sixteen-celled colonies are formed. Eventually they break apart and each cell lives as a whole plant. This production of offspring by the simple process of dividing into two parts is called cell division It represents the earliest type of reproduction. There is no sex here, for only one cell is involved, so it is called asexual (without sex).

This process of cell division has been observed many times in living cells under the highest magnification of the microscope. These observations show that division is not a mere pinching into two parts, but is rather a carefully controlled process.

For instance, Strassburger in Germany observed the division of a cell in a hair on the stamen of the wandering jew. In the normal living cell, he observed the nucleus as a clear ring with a small dot called the nucleolus, within it. As the cell prepared for division, he saw the nucleolus disappear and many fine granules appear within the nucleus. Then the edge of the nucleus disappeared entirely and the granules called chromatin collected onto a long thread called the linin. He saw then that the linin broke up into many short squirming rods which looked like eels in a box. We shall call these rods chromosomes. He also saw two stars appear at either end of the cell and these stars seemed to radiate lines into the squirming chromosomes. These lines are called the spindle.

In a few minutes more, he saw that each chromosome was splitting lengthwise into two halves. Then half of each chromosome seemed to move out on the spindle to one end of the cell and the other half of each chromosome moved the opposite direction on the spindle to the other end of the cell. In this position the chromosomes broke up again into the granular chromatin, an edge appeared around each of the two new nuclei, a cell wall came in between the two nuclei, and two normal daughter cells were visible where there had been only one mother cell. The process of division began at 10:10 and was completed at 11:30, according to Strassburger's report.

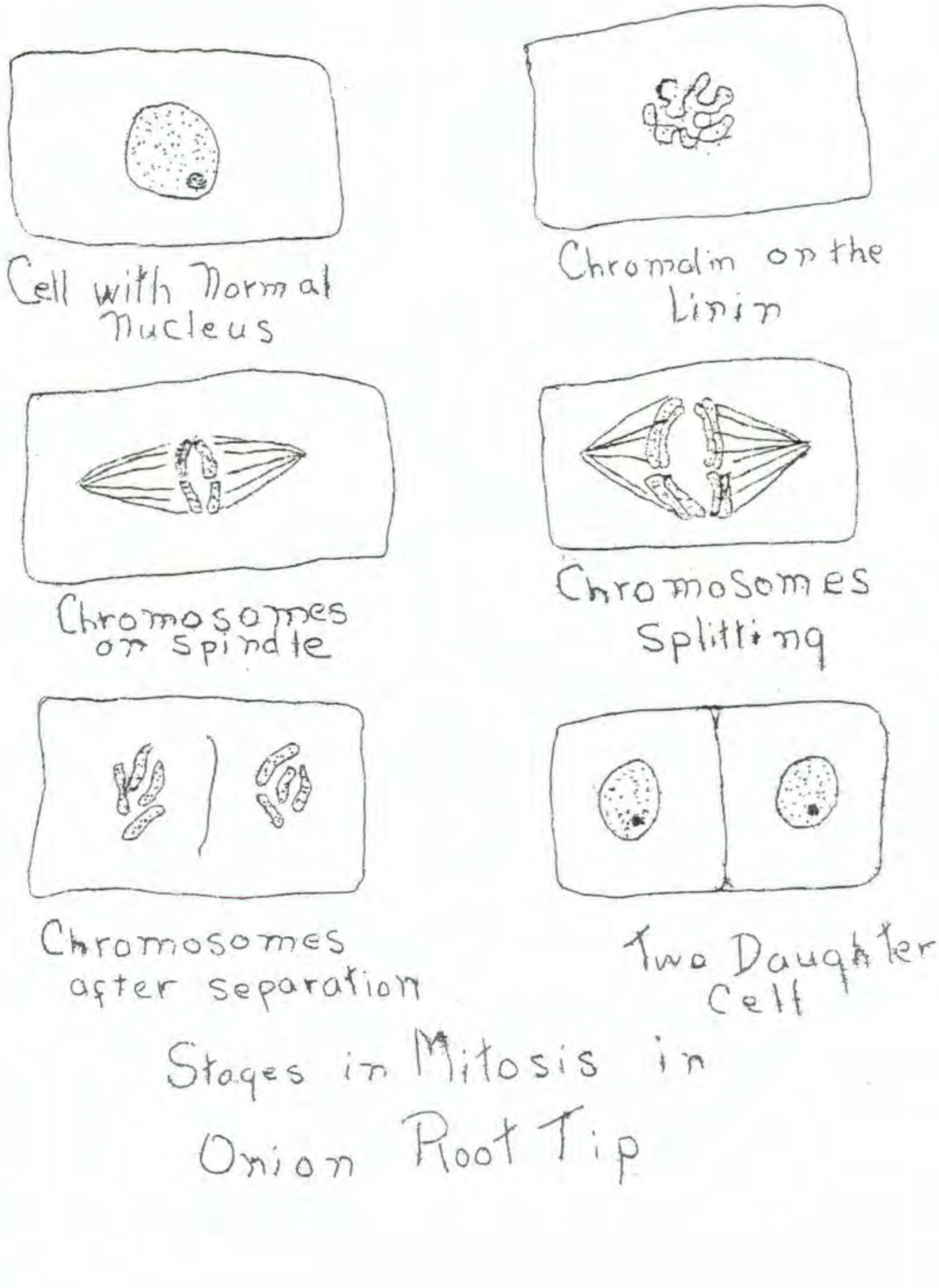
This process of cell division is called mitosis. We know now that it is the universal method of cell division, unless perhaps the bacteria do not divide in this manner, since no nucleus has ever been observed in bacteria. When a Gleocapsa or Ameba undergoes mitosis, two new organisms are the result, and this is their method of reproduction. When cells in the tip of an onion root undergo mitosis, new cells are formed which cause the root to grow longer. Mitosis may thus result in reproduction among one-celled organisms, or in growth among many-celled organisms.

Mitosis is a very exact process in that each chromosome of the mother cell splits in half longitudinally so that each of the daughter cells will receive the same number and kinds of chromosomes. Extensive research has convinced biologists that it is the chromosomes which make the offspring resemble the parent, so we speak of them as the determiners of heredity. Study diagram of mitosis carefully.

Pleurococcus is a green Alga which reproduces in the same way as Gleocapsa, as you already know. This is its only known method of reproduction, but some of its near relatives, which live in water, are able to produce spores under certain conditions. When this occurs, the cell wall of one cell thickens, the nucleus divides within the cell many times, and each new nucleus forms a spore. Then the old cell wall breaks open and the spores emerge as tiny cells with two cilia on each one so that they swim around in water. Eventually each spore settles down, loses its cilia, and becomes a typical one-celled plant again. This production of spores is also strictly asexual, since it starts from only one cell.

Ulothrix is a green Alga of a different type. One plant consists, not of one cell, but of a series of cells end to end like a string of beads. When a Ulothrix cell divides, it merely lengthens the string, which is called a filament. This results in growth of the filament, but is not reproduction, since a new plant is not formed.

The reproduction of Ulothrix illustrates the origin of sex. In reproducing itself, a cell within the filament divides into several spores within the one original cell wall. The cell wall then breaks open and the spores come swimming out into the water, for they possess cilia. After swimming around for a while a spore settles down, looses its cilia, and begins dividing. The new cell walls always come in transversely and the daughter cells remain together. The result is a new filament like the original Ulothrix. This is reproduction, since a new plant is formed, and it is asexual, since it begins with only one cell.



Stages in Mitosis in Onion Root Tip

This story of reproduction in Ulothrix sometimes shows an interesting variation. When a cell in the filament divides to form spores, it may form two, four, eight, sixteen, and thirty-two spores. When the number of spores is small, they are vigorous and healthy and readily grow into new filaments. On the other hand, when there are as many as thirty-two spores produced from one original cell, it has been repeatedly observed that they seem weak and many of them die, while only a few of them grow into filaments, which do not thrive as healthy plants. But if two of these weaker spores come near each other, they have been observed to flow together into just one cell. A remarkable result follows this fusion of two cells. The fertilized egg (for it may be so called) immediately regains vitality and grows into a healthy filament. This is reproduction, since it produces a new plant, and it is sexual, since it begins with the uniting of two cells. The two cells which fuse appear to be exactly alike and are called gametes.

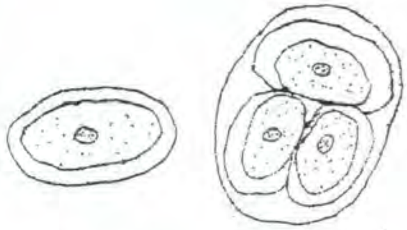
This is the botanist's story of the origin of sex, which did not exist in the beginning of life, when simple division was the only method of reproduction. Sex really arose, not so much as a means of reproduction, but rather as a means of restoring vitality to a race of one-celled or filamentous plants, weakened by long-continued cell-division. The first advantage of sexual reproduction is therefore the increased vigor of the race.

There is a second advantage, which is evident, if we consider that the daughter cells resulting from simple division must be almost exactly like the mother cell, since both receive identical sets of chromosomes. But when two cells fuse, as when the two Ulothrix spores unite, or the male cell of the pollen unites with the female cell of the ovule in a flower, each cell contributes its own set of chromosomes. Since these two sets of chromosomes may differ, there is a chance for the offspring to show considerable variation from either parent, in that it will combine inheritance from each. Variation in the offspring is necessary if there is to be any change or advancement in living things. The vital importance of this second function of sexual reproduction is thus evident.

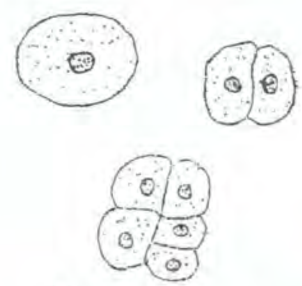
We may summarize by saying that the two functions of sex are to restore vitality and to make variation possible in the offspring.

In Spirogyra, which is simply the scientific name for the plants which make up the green pond-scum on lakes and ponds, the next step in the evolution of sex is readily learned. Spyrogyra is another plant made up of a thread of cells, end to end, like a string of beads. A plant having this structure is called a filament, as you learned in your study of Ulothrix. Each cell of the Spirogyra contains a nucleus, cytoplasm, a cell wall, and a long spiral green ribbon called the chloroplast.

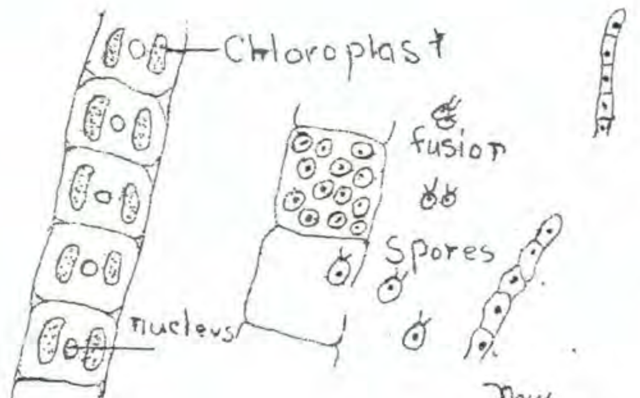
Spirogyra ordinarily reproduces by spores, just like the asexual method of Ulothrix. But the sexual method is different and more complicated. In this method two separate filaments (plants) come to lie beside each other. A little tube-like projection grows out from each cell toward the cell opposite in the other filament. Two of these tubes meet, and join end to end, thus forming a passage-way from the cell of one filament over into the cell of the other filament. The cell contents of each cell pull together into a mass. One of these masses moves over through the tube passage-way into the nearest cell of the other filament and fuses with the other mass there. This fertilized egg is then released from the filament by the breaking of the cell wall. On the outside, it divides many times transversely, thus growing into a new filament. This is sexual reproduction, since it begins with the uniting of two cells. It is called conjugation in Spirogyra.



Gleocapsa

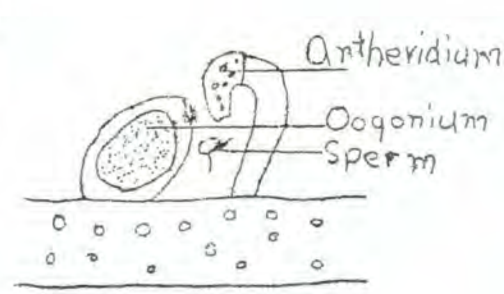


Pleurococcus

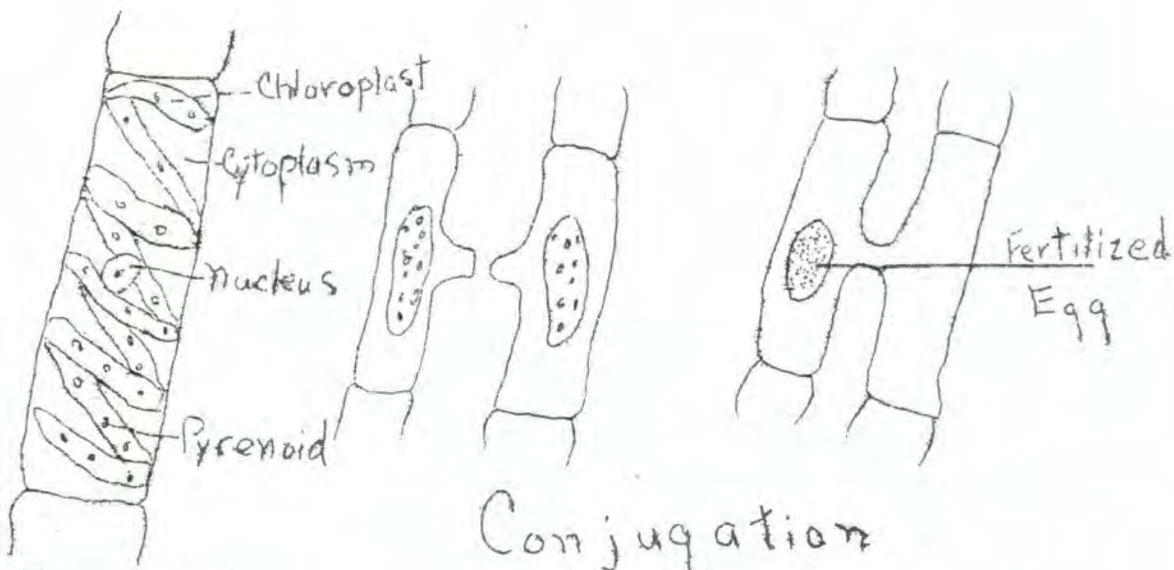


Ulothrix

New filaments of Ulothrix



Vaucheria



filament

Conjugation

Spirogyra

After fertilization has been completed in all the cells of the filaments, it is seen that one filament is left empty, while the other contains all of the fertilized egg. The empty filament is therefore a male plant, since it is the male cell which moves to the female cell in sexual reproduction. The male cell is called a sperm or male gamete and the female cell is called an egg or female gamete. This is the advance which Spirogyra has made over Ulothrix in the evolution of sex. In the latter, no one can tell which is male or female, while in the former the two sexes have been differentiated.

Vaucheria is another green Alga, which shows the highest evolution of sex in this group. It is both filamentous and it reproduces asexually by spores. In its sexual reproduction two structures grow out from the side of the filament. One of them is a round structure called the oogonium. Within it an egg(female gamete) is formed. The other is shaped like a question mark. Within it many sperms (male gametes) are formed. This latter structure is called the antheridium. It breaks open at the top and the sperms swim out. One of them reaches the egg in the oogonium and unites with it. The fertilized egg is then released and grows into a new filament. Here you have sexual reproduction, with male and female cells differentiated and with special sex organs evolved to produce them.

The red and brown Algae are marine forms, adapted to life in salt water. They have developed beyond even the filamentous structure, showing great variety in form. Some of them show simple branching and still others have such elaborate branching that they appear like delicate, complicated, feathery structures. The Sargasso Sea which was popularized in "The Isle of Lost Ships" consists largely of these sea weeds.

They also show highly developed sex organs, but they are interesting only as peculiarities because they do not appear to have developed into the higher plants, such as mosses and ferns, while there is every evidence to show that some of the green Algae did develop into simple mosses. Consequently, the study of the reds and browns belongs in an advanced course in botany, rather than in a high school course in general biology.

In tracing the evolution of sex in the green Algae, we may note first in Ulothrix the fusion of two similar cells which are called gametes, thus restoring vigorous reproduction by normal cell division. This appears to be the true origin of sex. In Spirogyra a second step in the evolution is reached, in that male and female gametes and individuals have both been differentiated. In Vaucheria the third and highest step for this group of plants is reached, in that actual female and male sex organs have evolved.

These stages may be summarized thus:

1. The origin of sex, with the fusion of two similar gametes.
2. The differentiation of gametes into male (sperms) and female (eggs).
3. The differentiation of male and female plants.
4. The appearance of special male and female sex organs.

Laboratory Study VII

The Algae

Gleocapsa: Look at a slide of Gleocapsa under the microscope. What surrounds each cell? sheath. How many cells do you see in any one colony? [illegible]. How does this plant reproduce? fission. What color is it, when alive? blue green.

Sketch a single cell, and a few colonies. Label the sheath, cell, wall, cytoplasm, colony.

Spirogyra: (Zygnema may be substituted, if at hand). Look at some living Spirogyra under the microscope. What shape is each plant? [illegible]. What name is applied to a plant of this shape and structure? [illegible]. What is the color of it? [illegible]. Can you see the spiral ribbon? yes. What is its name? [illegible]. What is its color? green. How can you tell where one cell ends and the next begins? [illegible].

Look at a slide of dead Spirogyra, which have been stained. Sketch one cell of the filament, labeling the nucleus, cytoplasm, cell wall, and chloroplast.

Look at a slide of dead, stained Spirogyra, which shows conjugation. Sketch and label the tube, male filament, female filament, and fertilized egg.

Look at a slide of Vaucheria and sketch a bit of the filament showing the sex organs. Label the egg, sperms, antheridium, oogonium, and filament.

What is the type of reproduction of each of the following?

Gleocapsa	fission				
Pleurococcus	"	and	spores		
Ulothrix		and	[illegible]		
Spirogyra	[illegible]	and	[illegible]		
Vaucheria	[illegible]	and	[illegible]	and	[illegible].

Laboratory Study VIII

Mitosis in Onion Root Tip

The division of cells within a tissue naturally results in growth, rather than reproduction. For instance, a root grows longer at the tip, by the dividing of the cells there. Consequently, the root tip is one of the best places to see mitosis.

You have already seen the root tip of the onion for a study of the normal cell.

Look at the same slide again. Do you see a cell containing rods? yes. What are they? chromosomes. Are any of them splitting? yes. Or have they already split and moved apart? yes. Can you see the new cell wall beginning to form? [illegible]

Sketch at least one cell, containing chromosomes. Label fully.

Review of Subtopic B of Unit V

1. The lowest phylum of the plant kingdom is the Thallophyte. Its two classes are fungi and algae.

2. Gleocapsa is [illegible] in color. Each plant consists of how many cells? one
   It reproduces by fission, which is sexual? asexual?

3. Pleurococcus is green in color. How does it reproduce? [illegible] and [illegible]. Does it have sex? no. Why? because [illegible]

4. Ulothrix is green in color. What shape is one plant? [illegible]. Its most common method of reproduction is by spores. When these spores become weak and begin to die, what may happen? they unite. What effect does this fusion have upon the vigor of the cell? [illegible]. Is this sexual? yes. Why? two cells unite

5. What color is Spirogyra? green. Where is it found? ponds. What shape is one plant? [illegible]. What parts has one cell? cellwall, nucleus, pyrenoid and chloroplast. What is the common method of reproduction? conjugation. Is this sexual? yes. Why? two cells. What is the other method of reproduction? spores. Is this sexual? no. Why? asexual.

6. Two advantages of sex seem to be to give variation and vitality to the offspring.

7. In the evolution of sex, first in Ulothrix there is the fusion of two like cell called gametes. Then in Spirogyra the male and female cells are differentiated. The male cell is called a sperm and the female cell is called an egg. Finally a special organ, called the oogonium, is developed in Vaucheria, to produce the female cell, and another special structure, called the antheridium, to produce the male cells.

8. Red and brown Algae are found in the ______________.

9. To what phylum of the plant kingdom do the Algae belong? ______________. Why is this phylum considered the lowest? ____

____.

UNIT V
Reproduction

C. Protozoa

Question: How do the one-celled animals reproduce?

You have already seen several kinds of Protozoa under the microscope. You may have seen a Paramecium which looked as though it were slitting into two parts, or you may have seen two Paramecia united along the side. In a hay infusion, there are sure to be many Protozoa reproducing. When the hay is first put in the water, there will be only a few Amebae or Paramecia present. As the hay decays, these Protozoa will find such an abundant food supply that they will begin dividing rapidly.

By mitosis, one Ameba divides into two Amebae, and these two divide again, in a manner similar to Gleocapsa and Pleurococcus. The number of Amebae which can be produced from one original Ameba in a few days is astounding. If you compare a drop of water from a new hay infusion with a drop from one a few days old, you will see the result.

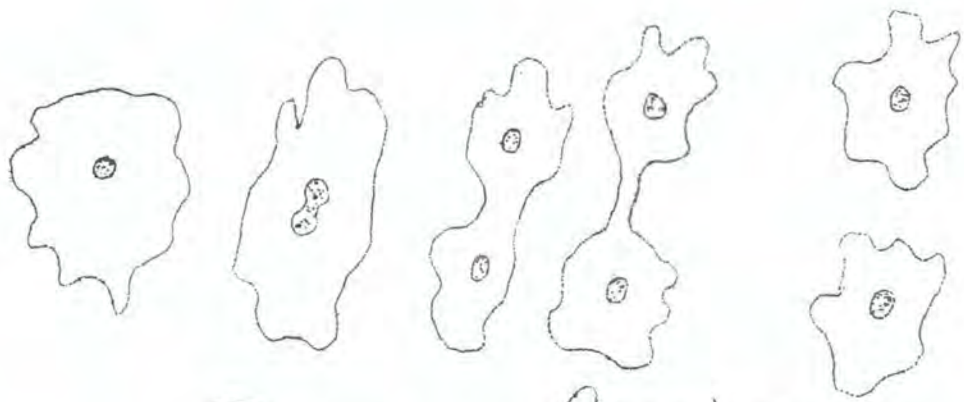
Ordinarily, Amebae reproduce by division. But if the water in which they are living begins to dry up, or the food supply becomes scarce, they are able to pull themselves up into a round ball and form a hard crust over the surface of this cell, which is now called a cyst. These cysts are light and can be carried in the wind, so some of them will be blown onto hay or any vegetation near by. As long as they are dry, they remain as cysts. But when the hay is placed in water, the cysts lose their hard coat, the Amebae regain pseudopodia, and again assume an active life. It is the division of these Amebae, which came out of the cysts, which gives us the numerous Amebae in the hay infusion.

There is a species of Ameba, called Ameba hystolitica, which grows in the intestine of man. There, they eat the lining of the intestine, causing ulcers. These ulcers cause amebic dysentery, a human disease which occurs very commonly in the tropics, and occasionally in the temperate zones. The disease is contracted by eating lettuce or some other uncooked vegetable, which has some of the amebic cysts on it. The cysts emerge, when they arrive in the intestine and the Amebae divide rapidly. The disease is very difficult to cure, but a cure is possible. Any recurrent case of diarrhea should be under the observation of a doctor as a possible amebic dysentery.

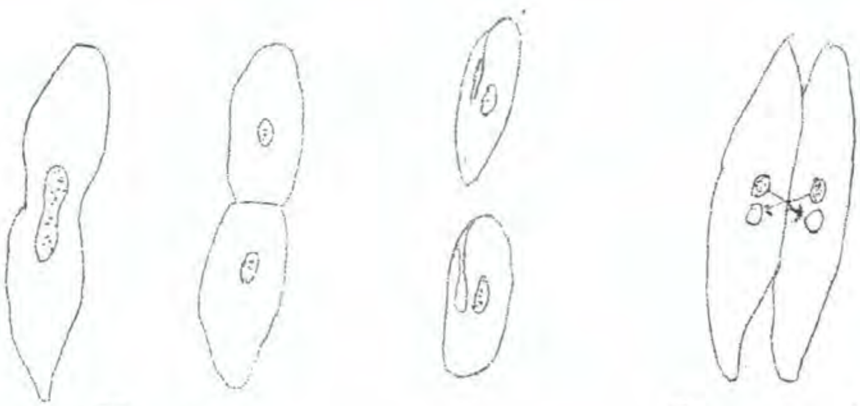
When a Paramecium divides, the nucleus forms its chromosomes which split in half to form two nuclei, then a new wall comes across the cell, and the two daughter cells break apart and swim away, each with its own mouth, gullet, and vacuoles. This is asexual reproduction, such as the Gleocapsa and Pleurococcus show, and is also called mitosis.

Paramecia also reproduce by another method, called conjugation. Two Paramecia are joined side by side. The cell wall between them disappears. The nucleus of each divides by mitosis. Half of each nucleus moves over into the other cell. The other half of each nucleus remains in its original position. The half which moves over into the other cell is the male and the half which does not move is the female. The male nucleus from one Paramecium unites with the female nucleus from the other. After this fertilization is accomplished, the cell wall reappears between the two Paramecia, they separate, and each assumes its own life again. This process of conjugation is sexual, and it seems to restore vigor to the animals just as the union of two cells restores vigor to the spores of Ulothrix.

There are many other kinds of Protozoa, but they live and reproduce very much as do the Amebae and Paramecia. Therefore, these two are typical of the phylum, Protozoa.



Division of Ameba



Division Conjugation

Paramecium

B — 9

Review of Unit V —C

1. To what phylum do the Amebae and Paramecia belong? Protozoa.
2. How does an Ameba reproduce, usually? fission. What may an Ameba form, if the water begins to dry up, or the food supply grows scarce? cyst. Do Amebae have sex, as far as is known? no.
3. In what two ways do Paramecia reproduce? fission and conjugation. Do Paramecia have sex? yes.
4. What human disease is caused by one species of Amebae? amebic dysentery How is this disease contracted? by eating some uncooked food. Can it be cured? yes. In what region is it most common? in the tropics

UNIT V
Reproduction

D. Mosses

Question: How do mosses reproduce?

Mosses are small plants which grow commonly on rocks or logs. They are more complex than the Algae, for they have little root-like structures, called rhizoids. They also have little leaves, but no true stems or flowers, such as seed plants have. They never grow very tall, because they do not have any woody (fibrovascular) tissue to give them strength to stand up from the ground or to carry water up from the rhizoids to the leaves. They belong to the second phylum of the plant kingdom, called Bryophytes.

You may have noticed that mosses sometimes have bristles projecting up above their leaves. Mosses with bristles are reproducing. The bristle has a stem and an enlargement on top, called the capsule. There is a cap over the capsule, called the calyptra. Under the calyptra is another cap which breaks loose from the top of the capsule along a row of teeth. This second cap is called the operculum.

When the capsule is ripe, the calyptra and operculum loosen and fall, leaving the top of the capsule open. Within it there are many ripe spores, which have been formed by simple division or mitosis of cells, just as a cell of Ulothrix divides to make spores. This is asexual reproduction. These moss spores are not ciliated, so they cannot swim. They are simple, round cells which are blown by the wind to another moist log or rock surface.

On the moist surface, a spore puts out a little filament, very much like Spirogyra or any filamentous green Alga. This filament is called a protonema and it is good evidence that green Algae were the ancestors of mosses. Buds next appear on top of the filaments, which grow into the moss plant with its rhizoids and leaves.

When a moss plant is ready to reproduce, a little rosette of leaves forms on top of it. If this rosette is cut through lengthwise, and a thin slice of it is looked at under the microscope, it will be found to contain two kinds of sex organs, an antheridium containing sperms, and an archegonium containing an egg. The archegonium is a flask-shaped structure with a neck. The egg is at the bottom of the neck which is hollow when it is mature. The antheridium breaks open and the sperms, which have two cilia (another suggestion of algal ancestry), swim out in the moisture on the moss plant. They swim around until they find the open neck of the archegonium. The first sperm down the neck reaches the egg and unites with it. The fertilized egg then begins to grow into the bristle which produces the capsule containing the spores.

The spore will again produce a protonema, which will grow a bud to be developed into a moss plant with its antheridia and archegonia. The sperm will again fertilize the egg, which will grow into a bristle with its capsule full of spores. This is the story of the life history of mosses. In one life history, there is an alternation between an asexual (spore-bearing) stage and a sexual (egg and sperm-bearing) stage. The spore-bearing stage of any plant is called the sporophyte and consists of the bristle in mosses. The sporophyte starts with the fertilized egg and ends with a spore. The egg and sperm-bearing stage of any plant is called the gametophyte and consists of the leafy plant in mosses. The gametophyte starts with the spore and ends with the fertilized egg. Thus mosses are said to have an alternation of generations.

Laboratory Study IX

Mosses

Bring into the laboratory a clump of moss plants with bristles. Carefully separate one plant from the rest. What are the little projections at the bottom of the plant called? rhizoids. What is the name of the enlargement at the top of the bristle? capsule. What are the two caps on top of it called? calyptra and operculum. Break the two caps loose. What do you find inside the capsule? pith and spores.

Sketch a moss plant and label the rhizoids, leaves, bristle, capsule, and calyptra. Beside your drawing, sketch a few spores under the microscope.

Look at a slide of dead moss protonemas. From what did the protonema grow? spore. Into what will the bud on the protonema grow? new moss plant. What is the shape of a protonema? filament. What plants already studied does this protonema resemble in form? spirogyra.

Sketch a protonema.

Under the microscope, look at a prepared slide, showing a thin slice through the rosette at the top of a moss plant. Can you see the antheridium and archegonium? yes. What does the antheridium contain? sperms. What is the shape of the archegonium? flask shaped. What cell do you see at the bottom of the neck of the archegonium? the egg. Is there an open tube down the neck? open. Why is it there? so the sperms can unite with the egg. Into what will the fertilized egg grow? bristle.

Sketch very carefully an archegonium and an antheridium. Label the sperms and egg.

Review of Unit V -- D.

1. To what phylum of the plant kingdom do mosses belong? Bryophyta.
2. Why do mosses not grow tall? Because they don't have any fibrovascular tissues.
3. The moss spore is formed by the process of division within the capsule of the bristle. When the spore lights upon a moist surface, it grows into the protonema, which produces buds which grow up into moss plant. On top of the moss plant, a rosette forms, which produces a male sex organ called the antheridium and a female sex organ called the archegonium. The male sex organ produces sperms which swim to the egg inside of the female sex organ. The fertilized egg then grows into the bristle which produces the capsule on its top. The spores again form here, to start the life history over again.
4. What is the name of the spore-bearing stage of any plant? sporophyte. With what cell does this stage begin in mosses? egg. end? spore.
5. What is the name of the egg and sperm-bearing stage in any plant? gametophyte. With what cell does this stage begin in mosses? spore. end? fertilized egg.

UNIT V
Reproduction

E. Ferns

Question: How do ferns reproduce?

The common house fern is familiar to everyone, but its method of reproduction is probably entirely unknown to you. Ferns are really abundant on the earth. There are many different kinds such as the Christmas, sensitive, maiden-hair, bracket, and walking ferns. In the past there was a time when ferns dominated the vegetation of the earth just as completely as the spermatophytes dominate it today. But many of the species, including most of the tree-ferns, have disappeared.

Ferns belong to the third phylum of the plant kingdom, called the Pteridophytes. They have a stem (which is usually underground) with fibrovascular tissue, which enables them to grow up from the ground. They have true leaves (fronds) and roots, but they do not have flowers or seeds.

You may have noticed that brown spots appear on the under side of the fern leaves at certain times of the year. These spots are not a symptom of disease, as many persons believe, but are a sign that the fern is beginning to reproduce.

One of these brown spots of the Christmas fern (the common house fern) under magnification is seen to consist of a little umbrella-like covering called the indusium, with small round structures, called sporangia, under the "umbrella". The whole structure is called a sorus, and the brown dots on the back of fern fronds are called sori.

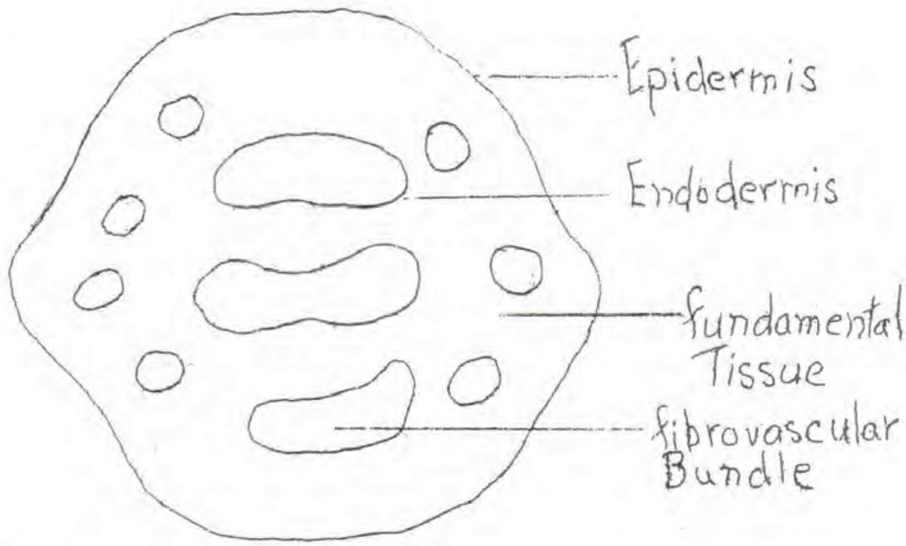
When the sporangium is examined under the microscope, it is found to consist of a peculiar ring of teeth-like springs around the edge, called the annulus, and a space within, which is filled with spores. These spores are produced within the young sporangium by simple division (mitosis) of the cells there. When they are ripe, the annulus springs open, throwing the spores out.

When the spores fall upon a moist rock or log, each one grows into a flat, heart-shaped, green leaf-like structure, about the size of your thumb nail. This structure is called the prothallium. On the under side of the prothallium, archegonia and antheridia form, very much like those of mosses. The sperms have many cilia, with which they swim to the egg within the archegonium.

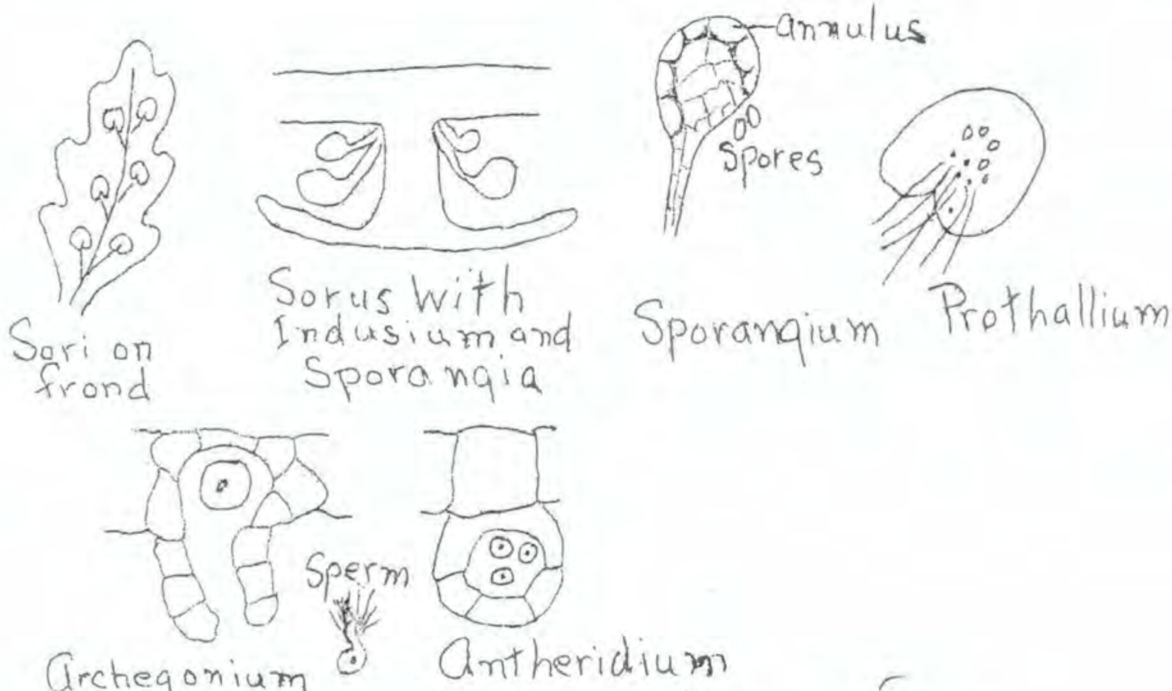
The fertilized egg in the archegonium then grows into the fern plant with which you are familiar. The frond of the fern plant again produces sori, with their sporangia, and spores. The fern plant itself is the sporophyte since it produces the spores asexually. The prothallium is the gametophyte, since it produces eggs and sperms, which mark the sexual generation. As in mosses, the sporophyte (fern plant) grows from the fertilized egg and ends with the spores. The gametophyte (prothallium) grows from the spores and ends with the fertilized egg. Thus ferns also are said to have an alternation of generations, similar to mosses.

Laboratory Study X

Ferns



Cross Section of Fern Stem



Stages in Life History of Fern

There are several different kinds of ferns available in the laboratory. Look at them and see if you can learn to recognize four or five kinds.

Observe a whole fern plant carefully. Where is the stem? underground Are there roots? yes. What are the parts above ground? leaves What other name do the leaves have? fronds. Do you find a frond with brown dots on the back? yes. What are they called? sori.

Sketch a portion of a frond from below, and label the sori.

Look at a prepared slide showing the cross section (thin slice cut cross wise) of a fern stem (also called rhizome) under the magnifying glass. Compare the slide with the diagram on page 43. What tissues do you see? epidermis endodermis fundamental tissue and fibrovascular bundle

Diagram the cross section of the rhizome and label these four tissues.

Do you notice large cells stained red and small ones stained blue both within the fibrovascular bundle? yes. The red cells are wood or xylem and they allow the water to go up the stem. The blue ones are phloem and they allow sap to flow down the stem. These woody cells look very much like the cork cells which Hooke saw in 1667. Do they have nuclei or cytoplasm? neither Do you understand now why Hooke named them "cells"? Yes. Even these wood cells had nuclei and cytoplasm, however, when they were young and alive.

Look at a sorus under the magnifying glass. Do you see the umbrella-like covering? yes. What is it called? indusium Do you see the little round bodies sticking out from under the "umbrella"? Yes. What are they called? sporangium

Look at some of these sporangia under the microscope. Do you see the ring of teeth around the edge? Yes. What is this ring called? annulus Do you see the cells inside? Yes. What are they? spores. How were they formed within the sporangium? cell division

Sketch the sorus as you see it under the magnifying glass, labeling the indusium and sporangia. Sketch also the sporangium under the low power of the microscope labeling the annulus and spores.

Look at a stained prothallium on a prepared slide. What shape is it? heart

What two structures are produced on the under side of the prothallium? archeg
and antherid. What is their function? to reproduce
________________. How do the sperms reach the egg?
By swimming. Into what does the fertilized egg grow? New plant.

Laboratory Study XI

Growth of Prothallia

(Optional)

Try to grow some fern prothallia by dusting some spores from the sori on an inverted moist flower-pot. Keep the flower-pot moist by turning a bell jar over it. If the spores grow, let the class see the prothallia. Watch them for germinating sporophytes.

Betty Hofmann

Review of Unit V -- E.

1. To what phylum do the ferns belong? Pteridophyta.
2. Name four common ferns. Christmas, Walking, Maiden Hair and bracken.
3. Are ferns more or less numerous than in past ages? less
4. What enables ferns to grow taller than mosses? fibrovascular tissue
5. What is another name for a fern leaf? frond.
6. Where would you look for a fern stem? underground
7. What are the brown dots, sometimes found on the back of fern fronds called? sori.
8. Within what structure do the fern spores grow? sori. Where are these structures containing the spores found? under the sorus. The spores are shot out by the springing up of the annulus.
9. When a spore lights on a damp log, it grows into the prothallus, which is filament shaped. This structure produces antheridia and archegonia on the under surface, which contain sperms / eggs and eggs / sperms respectively.
10. The fertilized egg grows into the fruiter, which again produces spores.
11. Which part of the life-history of the fern is called the sporophyte? beginning with the egg gametophyte? beginning with spore. With what cell does a sporophyte always begin? egg. end? spore.
12. Do you think ferns have any asexual reproduction? yes. Prove it. Because they have an alternation of generation.

Do they have any sexual reproduction? yes. Prove it. Because when the sperm unit with the egg to form a new plant

UNIT V
Reproduction

F. Fruits and their Dispersal

Question: What is a fruit? How is a fruit formed? In what way are fruits related to reproduction? How are seeds scattered to new areas?

You have now traced the development of the function of reproduction from the simplest Thallophytes through the Bryophytes and Pteridophytes. In the beginning of the unit, you studied the flower of Spermatophytes. You are now ready for a review of the flower parts, and their functions. Reread "A" of this unit, in order to be ready for this problem on fruits and seed dispersal.

Have you ever noticed apple blossoms in the springtime, other than to enjoy their beauty and fragrance? The humming of the bees in an apple orchard in full bloom should suggest to you that cross-pollination is in process and you will find it worth your while to examine a flower at this time and then to repeat your examination several times during the following weeks.

Underneath the apple blossom, you will find a small green ovary. The blossoms of cherries and peaches differ from the apples in that the ovary is above and within the petals. This green ovary below the apple will begin to enlarge as soon as the petals fall. This will tell you that fertilization has been completed, for it is always followed by the growth of the fruit. If you look closely you will find that the sepals, stamens, and pistils have not fallen, but remain on top of the enlarging ovary. As a matter of fact, the outer layer is made up of the lower part of the sepals or calyx. This layer of calyx over the ovary and the ovary itself thicken and become juicy as they grow into the fruit, so that you really eat ripened calyx and ovary when you eat an apple. The dried stamens, pistils, and sepals make the black blossom end of the fruit. The seeds inside an apple grow from the ovules of the flower. Thus you see that fertilization stimulates the growth of seeds and fruit. The apple is a fruit because it is a ripened ovary with its contents.

Do you see why a peach and cherry have no blossom end, such as the apple has?

In the flower of a bean plant, there are sepals, petals, stamens, and a pistil The pistil is enclosed in the lowest petal, but when you remove it, it is found to look like a very small bean pod. After pollination and fertilization have been com pleted, the petals and stamens fall, but the green pistil, which is almost all ovar begins to enlarge. Eventually it matures into the bean pod with the bean seeds inside. The bean pod is simply the matured ovary and the beans are the ripened ovule Sometimes a bean pod contains small, undeveloped ovules. How do you account for them? The bean pod is a fruit, also, strange as it may seem, for a fruit is any ripened ovary with its contents. The beans themselves are seeds, since they are ripened ovules.

Laboratory Study XII

The Bean

Obtain a bean pod (locust pod may be substituted) in the laboratory. Note th stem-end of the pod, where it was attached to the plant. Look at the other end of the pod. Do you see the pointed projection? yes. This projection is the remains of the old stigma of the pistil. In a green bean, what happens when you break this end off the bean and pull it back toward the stem? The old style comes off This "string" which you pull off when you "string" beans is really the old style, and the bean pod is the matured ovary. Sketch the bean pod, open. Label the stigma, style, ripened ovary, and ripened ovules.

Obtain a bean seed (lima beans are best) which has been soaked in water. Can you see a scar on one edge of the bean? yes. It is called the hilum, and it marks the spot where the bean was attached to the pod. Can you see a tiny hole at one end of the hilum? yes. It is called the micropyle (little door) and it is the opening through which the pollen tube entered the ovule. The covering over the outside of the bean is called the testa. What do you suppose its use might be? for protection.

Hold the bean with the edge showing the hilum and micropyle toward you and sketch it. Label the hilum, micropyle and testa.

Remove the testa, being careful not to injure any inside part of the bean. When the testa has been taken off, the remaining part tends to separate into two halves. These two halves are called cotyledons or seed leaves. Between the two cotyledons may be seen two small leaves called the plumule and a small root joined to the plumule, called the hypocotyl. These three parts, namely: the two cotyledons the plumule, and the hypocotyl, make up the embryo, or baby-bean plant which grew from the fertilized egg. When the bean seed begins to germinate, the hypocotyl will grow down into the ground to make the root, the plumule will grow up to make the stem and leaves, and the cotyledons will supply the food necessary to make the root and leaves begin to grow.

Sketch the bean embryo beside your drawing of the been seed. Label the hypocotyl, plumule, and cotyledon.

Laboratory Study XIII

The Corn Grain

As you already know each silk on the young corn ear is really a style and each grain of corn is really an ovary. After the pollen from the tassel has fallen on the silk, the pollen tube has grown down through the silk to the ovary, and the male cell has fertilized the egg, the ovule begins to enlarge and soon ripens into the grain of corn. Therefore, a grain of corn is really a fruit, since it is a ripened ovary.

Obtain a grain of corn which has been soaked. Note the darker yellow portion which shows through on one side of the grain. It is the embryo. The skin is the old ovary wall. Cut the grain lengthwise and put a drop of iodine solution on the cut surface. What happens? starch turns black. The part that turns blue-black is the endosperm. Iodine always causes starch to turn blue-black. Of what is the endosper composed, do you suppose? starch. This endosperm is to serve as food for the embryo, just as the cotyledons do in the bean. This endosperm is not part of the embryo, as are the cotyledons. It was formed by the union of one male nucleus from the pollen with the endosperm nucleus of the egg sac (see Unit V -- A, Page 20.)

The embryo itself has its cotyledon pressed close against the endosperm, for the cotyledon will later digest the endosperm and feed it to the new root and leaves. Next to the cotyledon are two projections; one pointed up and the other down. One is the plumule, the other is the hypocotyl. From what did the embryo grow? fertilized egg.

Diagram your grain of corn and label the endosperm, cotyledon, hypocotyl, plumule, and old ovary wall in this diagram.

Point out three differences between a corn grain and a bean seed.

1. Bean has two cotyledon and corn has one
2. Bean is a seed corn a fruit
3. Bean stores food in cotyledon and corn in endosperm

Any plant which has two cotyledons in the seed, such as the bean, is called a Dicotyledon. Any plant which has only one cotyledon in the seed, such as the corn is called a Monocotyledon. Lilies, grasses, orchids, and all grains, are Monocotyledons. Most of the rest of our common seed plants are Dicotyledons.

Laboratory Study XIV

The Apple

Cut an apple into two halves longitudinally. Note the blossom end of the apple. What three withered flower parts do you see? sepals, stamens, and pistils
What has become of the petals? They have dropped off

Do you see a green line outlining the edge of the core? yes. It marks the outside of the ovary and the rest of the outer part of the apple, including the skin came from the thickened calyx. What flower parts do we eat, when we eat an apple? ovary and calyx.

Within the core are the seeds. From what did they grow? fertilizing Do you see any black specks in the core? yes. What do they appear to be? unfertilized seeds
How do you account for their failure to mature into seeds? they were never fertilized.

Sketch the longitudinal section of the apple. Label the blossom-end, core, thickened ovary wall, thickened sepals, and ovules.

All fruits are formed in a manner similar to apples, beans, and corn. After fertilization, the ovary enlarges and the ovules within it grow into seeds. This ripened ovary with its contents is always a fruit. For instance, the acorn of the oak tree is a fruit because it is the ripened ovary of the flower. A black walnut is a seed, but the green covering which must be shelled from the walnut, with such a staining of hands, is the fruit, because it is the ripened ovary. Spanish needl "Indian tobies" of catalpa trees, pumpkins, and tomatoes are fruits in the botanic sense, because they are all ripened ovaries.

After the fruit is ripe, the next problem of the plant is the distribution of its seed to a new location. If all of the acorns fell to the ground beneath the parent tree, the competition for soil, water, and light would be so keen, that very few, if any, of the seeds would grow. The food stored in the cotyledons of the acorn tempts squirrels or other animals to carry it off for food. They drop some of the acorns along the way, and store others where they forget them. As a result, the squirrel has his winter food supply, and the oak tree has its fruit containing the seed carried to a new location.

Fruits and seeds have developed all kinds of devices to secure their dispersal. The dandelion seed has a tuft of hair on it, which enables it to be carried by the wind. Many other seeds such as the milkweed have this same device.

The fruit of the maple tree has two wings on it, which make it float on the wind for considerable distances. Other fruits that have the same adaptation are the linden (monkey nut tree), tulip poplar, ash, and tree of heaven.

The bur of the burdock has hooks all over it. These hooks catch in the fur or hair of animals, which carry them to new areas. Other fruits having hooks on them are cocklebur, beggars' lice, and Spanish needles.

The fruit of the witch hazel looks like a little solid nut. When it is ripe, the shell suddenly snaps open with such force that the seeds are shot as far as twenty or thirty feet. This adaptation is called a mechanical device and may be observed in the touch-me-not also.

Field Trip
Seed Dispersal

Make an excursion into a weedy field and spend some time observing the fruits and seeds. Try to find as many types of seeds to illustrate the various adaptations for dispersal as possible. Make a collection of fruits and seeds which you find, to bring into the laboratory for further study.

Laboratory Study XVI

Seed Dispersal

Sketch and name three fruits, which have wings.

Sketch and name five fruits or seeds which have feathery attachments.

Sketch and name three fruits which have hooks on them.

What advantages to the plant do you see in the sweet juicy fruit of the apple? To attract animals to eat the fruit and so get scattered.

Why do fruits need to be scattered? So they can get to soil, to be placed where there is plenty of water so they can grow a new plant.

Name five adaptations for dispersal. Wings, feathers, hooks, [illegible], and sweet pulp. By what different means may dispersal be accomplished? Wind, water, hooks, [illegible], Mechanical devices

Laboratory Study XVI

Other Fruits

(Optional)

Study a peach or plum. Are the sepals thickened to form part of the fruit, as they were in the apple? _____. Why do you answer thus? ____.

Crack open the seed. Do you see the brown skin over it? _____. To what part of the bean would you compare this brown skin? ________. Is the peach a Monocot or a Dicot? ____________. Why? ____.

Look at some chestnuts. Note the projection on the end of each chestnut. This is the old style. How many stigmas were there? ______. Is the chestnut a fruit or a seed? ________. Why? ________________________________. When you shell a chestnut to eat it, what do you throw away? ________. What do you eat? ________. Is the chestnut a Monocot or a Dicot? __________. (The bur on the chestnut is an involucre and not an ovary wall.)

Look at some hickory nuts or horse-chestnuts (so-called buckeyes) before they are out of the green covering. This whole structure is the ripened ovary. Is a hickory nut itself or a horse-chestnut a fruit or a seed? _______. Why? _______

____.

Are they Monocots or Dicots? ________________________.

Make a similar study of any other available fruits. Answer the following questions about each one.

a. What constitutes the whole fruit? __________________.

   Why? ____.

b. How are the seeds scattered? ____

   ____.

c. Is the plant a Monocot or Dicot? __________________.

d. If the fruit or seed within is edible, exactly what part of it is eaten?

   ________________. From what part of the flower did this edible portion develop? ________________.

Billy Hoffman

F – 1/6

Review of Unit V -- F.

1. The four phyla of the plant kingdom are the Thallophyta Pteridophytes Bryophytes and Spermatophytes
2. What is a fruit? A fruit is a ripened ovary with its contents.
3. From what parts of the flower does the apple develop? ovary and ovules
4. Why is the bean pod a fruit? Because it is a ripened ovary
5. Is the corn grain a fruit or a seed? fruit.
   Why? Because it is a ripened ovary.
6. In the bean seed, the covering is called the testa. Its function is for protection. The opening where the pollen tube entered is called the micropyle and the scar where it was attached to the pod is called the hilum.
7. The embryo of the bean consists of two cotyledons, a plumule, and a hypocotyl. It developes from the fertilized egg of the ovule.
8. When the bean starts to grow, the hypocotyl grows into the root, and the plumule grows into the stem and leaves. The two cotyledons supply the food for the young plant.
9. What is the covering of the corn grain? old ovary wall
10. What is the name of the tissue in which the food is stored in the corn grain? endosperm. From what did this tissue develop in the ovule? the nucleus united with endosperm.
11. Name the three parts of the embryo in the corn seed. plumule, cotyledon, and hypocotyl. From what did the embryo develop? fertilized egg
12. What is the name of the part of the corn embryo which digests the food for the young plant? cotyledon. What is the function of this same part of the bean embryo? stores food

Betty Hofmann

13. How many cotyledons does a bean embryo have? two. What do botanists call plants which have this number of cotyledons in the seed? dicotyledon

How many cotyledons has a corn embryo? one. What do botanists call plants which have this number of cotyledons? monocotyledon

14. Why is seed dispersal necessary? [illegible]

15. Name five types of adaptation for dispersal. [illegible], [illegible], hooks, mechanical devices and [illegible].

16. By what means are fruits and seeds scattered? animals, wind, water, mechanical devices and [illegible].

26. cotyledons
27. the ovule
28 ripened calyx
29 ripened seed, calyx and ovary
30 the ripened ovules
31 the ripened ovules
32 ripened ovary
33. ripened ovary
34 ripened ovules
35 ripened ovaries and ovules,

UNIT V
Reproduction

G. Insects -- Phylum - Arthropods, Class - Insecta

Question: How do butterflies and moths, bees, and other insects reproduce?

You are familiar with the large green "tomato worm", so called, and you probably consider it ugly. If you will overcome your feeling of repulsion long enough to place one of these green "worms" in a glass jar with some leaves from the plant on which you find it, you will become so absorbed in watching what happens that you will forget entirely that it was once ugly to you. At first your specimen will devour the leaves you have put in the jar, for this "worm" has a ravenous appetite. When he ha eaten his fill, you will notice that he comes to rest and begins to spin a thread, like a thread of dainty silk. He will wrap this thread round and round himself unti he is completely covered. If you hold the structure to your ear, you can still hear him spinning within. Finally he has finished and you are in possession of a cocoon.

If you will keep your cocoon over winter and watch it during the early spring, one day you will find a wet worm-like thing crawling out of one end of it. You will notice four small wings perhaps an inch long hanging limply at the sides, and two large feathery antennae or feelers projecting from the head. And the head itself will have changed greatly from that of the worm. As you watch, you will see the wings become longer as the new moth tries feebly to spread them out. It will seem though these wings are actually growing before your very eyes, for in half an hour' time, they will be as long as the abdomen, and as the moth continues to try to spre them, they will continue to enlarge and dry. In a couple of hours you will have a beautiful specimen of a cecropia moth with a wing spread of several inches.

Thus you see that the ugly green "worm" is not a worm at all, but really only one stage in the development of a georgously colored moth. This stage in moths and butterflies and all insects is called a larva. Larvae have feet, so that you need never again make the popular mistake of calling a larva a "worm", since true worms do not have any feet, and larvae always do.

After a few hours, the moth which has emerged from your cocoon will spread his newly-dried wings and fly away. Do not try to handle him, for if you do, you may rub the small scales from his wings, making him unable to fly. His flight is very important, if he is to serve his only purpose, which is to find and mate with a fe male cecropia. In the mating, the sperms of the male will be discharged over the eggs of the female, still within her body.

After the eggs are fertilized, a shell is formed over each egg, and the femal then lays the eggs on the leaves of such a plant as the tomato. The eggs hatch i larvae with their enormous appetites. It was one of these full grown larvae which you caught as a specimen.

A butterfly's life history is very similar to that of the moth, except at on point. Let us trace the common white cabbage butterfly through its lifetime to s how it resembles and differs from the moth.

The cabbage butterfly is the common white butterfly, with black dots on the wings, which you see flitting about over the fields and hovering over mud puddles the spring. Pioneer mothers used to tell their children that they could go bare-footed when these butterflies arrived.

As they fly hither and thither, you may see them visit various spring flowers to sip the nectar (and incidentally they carry pollen from flower to flower), or you may see them alight on the leaves of a cabbage or other plant of the mustard family, where they will lay several small yellow eggs, which are fastened to the leaf by a kind of glue. Before the eggs are laid, a male and female have mated, otherwise the eggs would be unfertile and fail to hatch.

A small green caterpillar or larva emerges from the egg after a week or so. These larvae or "cabbage worms" devour the cabbage leaves to such an extent that they are considered the worst enemy of the cabbage crop. Naturally the ingestion of such quantities of food causes the rapid enlargement of the larvae, so that after a few days their skin becomes too small for them and they shed it. This moulting of the skin is repeated several times during the next two or three weeks, until they become full grown caterpillars.

The full grown larvae is still pale green, much the color of the cabbage leaf. At this stage they usually leave the cabbage plant to find a board or fence post to which they cling. Here they spin a chrysalis about themselves much as the moths spin cocoons. Compare pictures of a chrysalis and a cocoon. In both, there is a period of rest, at the end of which the adult emerges, changed completely from the larva which made it. The chrysalis stage of the cabbage butterfly lasts only about a week, so that at least two life histories may be completed in one season. They also live over winter in the chrysalis stage.

The life history of a moth or butterfly may be summarized in four stages; namely: the egg, the larva, the pupa (cocoon or chrysalis), and the adult. Insects are said to undergo a complete metamorphosis, which word means change.

Other insects, such as bees and grasshoppers pass through similar stages in their life histories, but they may skip one or more stage, when they are said to have an incomplete metamorphosis.

The life history of honey bees shows some unusual variations. Adult bees are generally known to exist in three forms instead of two, as most animals do. There are drones or males, queens or females, and workers or undeveloped females. One hive of bees has only one queen, who lays all the eggs which are laid in the cells of the comb. Before a newly hatched queen begins to lay eggs, she must make the so called wedding flight. She emerges from the hive and sails high into the air. She is followed by many drones or males. When one male reaches her, they mate. During the mating, he attaches the sperm glands from his own body to her body and leaves them there. The drone then dies and the queen returns to the hive possessing not only ovaries but also sperm glands which she keeps for the rest of her life, so that she need never mate again.

As the queen lays an egg in a cell of the comb, she may or may not allow sperms from the sperm glands attached to her body to reach the egg. If she does allow sperms to fertilize the egg, it will develop into a worker if it is laid in an ordinary small cell of the comb. But if she places the fertilized egg in the large queen cell, the larva, when it hatches will be fed royal jelly in abundance. This larva will develop into a queen. Queens and workers are both produced from fertilized eggs.

If the queen does not allow sperms to reach an egg, this unfertilized egg will grow into a larva, which larva will emerge as a drone. Therefore, male bees are produced from unfertilized eggs.

The queens and drones do nothing except to provide for reproduction. The workers literally work themselves to death in caring for the hive. They build the comb, keep the hive clean, collect the nectar, make the honey, store it in the cells to feed the young larvae, gather propolis to seal off waste material which is too large to drag out of the hive.

You probably do not realize how the honey, which man steals from the combs, is produced. These workers sip nectar from flowers such as clover blossoms, incidentally bringing about cross-pollination. They swallow the nectar and partly digest it. This partly digested nectar is regurgitated and stored in the cells of the comb. Then hundreds of workers hover in front of the comb and fan it with their wings. As they fan the nectar, the water in it gradually evaporates and the nectar grows thicker and thicker until it becomes honey. Man boils sugar water down into maple syrup, thus evaporating the water. Bees fan the water out of nectar, thus making honey to feed the larvae.

Insects in general are considered one of the greatest enemies of man, because they are so very destructive of his crops. It is the ravenous food-devouring larvae which do the damage. Our increased ability to control the insect crop pests has come about largely through a study of their life histories.

If you wish to follow up the subject, you will find a great deal of available literature on it. The following are some suggested references:

Lutz -- "Field Book of Insects"
Hodge -- "Blossom Hosts and Insect Guests"
United States Department of Agriculture Bulletins

Laboratory Study XVII

Bees

Obtain a specimen of the bee at the desk. Spend some time looking at all the parts of it. Do you see anything that would make the bee sure to carry pollen? hairs on the body. Notice his long tongue. What is its function? for sipping nectar

Look for three body regions, known as head, thorax, and abdomen. All insects have these three regions. How many legs does your bee have? 6. Compare with the number on a grasshopper on the desk. 6. Catch a fly and count its legs. How many are there? 6. Look at the moths and butterflies and other insects on the desk, and count their legs. How many are there? 6. Animals which have six legs and three body regions (head, thorax, and abdomen) are called Insecta

Remove the bee's hind leg and sketch it. Do you notice that it is jointed? yes. How many joints do you count? 5. Note that the bee is covered by a kind of shell called an exoskeleton. Flies and grasshoppers, crayfish and lobsters also have external or exoskeletons. All animals with jointed legs and exoskeletons belong to the Phylum Arthropods.

What is the Phylum of the bee? arthropods. The class? insecta
The order? Hymenoptera
Do you see the bee's stinger? ✓. Where is it located? end of abdomen It
The order? ———
is really an ovipositor used at one time to place the egg in the cell, but now used as a weapon of defense.

How many eyes do you see on the bee's head? two. These prominent eyes are compound. There are also three simple eyes which are much smaller. Look at the picture of a bee for the simple eyes, then see if you can find them on your specimen. Do you see the two antennae projecting from the head? yes. What is their function? feeling.

Sketch the bee. Label the head, thorax, abdomen, antennae, eyes, legs and stinger.

Observe the stages in the life history of the Honey Bee as shown by preserved specimen on desk.
Where do Honey Bees lay their eggs?
in the comb.
From what kind of an egg does the drone hatch? unfertilized.
From what kind of egg does the worker hatch? fertilized
From what kind of an egg does the queen hatch? fertilized.
With [illegible] ?
[illegible] flight does [illegible] take? one
Why? Because the drone [illegible] has [illegible]
What are the stages in the life history of a bee? egg, larva, pupa, adult.
Sketch [illegible]

Review of Unit V -- G.

1. What is the correct name for the so-called "worm" stage of an insect? ________.

2. From what kind of egg does the drone of the honey bee develop? ________.
the queen? ________. the worker? ________.

3. By what means is a queen made to develop? ________________
________________.

4. Of what advantage is it to a flower to have bees and other insects visit them?
____
________________________________.

5. What are the four stages in the development of an insect? ________,
________, ________, and ________. What term is
applied to a development involving such a series of changes in one life history?
________________.

6. Which stage in an insect's life history does the most damage to our crops?
________.

UNIT V
Reproduction

H. Higher Animals -

Earthworm: Phylum Annulata
Fishes: Phylum Vertebrates; Class Fishes
Frogs: Phylum Vertebrates; Class Amphibians
Snakes: Phylum Vertebrates; Class Reptiles
Birds: Phylum Vertebrates; Class Birds
Mammals: Phylum Vertebrates; Class Mammals

Question: How do some of the higher animals, such as earthworms, fishes, frogs, and mammals reproduce?

You may share the popular conviction that reproduction among the higher animals is a topic to be avoided at all times. If you do have such a belief, here is your opportunity to let the light of scientific facts dispel it. There is no more awe-inspiring story in the whole range of life than that of the growth of the human child from a single ameba-like cell (fertilized egg) into the tiny human being with heart and lungs, hands and feet, brain and nerves, all growing from one original cell, and there is no reason why a sense of false modesty should keep the story out of a course in the science of life.

Biologists believe that <u>any</u> life function may be studied in the scientific manner, and the reproductive function is truly one of the most amazing. If we were not so used to seeing an acorn grow into an oak tree, or a hen's egg hatch into a baby chick, we would look upon such events as miracles and welcome any chance to learn just how they happen. In this problem you have the chance to learn some of the simplest facts about how earthworms, fishes, frogs, rabbits, and even human beings, reproduce their kind. The stories are to be presented frankly and honestly, with the doctor's candid attitude rather than the old-fashioned false evasions, such as the stork story. There is no more reason to be embarrassed by the mention of birth than there is to be embarrassed about the germinating of a seed or the hatching of a chick egg. For that matter, in a course in biology, it is just as proper to discuss the fact that the male frog fertilizes the eggs as the female lays them, or that the young of mammals develop within the mother's body, as it is to discuss the process of digestion of food in the stomach, for in both cases we are talking about the functions of living things.

It is essential that you adopt and maintain this scientific attitude toward all life functions, including sexual reproduction, just as biologists the world over maintain it. If you do so, the frank discussion in the following pages will prove to be among the most interesting in the whole course.

You have already learned how the Ameba and Paramecium reproduce asexually by cell division, and sexually by conjugation in the Paramecium. These one-celled animals illustrate the simple beginnings of sex in the animal kingdom, just as the green Algae illustrate it for plants.

Among the higher animals, the ability to reproduce asexually by cell division is lost. When a cell in the body of an earthworm, for instance, begins to divide, the division merely makes the worm grow larger but does not produce a new worm. It is true that earthworms can be cut into two parts as such a point that the head will grow a new tail and the tail a new head, thus making two worms. This is asexual reproduction, to be sure, but even this power is lost as we go higher in the animal kingdom.

The way an earthworm produces baby worms is worth recording, for it is not understood generally. In most animals, the sperms and eggs are produced by separate individuals, known as male and female, respectively. You are aware that all of our domestic animals exist as male and female, and that both parents are necessary for reproduction. The earthworm is a notable exception, for every worm is both male and female, since it contains both sperm glands (testes) and ovaries. So, theoretically, at least, any given earthworm, alone, is capable of producing young, since it can produce both eggs and sperms. As a matter of fact, however, two worms meet and exchange sperms with each other, in order that there may be cross fertilization, just as flowers arrange for cross-pollination, even though any particular individual is both male and female.

After two worms have exchanged sperms, there is a swelling of the girdle of each worm. (The girdle of a worm is the enlargement found about one-third of the way back from the head, or anterior end of the worm. Many boys and girls call the girdle the "head", but it is not.) The outer layer of the girdle loosens and this cocoon-like sac begins to slip up toward the anterior end of the worm. About half way between the girdle and the anterior end, on the lower (ventral) side of the worm, there are two pairs of tiny openings. As the "cocoon" from the girdle slips over these openings, eggs from the ovaries of this worm are discharged into it through one pair of openings, and through the other pair the sperms stored there by the second worm are discharged amongst the eggs within the sac. The sac, or cocoon, now slips off over the head and is left in the soil. The sperms swim around until each one finds an egg. One sperm unites with one egg and the fertilized eggs at once begin to grow into baby worms. As soon as they are old enough to take care of themselves, the old "cocoon" dissolves away, leaving the young worms in the soil.

It is evident that reproduction in earthworms is fundamentally the same as in flowers, although the details vary, for there is the same union of egg and sperm, resulting in the growth of the embryo.

It is the same with all animals. For instance, the female fish contains ovaries which produce enormous numbers of eggs, some kinds laying as many as two million of them. The male fish has sperm glands (testes) which also produce enormous numbers of swimming sperms. The female fish deposits her eggs (roe) in shallow water, and then the male fish discharges the sperms (milt) over them. When a sperm finds an egg, it unites with it and the fertilized egg develops into a baby fish. Thousands of the eggs are never fertilized, however, because no sperms reach them, so that this is really a very wasteful method of reproduction. It is therefore necessary for fishes to produce great numbers of eggs and sperms to be sure that a few of them will meet and unite. Otherwise there would be no young fish produced.

The details of nest building, migration, and care of young among fishes make an exceedingly interesting subject. For instance, there is the Pacific Salmon, a salt water fish, which migrates up the Columbia River to reproduce. The struggle upstream is very strenuous, and the salmon have been observed to leap over falls as much as six feet high. It is on the way up-stream that man catches his salmon for food. The need for regulating the catch in order to keep this fish living at all is evident when you consider that both the male and female fish die after depositing the eggs and sperms.

Man has learned to take advantage of the fish's methods of reproduction. In hatcheries the eggs are squeezed from the female into shallow pans. Then the sperms (or milt) are similarly squeezed from the male into the same pans. In this situation there is a much better chance that most of the eggs will be fertilized, for there are no water currents to carry the reproductive cells away, nor enemy fish to eat the young. The young fish which are obtained in this way are shipped out to stock ponds and lakes.

If you have ever seen frog eggs before they were hatched, you will remember that they looked like black and white dots within a mass of jelly-like substance. These black and white dots are the fertilized eggs. The eggs are formed by two ovaries within the body of a female frog. As the eggs ripen they leave the ovaries and collect within the body cavity of the female. When they are laid they pass out through the two egg tubes (oviducts). The number of eggs within any female is quite large, as you know if you have ever killed and opened a female frog during the early spring, although frogs do not need to lay nearly such large numbers of eggs as fishes. The reason is that the male frog clings to the female as she lays the eggs, and he deposits sperms from the sperm glands (testes) directly over them as they are laid. Consequently, nearly all of the eggs are fertilized so that very few of them are wasted. A toad lays her eggs in long strings, rather than in masses, as frogs do.

If you will collect a mass of frog eggs next spring and put them in a pan of water with some grass blades, you will be able to observe some of the stages in their development, although there are many details which can not be seen with the naked eye at all.

During the first few days the black and white dots seem to swell into large dots. Then they will be seen to elongate and begin to wriggle around within the mass of jelly. In another twenty-four hours, these elongated black structures will wriggle out of the jelly entirely, swim around for a little while, and attach themselves by their mouths to the blades of grass. At this stage you may see two little feathery projections on either side of the body just back of the head. These projections are external gills with which the newly hatched tadpoles breathe.

A microscopic study of the changes which have come about in the growth of the black and white fertilized eggs into the tiny tadpoles reveals a much more complete story. We find that the enlarging of the dots during the first few days is due to cell division, as follows: The fertilized egg divides vertically into two cells which remain together; the two cells again divide vertically, making four cells; then all four cells divide transversely, making eight cells; these divisions continue through sixteen, thirty-two, and sixty-four celled stages until a hollow ball of cells, called the blastula is formed. The blastula next folds in on one side, something the way a child's rubber ball may be pushed in on one side. The result appears somewhat like a raspberry and it is called the gastrula.

Rapid cell division continues, resulting next in the elongation of the embryo into a tiny, worm-like, hollow tube. This tube becomes segmented, like an earthworm and soon develops gills, tail, lateral line, tiny fins and scales exactly like a little fish. It is at this stage that the embryo emerges from the jelly and you see the tiny tadpoles swimming around.

The newly hatched tadpoles soon lose their feathery external gills and breathe by internal gills, just like a fish. They grow fairly rapidly into the ordinary familiar tadpole. The tadpole stage may continue as long as two years before changing into frogs. Finally the legs appear, the tail is used up as food, the mouth widens, and the intestine shortens; in fact, the tadpole undergoes all the changes necessary to become an adult frog.

Frogs are said to develop by metamorphosis, since their life history shows so many progressive stages. Can you name some insects which also undergo metamorphosis?

Recent research has revealed some interesting facts about the cause of the change of the tadpole into a frog. In the neck of the tadpole a thyroid gland has been found. (The thyroid gland, in man, is the gland which is called a goitre when it is enlarged.) The function of any thyroid gland is to secrete thyroidin (an iodin compound) into the blood stream, but these glands in the young tadpoles were found to be without function, for they were not producing thyroidin. As the tadpoles matured, the thyroid glands were found to enlarge and to begin to produce their secretion into the blood stream. The change of the tadpole into a frog, which accompanied the production of the thyroidin, suggested to the investigators that perhaps this secretion of the thyroid gland caused the tadpole to change into a frog.

They wondered what would happen if they fed thyroid extract (which can be bought) to younger tadpoles. The results were surprising and amusing for they found that they could produce frogs as small as flies by feeding thyroid extract to tiny tadpoles.

If you have any desire to read more of the details of this research, you will find an account of it beginning on page 526 of Wells, Huxley and Wells' "Science of Life".

Let us summarize the stages in the growth of the frog embryo. We have

(a) the fertilized egg
(b) the two-celled stage
(c) the four, eight, sixteen, thirty-two, and sixty-four celled stages
(d) blastula
(e) gastrula
(f) worm-like tube
(g) segmented worm
(h) fish-like stage
(i) tadpole
(j) adult

When you have learned how the fertilized egg of the frog grows into the adult you have learned also how the fertilized egg of a bird, or a snake, or a rabbit, or any other animal, including man, grows into the adult. For the early stages in the growth of any animal from the fertilized egg are the very same as those in the frog.

You may object that you do not understand how a rabbit, for instance, can have these same stages, since rabbits do not lay eggs. True, rabbits and the other mammals do not lay eggs. The female rabbit produces eggs (called ova) from the two ovaries, just the same as the frog does. But she produces very few ova and when they leave the ovary they are not laid, but collect within the two egg-tubes, or oviducts, within her body and are retained there. These ova are microscopic in size. Sperms from the testes of the male rabbit reach the ova within the oviducts, where fertilization occurs. If the eggs are not fertilized they die and are lost. Therefore it is necessary for rabbits to mate in order for sperms to reach the eggs to fertilize them, just as it is necessary for pollen to reach the pistil if seeds are to be formed in a flower.

After the rabbit ovum has been fertilized within the oviduct it begins to divide, just as the frog egg did. The growing rabbit embryo remains within the mother's body in the oviducts, where they are protected and nourished until they have grown large enough to be able to live alone. Then the baby rabbits are born.

The number of eggs produced by a female rabbit is very small compared with fishes and frogs. One reason is that they have a far greater chance of being reached by sperms after mating than have fish or frog eggs. A second reason is that the development within the mother's body protects the young from external dangers such as young fish and tadpoles have to face.

All animals whose young are born are said to be viviparous, in contrast with egg-laying animals, which are said to be oviparous. Common black snakes are viviparous, while garter snakes are oviparous. Viviparous animals which nourish newly born offspring with milk from the mammary glands of the mother are called mammals. Thus you see that man himself must be classified as a mammal.

The story of reproduction in man is essentially the same as in the rabbit, except that the human embryo develops within a special structure called the uterus, in the mother's body. The child, however, grows from a fertilized egg and passes through a worm-like stage and a stage with gills, just the same as all of the other animal embryos. The growth of the human child requires nine months before it can be born, and even then the baby is so helpless that it would perish without parental care (or the care of some other adult).

You can see, therefore, that the reproductive process in mammals, including human beings, is fundamentally the same as in lower animals, or even in flowers. Fertilization is the first step in reproduction in all cases. All embryos grow from the fertilized egg. In fact, the fertilized egg of a human being looks so much like the fertilized egg of a lily, for instance, that you would be unable to tell from their appearance which would grow into the lily. It is the forty-eight chromosomes within the nucleus of the human cell which control ( ) growth of the embryo and cause it to develop into the child, just as the chromosomes in the nucleus of the lily egg make it grow into the lily plant. The observation and counting of these chromosomes is very difficult, even with the highest-powered microscope, and would not be evident to you in looking at the two eggs. So we repeat that all higher animals and all plants with sexual reproduction grow from single cells which look very much alike.

Furthermore, the embryos of the chick, opossum, cat, rabbit, or any other such animal, including man, look so much alike in their early stages of growth that they absolutely can not be distinguished. Look at the pictures in the following references to observe this fact.

Ask for reference books on the reproductive process in animals and man if you wish to know more about them, for you have a right to every bit of available scientific information on the subject.

In this brief account, we have merely shown you that all animal reproduction is fundamentally the same and that there is a remarkable uniformity about the development of all embryos. This presentation ought to serve as a mere introductio to the subject, which a whole lifetime of study could never exhaust completely.

Laboratory Study XVIII

Frogs

Observe a female frog which has been opened. What do you see? eggs

Look for the testes of the male frog.

Look at some frog eggs. How can you tell them from toad eggs? the frog eggs are in masses

What organs within the female frog produced these eggs? ovaries. When does the male frog fertilize the eggs? as they are laid. What two organs within the body of the male produce the sperms? testes. After the egg has been fertilized, name the stages through which the embryo passes before the tadpole comes out to swim around.

fertilized egg	worm like tube
2 cell stage	segmented
4, 8, 16, 32, 64 stage.	fish like stage
blastula	Tadpole
gastrula	adult.

With what does the tadpole breathe? gills. What else about the tadpole make it look like a fish? tail, fins, scales, lateral line

What finally caused the tadpole to become a frog? Thyroid gland.

Observe the preserved specimens of tadpoles at various stages. Sketch the eggs, the tadpole hatching, the normal tadpole, the tadpole with legs, and the frog.

What do we call animals that lay eggs? oviparous

Laboratory Study XIX

Other Animals

Look at available pictures of the early stages of several kinds of embryos. You will find pictures of embryos on page 270 of Atwood's "Biology". In the early stages, can you tell a human embryo from any other? no.

There are preserved embryos of a chick (three days old), kittens, and opossums available. A living chick embryo may also be at hand, after three days incubation. Sketch one of them. Would you be able to tell the preserved chick embryo from the young kitten if they were in the same bottle? no.

The organs of reproduction of the female cat are available. They consist of two ovaries, which produce eggs (ova) and two oviducts. Sketch and label.

From page 8 of Prentiss and Arey's "Embryology", copy the drawing of the human ovum (egg), and sperm. Be sure to mark your drawing as being copied.

Look at the pictures of the developing human embryo on page 86 of the same book.

Observe the demonstration of the organs of reproduction of the female human being from the plaster of paris torso. What organ produces the ovum? ovary. Within what organ does the child develop? ____________. Through what tube does the egg pass, to reach this organ? ____________. How long a time is required for a child to develop to the stage where it can be born? ____________________. Does the human embryo pass through the same stages any other animal embryo does? ________. What do we call animals which have the young born alive? ____________. To what class of animals do rabbits, cats, and human beings belong? ____________.

Review of Unit V -- G.

1. What is the name of the organ which produces ova (eggs) in animals? ________. What is the name of the organ which produces sperms? ____________. What animal has these organs both in the same individual? ________________. What do we call such an animal? ____________________.

2. What is the function of the girdle of the earthworm? ____________________ ____.

3. Where do the sperms of the earthworm reach the eggs? ____________________ ____.

4. Where do the embryo worms develop? ____________________________________.

5. When does the male frog fertilize the eggs? ______________________________.

6. What is the name applied to fish eggs? __________. sperms? _____________.

7. When do the sperms of fish reach the eggs? ________________.

8. The fertilized egg of an animal divides into two cells. The division continues through ________, ___________, ___________, and ____________ celled stages, until a hollow ball of cells is formed, which is called the _________. This hollow ball folds in on one side to form the ___________. Then come the ___________ and _____________ stages before the adult form is reached. These stages apply to all higher animals.

9. The egg-tube of an animal is called the ________________.

10. What is the name of a young plant or animal, before germination, hatching or birth? ______________.

11. What is the name of the structure in the female human being within which the child develops? ______________. How long does it take the child to develop? __________________.

12. Within what structure in the female rabbits do the baby rabbits grow? ____________________.

13. Why do eggs from a flock of chickens without a rooster, fail to hatch? __________________________.

14. Name ten mammals.

_______________ _______________

_______________ _______________

_______________ _______________

_______________ _______________

_______________ _______________

15. Animals that lay eggs are called _______________ and those that have the young born alive are called _______________.

16. Sexual reproduction of all plants and animals is the same, in that it begins with _______________.

UNIT VI

Classification of Plants

Plant Kingdom

Phyla

1. Thallophytes

   Classes

   a. Algae
      1. Blue-greens
      2. Greens
      3. Reds
      4. Browns

   b. Fungi -- mushrooms, molds, yeasts.

2. Bryophytes -- mosses, liverworts.

3. Pteridophytes -- ferns, horsetails, clubmosses.

4. Spermatophytes

   Classes

   a. Gymnosperms -- cone-bearing plants.

   b. Angiosperms -- flowering plants.

      Sub-classes

      1. Dicotyledons -- bean.
      2. Monocotyledons -- corn.

UNIT VI

The Whole Seed Plant

A. Introduction

Have you ever wondered how a plant, such as a bean vine, lives and grows? For a plant is alive just as truly as an animal, and must have food and water and air, even as you and I.

Many years ago a man possessed of much curiosity began to puzzle over the growth of a large apple tree from a small one. He wondered whether the tree took enough matter out of the soil to make its new leaves and branches or whether its increase in weight came about in some mysterious way, for he felt that, unless the loss of weight in the soil equalled the gain in weight in the tree, the tree must be making something out of nothing. He decided to try an experiment to find out. He filled a tub with soil and planted a small apple tree in it. Then he weighed the tub and its contents. He also weighed every bit of water which he put on the soil. He kept a record of the original weight and of the weight of all the water added. He re-weighed the tub and its contents frequently for several years. As the tree grew the weight increased, and the weight gained year by year proved to be considerably more than the weight of the water added. Naturally it was hard to understand where this extra weight came from.

At that time nothing was known about the way a plant lives. The man believed that he had checked every possible way for the tree to take on any weight from its surroundings when he had weighed the soil and water. When the increase proved to be more than the weight supplied by the soil and water, he came to the natural conclusion that the tree was able to make new substance out of nothing, since he supposed it had no other source from which to absorb anything. He was justified in this conclusion at that time, but new facts have come to light which have proved it absolutely false.

Since the time of this experiment, such extensive research has been done that it is now possible to explain the exact source of every grain of increased weight in the apple tree or any other plant. Among other facts, the obvious one which would have solved the old experimenter's problem is that plants absorb large quantities of gases from the air, and these gases have weight, just the same as soil and water, which fact was unknown at that time.

It is the aim of this unit to give you some understanding of a plant's life. As you know, a bean vine has roots, a stem, green leaves, flowers and fruit. Each one of these parts is as important to the plant as the heart or stamach is to an animal. If you would know why this statement is true, it is important that you learn first how each of these parts of a plant is constructed, in order that you may understand how it functions.

The statement may be made boldly that a plant is able to carry on all the life functions of any organism which have already been enumerated, as metabolism, sensation, motion, and reproduction. In addition, green plants are able to do one thing no animal can possibly do. They are able to make starch and sugar, fats and proteins, and even protoplasm itself, out of soil, water, and air. No animal in the world can thus function, and a clear knowledge of how the green plants really feed all life is worth seeking.

In order to present this function of food-making in plants, it is necessary, first of all, to study the root in considerable detail. The stem and green leaf must also claim your attention as separate plant organs, whereupon you will be in a position to understand the life process of the whole plant. The minute cellular structure of these three organs of the plant will be presented in the following discussion.

UNIT VI

The Whole Seed Plant

B Roots

Question: What part of the seed grows into the root system? What tissues are found in a normal root? How do roots function? What are some special types of roots?

Laboratory Study XX

Germination of Bean

Line a glass with a piece of paper. Fill the glass with sawdust and moisten. It is important that you avoid making the sawdust too moist.

Between the glass and the paper place two or three beans which have been soaked in water several hours. Watch these beans begin to grow.

At what point does the testa break? ______________. What part of the embryo comes through the testa first? ______________. What direction is this first sprout pointed as it breaks the testa? __________. Does it continue to point the same direction? ________. Into what does it grow? ______________. Try turning your glass wrong side up a few days. (Arrange for air to enter in some way.) Does the root still continue to point the same direction? __________.

As the two cotyledons come out of the testa, and push upwards, what do you see between them? ______________. What part of the embryo made this structure? ______________. What color is the whole seedling at this stage? ______________. As the cotyledons come above the surface, the color of one part of the embryo changes to green. Which part is this? ______________.

Watch the cotyledons for several days. What happens to them? ______________ ______________. What do you suppose causes them to change in this manner?

____

____

From what part of the bean embryo in the seed does the root of the plant develop? ____________. the stem? ____________. the leaves? ____________.

Sketch two or three stages in the germination of the bean to illustrate these facts.

Laboratory Study XXI

Geotropism vs. Hydrotropism

(Optional)

Moisten a good sized sponge. Then sprinkle a few radish seeds over it. Tie a string around your sponge so that the radish seeds are on the lower surface of it. Hang it up a few days by the string.

When the radish seeds begin to germinate, which way do the roots grow? ________. Why do you suppose they do this? ______________________________.

Plant some radish seeds on a fine sieve and then cover them with sawdust. Keep the sawdust moist. When the roots first sprout, where do they go? ________. But in a few days more where do they go? ______________________________. Why? ____

If the turning of roots toward gravity is called geotropism, while their turning toward water is called hydrotropism, which is the stronger tendency?

____________________.

Your observations of the germinating bean in the laboratory have shown you that roots originate from the hypocotyl of the seed. You have also seen how the roots grow downward, no matter if you turn them wrong side up. Gravity causes this reaction, which is called geotropism (turning toward gravity).

You may have noticed that the first root out of the testa soon branches and that there is much continued branching as the whole root system grows. The first root to grow from the hypocotyl is called the primary root and the branches are called secondary roots. A root system like this of the bean plant is spoken of as fibrous, in contrast with fleshy roots, such as the carrot has.

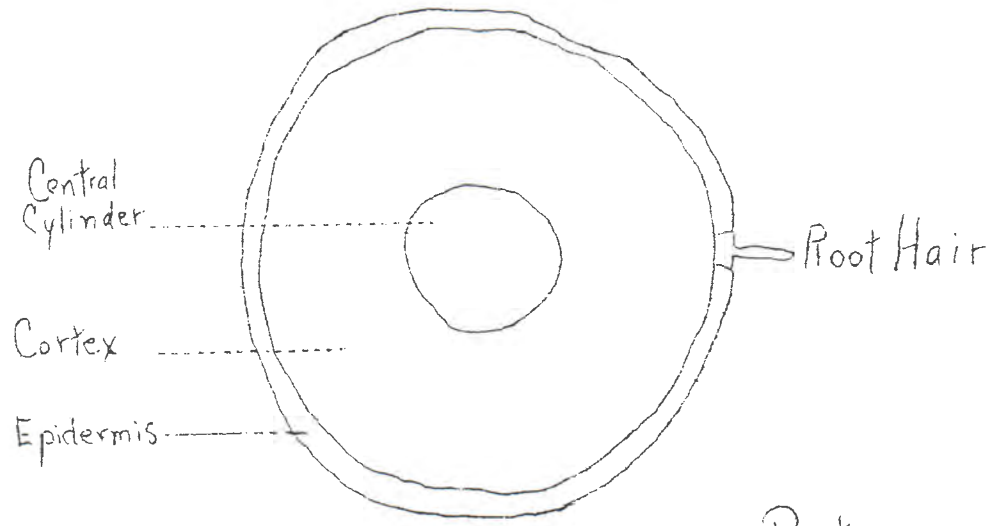
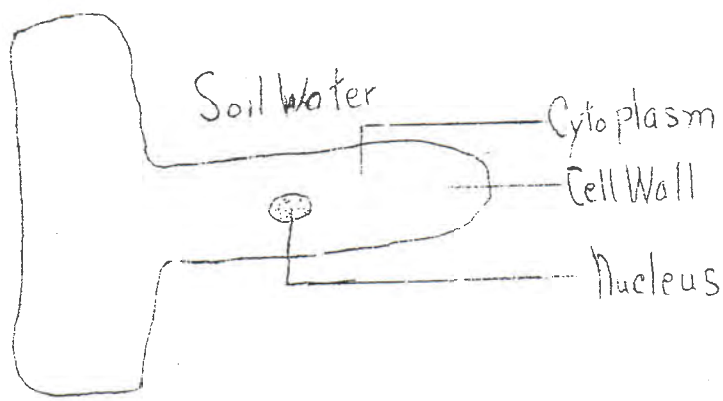


Diagram of Cross Section of Root



Root Hair

A cross section of a normal fibrous root under the microscope reveals the structure in detail. The root is seen to be composed of cells, as you already know. The cells are not all alike. Those on the surface are brick-shaped and make up the epidermis, which serves as a protective covering for the root. Occasional cells of the epidermis show an elongation, known as the root hair, which absorbs water from the soil.

In the center of the root the central cylinder, or fibrovascular tissue, is found. Within the fibrovascular tissue there are two kinds of cells, large irregular thick-walled ones, called wood or xylum, and small fine ones, called phloem. This is the tissue of the root through which fluids flow up and down, and they always travel up toward the stem through the xylem, while they travel down from the stem through the phloem. Besides, the thick walls of the wood or xylem cells, give strength to the root.

Between the central cylinder and the epidermis, the space is filled with the cells of the cortex. This is the region where food is stored in the root. Water from the root hair also passes through the cortex to reach the xylem to travel up to the stem.

It is evident that roots absorb water, store food, and circulate sap by means of their various tissues. They have another important function, which you will appreciate if you try to pull up a plantain in the yard. It is the root system which makes it hard to pull out of the ground, thus giving it anchorage.

Some roots, such as dahlias, are also able to live over winter and reproduce the plant in the spring. Is this sexual or asexual?

Root functions may be summarized as absorption, anchorage, storage of food, circulation, and sometimes reproduction.

Laboratory Study XXII

Roots -- The Carrot

The gross structure (that which is visible to the naked eye) of roots is most easily observed in a carrot. The part of the carrot which we eat is the primary root thickened into a fleshy root by the storage of food in it.

Cut a carrot lengthwise. What do you suppose the tough central portion is? ____________________. What is the name of the skin? ______________. What tissue fills the region between the skin and central portion? __________. Do you notice branches of the central cylinder extending out through the cortex into the secondary roots? ________. Do you see any reason why the secondary roots should connect with the central cylinder? (Before answering, consider that the root hairs are on the secondary roots.) ____

____

Make a similar study of the cross section of a carrot.

Do you see any advantage to the plant in storing as much food in the root as the carrot has? ____

____

Have you ever eaten parsnips? What do you suppose the tough center, sometimes found in cooked parsnips, is? fibrovascular tissue

Sketch the carrot, both in cross and longitudinal section. Label the central cylinder, cortex, epidermis, and secondary roots.

Laboratory Study XXIII

Roots - Microscopic Structure

Look at the prepared slide of the cross section of a normal root under the low power of the microscope. (You will not find any root hairs on this slide.)

Note the cells of the epidermis. What are they like? they are brick shape. What is their function? for protection.

Locate the central cylinder. What other name does the central cylinder have? fibrovascular bundle. Look within the central cylinder. The cells stained red are wood, or xylem, cells. Do they contain any nuclei.? no. What kind of cell walls do they have? heavy wall What shape are the xylem cells? irregular. What is their function? carry water up. Do you see why it is that the nuclei have died and disappeared from the wood cells? yes. The smaller cells in the central cylinder stained blue are phloem cells. Do they have nuclei? no. Are their cell walls thick or thin? Thin. What is their function? carry sap down.

Look at the cells of the cortex. What shape are they? brick shape. Do they contain nuclei? yes. Are their cell walls thick or thin? thin. What is the function of the cortex? storage of food.

Diagram the cross section of a normal root, indicating the area where xylem, phloem, cortex, and epidermis are found.

Look at some corn seedlings grown in a glass as the beans were grown.

Do you see some white fuzz on the new root? yes. This is a dense mass of root hairs. Look at a portion of such a root under the microscope. Can you distinguish a single root hair in the mass? yes. Note its thin cell wall, the cytoplasm, and the nucleus if possible. How many cells make up one root hair? one.

Beside your diagram of the cross section of a normal root, sketch a root hair, marking all parts seen.

Summarize the root functions:

a. anchorage
b. circulation
c. absorption
d. reproduction
e. storage of food

The fact that water passes from the soil into roots through the root hairs is rather difficult to explain. You may best understand just how it comes about if you will first try the following experiments with the potato and egg.

Pare a raw potato; cut it in half crosswise, and hollow out the contents so that you have a sort of cup. Fill this cup half full with a solution of sugar in water. Set the half potato in a flat dish of clear water. Observe after several hours.

Has the amount of fluid inside the potato shell increased or decreased? increased

Observe at the desk a similar experiment set up with an egg. One end of the egg is dipped in dilute hydrochloric acid and left there until the shell has been eaten away by the acid. The thin skin inside the egg shell will now be exposed. A small opening is carefully broken through the shell at the top and a glass tube is inserted into the egg. This tube is sealed around its contact with the egg shell by means of wax. The lower end of the egg is submerged in water and the glass tube is clamped upright to a ring stand.

After half an hour, a liquid will begin to rise in the glass tube. What happens to the level of this liquid during the next hour? It Rises [illegible].

Both of these experiments illustrate the same process. In the potato, the cell walls of the cells represent a semi-permeable membrane. The sugar water inside the potato is denser than the pure water outside. Consequently, the pure water flows through the cells of the potato into the sugar water. This flow naturally causes the liquid inside the potato to increase.

In the egg, the thin skin exposed by eating away the shell is the semi-permeable membrance. The egg white is much denser than the water outside the membrane. Consequently, water will flow into the egg and liquid will rise in the glass tube.

You are justified in concluding that the situation in the root hair is similar to that in the potato and egg experiments. The cell wall around the root hair is the semi-permeable membrane. The cytoplasm within the root hair is denser than the soil water outside of it. Consequently, the soil water enters the root hair, for the less dense liquid always flows through the semi-permeable membrane into the denser liquid. (Note: There is always some flow back from the denser liquid to the less dense. It is so little, however, as to be negligible in your study.) This process is called osmosis.

Have you ever poured the salt water from the ice cream freezer on the lawn? You are now in a position to explain why the grass was killed. Ordinary soil water is less dense than the cytoplasm within a root hair which causes it to enter the root. But salt water is denser than cytoplasm. Naturally the cytoplasm flows out through the cell wall into the denser salt water, thus reversing osmosis. This withdrawal of liquid from the roots kills the grass.

Osmosis is thus revealed as one of the most important processes in the life of the plant, for the absorption of water by the roots is the first step in supplying the materials of food-making. This soil water also contains certain minerals, such as nitrates, phosphates, and potashes, which the plant needs.

The water which a root absorbs is useful to the plant in still another way. If you will contrast a rubber balloon filled with air with one only half filled with it, you will have a good impression of the difference between plant cells which are filled with water and those which are only half-filled. When a plant loses water into the air on a hot day faster than the roots can absorb it, the plant wilts, because its cells are like half filled-balloons. So it is the water which gives the plant tissues firmness (called turgescence), and the loss of water which causes wilting.

In summary: Water is used in food-making, brings certain minerals from the soil into the plant, and gives the plant turgescence. Its absorption depends upon osmosis; hence, the very life of the plant is dependent upon this process.

seeing hyphoism

-2

Review of Unit VI -- B

B

1. Which part of the seed produces the root of the new plant? hypocotyl the stem? ~~hypocotyl~~ plumule the leaves? plumule

2. If a root must choose between growing toward water and growing toward gravity, which does it choose? water. What are these two responses of roots called? hydrotropism geotropism

3. What is the first root to come out of the testa called? primary root. What are its branches called? secondary roots

4. What two tissues make up the fibrovascular central cylinder of a root? (a) Xylem and (b) phloem. Give the function of each.

(a) Xylem carries water up

(b) Phloem carries sap down

5. What tissue surrounds this central cylinder? cortex. What is its function? to store food.

6. What is the function of the epidermis? to protect.

7. How many cells make up a root hair? one.

8. What three things are necessary in order for the process of osmosis to occur? (a) dense liquid, (b) less dense liq., and (c) semi-permeable membrane. What represents each one of these things in absorption in the root hair?

(a) cytoplasm, (b) water in soil, and (c) cell wall

9. Five functions of roots to the plant as a whole are anchorage circulation reproduction storage and absorption

UNIT VI

The Whole Seed Plant

C. Stems

Question: Of what tissues are stems composed? How do they function?

If you look at the stem of a bean plant or geranium and compare them with the trunk (stem) of an apple tree, or the twining vine stem of the ivy, it is difficult to realize that they are essentially alike. They may differ in the amount of woody tissue present, but all of them contain the same tissues and perform the same functions.

The most evident advantage to a plant in having a stem is its ability to grow up into the air, as algae and mosses can not. Since the stem supports the plant in its upright position, it must be strong enough for this function. When the leaves are thus lifted far above the roots, the stem must certainly provide some means by which the water which enters the roots can circulate up into the leaves, as well as a way for the food made in the leaves to flow down again into the roots or out into the flowers and fruits.

Just as in the underground stem of ferns, and in the central cylinder of roots, so in the stem of the seed plant it is the fibrovascular tissue which supplies the strength and means of circulation. This fibrovascular tissue is organized into bundles. When you eat celery, the strings which pull out are the fibrovascular bundles. The fibers running through a corn stalk are the same thing. Furthermore, the boards from which your desk was made are simply slices out of the fibrovascular tissue of a tree trunk.

With this idea in mind, go to the laboratory to study the structure of stems.

Laboratory Study XXIV

Stems of Dicotyledonous Plants

Cut an elderberry twig (stem) in cross section and look at the end of it.

What kind of tissue do you find in the center of the stem? ____________________.

This is called pith. What do you find around the pith? ____________________.

This is the fibrovascular tissue. What tissue covers the outside of the twig?

______________________________.

Look at a prepared slide of a similar cross section of some such stem as the geranium, under the microscope. Compare with page 242 of Coulter, Barnes, and Cowles' "Textbook of Botany". Notice the large pith cells in the center. Locate a bundle showing cells stained red and others stained blue (or green). This is a fibrovascular bundle; the red cells are xylem and the blue (or green) cells are phloem. Notice also that the fibrovascular bundles are arranged in a sort of circle. Outside this circle there is a tissue similar to pith, ~~but called cortex~~. The outside layers make up the epidermis.

Make a diagrammatic sketch of the cross section of the stem under the microscope. Label the pith, xylem, phloem, fibrovascular bundle, cortex, and epidermis.

Place the lower end of a twig of elderberry in some red ink. After a few hours, cut the top off the twig. What tissue has become red? Xylem. What tissue, do you conclude, carried liquid up the stem? Xylem. What tissue, have you learned, carries food down the stem? phloem. To what part of the human body might you compare these tissues in the plant? [illegible].

Both the geranium and elderberry are Dicotyledons.(The seeds have Two cotyledons). It is typical of a Dicot stem to have pith in the center and the wood in one or more rings.

Our trees are Dicots which have many rings of wood, for they add a new ring each year. Loosen the bark from a twig of the horse-chestnut tree (or any other available twig). What color do you find the layer just under the bark? Green. It is the cambium, or growing, layer. In a tree, the cambium layer is found between the xylem and phloem. The cambium is alive and its cells divide constantly. The new cells thus formed enlarge, loose their nuclei, and thicken their cell walls, thus becoming xylem. In the spring these new cells grow large rapidly, but in the fall and winter the new cells remain small, making a ring. These are called annual rings. Look at the available cross sections of tree trunks and count the annual rings of one. How old was the tree? 24. Look at an annual ring in a thin cross section of pine wood. Sketch enough cells to show how the ring grew. Sketch also a few cells from the longitudinal section of pine wood.

Study the external features of a horse-chestnut twig in the fall. Are there

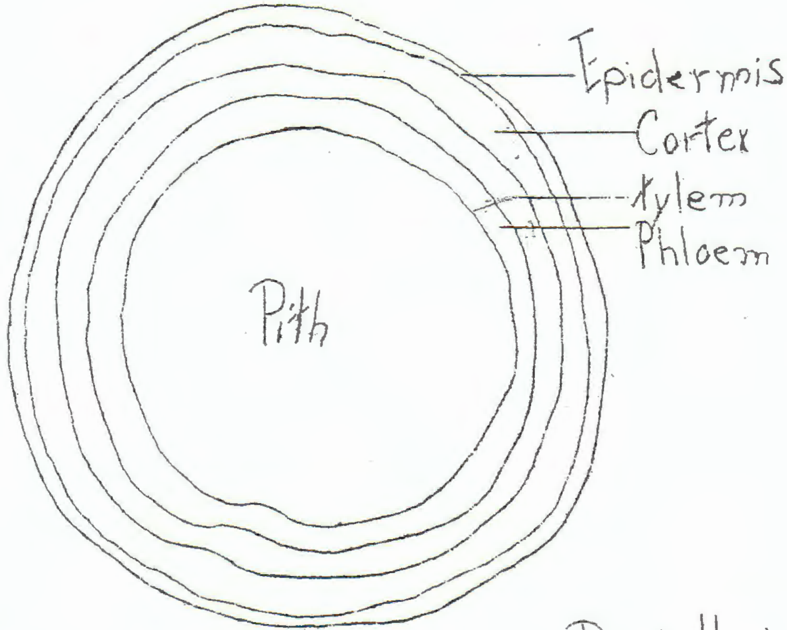


Diagram of Cross Section of Dicot Herb Stem

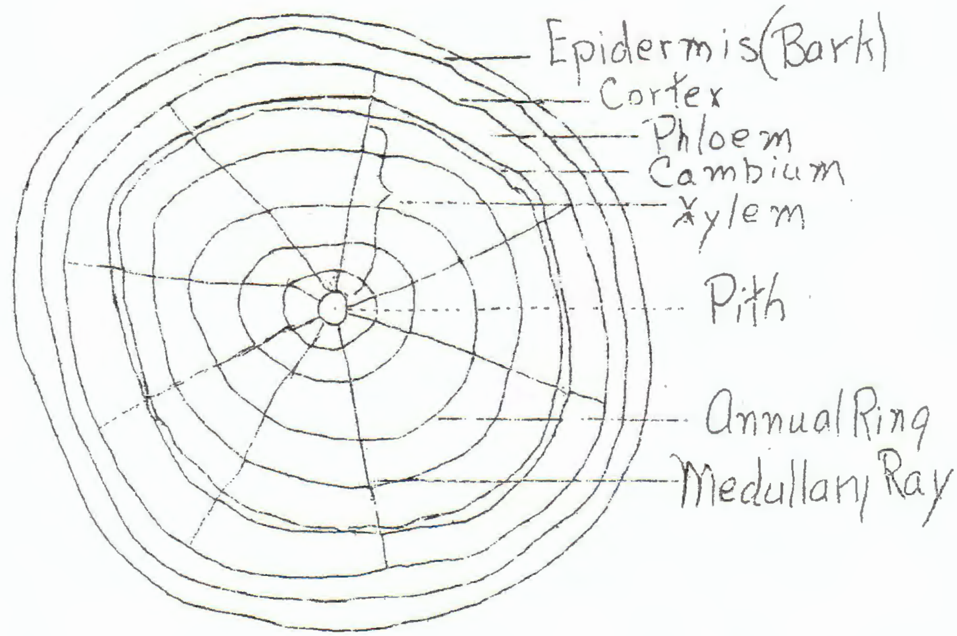
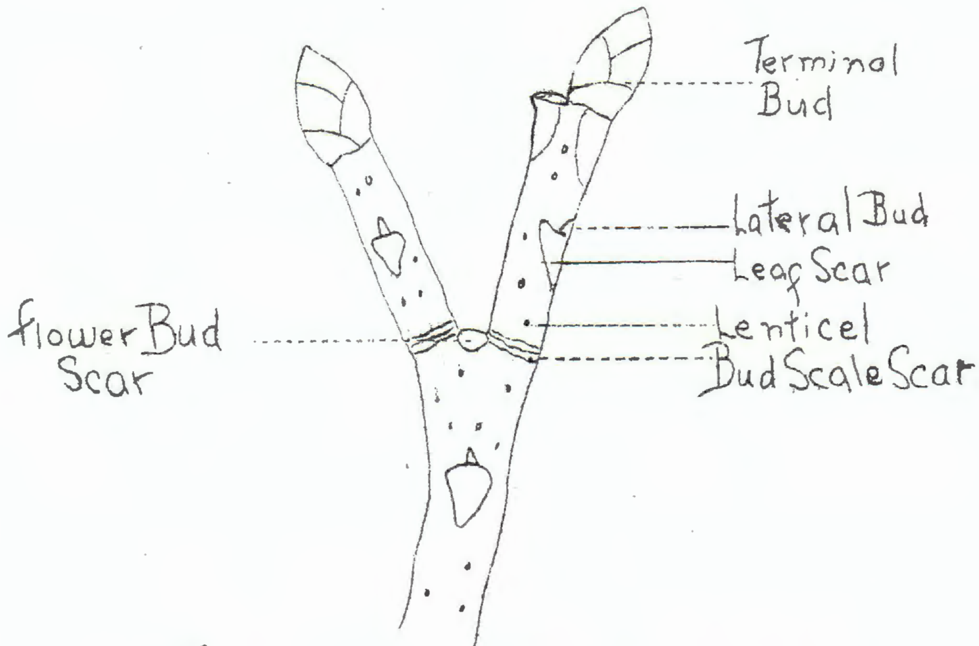


Diagram of Cross Section of Dicot Shrub or Tree Stem



Twig of HorseChestnut

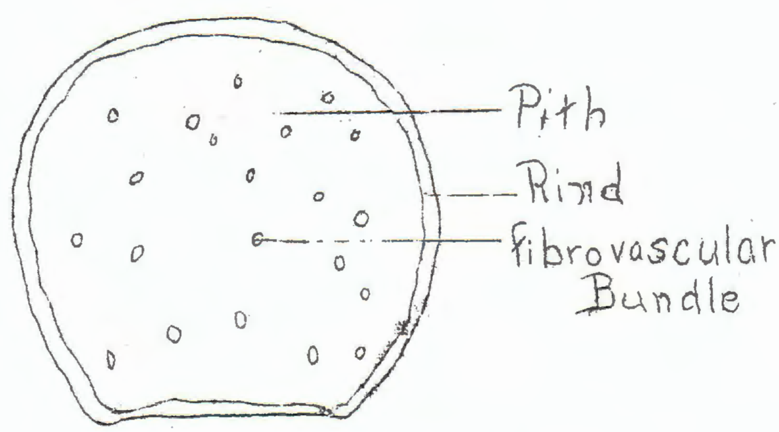


Diagram of Cross Section of Monocot Stem sunlight.

The Giant Red Woods of California are simply tree stems which have been growing in some cases ever since the time of Christ. Imagine the time required to build tiny xylem and phloem cells into a tree trunk wide enough to have its stump used as a dance floor!

Review of Unit VI -- C

1. What tissue is found in the center of a Dicot stem? pith.

2. What is the tissue which carries water up the stem? xylem.

What is the tissue which carries sap down the stem? phloem.

3. What tissue causes the growth of new wood rings in the tree? cambium

4. How may the age of a tree be estimated? by counting the rings

5. In what two ways do Monocot and Dicot stems differ?

(a) the Dicot has its part arranged around pith an monocots doesn't.

(b) a Monocot has not an cambium and as Dicot does

6. What are the breathing pores in the bark of a tree called? lenticels.

7. During what season do the new buds form? fall and winter.

8. What are the two main functions of stems? to support and circulate.

UNIT VI

The Whole Seed Plant

D. Leaves

Question: What makes leaves green? What tissues are found in leaves? Why does a plant have leaves?

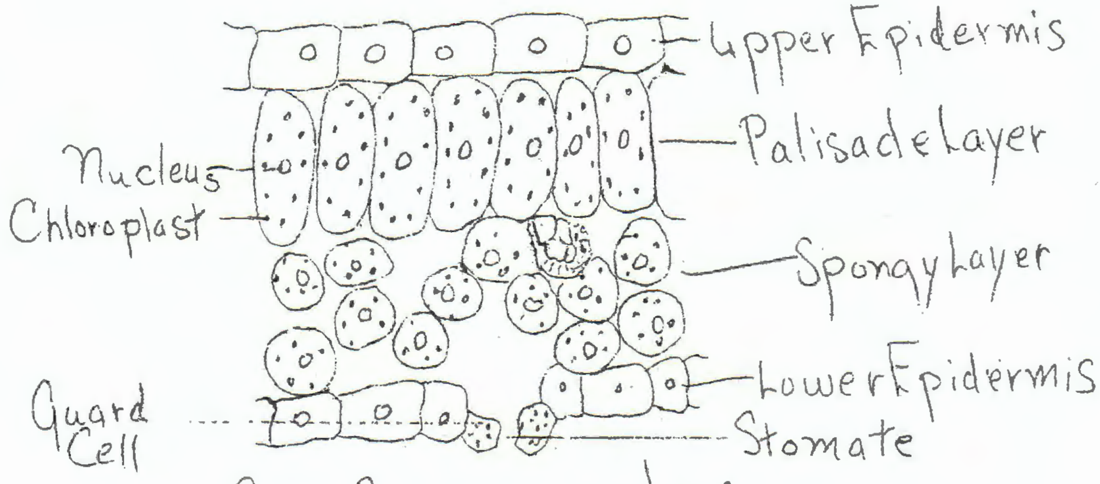
You may have noticed that there is as much variety among leaves in shape and size as there is in the color and odor of flowers. Contrast such leaves as pine needles, corn blades, geranium leaves, pea vines, castor bean leaves, dock leaves, and leaves of the tree of heaven and then try to realize that the same stuff (chlorophyll) makes them all green, and that they are all made up of the same tissues, and that they all perform the same functions for the plant, as you are now about to learn.

For a leaf is not so simple a structure as it appears. Of course, outwardly, the normal leaf has a blade, with veins branching through it, and a stem, or petiole. Microscopic study has proved that the fibrovascular bundles of the plant's stem, with the xylem and phloem, run out through the petiole of the leaf and spread out in many branches, called veins, in the blade. These veins in the corn blade, which represents a Monocot leaf very well, run parallel to each other, as do the veins of Monocot leaves in general, while those of the geranium leaf, which represents a Dicot, form a net work in the blade. Thus Monocot and Dicot leaves are usually easy to distinguish.

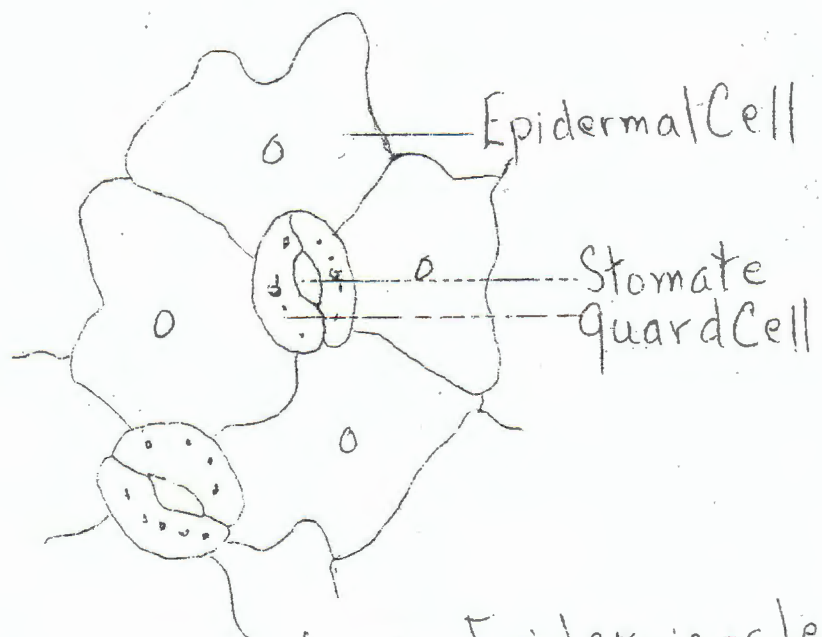
If you will undertake to know the minute cellular structure of a leaf, as you must, in order to understand the work they do, considerable study will be necessary for, as was hinted above, a leaf is not a simple structure made up of a flat layer of cells, all alike. As a matter of fact, the microscope will show you four layers of different kinds of cells in the cross section of a typical leaf. This means that a leaf is four layers thick. The top layer of cells is the upper epidermis and the bottom layer the lower epidermis. In these layers of epidermal cells, especially the lower one, there are small openings, or breathing pores, which are called stomates (little mouths). Around each stomate there are two guard cells which can be opened and closed to allow more or less air to enter the leaf. On a hot dry day, the stomates will remain almost closed, so that the leaf will not lose too much water. On a rainy cool day they will open wide to let in as much air as possible. You might compare the guard cells around the stomates to your own two eye-lids, which you may draw close together in very bright light, or relax when the light is less intense.

Between the upper and lower epidermis layers you may see two other layers. Next to the upper epidermis is a layer of long cells called palisade cells. Filling the space between the palisade layer and lower epidermis is the spongy layer, where you will find many air spaces scattered between the cells.

Study the diagrams of leaf structure in preparation for your next laboratory study.



Cross Section of Leaf



Few Cells of Lower Epidermis of Leaf

Laboratory Study XXVI

Structure of a Green Leaf

Sketch an ordinary geranium leaf and a lily leaf beside each other. Label: petiole, blade, and veins.

How do these two leaves differ? monocot has straight veins and a dicot has net veins.

Which is the Monocot? straight veins. Dicot? net veins.

Tear a green leaf in such a way that you obtain a little of the thin skin from the lower side. Place this skin in a drop of water on a slide; cover with a cover slip and examine under the microscope. Do you see the small openings? yes. What are they called? stomata. Why are they there? to let water vapor out. Do you see the two guard cells around each one? yes. Do you see some small green dots in each guard cell? yes. They are chloroplasts and the chlorophyll in them makes them green. All green leaves owe their greenness to these chloroplasts, just as your blood owes its redness to the red corpuscles.

The cells around the guard cells on your slide are cells of the lower epidermis. Are they green? no. What do you suppose the function of the epidermis is? to protect.

Look at a prepared slide showing the cross section of a leaf. What shape are the cells of the epidermis, seen thus? brick shape. What shape are the cells of the palisade layer? brick shape. of the spongy layer? round. Can you distinguish nuclei and chloroplasts in any of the cells? yes. If so, which? palisades. The xylem and phloem of the vein are also visible. The stomate with its two guard cells may be seen in the lower epidermis. Sketch the leaf in cross section from this slide. Label the upper epidermis, guard cells, stomates, chloroplasts, nuclei, and veins. Sketch also a bit of the lower epidermis, showing stomates and guard cells as they appear from below.

Read again the story of the growth of an apple. Whence comes the food material out of which the apple makes its new tissue as it enlarges? It comes through the phloem from the leaves of the apple tree. The starch made in the leaves changes to sugar and circulates through the phloem into the small apple ovary. Here it is again changed into starch or built into tissue, thus causing the gradual enlargement of the ovary into the fruit. In the ripe fruit considerable food is stored in the form of sugar, giving the apple its sweetness. Potatoes are made in a similar way. In fact, the fruits and vegetables which man uses in his daily diet are all produced in just this manner.

Some keen person might be prompted to ask at this point where the sugar water comes from which man steals from the sugar-maple tree in the spring, for there are no green leaves on the tree to make starch during the early spring. As a matter of fact, the green leaves of the preceding summer made the starch and changed it into sugar, which flowed down to the roots and was stored in them during the winter months. On a warm spring day, the sap or sugar water flows up the stem again to feed the buds so that they may begin to grow. It is on the way up the stem that man makes his collection of sap by inserting a spile into the xylem of the tree trunk. Cold nights send the sap back down to the roots, so cold nights and warm days are productive of a large sugar water collection since they keep the sap flowing up and down the trunk every day.

Leaves thus carry on the functions of respiration and photosynthesis for the plant. They also lose water by evaporation through the stomates. This fact is easily demonstrated by turning a bell jar over a plant which has had the pot and soil covered with rubber dam. Droplets of water collect on the inside of the bell jar, just as steam collects on a window. This loss of water is called transpiration. It has been estimated that a large field of corn loses several barrels of water daily in this manner.

Plant leaves are sensitive to light just as roots are sensitive to gravity and water. You have seen evidence of this fact at home if you have ever noticed how the leaves on any house plant turn toward the window. Try turning a geranium so that its leaves are turned away from the window. In a day or so they are faced back toward the light again. This response of leaves to light is called phototropism. It, along with geotropism and hydrotropism, illustrate the function of sensation in plants.

Betty Hoffmann

-7 C

Review of Unit VI -- D

1. What makes leaves green? chloroplast.

2. How do the leaves of a Monocot and Dicot differ? They have parallel veins, Dicot have net veins

3. What tissue forms the veins of a leaf? fibrovascular bundles.

4. Name the layers of cells found in the cross section of a leaf.

Upper Epidermis, palisade layer, Spongy layer, and lower epidermis

5. What cells contain chloroplasts? pallisade, spongy layer and guard cells.

6. Through what openings does air enter and leave the leaves? stomata. What cells regulate the size of these openings? guard cells.

7. What gas is taken in when a leaf breathes? oxygen. given off? carbon dioxide. A leaf breathes 24 hours a day.

8. Out of what raw materials does a green leaf make starch? water and carbon dioxide. Where does it get each one? out of soil and out of air. What is the source of energy used? sunlight. What waste product is given off? oxygen.

9. What is the scientific name for the process of starch manufacture? photosynthesis

10. After the starch is made in the leaf, what becomes of it? It is stored in the ~~potatoes~~ plant.

11. What two uses may plants make of food? for energy or proteins.

12. What other food materials are built up from the starch molecules? protein and carbohydrates fats.

13. What is the scientific name for the loss of water by leaves? Transpiration

14. What are the three chief functions of leaves? manufacturing food, breathing, and transpiration

UNIT VI

The Whole Seed Plant

E. Digestion

Laboratory Study 27
Digestion

You have learned in this unit that the starch which leaves make is changed to sugar before it circulates into other parts of the plant. Try to dissolve some sugar in water. Does it dissolve? yes. Try to dissolve some corn starch, which is almost pure starch, in water. Will it dissolve as the sugar did? no. Any food material must be in a liquid form in order to circulate through the fibro-vascular tissue. Why does the starch need to be changed to sugar in the green leaf? [illegible].

Test the endosperm of a dry grain of corn for starch by applying iodine. You will recall that iodine turns starch blue. Does the dry grain of corn contain much starch? yes. Similarly test a germinated grain of corn. Does it contain as much starch as the dry grain? not.

The presence of sugar in any substance can be shown by boiling a little of it in a test tube with Benedict's Solution (Fehling's Solution may be used.) If sugar is present, the blue Benedict's Solution will turn a yellow red to a brick red color, depending upon the quantity of sugar. If it remains blue, there is no sugar in the substance.

Boil the dry grain of corn in Benedict's Solution. Does it contain sugar? no. Boil the germinating grain. Does it contain sugar? yes. Where did this sugar come from, do you suppose? [illegible] starch.

From your study of the corn grain, do you remember where the starch is stored? endosperm. Which parts of the corn grain grow into the root and leaves? [illegible]. Can new tissue grow without food? no. Why can not the starch in its original position flow into the young root and leaves to make them grow? [illegible]. Why can sugar? soluble. Do you see why the starch must be changed to sugar? yes [illegible].

Review of Unit VI

The Whole Seed Plant

Food Getting	-- Roots, leaves
Digestion	-- Enzymes in leaves, seeds, etc.
Absorption	-- Roots
Circulation	-- Fibrovascular tissue
Assimilation	-- All tissues
Respiration	-- Leaves (Also stems and roots to some extent)
Excretion	-- Leaves
Motion	-- Responses of roots to gravity and water of leaves to light
Sensation	-- Tropisms
Reproduction	-- Sexual in flowers. Asexual in roots, stems, etc.
Photosynthesis	-- Chloroplasts

UNIT VII

Fungi

Question: Where do Fungi get their food? What relation do they bear to human welfare?

Laboratory Study XXVIII

Place a slice of bread on a plate and moisten it thoroughly; then cover it with a bell jar. Keep it in a dark warm place for a few days. What do you find growing on the bread? mold. What color is this plant? white. Would such a plant be able to make its own food? no. Why? It lacks chlorophyll.

From what source is this mold plant obtaining its food? the bread.

Look at a prepared slide of bread mold. There you will see that the plant body consists of a branching filament called mycelium. Projecting down from the mycelium into the bread there are little rhizoids, which change the starch in the bread into sugar which they absorb by osmosis. Thus the mold obtains its food. Make a sketch of some bread mold and label the mycelium and rhizoids.

Look at the mold on the bread again, after another twenty-four hours. What color is appearing here and there on the mold? white. This color is due to the growth of sporangia with their spores. The spores, when mature, are blown away into the air. They are so small that they may float in the air without being seen. Eventually, some of them fall upon some new food material, such as another slice of bread, where they grow into new mold plants. Where did the mold come from, which grew on your slice of bread? spores in the air. Mount a few of its spores and look at them under the microscope. Sketch a few of them with a sporangium, if you see one.

You have now observed a plant which is unable to make its own food because it has no chlorophyll. Such plants must depend entirely for their food supply upon organic materials. Mold is a very simple plant, much like the Algae in structure, so it belongs in the Fungus class of Thallophytes.

When you eat mushrooms you are eating part of another kind of Fungus. The plant-body, or mycelium, of mushrooms is underground. There must be organic material, such as leaves or rotten wood, in the soil, from which the mycelium can absorb food by osmosis, in order for mushrooms to grow. The mushroom which you eat is only the spore-bearing branch of the plant.

You may have noticed fields of clover showing many whitened leaves. If you look at one of these whitened leaves in cross section under the microscope, you will find that the whiteness is due to a mildew of the Fungus class. It is known as Albugo bliti and lives upon the clover leaves, sending its hyphae (little hairs) into the stomates and stealing its food from the living clover plant. Such a plant is called a parasite, since it lives upon another living organism. Wheat rust and corn smut are similar parasitic Fungi.

A mildew which is another parasite is the one which sometimes grows on starched clothing which has been dampened for ironing and then allowed to stand too long in hot weather.

Yeasts are also Fungi of a simple type, for each yeast plant consists of only one cell. Yeast plants may be studied readily in the laboratory.

Laboratory Study XXIX

Put some yeast from a yeast cake into a dilute sugar solution in a flask and let stand a few hours in a warm place. When the bubbles begin rising in the solution, what process is starting? fermentation.

Look at a drop of this solution under the microscope. Each small cell is one yeast plant. Can you count the number visible in one microscopic field? no? Do you see some large irregular starch grains among the yeast plants? yes. They were put into the manufactured yeast cake to serve as food for the yeast plants. Do you see any small chains of yeast cells? yes. Are all of the cells in a chain of equal size? no. The chains show reproduction of the type known as budding. Sketch a few yeast plants, showing budding, if you see it.

Man has known for centuries that fruit juices ferment, but no one had any idea what causes fermentation until less than a century ago, when Louis Pasteur discovered the true explanation, more or less accidentally. He was a chemist in his early youth, when a brilliant discovery made him famous. Consequently, a fellow citizen of Lille asked Pasteur one day if he would be willing to visit his brewery, for some of the wine vats were turning out bad wine which would not sell. Pasteur consented to take a look at the wine vats, more to please the owner of the brewery than with any notion that he could be of any real help in solving the problem of bad wine. He had no more idea what made grape juice ferment at all than anyone else living at that time, to say nothing of trying to find out what made some of the fermentation turn out badly.

In his work in chemistry he had learned to use the recently improved microscope, so, in a sort of aimless way, he dipped up some of the materials from various wine vats and took them to his laboratory to look at under his microscope. You may read a full account of his solution of the wine merchant's problem in Paul DeKruif's "Microbe Hunters".

Briefly, he discovered the yeast plants, learned that they grow and reproduce as real living things, that they use sugar in the fruit juices as food, and that they throw off alcohol and carbon dioxide as waste products. Here, at last, was a natural explanation of this mysterious, familiar process, called fermentation. The metabolism of one-celled yeasts causes it. The bubbles in hard cider, wine, or in the flask in the laboratory into which you put sugar water and yeasts, are only bubbles of carbon dioxide. Yeasts make starch in bread dough into sugar, which they use as food, giving off alcohol and carbon dioxide. The bubbles of the latter fill the bread dough with the little pores which make it light.

Little does the drunken reveller dream that he owes his hilarity to the methods of using food in colorless one-celled plants. But the fact stands; man uses this knowledge of the activity of yeast plants for both his own "weal and woe".

In the course of Pasteur's study of fermenting wine, he hit upon something else of far greater importance in its results than the mere discovery of yeasts as the cause of fermentation. In the bad wine he found another kind of living organism, infinitely smaller than the yeast plants, but alive and reproducing. He found that wine never spoiled unless it contained these dancing, rod-shaped, organisms. Incidentally, he was able to show the wine merchant how to keep these "microbes" out of his wine vats, thus making all of his wine turn out well, but this is of no importance as compared with his next research.

At the conclusion of his research on fermentation, Pasteur was called to southern France to study sick silk worms, for the whole silk industry was threatened. Here, again, he hit upon the idea of looking at silk worm contents under his microscope. Much to his excited amazement, he found similar dancing, rod-shaped, organisms in the contents of the sick worms. The idea struck him that, perchance, these "microbes" made the silk worms sick, even as they had spoiled the wine. He began extensive experimentation to test out his idea, which he established as true. He saved the silk industry of France, but this also is of little significance, comparatively speaking.

For the first time in the history of mankind, the idea that disease might be caused by minute living organisms had dawned upon the intelligent mind of one man. Previous to Pasteur's work, which was done less than a century ago, no one knew what caused the dread tuberculosis, diptheria, small pox, or plague. There had been many fantastic theories of disease. Most races had believed, at certain stages in their savagery, that devils entered one's body and caused his illness. Hence the beating of tom-toms by the medicine man to drive out the devils. Sometimes, for headache, men used to bore a hole through the skull with a piece of flint to let out the devil. Witches, night air, the stars, and body humors had been blamed as the cause of disease. During all the ages of human life before Pasteur, the treatment of disease was highly unsuccessful, since the cause of disease remained unknown.

Once the idea dawned upon Pasteur, his fascinated interest never left the problem. First he attacked the disease of cattle known as Anthrax. He found it to be caused by a certain kind of bacteria (for we may now call these "microbes" bacteria) which lives in the blood stream of the animal. As these bacteria grew and reproduced within the animal's body, they drew their food supply from the living animal. They threw off waste materials which were poisonous to the animals. These toxins (poisons) caused the illness, and eventually the death, of the cattle.

Now Pasteur knew of the work of Edward Jenner, who had discovered vaccination against small pox in 1796. He knew how Jenner happened to make the discovery. Jenner had noticed that milkmaids were practically the only people of his time who did not contract small pox, for in those days practically everyone had small pox sooner or later. Only milkmaids seemed to be exempt. Jenner knew that cows had cow pox, which seemed to resemble a light case of small pox. He knew, too, that milkmaids often contracted sores on their hands, when milking cows with cow pox. He wondered if these milkmaids might not have cow pox, thereby becoming immune to small pox. He tried out his theory by vaccinating his own children, and it proved true. It was the world-wide application of vaccination which finally controlled the dread small pox.

From his knowledge of Jenner's work, Pasteur wondered if he might discover some means of rendering cattle immune to anthrax. He had learned to grow the bacteria of anthrax in cultures outside of the animals. He wondered if he were to weaken a culture of anthrax germs by diluting it, what would happen to a cow if he injected some of this dilute germ broth into her blood. He decided to make the trial and found that, sure enough, the cow contracted a light case of anthrax, but did not die. Thereafter, she was immune to anthrax, no matter how strong a germ broth he injected into her blood stream. "Microbe Hunters" tells a very dramatic story of his public demonstration of anthrax immunity.

Once the idea that bacteria might infect the human body and cause disease had occurred to Pasteur, he began to experiment extensively in testing the idea. He gathered about him brilliant students who worked with him at The Pasteur Institute in trying to solve various human diseases. It was here that Robert Koch found the germ known as Bacillus tuberculosis and proved that it causes the disease known then as consumption. Since his discovery in 1882, the methods of preventing and treating tuberculosis have been developed so well that the death rate from this disease has been reduced seventy-five per cent.

Pasteur himself found the successful means of preventing rabies. Lister made modern surgery possible by showing how to keep bacteria out of the incision. Behring and Roux discovered the Bacillus diphtheriae and developed an anti-toxin against it.

The relief of human suffering, brought about by Pasteur's application of the scientific method to the problem of human disease, gives to Louis Pasteur his deserved rank as the greatest benefactor of the human race.

The study of bacteria has become a science in itself, called bacteriology. In this course you can learn only a few elementary facts about them.

Bacteria are one-celled plants, the smallest living things that have yet been seen. They are not green, so they must take their food from the bodies of other plants or animals, living or dead. When they live upon a dead body they cause it to decay, thus proving useful, for without these bacteria of decay the carcasses of previous plants and animals which had died would have cluttered up the earth to the exclusion of further life. Living organisms which live upon the bodies of dead organisms are called saprophytes.

Bacteria are classified according to their shape. Round bacteria are called cocci; rod-shaped ones are called bacilli; spiral-shaped ones are called spirilla. There are different kinds of bacteria, just as there are different kinds of flowers. Bacillus tuberculosis can not cause diphtheria, nor can pneumococci make milk sour.

Milk swarms with bacteria, most of which are harmless. Harmful bacteria, such as the germ of tuberculosis or undulant fever, which may occur in milk, can be killed by heating the milk to the temperature of 170° F. If this milk is cooled rapidly, it will keep much longer than unpasteurized milk and the danger of its causing disease will be eliminated.

Some bacteria grow on the roots of plants. One particularly interesting kind grows on the roots of such plants as beans, peas, or clover, which plants are legumes (plants which have a blossom like a sweet pea and a fruit like a bean pod). Pull up a clover plant and examine the roots for small nodules, called tubercles. These tubercles have been found to contain millions of bacteria which possess a strange power, for which they have been named nitrogen-fixing, or nitrifying, bacteria.

As you know, protoplasm must contain nitrogen as one of its elements. About four-fifths of the air is free nitrogen, but neither plant nor animal can use free nitrogen, but must use nitrogen compounds. Plants, for instance, absorb nitrates (nitrogen compounds) from the soil, and animals get their nitrogen compounds from plant tissues. However, these so-called nitrogen-fixing, or nitrifying, bacteria have the power to use the free nitrogen from the air (there is air in the soil) and to make it combine with oxygen and some other element to form nitrates. They leave quantities of these nitrates in the soil at the end of the growing season. Do you see now why the clover crop improves the soil when used in the crop rotation? The bacteria on its roots make new nitrates out of nitrogen, oxygen, and some other element, and these nitrates remain in the soil to be used by the crop planted there the following year.

Previous to the time of the world war this was the only known way to use free nitrogen from the air. German chemists, however, discovered a way to do the same thing chemically, just before the time of the world war. Explosives, you know, are all nitrogen compounds. In war times all nations had to have nitrates shipped in (recently they have been made in Chile, South America) in order to make explosives. So German Chemists decided to try to discover a way to make nitrates, using the free nitrogen of the air, in order to be independent of shipping supplies. They succeeded, and since then chemists of other countries have done likewise. Until recently, however, the nitrogen-fixing bacteria had no competitors in the manufacture of nitrates.

When bacteria attack the tissues of a living animal, they throw off waste products, called toxins, which are poisonous to the host. Man possesses three main lines of defense against the attack of bacteria. The first of those is the skin. Bacteria are unable to attack the cells of the skin, but they enter readily through cuts or other breaks in the epidermis. They are also able to enter the body through the mouth and nostrils. In fact, the human mouth swarms with bacteria at all times, but fortunately they are usually harmless kinds.

Man's second line of defense against the bacteria consists of his white blood corpuscles, whose ability to digest these organisms is already familiar to you.

The third line of defense consists of antitoxins. An antitoxin is a substance in the blood which counteracts the ill effects of the toxins produced by disease germs in the body. For instance, Bacilla diphtheriae attack the throat of an individual. They throw off a toxin into that person's blood stream, causing him to become dangerously ill. Before Pasteur's time, a large proportion of the cases of diphtheria ended fatally because of the inability of those suffering from the disease to produce antitoxin rapidly enough to counteract the toxin. Those individuals who survived an attack of diphtheria were those who were fortunate enough to produce the antitoxin rapidly. Bacteriologists discovered that horses may be given diphtheria and that they also produce the antitoxin. Consequently they withdraw blood from the veins of a horse just recovered from diphtheria and use the serum in treating human diphtheria. Naturally this horse serum contains the specific antitoxin for this disease. Thus the physician comes to the aid of nature in supplying antitoxin artificially to the blood of the patient. This treatment has proved so successful that practically no one dies from diphtheria if the treatment is given early in the attack.

It is known today that many persons are naturally immune to diphtheria. The Schick Test is a recent discovery whereby a physician may discover very easily whether a person is naturally immune , or whether he is susceptible, to diphtheria. If he prove susceptible, the administration of toxin-antitoxin (which has been produced very recently without the horse serum content) will render him immune for a considerable length of time. The use of the Schick Test and the follow-up toxin-antitoxin treatment among children in the public schools has reduced the occurrence of diphtheria to a striking extent.

The Dick Test is a similar test for susceptibility to scarlet fever.

Here you have an example of the value of natural and artificially-supplied antitoxins in disease resistance. We also noted the fact that an individual may have a natural immunity to a particular disease. By this we mean that he is born with this immunity. Artificial immunity to a particular disease may be built up in several ways. First, a person who undergoes an attack of scarlet fever, for instance, is immune thereafter to scarlet fever, because he carries the antitoxin, which he produces during the attack, in his blood stream. Secondly, a person may be given a light attack of a particular disease artificially, causing him to produce enough antitoxin to make him immune thereafter. Vaccination against smallpox and Pasteur's treatment to prevent anthrax are examples of this method. Thirdly, bacteriologists may grow the bacteria of a particular disease artificially, allowing them to produce toxins. This germ-broth is then sterilized to kill the germs and then injected into the human body. The toxin present will stimulate the production of antitoxin, thus rendering this individual immune to this particular disease. Typhoid "shots" are an example of this treatment. Fourthly, a person may be rendered immune to a particular disease by the administration of the antitoxin which some animal has produced or by the joint administration of toxin and antitoxin. The treatment to prevent diphtheria is an example of this method.

The list of human diseases which are known to be caused by bacteria or viruses is very extensive. (A virus is probably a living organism, but it has never been seen because it is so small that our highest powered microscopes do not magnify it sufficiently for us to see it.) Among the most common are tuberculosis, diphtheria, tetanus (lock jaw), typhoid fever, colds, pneumonia, scarlet fever, whooping cough, measles, mumps, infections, influenza, gonnorhea, chicken-pox, meningitis, and appendicitis. Since the discovery of the cause of these diseases, the methods of treating and preventing them have developed very rapidly.

Laboratory Study XXX

Bacteria

Bacteria may be grown in the laboratory on a culture medium. A culture medium which is generally satisfactory may be made as follows:

Take Agar agar 5 gr.
Beef bouillon 5 gr.
Water 500 cc.
Pinch of salt
Pinch of soda

Boil together until the agar is fully dissolved. Filter into Minot dishes. Place these Minot dishes in the top of a double boiler(a sterilizer is desirable, if available) and boil the water in the lower part of the double boiler for one hour. These dishes can not contain any living things after being kept at the boiling point for an hour, so we call them sterile culture media. Each culture medium is like a garden ready to be planted. Take one dish of culture medium, uncover it, touch it with your finger, then recover. You have now planted bacteria from your finger in the medium where they will eat and reproduce rapidly. If you place the dish in a warm, dark place, in two or three days you will be able to see growths of bacteria upon it. Each speck is called a colony.

Similarly expose other sterile media to air of the room, a pencil, the tongue, a coin, milk, water, or any other object you wish. Mark each exposed dish before placing it in a warm, dark place. After a few days, count and record the number of colonies of bacteria growing in each dish. Which source seems to have supplied the most bacteria? Soil. Mount one colony and observe under the microscope. What do you see? Bacteria. Could you count the number of bacteria in one microscopic field? no. Do they move? no

With a sterile swab, collect some bacteria from your teeth. Spread them on a clean microscope slide. Pass the slide through a flame four or five times to fasten the smear to the slide. Apply some methylene blue stain for two minutes. Wash, dry, and observe under the oil immersion lens of the microscope. Can you see any round bacteria? yes. What are they called? cocci. Any rod-shaped ones? yes. What are they called? bacilli. Any spiral shaped ones? yes. What are they called? spirilla. Are you surprised at the fact that your mouth is swarming with bacteria? yes.

Sketch a few of the bacteria from this slide and label each kind.

Look at a stained slide of Bacilli tuberculosis and sketch a few organisms.

Look at slides of any other available bacteria and sketch.

finger
air in room
pencil point
tongue
coin
city water
soil

Witty Hofmann 108

89 5/10 -7 B

Review of Unit VII

1. Whence comes the mold which grows on bread? from the spores in the air.

2. What are the two parts of a mold plant? rhyzoids and spores.

3. How do molds reproduce? spores.

4. Can molds make their own food? no. Why? Because they donot have any chloroplast.

5. What part of the plant do we eat when we eat mushrooms? spores bearing part

6. Can mushrooms make their own food? no. Why? They do not contain any chloroplast.

7. What are Fungi? Fungi are a class of Thallophyta that can not manufacture thier own food

8. Name six kinds of Fungi.

mildew	mushrooms
shelf fungi	puff balls
wheat rust	smut

9. How do yeasts reproduce? budding. What two waste products do they give off? carbon dioxide and alcohol.

10. Who discovered that yeasts cause fermentation? Pasteur.

11. What are the three types of bacteria, according to shape? cocci, bacilli, and spirilla.

12. How do bacteria reproduce? spores.

13. Name two ways in which bacteria are useful.

to crops to decay leaves &c

... beans nitrogen fixing

14. Who discovered that bacteria cause disease? Pasteur. About how long ago? 50 yrs.

15. Name several diseases known to be caused by bacteria.

Hemmorhoids   dithiria

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whooping cough — colds
measles — Trench mouth
scarlet fever — influenza

16. What three lines of defense does man possess against the attacks of bacteria?

skin, White Blood Cell and antitoxin.

17. In what four ways may a person acquire immunity to diseases? vaccination

toxin, antitoxin, and have a disease.

18. Who discovered vaccination against smallpox? Jenner. When? 1796

19. What is the name of the test of susceptibility to diphtheria? Schick.

to scarlet fever? Dick.

20. Who discovered the germ of tuberculosis? Koch. When? 1882

What has happened to the death rate from this disease since the discovery of its cause? It has decreased 75%.

1 Digestion is the changing of an insoluble substance to a soluble form
2 ~~Diastase~~
3 Trypsin Ptyalin
4 sugar
5 gastric
6 intestinal juice
7 endosperm
8 cotyledon
9 so there can be circulation and the
10 food can be supplied to new tissues
iodine
11 Benedict solution
12 starch
13 sugar
14 Lister
15 Reed and Banting
16 Pasteur
17 plural
18 ~~yes~~ no couldnot [illegible] destroys the liver of man

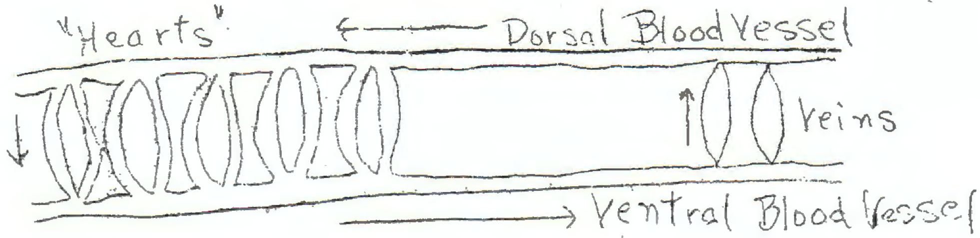

Diagram of Circulatory Sytem of Earthworm

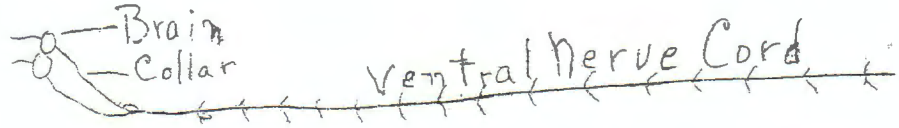

Diagram of Nervous System of Earthworm

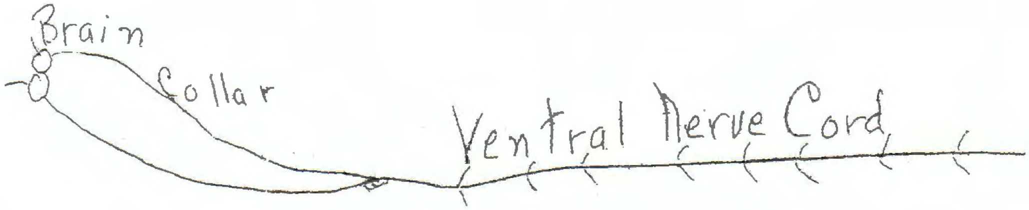

Diagram of Nervous Sytem of Crayfish

digested food, thus giving off heat and energy. Water and carbon dioxide are waste products which are eliminated (excreted) through the skin and nephridia. This union of oxygen with digested food is called oxidation. It is the exact reverse of photosynthesis. Oxidation gives the worm every bit of its energy. As the energy of sunshine was used in photosynthesis, so it is released in oxidation. We may say, then, that an earthworm's energy comes, indirectly, from the sun.

Besides using its digested food to supply heat and energy, a worm may use it to build and repair its own tissues. This is called assimilation. Thus you see, the earthworm, in a rather simple way, carries out the seven phases of metabolism, namely: food getting, digestion, absorbtion, circulation, assimilation, respiration and excretion.

Laboratory Study XXXI

Obtain a specimen of the earthworm which has been preserved in formaldehyde. Can you locate the mouth? yes. Do you see the dorsal blood vessel? yes. Rub the ventral side of the worm. Do you feel the bristles or setae? yes. They are used in crawling. When you have tried to pull a live worm out of his hole in the ground, it was these setae with which he fastened himself to the walls of his burrow and made it difficult, or perhaps impossible, for you to get him, whole. Th earthworm consists of many rings, called segments. How many segments does your specimen have? 174. Do all earthworms have the same number? no.

You now have the opportunity to note the girdle. In what segment does it start? 32. What is its function? to form the cocoon. You may also find the oviduct and spermatiduct openings in the 13th and 14th segments on the ventral side. What is their function? reproduction or giving off eggs sperms

Sketch the ventral view of the worm. Label the prostomium (projection above the mouth), the mouth, the oviduct and spermatiduct openings, the girdle, and the anus (opening from intestine).

Make a dorsal longitudinal slit through the body wall, being careful not to cut the internal structures. Loose the body wall from the food tube and pin it to the wax in the dissecting pan, so that the internal organs (viscera) lie exposed. Look first for the crop, gizzard, and intestine. Do you see the dorsal blood vessel running along on top of them? yes. Look also for the muscular pharynx just back of the mouth. Between the pharynx and the crop, you will see the ovaries and sperm glands as white bodies. The five pairs of veins which beat like "hearts" are found between these white reproductive glands. Can you find five pairs of them? yes. Sketch and label viscera. Diagram circulation

In preparation for a later unit, you should at this point remove and sketch the "brain", collar, and ventral nerve cord of your specimen. You will find the so-called "brain" at the anterior end of the pharynx, dorsal to the mouth. It consists of two white bodies about the size of a pin head. You will find the ventral nerve cord running the entire length of the worm just below the food tube. This nerve cord branches into the collar which passes around the pharynx and joins the "brain". Look for fine nerves running into the prostomium (nose). Look also for small nerves branching off from the ventral nerve cord.

C. Crayfish.

The crayfish is another animal which may be studied as a type with a little higher organization than the earthworm.

Laboratory Study XXXI

Obtain a specimen of crayfish which has been preserved in formaldehyde. What structures do you see which might be used in food getting? pinchers. Can you find the mouth? yes. Is it dorsal or ventral? ventral. Are there any noticeable parts on either side of the mouth? yes. They are called appendages and there are three kinds of them near the mouth. Watch a living crayfish eat a bit of meat. What seems to be the function of the mouth appendages? to hold and bite food Remove these appendages one by one from around the mouth of your preserved specimen How many pairs of them do you find? six. The first three pairs are called maxillipeds, the next two pairs are called maxillae, and the last pair is called the mandibles. Sketch one of each.

What sense organs do you find on the crayfish? antennae, antennules and eyes. Touch the eye of the living crayfish. What happens? it pulls it in.

The body of the crayfish consists of two parts, the cephalo-thorax and the abdomen. In what way does the abdomen resemble a worm? by segments.

What kind of covering do you find over the crayfish's body? exo-skelton It is called an exoskeleton. What advantage can you see in it? it is for protection. Does the earthworm have any skeleton at all? no.

Watch the living crayfish move around. What parts does it use in locomotion? legs, Tail. How many walking legs does it have? five pair. Are they all alike? no. Prove it. to pair have pinchers and two don't.

Sketch whole animal, dorsal view. Label the antenna, antennule, eye, cephalo-thorax, abdomen, tail, walking legs, and pincers.

Underneath the abdomen you will find appendages called swimmerets. In the embryo crayfish all of its appendages resemble these swimmerets, but as the embryo matures, some of these swimmerets become antennae, antennules, mandibles, maxillae, maxillipeds, pincers, walking legs, and tail. Remove and sketch one of each, trying to show any resemblance to the swimmeret, which you see.

Carefully remove the carapace (exoskeleton covering the cephalo-thorax). Immediately under the posterior dorsal portion of the carapace you will find an elongated sac which is the heart. Do you see any veins attached? yes Sketch the heart. Cut the heart open. How many cavities does it contain? [illegible].

Underneath the lateral edges of the carapace and attached to the walking legs, you will find the feathery gills. In the live crayfish these gills are filled with blood. From what source do you suppose this animal gets its oxygen? from the water How many pairs of gills are there? 8 pair.

Stick a dissecting needle up into the mouth. Look inside the animal. Where does the needle reach? stomach. Open this stomach. What do you notice about its lining? It contains 3 pr teeth.

What function do you suppose these "teeth" have? to aid digestion

In the body cavity you may find the ovaries or sperm glands and a large liver.

Trace the intestine back through the abdomen. In the anterior end of the body cavity, in front of the stomach, there are two green glands which function as kidneys for throwing off waste material. It is an interesting fact that the kidneys of a child begin to develop in the shoulder in much the same location as you see them in the crayfish but in the child they are crowded out by the lungs and develop back in the abdomen.

Notice the muscles in the abdomen. What use does man make of these muscles in shrimp or lobster? uses them for food.

Notice the five pairs of swimmerets on several different crayfish. Are they all alike? no. Those with the anterior pair of swimmerets enlarged are males and they use this structure in fertilizing the eggs. Look at the reproducing female in the specimen jar. What do you see attached to her swimmerets? eggs

She will carry them there until they hatch. What advantage does this give them?

It is protect them from being eaten by other animals

Ask your instructor to demonstrate the brain, collar, and ventral nerve cord to you and sketch them beside those of the earthworm.

Name two ways in which the crayfish resembles an earthworm. segments

[illegible], nervous system.

Make a list of ways in which the crayfish is more advanced than the earthworm.

exo-skeleton
teeth in stomach
Gills
Well developed mouth parts
One true heart

With what organs does the crayfish get its food? pinchers

mandibles maxilla Where is this food digested? in the stomach

What parts of the circulating system did you see? veins and

hearts.

What organs of the nervous system (sensation) did you see? brain, collar ventral nerve cord.

locomotion? walking legs flippers, tail

and swimmerets

Have you already studied any animal which the crayfish resembles more than it does the worm? no. The crayfish is classified in the Arthropod phylum because it has an exoskeleton and jointed appendages just like the Insecta. But it has a cephalo-thorax and more than three pairs of legs so it is put in the Crustacea class along with the crabs, shrimps, and lobsters.

Betty Hofman
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-7 B

Review of Unit VIII A-B-C

1. What is oxidation? It is the uniting of oxygen with some other element [illegible].
What is released in the body when food is oxidized? heat and energy.
Into what two substances does oxidation change sugar? ~~heat~~ water and ~~energy~~ carbon dioxide.

2. Of what process is oxidation the reverse? Photosynthesis

3. What are the rings of the earthworm called? segments

4. To what phylum does the earthworm belong? annelida

5. What is the name of the bristles of the earthworm? setae. On which side are they? ventral. What is their function? to help in motion.

6. Name the parts in the food tube of the earthworm. mouth, pharynx, esophagus, crop, gizzard, and intestines.

7. What do earthworms eat? the soil.

8. Name four parts of the circulatory system of the earthworm. arches, Ventral Blood vessel, Dorsal Blood vessel, and "hearts".

9. What are three parts of the earthworm's nervous system? brain, collar and ventral nerve cord.

10. Through what structures does the earthworm excrete waste materials? anus, nephridia, and skin.

11. Where does the earthworm obtain its O_2? from soil. Through what structure? skin.

12. How do you account for the abundance of earthworms on the side walk on a rainy morning? Because the [illegible] to [illegible] soil.

13. To what phylum and class does the crayfish belong? crustacean arthropod

14. What are two main characteristics of this phylum?

(a) jointed feet

(b) exoskeleton

15. Name three other animals which are closely related to the crayfish. shrimps sowbug, lobster.

16. What parts does the crayfish use for locomotion? walking legs flippers and swimmerets

17. Where is the mouth in reference to the stomach? It is down on ventral side.

18. Where is the food masticated? In the stomach

19. Name the parts of the food tube? esophagus, stomach, mouth, intestine

20. With what do they breathe? gills.

21. How many cavities does the heart contain? one.

22. What are the appendages underneath the abdomen called? swimmerets. What other appendages are there? antennae, antennules, jaws, maxilla, maxillipeds, walking legs, and flippers.

23. Name two things which suggest that crayfish developed from worms.

a. segments

b. appendages

24. What are the organs of excretion? anus and green glands. Where are they located? ventral side.

25. What organs of sensation do they have? brain, cells, ventral nerve cord

26. In what ways do crayfish show greater advancement than earthworms?

a. exoskeleton

b. eyes

c. gills

d. one true heart

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    a. segments

    b. appendages

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26. In what ways do crayfish show greater advancement than earthworms?

    a. exoskeleton

    b. legs

    c. gills

    d. one true heart

sides of the gill arches which fit together forming a sort of sieve to strain the water.

The operculum is the hard covering on the side of the head which covers the gill slit. Lift up the operculum. What do you find under it? gills. How many can you count? 4 pair. What color are these gills in a living fish? red. Why? blood. In the living fish, water is constantly pouring out of the mouth over the gills. O_2 from the air which is dissolved in the water is absorbed into the blood thru the gills by osmosis and CO_2 and H_2O from the blood are given off at the same time. Thus a fish gets oxygen into its blood stream. Does the fish's nostril join the mouth? no. Why? The water goes in on one side and comes out on the other

Do you find teeth in the fish's mouth? no. Is there a tongue? yes. Some fish, such as sharks, have large sharp teeth upon which they depend largely for food getting. Yellow perch eat smaller fish which they are able to swallow without the need for well-developed teeth. Sketch and label the outer view of perch

Make a ventral longitudinal slit through the body wall of the preserved specimen from the anus (opening from the intestine) to the mouth. Be careful not to cut any of the viscera. Remove the flaps of body wall, leaving the viscera exposed.

Open the mouth and probe down the throat with a needle. Where does the needle go? down the food tube to stomach. Trace the food tube. What parts do you find? stomach, esophagus, mouth, intestines. The liver is a digestive gland. Is there a green sac on the liver? yes. What is it? gall bladder. How long is the intestine? 4 inches. Look also for the spleen, swim bladder, pancreas, kidneys. What is the function of the swim bladder? to regulate it to pressure.

Does your specimen contain roe or milt? milt. Are the male and female glands in the same fish? no. Which kind do you have? male.

Open the stomach. What is the lining like? It is rough.

As you have noted, fish have no antenna. Can you find anything on the surface of the fish which looks as though it might be sensitive? lateral line Sensation is located in the lateral line.

Did you ever pick up a live fish? no Why was it hard to hold? because the scales are covered with slime.

Make a list of adaptations of fishes for life in the water.

fins	scales
gills	air bladder
tail	eyes
streamline form	lateral line

Count the fins. 8. Are any of them in pairs? yes How many? 2. All Vertebrates have two pairs of appendages.

Sketch the fish, lateral view. Label the head, trunk, tail, lateral line, nostril, mouth, gill slit, operculum, dorsal fin, pectoral fin, pelvic fin, anal fin, and anus

Sketch the food tube. Label mouth, gullet, stomach, intestine, liver, pancreas

Almost immediately back of the mouth, you can find the heart. How many cavities does it contain? 2. Can you trace the artery forward from the heart? yes. It goes to the gills. What happens to the blood in the gills? gills to body back to the heart.

After the blood flows through the gills, it is circulated through the whole body. Part of it reaches the food tube where it absorbs digested food. When it comes back to the heart, it enters the auricle, or large dark sac of the heart, whence it is pumped into the light colored ventricle. From the ventricle it is pumped through the artery to the gills again. Sketch the heart, labeling the auricle, ventricle, and artery.

Pare off the top of the fish's skull, exposing the brain. How is it protected? bones and skull. Remove the brain and spinal cord as carefully as you can. Do you see the two nerves running up to the nostrils? yes

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Pare off the top of the fish's skull, exposing the brain. How is it protected? bones and skull. Remove the brain and spinal cord as carefully as you can. Do you see the two nerves running up to the nostrils? no

They are the olfactory nerves and are joined to the olfactory lobes of the brain. Next to these lobes are the two halves of the cerebrum. The two large lobes back of the cerebrum are the optic lobes. The cerebellum and medulla are at the back of the brain and the medulla tapers off into the spinal cord. Sketch the central nervous system, labeling all of these parts.

The food which the fish swallows into its stomach is acted upon by digestive juices and parts of it are made soluble. These soluble foods are absorbed from the wall of the intestine into the blood stream and carried to all parts of the body. The undigested foods are thrown off through the anus as wastes.

In the gills the blood absorbs oxygen which is also carried to all parts of the body. When the oxygen unites with the digested food in any tissue, heat and energy are produced, and CO_2 and other waste products are carried away by the blood to the gills and kidneys where they are excreted.

Digested foods may also be used to build new tissue or to repair old tissue, which process, as you know, is called assimilation.

Thus you see the fish carrying out the same seven phases of metabolism as the worm or crayfish, but in a little more complex way.

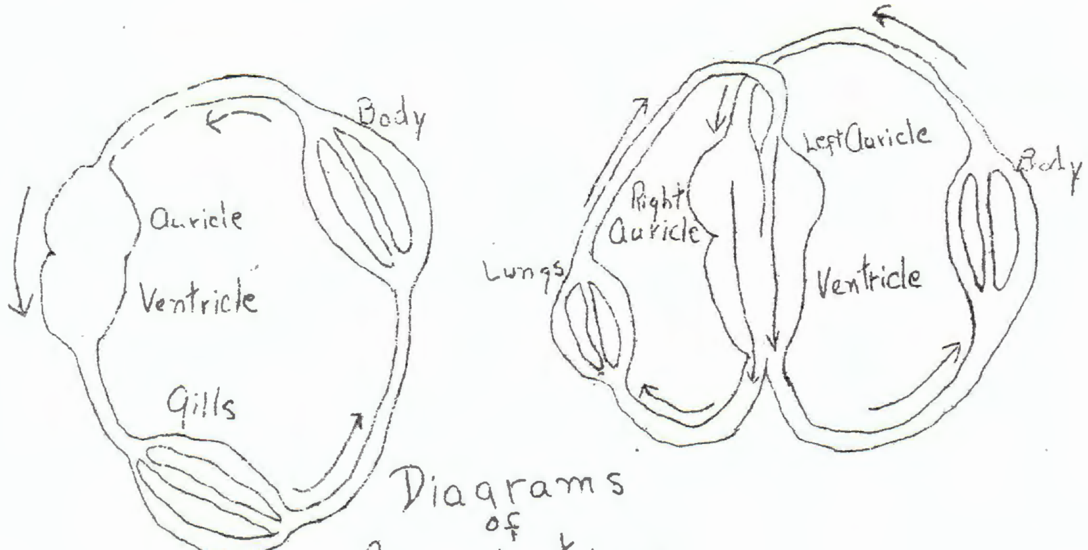
Make a list of ways in which a fish shows advancement over the crayfish.

swim bladder	nervous system
gills	stream line form
fins	lateral line
brain	scales

Rewrite your definition of fishes. A fish is a vertebrate that has scales, fins and gills.

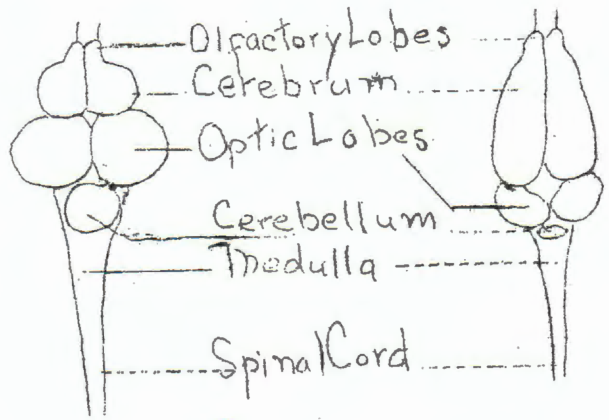
F. Amphibians.

Frogs and toads belong to the second class of Vertebrates. They are closely related to the small animals which you find under logs and stones and which you call "lizards." They probably are not lizards at all, for a real lizard has a scaly skin like a snake's and these little "lizards" in the temperate zones are nearly always newts or salamanders for they have a soft smooth skin and they also live part of their lives in the water. Animals of this type are grouped in the class of



Diagrams of Circulation

fish frog



fish Brains frog

Amphibians ("two lives").

Define Amphibians. amphibians belong to the [illegible] breathe by gills in tadpole stage and lungs in adult stage. [illegible] smooth skin

The adult frog is extremely difficult to hold in your hands, as you know. This fact is due to the secretion of a slimy substance by glands in the skin. In fact, a frog will die if its skin becomes thoroughly dry, for the skin is richly supplied with small blood vessels which absorb oxygen from the air dissolved in the water. Thus the moist skin serves two purposes, respiration and protection. The adult frog also breathes by means of lungs, while the tadpoles breathe by gills, like fish, as you learned in the unit on reproduction. Consequently, we say that frogs have "two lives," one in the water and one on the land. This fact makes them Amphibians, just as are the toads, newts, and salamanders.

Laboratory Study XXXIII

Observe a live grass frog in a tank. What color is he? green. Do you see any advantage in his color? no. Are all frogs the same color? no. This particular frog is known to scientists as Rana pipiens. This name was given him by the first scientist who wrote and published a description of this particular kind of frog. All frogs belong to the genus Rana, but only grass frogs belong to the species, pipiens. Every plant and animal in the world has a similar scientific name consisting of a genus name and a species name. Man himself is called Homo sapiens. These scientific names are very useful to the scientist because they are the same in all languages and they usually describe the organism and indicate his classification.

How many legs has the frog? 4. Are they equally developed? No. Why? Because the hind legs are used for swimming. Do the fore and hind legs have the same number of toes? no. What adaptation does the hind foot show for swimming webbed feet. What other use does the frog make of his hind legs besides swimming? jumping. What use does man make of the well developed muscles of the hind legs of the frog? food. Obtain a preserved specimen of Rana pipiens. Remove the skin from one hind leg. How many muscles can you count? 4. What shape are these muscles? long and spiral. In what does each muscle end? joint. Sketch the leg showing the muscles. Tr

to trace a muscle its full length. Are its two ends attached to the same bone? No
Why? [illegible].
Remove the muscles from the bones. Are they easily removed? yes Sketch the bones, labeling femur, crus, astragolus, calcaneum, and phalanges.

Look at the inner surface of the skin. What do you see? blood vessels
Why are they there? blood circulation Look at the web of the live frog's hind foot under the low power of the microscope. What do you see? blood vessels
____.

Probe the nostril of the preserved specimen. Where does it go? mouth.
Does the fish's nostril go there? No. Can you see any reason why the frog's nostril should reach the mouth? So they can breathe [illegible] on land. Watch the living frog breathe. Note how his throat swells and contracts alternately. How fast does he breathe? 105. He sucks the air into his mouth through his nostrils and swallows it into his lungs. Try to swallow a mouthful of air. Can you do so? No. Where does the air go if you swallow it? stomach
Open the frog's mouth and look for the entrance of the nostrils. In the back of t[he] mouth look for a vertical slit called the glottis. It is the opening into his trachea or "wind pipe." In the top of the trachea is the vocal box. What use does the frog make of it? for croaking.

Examine the tongue. Which end is attached? anterior. Have you ever watched a frog or toad snap up a fly? yes. Could you see just how he caught it? yes. As a matter of fact, he catches it with the free or posterior end of his tongue, crushes it against his two teeth (Do you see them? yes) and pokes it dow[n] his gullet (Do you see it? yes) so rapidly that you cannot see the movements eve[n] though you watch closely.

Diagram the open mouth of your preserved specimen. Label the tongue, teeth, glottis, gullet, nostrils, and eustachian tubes. These eustachian tubes are far back in the mouth and are located, one on either side of the upper jaw. Probe one and watch outside to see where the probe goes. The brown ring back of the eye is the tympanum or ear drum. What does the eustachian tube join at either end? ______ mouth and ear.

How many eyelids do you find on your specimen? 3. Try to touch the eye ball of a living frog. What happens? Eye lids cover it ______. This thin membrane, or third eyelid is called the niclitating membrane. What is its function? to protect it under water.

Cut your preserved specimen open by making a ventral longitudinal slit. Remove the flaps of skin thus exposing the viscera. Run a probe down the gullet. Where does it go? [illegible]. Trace the full length of the food tube from the stomach. Is there a larger portion at the posterior end of the intestine? yes. It is called the cloaca. Did the fish have a similar structure? no. How long is the intestine? about 4½ in. How many lobes does the liver have? 3. What is the green sac on the liver called? gall bladder. What is its function? to store bile. Look for the pancreas and spleen.

Remove the food tube and sketch it.

Lying along the backbone of the frog, look for two long dark kidneys. Trace two tubes leading from the kidney down to the bladder. These are the ureters. There is a yellow streak along the ventral side of each kidney. It is called the adrenal gland. These adrenal glands are very important in all of the higher animals because they secrete a hormone called adrenalin into the blood stream. Adrenalin stimulates many reactions and either induces or increases many emotions. For instance, when a person who is driving an automobile narrowly escapes being struck by a train, he feels the emotion called fear. As a matter of fact, recent investigations show that at the instant he realizes the danger, the adrenal glands pour adrenalin into the blood stream. This adrenalin goes to the liver and causes the starch stored there to be released into the blood as sugar. This sugar burns rapidly to produce more energy for a frightened person needs energy to run or fight. The adrenalin also quickens the heart beat and contracts the blood vessels thus increasing the blood

This means that the frog does not have completely oxygenated blood in its general circulation at any time, so that it is not able to oxidize sugar rapidly enough to maintain a warm body even though its blood does flow more rapidly than the fish's. Consequently, we say the frog is cold-blooded. You will recall that in the fish, the blood flows directly from the gills to the body in general. In this case, the blood is well enough oxygenated but it is slowed down in its flow by passing through the gills so that it does not circulate rapidly enough to maintain a warm body. Consequently, fish are also cold-blooded. In the frog, there is an additional absorption of oxygen in the skin.

In addition to excreting CO_2 through the lungs and skin, the frog also excretes its nitrogenous wastes through the kidneys and its undigested foods through the cloaca.

What are the organs of the fish and frog, used in each of the following functions:

	Fish	Frog
1. food getting	mouth	mouth tongue
2. digestion	stomach intestine	stomach intestine
3. absorption	villi of intestine	villi of intestine
4. circulation	vein arteries blood heart	veins arteries heart
5. respiration	4 pr gills	2 lungs [illegible]
6. excretion	anus kidney	cloaca kidneys bladder.
7. motion	fins tail trunk	legs
8. sensation	lateral line nostril mouth eye	eyes nostril ear skin
9. reproduction	eggs, milt	eggs, sperms.

viewing of ...

—2

B+

Review of Unit VIII D - C

1. To what phylum and class do fishes belong? vertibrate and fish
   What is characteristic of the animals of this phylum? Backbone
2. What adaptations does a fish have for life in the water?

   swimming bladder — gills
   fins — eyes
   streamline form — lateral line

3. How do fish obtain their O_2? through gills
4. How many cavities does the fish's heart contain? 2. Name them. auricle and ventricle
5. Where does the blood go from the heart? gills. Then where does it go? body. Why is the fish cold-blooded? because it has only two chambers in its heart.
6. How many cavities does the frog's heart contain? 3. Name them. Right and left auricle and 1 ventricle
7. How many times does one drop of blood go through the fish's heart in one complete circulation? once. the frog's? ~~once~~ twice ✓.
8. How do frogs obtain their O_2? by lungs.
9. How do tadpoles get their O_2? by gills.
10. Name the organs in the food tube of the fish. mouth gullet stomach, intestines.
11. Name the organs in the food tube of the frog. mouth, gullet, stomach, intestine cloaca. What advance does the frog's digestive canal show over that of the fish? It has a cloaca beginning of large intestine.
12. How do the muscles of a frog differ from those of a fish? They are attached in joint of bones.
13. What is the name of the frog's third eyelid? nictitating
14. To what phylum and class does the frog belong? vertebrate amphibian
15. Define the class, Fishes. it's body is covered with scales breathes by means of gills and

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____

____.

16. Define the class, Amphibians. It breathes by means of gills in Tadpole stage and by lungs in adult stage and has a smooth glandular skin.

1. Kidney
2 adrenal gland
3 ureter
4 bladder
5 auricle
6 ventricle
7 artery
8 heart of fish
9 Right auricle
10 Left auricle
11 ventricle
12 lung
13 gill raker
14 gill arch
15 gill filiment
16 gill of fish
17 olfactory nerve
18 olfactory lobe
19 cerebrum
20 optic lobe
21 cerebellum
22 medula oblongata
23 spinal cord
24 fishes brain
25 frog brain
26 ~~gland~~ gullet
27 liver
28 Gall bladder
29 Stomach
30 Cr[illegible]

31. spleen
32 pancreas
33 intestine
34 kidney
35 food tube of fish
36 esophagus
37 heart
38 lung
39 liver
40 gall bladder
41 stomach
42 pancreas
43 intestine
44 spleen
45 cloaca
46 food tube of frog.

UNIT VIII

F. Reptiles

Reptiles represent the third class of Vertebrates. They include turtles, lizards, snakes, alligators, and crocodiles. They never breathe by means of gills, but obtain their O_2 from the air through lungs. They are also characterized by their possession of an epidermis covered with scales. They represent the first Vertebrates which are adapted to live their complete lives on land. They do not show many marked advances over the Amphibians in structure. All of them have hearts with three cavities except the alligator and crocodile, which show four cavities. Consequently, they are still cold-blooded.

Reptiles at one time ruled the animal life on the earth. The huge dinosaurs, whose skeletons have been unearthed, lived in an age when reptiles abounded. Some of the later forms developed feathers on the tail and forelimb as we know from fossils of flying reptiles which have been discovered in the rocks. Most of the many kinds of reptiles have long since become extinct, so that today, we have comparatively few species living.

Define reptiles. a reptile is a vertibrate animal with lungs, scales and 3 chambered heart.

G. Birds

The fourth class of Vertebrates is Aves or Birds. They do represent a marked advance over the reptiles. They have a four chambered heart, which means that they are warm-blooded since the oxygenated and deoxygenated blood are kept separate in the two ventricles.

Birds are just as well adapted for life in the air as fishes are for life in the water. They are covered with feathers, they have small hollow bones, and they have no teeth. All of these facts make them light so that they can fly. Make a list of several other features of birds which seem to you to be adaptations for flying.

they have wings
higher body temperture
four chambered heart
stream line form
a Tail
feathers are hollow for insulation

Laboratory Study XXXIV

The Chick

What does the chick use in getting its food? beak. Does it have teeth? no. tongue? yes.

Observe the living chick. How rapidly does it breathe? 66 per min. How does this rate compare with the frog? it is slower. Count the rate of heart beat, if possible. What is it? 128. What is the normal temperature of a bird's body? 103. Is it warm or cold-blooded? warm.

After the chick has been anaesthetized, observe the dissection. Look first for the beating heart. Is it beating more or less rapidly than it was before the ether was given? less. What do the lungs look like? pink sacs. How many cavities does the heart contain? 4.

In this four chambered heart, the deoxygenated blood from the body comes back to the right auricle of the heart and is then pumped into the right ventricle. Thence it is pumped to the lungs where it takes on O_2 and gives off CO_2. This oxygenated blood returns to the left auricle, thence to the left ventricle which pumps it over the body. Notice how thick the muscular wall of the left ventricle is, to enable it to pump the blood rapidly. Birds are warm-blooded; that is, they maintain a constant body temperature of 102° to 110° F.

What are the parts of the food tube as you saw it traced back from the mouth? esophagus crop, gizzard small intestine, large intestine

Is there an appendix? no

When the gizzard is opened, what is found inside of it? [illegible]. Why are they present? In order to mix the food with digestive juices

How long is the intestine? 8 inches. When you consider that digested food is absorbed into the blood in the small intestine, you will see that the longer the intestine, the more absorbing surface there is. Birds need more energy than any other animals because they fly. Try flapping your arm like a wing for five minutes and you will have some idea how much more energy a bird needs for flight than you need for anything you do. Oxidation of sugar and digested fat produces this energy. Consequently, birds need more food in proportion to their size than other animals. Many birds eat three or four times their own weight of food daily. This food is stored in the crop, ground and mixed with digestive juices in the gizzard, digested and absorbed into the blood stream in the small intestine. The rapid breathing rate supplies O_2 faster than in other animals. The four chambered heart keeps the oxygenated and deoxygenated blood separate, and the rapid heart beat keeps the blood flowing rapidly. This rapid metabolism in birds not only supplies sufficient energy for flight, but also makes them more sensitive to gases in the air than man is. Hence birds are used to detect poisonous gases in mines or in warfare since they feel their effect sooner than man does.

Sketch the heart and lungs. Label right auricle, right ventricle, left auricle, left ventricle, aorta, trachea (wind pipe), and lungs. What holds the trachea open? muscles. Look at the vocal cords in the vocal box. How many vocal cords are there? __________. What is their function? [illegible].

Sketch the food tube. Label the mouth, gullet, crop, gizzard, small and large intestine, liver, pancreas, and spleen.

Observe the removal of the brain. Sketch it beside that of the frog and label the same parts for later study.

Define birds. a bird is a vertebrate has feathers wings and a 4 chambered heart

What organs do birds use for each of the following functions?

- food getting beak and mouth
- digestion gizzard, small intestine
- absorption villi in small intestine
- circulation heart, veins, arteries, blood
- excretion cloaca, kidneys, bladder, ureter
- motion feet wings, tail
- sensation [illegible] nostrils [illegible]
- respiration 2 lungs [illegible]

Betty Hoffman

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A - -10

Review of Unit VIII F-G

1. What are reptiles? a vertebrate animal covered with scales breathes by lungs has a 3 chambered heart.

2. Name several animals which belong to this class. crocodile alligator and lizard.

3. Are reptiles more or less numerous than they were in past ages? less. How do you know? Because they have been killed off and there are no longer jungles or [illegible] places for them to live.

4. Define birds. A vertebrate, breathing, 4 chambered heart, covered with feathers, breathes by lungs, lay eggs.

5. What adaptations do birds have for flight? Bill, light body, no teeth, wings, feathers, [illegible], 4 chambered heart.

6. How many cavities are there in the reptiles heart? 3. the birds? 4. What is the normal temperature of a bird's body? 102° to 110°.

7. Why do birds have a very rapid breathing rate and pulse rate and a high temperature? Because the food in their body must be oxydized [illegible] rapidly in order that they may fly.

8. Name the organs in the food tube of a chick. mouth, [illegible], crop, [illegible], and intestine. What does the gizzard contain? [illegible]. Why are they there? to mix the food and help grind it.

Review of Unit VIII F-G

1. What are reptiles? a vertebrate animal covered with scales, breathes by lungs, has a 3 chambered heart.
2. Name several animals which belong to this class. crocodile alligator and lizard.
3. Are reptiles more or less numerous than they were in past ages? less. How do you know? Because they have been killed off and there are no longer jungles or almost places for them to live.
4. Define birds. A vertebrate, breathes by lungs, 4 chambered heart, covered with feathers, breathes by air sacs and lungs.
5. What adaptations do birds have for flight? tail, lighter body, no teeth, wings, feathers, streamlined form, 4 chambered heart.
6. How many cavities are there in the reptiles heart? 3. the birds? 4.
   What is the normal temperature of a bird's body? 102° to 110°.
7. Why do birds have a very rapid breathing rate and pulse rate and a high temperature? Because the food in their body must be oxidized rapidly in order that they may fly.
8. Name the organs in the food tube of a chick. mouth, gullet, crop, gizzard, and intestine. What does the gizzard contain? gravel. Why are they there? to mince the food and help digest it.

H. Mammals

The fifth and highest class of the Vertebrates is Mammals. Most of the animals which you see every day belong to this class. Dogs and cats, horses and cows, sheep and goats, whales, bears, walruses, monkeys, apes, and men are mammals. They breathe air, have more or less hairy body coverings, are viviporous, and nourish the young with milk.

I. What kinds of food does man use?

All of the foods which we eat have been classified as carbohydrates (starches and sugars), fats, proteins, mineral salts, and vitamins. As you already know, man must fulfill two purposes with his food. First, he must use it as fuel to burn in order to supply energy; secondly, he must use it to build and repair his own living tissues. These five classes of foods are necessary in order that these two functions may be fulfilled. On the other hand, you are very apt to choose your food on some other basis entirely, such as a whimsical taste, price of food, or mere habit. You may be interested in a few general biological principles which ought to help you to choose your food wisely.

The first function of food is to supply energy. Now the unit of heat energy is the calorie, which has been defined arbitrarily as the amount of heat necessary to heat one liter of water from 0° to 1° Centigrade. The number of calories which any given amount of a particular food will supply has been measured and tables recording the amounts are available from the government and in various printed forms.

It has been established that the average man needs about 3000 calories daily. One who does hard muscular work needs more. Women need less. Most of you who are students need about 2500 calories daily. You could get all the calories you need by eating a pound and a half of cheese a day, or three pounds of sugar, or five pounds of apples. It is wiser, as well as more enjoyable, however, to use a mixed diet containing plenty of fruits and vegetables, since the carbohydrates offer your chief source of calories. Fats also are burned to produce calories, but should constitute a much smaller portion of your diet than the carbohydrates, because they are harder to digest and absorb. The most recent research on human nutrition has convinced biologists that one is much more apt to eat a diet too high in calories than one too low.

The second function of food is to build and repair tissue. In order to fulfill this end, your food must contain those chemical materials necessary for the tissues. Carbohydrates and fats consist of oxygen, hydrogen, and carbon, while protoplasm must also contain nitrogen and sulphur, and sometimes phosphorus. Other chemicals occur in certain tissues, such as calcium phosphate in the bones and teeth. The food must supply all of them. Protein foods contain nitrogen in addition to carbon, hydrogen, and oxygen. Lean meat, white of egg, milk, peanuts, beans, and peas are rich in proteins and consequently are useful in building and repairing tissue. Mineral salts, such as table salt, are also necessary in small amounts. Here again, if you eat a sensibly mixed diet, your protein supply will be all or more than you need.

Students of human nutrition now know that the average person faces far less danger of suffering from lack of carbohydrates, fats, proteins, and mineral salts, than he does of suffering from lack of enough fresh foods. In this age of candy, white flour, and canned foods, human beings depend less and less upon raw fruits and vegetables. The danger that lurks in a diet lacking in fresh uncooked foods has only been realized in comparatively recent years. Let us trace the story of its discovery.

As long ago as the sixteenth century, men were suspecting that the disease known as scurvy, which sailors developed after being at sea a few weeks, had some relation to their monotonous diet of salt meat and biscuit, without any kind of fresh fruit or vegetable. The suspicion was confirmed in 1593 when Sir Hawkins cured a whole crew of scurvy by making them drink lemon juice. By 1795 the use of lemon juice by sailors was made compulsory under the British Admiralty. No one had any idea why raw potatoes, onions, or lemon juice prevented or cured the disease; they only knew the fact.

The Japanese discovered a similar fact about a disease known as beri beri, which occured among the sailors in their navy, whose diet consisted largely of polished rice. They found that unpolished rice (with the husk on), or barley, prevented beri beri. Both scurvy and beri beri are eventually fatal, if the proper food is withheld.

These two diseases were known to be prevented by particular kinds of food, although no one knew why. The natural conclusion to draw from these facts is that fresh fruits and vegetables contain some substance necessary to life, since its absence causes scurvy and eventually death, and that the husks on grains contain another similar substance, whose absence causes beri beri and eventually death. The proof that this conclusion is true was not fully established until 1912. F. Gowland Hopkins at Cambridge, England, experimented with the diets of rats and published his results in that year. He fed rats on a pure diet containing all of the carbohydrate fats, proteins, and minerals known to be necessary, but he synthesized these foods instead of feeding natural foods. His rats gradually lost weight and died. He fed other rats on the same diet, plus a small amount of fresh milk daily. These rats grew and thrived. It is evident that a few drops of milk could not add enough carbohydrates, fats, proteins, or mineral salts to make the difference of life and death in rats. Hopkins concluded that there must be something present in small quantities in fresh milk which is in some mysterious way necessary to life. The facts about scurvy and beri beri were recalled and put to experimental test. The fact was thus established that there are mysterious agencies present in minute traces in certain articles of food which are necessary to life and these agencies were named vitamins.

The existence of vitamins is proved, but they have not been analyzed chemically as yet, although one of them has been shown to give a characteristic color reaction and there is a very recent claim that another has been obtained pure.

Six vitamins are known definitely now. Vitamin A which is found in fresh milk, butter, codliver oil, and various vegetables, is necessary for young growing animals Vitamin B which is found in rice husks, prevents beri beri. Vitamin C which is found in lemon juice and other fresh fruits and vegetables, prevents scurvy. Vitamin D which is found in fresh natural oils and fats, prevents the disease of children known as rickets. In rickets, the child's bones remain soft because, for some reason, if vitamin D is lacking, calcium phosphate (lime) fails to be infiltrated and deposited in the cartilage tissue to form hard bone. Since codliver oil is particularly rich in vitamins D and A, it has become an important item in the food of growing babies.

Recently, there has been considerable interest in direct sunlight as a substitute for codliver oil in supplying vitamin D. We now know that the ultra violet rays of sunlight act upon a certain substance, called ergosterol, which is found in small amounts in all animal tissues, and actually change it into vitamin D. Ergosterol has been analyzed chemically so that its formula is known. Probably from this beginning, we shall soon discover the formula for vitamin D itself and then at last we shall know exactly what it is.

Vitamin E is another vitamin recently recorded which occurs in various vegetasupply vitamin D in order that the calcium phosphate may be properly deposited to form a good enamel on the teeth.

In the mouth you also find the tongue, which keeps the food between the teeth for mastication and also aids in swallowing. What other important function of the tongue can you think of, in relation to the use of food? It contains taste buds used for tasting. Do you consider taste a single sense? no. As a matter of fact, it is four separate senses. Look at your tongue in the mirror. Do you see the little projections all over it? yes. These projections are called papillae and they contain taste buds. The taste buds on the tip of the tongue are sensitive to sweetness, those on the sides to sourness, those on the back to bitterness, and some scattered over the whole tongue are sensitive to one of the four "tastes". In order to be tasted, a substance must be in liquid form.

Most of us imagine that we taste onions, for instance, but we really do not. We smell them. Try blindfolding a member of the class. Let him hold his nose. Place bits of apple on his tongue and ask him what it is. Of course he cannot masticate it or he will smell it through the back of his nose. Similarly try potato, and onion, cut in bits like those of the apple. Can he tell them apart by taste alone? no.

With a mirror look under your tongue for a flow of saliva into your mouth. Can you see it? yes. Whence does the saliva come? from the salivary glands. There are three salivary glands on each side. That under the ear is called the Parotid. When they become infected with a particular infection, you have the mumps. The other two pairs are called Sublingual and Submaxillary.

Test a dry cracker for grape sugar by boiling a little of it in Benedict's solution. Is there any sugar? no. Masticate part of the cracker and test. Is there any sugar? yes. What effect does the saliva seem to have upon starch? It changes it to sugar. As you already know, sugar is soluble and can be absorbed into the blood. What enzyme in the saliva hastens the digestion of starch? Ptyalin. What class of food should be

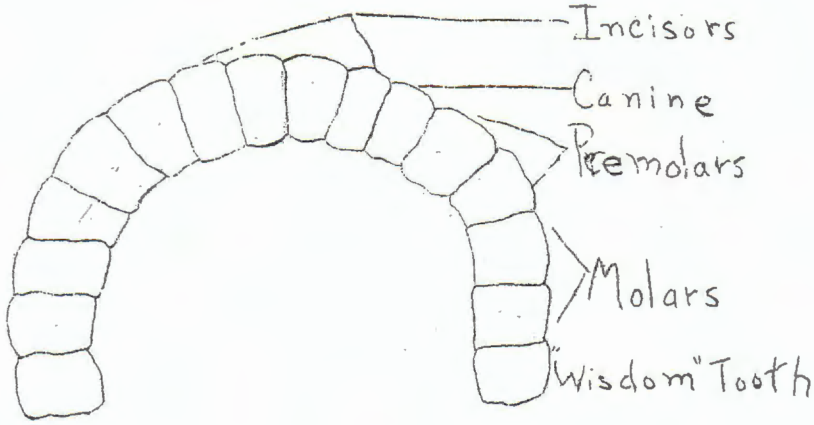
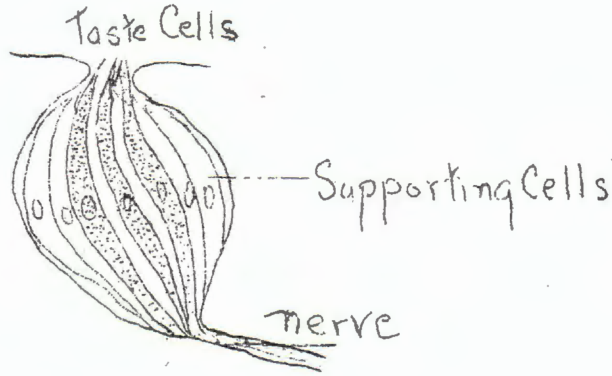


Diagram of Teeth of Adult



Taste Bud

most thoroughly mixed with saliva before swallowing? starch.

When the food has been masticated, it is swallowed through the gullet into the stomach. What keeps the food from going down the trachea? the epiglottis. Could you swallow food or water if you were standing on your head? yes. Why? because the rings in the esophagus push the food toward the stomach.

Look at the stomach of a human being in a plaster-of-paris torso or in a picture. What is its shape? squash. color? gray. Does its shape remain the same at all times? no. What large organ covers the stomach on the right? liver. What color is it? red. What sac is attached to it? gall bladder. What is its function? secrete bile. What disease often develops in this sac? gall stones. What is the only cure for this disease? have an operation.

The walls of the stomach are muscular so that they may contract repeatedly, thus kneading the food within. They also contain gastric glands which pour gastric juice into the stomach. Gastric juice contains hydrochloric acid, rennin, and pepsin. Rennin curdles milk, and pepsin, in the presence of hydrochloric acid, acts upon protein, changing it into soluble peptone.

Look at the torso again. Where does the food go when it leaves the stomach? small intestine. About what is the diameter of the small intestine? 1/4 to 1 inch. Here bile and pancreatic juice are poured over the food. Bile is made in the liver and stored in the gall bladder, whence it flows into the duodenum (first few inches of small intestine) through a tube or duct. The pancreatic juice is secreted in the pancreas and flows through a small duct which unites with the duct from the liver. Bile and pancreatic juice thus flow into the intestine through a common duct. Look for the pancreas back of the stomach. What color is it? white.

Bile is necessary in the digestion of fats. The pancreatic juice contains three enzymes, steapsin, trypsin, and amylopsin. Steapsin, in the presence of bile acts upon fats, changing them into a kind of soap which forms an emulsion which can be absorbed into the blood. Trypsin acts upon proteins, and amylopsin upon starches, making them soluble.

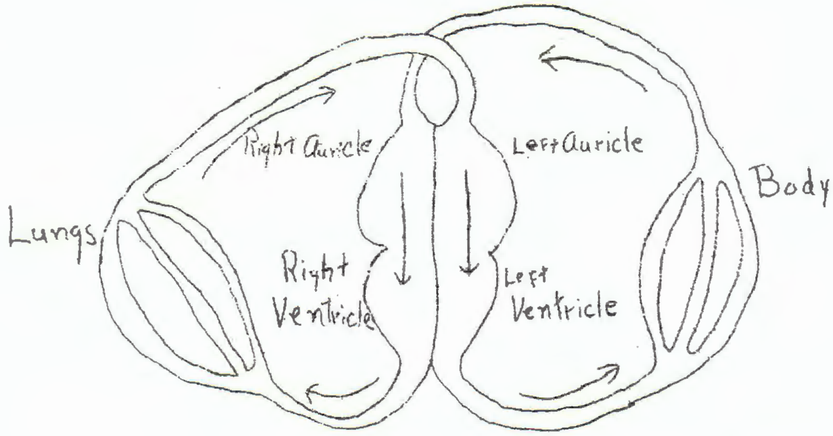
Look at a slide of the cross section of the intestine of any mammal. What is the lining like? rough. These projections make the lining of the human intestine seem like velvet. Each projection is called a villus and it is through the villi that your digested foods are absorbed into your blood stream. In each villus, the surface is permeated with small capillaries. The digested starch and protein, namely, sugar and peptone, pass into the capillaries by osmosis and are carried out of the villus through a vein. All of these veins carrying blood rich in absorbed sugar and peptone, unite into the portal vein, which flows into the liver. In the liver, much of the sugar is removed and stored as glycogen or animal starch. From the liver the blood goes to the right auricle of the heart.

The emulsified fats reach the blood by another pathway. In the center of each villus there is a lacteal which absorbs digested fats. These lacteals unite to form the thoracic duct, a tube which goes up the back and joins the vein just before it enters the right auricle of the heart.

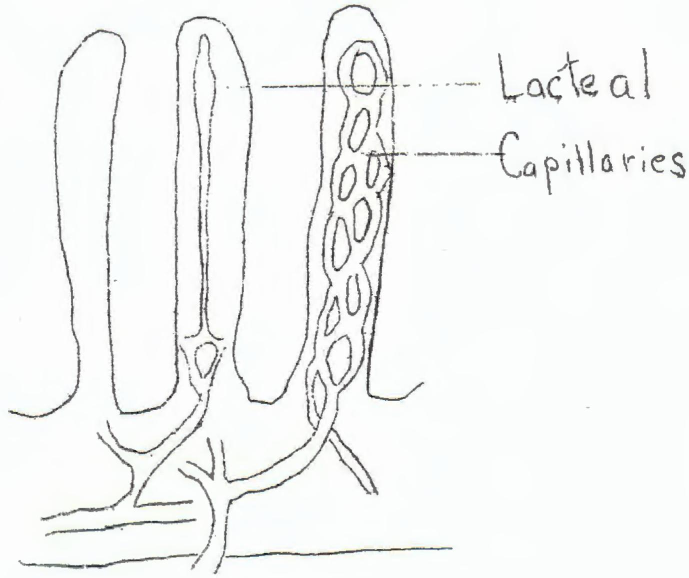
The lining of the intestine also contains glands which secrete the intestinal juice which finishes the digestion of any foods not already acted upon by the saliva gastric juice, bile, or pancreatic juice.

The folds in the lining of the intestine greatly increase the amount of absorbing surface.

In the food that you eat, there is a quantity of indigestible material. It is desirable that you eat a certain amount of roughage in order that the muscles in the intestine may have something to grip in their contractions, for it is the progressive contractions of the rings of muscles in the walls of the food tube which force the food along. We call this ryhthmic contraction of the muscles peristalsis. You may see it in the intestine of an anesthetized cat, if the abdomen is opened.



Diagrum of Bird or Mammal Circulation



Villi from Lining
of Intestine

The undigested foods pass on into the colon or large intestine. Look for it in the torso. About how large is it in diameter? 1 to 1½ in. The pouch of the large intestine found at the junction of the small and large bowel is called the caecum. What do you find projecting from the lower wall of the caecum in the torso? appendix. About how long is the appendix? 1 in. How large around? ½ inch. There is a very small opening from the caecum into the appendix in man. In rabbits the appendix is large and is used as a storage place for food. In man, however, the appendix has no known use, but is considered a remnant of a useful organ in our past ancestry. Such an organ is called rudimentary or vestigial.

To what common disease is the appendix liable? appendicites. Suppose a lump of fecal material with its bacteria were to become lodged within the small opening in the appendix and remain there. The bacteria will reproduce rapidly and since the opening is blocked, they cannot get out of the appendix. Consequently as the bacteria increase, white blood cells rush to the appendix to eat the germs. This forms pus rapidly, and the appendix swells and becomes inflamed. Thus is developed acute appendicitis. The rapid formation of pus within the small cavity of the appendix eventually causes it to burst (ruptured appendix) if the attack continues without surgical aid, although an acute attack will sometimes quiet down of itself, especially if an ice bag is kept on the side.

Outwardly, the symptoms of appendicitis vary. The most common symptom is pain in the abdomen. The pain may be anywhere in the beginning, but eventually the soreness localizes at McBurney's Point, which is located on the right side of the abdomen, halfway between the umbilicus and the top of the hip bone, and down one inch. There may also be vomiting and a slight temperature. Constipation is a very common forerunner of the disease.

When you develop a pain in the abdomen, never take a laxative, such as castor oil, for it is very apt to rupture the appendix if it is causing your trouble. The best procedure is to use an enema and keep ice on your side. If the pain persists, call a doctor. Deaths from acute appendicitis practically never happen if it is diagnosed early and removed before rupturing, while the death rate from acute appendicitis where the appendix ruptures is exceedingly high. In fact, it is higher here in the United States than in Europe because the population is more scattered and cases among rural people are not diagnosed early.

The waste materials from the food tube collect in the colon and are discharged through the rectum. Defecation (discharge of wastes from bowel) should occur at least once daily and it is wise to cultivate very regular habits in this respect.

Diagram the food tube of man. Label the mouth, gullet, stomach, small intestine, large intestine or colon, appendix, liver, gall bladder, and pancreas.

3. What are the organs of respiration and circulation and how do they function?

Laboratory Study XXXVI

In the human torso, what muscle separates the chest, or thorax, from the abdomen? diaphragm. Have you found such a division of chest from abdomen in any of the other animals which you have dissected? No. This diaphragm is very important in mammals because of its relation to breathing. When something, such as pressure from the stomach, irritates this muscle, it contracts spasmodical causing hiccoughs.

What organs are contained in the thorax or chest cavity? heart and lungs. Remove the heart from the model, and open it. How many cavities does it contain? 4. Look at the valves. What color are they? white. Can you imagine why they are present? to let the blood from the auricle the ventricle. Which cavity has the thickest wall? left ventricle Why? To give the blood a push so it can circulate

The blood comes back from the general body circulation through a vein to the right auricle, whence it is pumped into the right ventricle, thence through the pulmonary artery to the lungs. In the lungs it loses CO_2 and takes on O_2 and returns to the left auricle of the heart through the pulmonary vein. It is then pumped into the strong walled left ventricle, which pumps it out over the body through the aorta. Note the first branch from the aorta in the torso. Where does it go? to head. Can you see any advantage in this? to nourish the brain.

Sketch the human heart and label the right and left auricles, the right and left ventricles, the aorta, the superior vena cava, and the pulmonary ~~vein.~~ artery

A blood vessel which carries blood toward the heart is called a vein, while one which carries it away from the heart is called an artery. The blood is pumped through the arteries, which branch into smaller and smaller tubes until finally they become the very tiny capillaries, which gradually unite into larger and larger tubes which are the veins. It is possible to feel each heart beat in the larger arteries. When you feel your pulse, you are simply feeling an artery which is near the surface

When an artery of fair size is cut, the blood comes from it in spurts, while it flows evenly from a cut vein. In any case of severe bleeding, the best treatment is to press a clean cloth tightly over the wound and keep it there until a doctor can be reached. Doctors do not recommend the use of a tourniquet by inexperienced persons, because in most cases it does not apply pressure at the correct point. Pressure directly on the wound proves far more successful in stopping bleeding until medical help arrives.

The walls of the arteries are tough and firm enough to keep their shape even when empty. Consequently, after death, the arteries stand open, although they are empty, since the blood is contained chiefly in the veins of an organism that is dead As a result, men used to believe that the arteries carried air throughout the body, and they were entirely unaware of the fact that blood flows through the arteries during life. In fact, it was not known that the blood circulates at all until William Harvey, an Englishman, discovered and demonstrated the fact in 1616.

Besides the blood circulation through arteries, capillaries, and veins, there is also a separate lymph system through which lymph (blood serum) circulates outside of the blood vessels. The cells of the tissues do not fit together tightly like bricks in a wall, but loosely like potatoes in a basket. The serum from the blood moves out through the capillary walls into these spaces between the cells. Thus the cells are bathed constantly in lymph.

The food and oxygen from the blood stream pass out through the walls of the capillaries into the lymph which in turn carries them to the cells themselves. Likewise, the waste products from the cells are given off into the lymph and transferred by it back to the blood in the capillaries.

The lymph itself flows sluggishly into lymph ducts which join finally with the thoracic duct in the back and thus the lymph and emulsified fats are emptied into the blood stream together just before the blood enters the right auricle of the heart

The lymph system is also protective. At various points along its course are located lymph nodes through which the lymph passes on its way back to the heart. If you have ever had an infected tooth, you have probably felt the sore kernels in your neck. They were simply swollen lymph nodes which were straining some of the poisons and germs from your infected tooth out of your lymph before they reached your blood stream.

groin was a swollen lymph node. The tonsils function in a similar way in the throat. Since it is very dangerous for bacteria to enter the blood stream, the value of these lymph nodes cannot be overemphasized.

You have probably seen a case of infection in a cut, on the hand for instance, where a red streak started up the arm. That red streak marks the course of a lymph duct and the redness is due to inflamation in that duct. It is a danger signal because there is grave danger that the bacteria in the infection may escape the protective lymph and reach the blood stream, resulting in the condition popularly known as "blood poison" but spoken of medically as septicemia. In any such infection, it is urgent that you have a doctor's attention even before the red streak begins to show. An infection localized in the hand is easily treated and cured but an infection which reaches the blood stream is very apt to prove fatal. Consequently, you see the need for early treatment.

In fact, the right method is to avoid infection in cuts or wounds in the first place, if possible. Any break in the skin may become infected by bacteria. Consequently, any break in the skin should be thoroughly cleansed with soap and water and covered with a sterile dressing, if available. The application of iodine or mercurochrome is desirable if soap and water and sterile dressing are not at hand. The important thing is to keep germs out of any break in the skin, thus preventing the possible infection with its possible serious results.

Laboratory Study XXXVII

Examine the lungs in the torso. What color are they? ___red___. Through what passageways does the air come from the outside into the lungs? ___nose___, ___Trachea___, ___bronchi___. How is the trachea kept from collapsing? ___by muscular rings___. Where is the vocal box located? ___at top of Trachea___. The trachea branches into two bronchi in the chest and these subdivide into many bronchial tubes through which the air passes out into the small air sacs (alveoli) at their ends. These air sacs are surrounded by capillaries. The O_2 passes into the blood by osmosis and the CO_2 of the blood is given off into the air. The air is sucked into the lungs by the downward contraction of the diaphragm muscles and forced out again by the contraction of the muscles between the ribs.

Sketch the lungs from the torso. Label the trachea, vocal box, bronchi, bronchial tubes, and alveoli.

How many times do you breathe per minute? ___20___. Count your pulse rate. What is it? ___84___. What is the normal pulse rate of an adult? ___86___. Take your temperature with a clinical thermometer. What is it? ___98.6___.

per 100 cc. This condition is called diabetes and is a fairly common disease, which was very serious and ultimately fatal until 1921, when Doctors Banting and Best found a way to take insulin from the sheep's pancreas and administer it by hypodermic needle to the diabetic human being. As a result, nowadays, a diabetic can live fairly normally and comfortably if he will put himself under the care of a good physician.

Normal blood also contains at least three elements which are related to causing the clot to form, namely, blood platelets, calcium, and fibrinogen. Normally, it requires from two to seven minutes for blood to clot. Occasionally, a boy is born whose blood requires from five to fifteen times as long to form a clot. He is called a bleeder or hemophiliac. He bleeds profusely from the slightest bruise or cut, so that any cut of any size may prove to be fatal. The disease is inherited through the mother but only shows up in males in the family. The royal families in Europe have been cursed with this disease and the son of the last Tsar of Russia was afflicted with it. There is no known cure so it is highly undesirable that persons who come of families which contain bleeders should have children.

Thus you see that the blood is the system of transportation and distribution of the body just as the sap in the fibrovascular tissue is in plants. It carries O_2 and CO_2 between the cells and the lungs, digested food from the intestines to the cells, waste materials from the cells to the kidneys and skin, white blood cells to any points of infection, and water to all of the cells. It also carries the product of the ductless glands, such as adrenalin and insulin, over the body. Someone has said that when we come to know all that there is to be known about the human blood and its chemistry, we shall be close to the secret of life itself. Whether this be true or not, the fact remains that it is one of the most remarkable tissues in existence.

4. How are nitrogenous wastes eliminated?

Laboratory Study XXXVIII

Look for the kidneys in the model torso. Where are they located? in small of back. Trace the tube from the kidney to the bladder. It is called the ureter. Can you see the adrenal glands? yes. Where are they located? on the kidneys. Sketch the kidneys, ureters, bladder, and adrenal glands.

You already know that the function of the kidney is excretion. Wastes from the food tube are eliminated from the bowel and the CO_2 waste is eliminated from the lungs, but the waste products from the destruction of protein materials are eliminated through the sweat glands in the skin and through the kidneys. In other words, the nitrogenous waste materials, such as urea and the ammonia compounds, are removed from the blood stream in the kidneys and sweat glands. In the disease known as nephritis, the kidneys cease functioning properly in the removal of these wastes and a very serious condition results. Normally, the kidneys excrete about a quart of urine daily, although the amount varies considerably in proportion to the amount of liquid taken in by mouth

Fill the following table:

	Organs in Man
Food getting	mouth hands
Digestion	mouth stomach & intestine
Absorption	villi of intestine
Circulation	heart vein arteries blood
Respiration	~~trachea~~ nose lungs
Excretion	kidney lungs intestine

Review of Unit VIII - H.

1. To what phylum and class does man belong? vertebrate and mammal. Name several other animals which belong in the same class. Cat, tiger, dog, wolf, fox, sheep, horse, cow, skunk, ape.

What common characteristics do the animals of this class possess? have backbone, bear young alive, feed the young by means of mammary glands, have hair on some part of the body.

2. Why does man need food?

   a. To produce heat and energy.

   b. Build up Tissue.

3. What do we call the unit of heat? calorie. How much heat is this? Enough heat to raise one litter of water from 0 centigrade to 1 degree centigrade.

How many of these heat units should your food supply contain daily? 2500

4. What classes of food supply most of your heat and energy? fats and carbohydrates

5. What elements compose starch, sugar, and fat? Carbon, oxygen and hydrogen. What elements compose protein? carbon, hydrogen, oxygen, nitrogen, and sulphur and sometimes phosphorus

6. Why is protein necessary for building and repairing tissue? Because it contains all the elements necessary for protoplasm.

7. What parts of the body depend upon the mineral calcium phosphate? Teeth bones. What vitamin must be present in the body before calcium phosphate can be deposited? D. Name two ways of supplying this vitamin: codliver oil and sunshine.

8. Fill the following table.

-5 Betty Hofmann

Name of Vitamin	Prevents	Found in
Vitamin A	[illegible] children [illegible]	Dairy products
Vitamin B-1	Beri beri	grain husks
Vitamin B-2	Pellagra	grain husks
Vitamin C	Scurvy	fruit juices
Vitamin D	rickets	Sunshine, Codliver oil
Vitamin E	Sterility	vegetable oil and animal fats.

9. Name the kinds of teeth and give the number of each in an adult.

incisors 8
canine ~~8~~ 4
premolars ~~16~~ 8
molars 12

10. How many separate senses are involved in taste? ~~2~~ 3. Name them.
Smelling, Tasting, feeling.

11. Where does the saliva come from? salivary glands. What effect does it have upon starch? changes it to sugar. What is the enzyme in saliva? Ptyalin.

12. What disease may one develop in the Parotid salivary gland? mumps

13. Could you swallow if you were standing on your head? yes. Why? Because the [illegible] of the esophagus force the food down. [illegible],

14. What is the digestive juice which is found in the stomach? gastric
What ~~three~~ two enzymes does it contain? (a) renin,
(b) pepsin, and ~~(c)~~ ______. What is the function of each?

(a) to change milk to a ~~[illegible]~~ form
(b) to change protein to peptones.
~~(c)~~ ______

15. What three digestive juices are found in the small intestine? (a) bile
(b) intestinal, (c) pancreatic. Where is each

-4

produced? (a) liver, (b) small intestine, and (c) pancreas. What is the function of each?

(a) purifies vegetable proteins

(b) acts upon all sugars

(c) juice to protein digest

16. What makes the food move along through the digestive canal? peristalsis

17. Where do gall stones form? in Gall Bladder What is the only cure for them? an operation.

18. What is the lining of the intestine like? it is raised

19. How do sugar and peptone reach the blood stream? through the portal vein thoracic duct in the neck

How do emulsified fats reach the blood stream? through the lacteal vessel in the thoracic duct in the neck.

20. What is the value in eating a certain amount of indigestible material? to remove the waste from the grooves of the intestine

21. Name the parts in the food tube of man. mouth, gullet, liver, gall bladder, small intestine, pancreas, large intestine, appendix, and spleen.

22. What is the most common symptom of appendicitis? pain at McBurney's point What other symptoms may there be? vomiting, constipation, fever, high white blood count

23. What must be avoided in attacks of appendicitis? laxatives. What should be done? call a doctor, ice applications, and don't take anything.

24. Why is the death rate from appendicitis higher in the United States than in Europe? Because in the United States so many people live in the country districts

25. What organs are contained in the thorax? heart and lungs.

Betty Hoffman

36. In what medium do the red and white blood cells float? serum. What materials are found dissolved in this medium? salt, sugar and insulin.

37. What happens to the sugar content of the blood in diabetes? [illegible]
What causes this? There is not any insulin in the [illegible]
What treatment is given for diabetes today? given insulin.
Who discovered it? Best and Banting.

39. To what tissue in plants might we compare our blood and blood vessels?
[illegible]

40. How would you recognize a cut artery? the blood spurts.
How would you treat any wound which was bleeding seriously? Tie a [illegible] over the wound, or a tourniquet.

41. By what means are nitrogenous wastes eliminated from the body? kidneys and bladder. skin

42. Where is lymph found? outside the vein. capillaries and arteries Of what does it consist? serum. What does it carry to the cells? oxygen and food. away from the cells? carbon dioxide.

43. What function do the lymph nodes perform in connection with infections?
They filter the poison [illegible]

44. Where are some lymph nodes located? Neck, groin under the arm.

45. How does the blood get from the arteries into the veins? capillaries
Who discovered the circulation of the blood? Harvey.
When? 1616.

UNIT IX
Irritability & Behavior

You are now ready for one of the most interesting studies in the whole field of biology. In the beginning you learned that the fundamental properties of protoplasm are metabolism, reproduction, motion, and irritability. By irritability of protoplasm, we mean its power to respond to its surroundings. All organisms have this power. As you know, even an Ameba will move toward food and away from extreme heat. It is this elemental power of all protoplasm to react to the influence of external things which lays the foundation of all behavior, all feeling, yes, and even of all thought.

Wells, Huxley, and Wells, in their "Science of Life" have named three phases of behavior. They are: receptivity, or the ability to be affected by an outside influence; activity, or the ability to act in response to the outside influence; and correlation, or the ability to suit the acts to the circumstances and to coördinate the acts of the organism as a whole.

In order to understand what they mean by receptivity, observe the following experiment.

Laboratory Study XXXVIII

To be demonstrated by the instructor.

Pith a frog's brain and remove the muscle from the calf of the leg with its nerve still attached to it. Note that this muscle is a bit of living protoplasm and can be kept alive for hours in a warm salt solution.

If we pinch the muscle, it quivers and shortens in response to the stimulation. Pinch the nerve. The nerve itself shows no outward response, but the muscle to which it is attached quivers and shortens just as it did to direct stimulation. So, you see, the nerve is also irritable but its function is to conduct rather than to contract, so pinching the nerve simply sends impulses along it to the muscle stimulating activity there.

The impulses which travel along a nerve probably resemble an electric current. At any rate, if an instrument for detecting an electric current is attached to the nerve, it will register when the nerve is pinched.

You have just witnessed a very simple demonstration of irritability. It is this very fundamental property of protoplasm which enables living things to develop specialized nervous tissue and sense organs. But in the simple one-celled animals such as the Ameba, irritability is a generalized function of the whole cell. This has been proved by focusing a beam of light on one end of the Ameba. This spot contracts and moves away into the other end of the cell thus removing the animal from the light. No matter where the light is focused on the animal, the response is the same. All of the protoplasm of the Ameba is sensitive to light. From this beginning it is possible to trace the development of eyes, as follows.

Another Protozoan, called Stentor, is sensitive to light at one end only. One of the kinds of Paramecia eats green Algae which live within it. This Paramecium swims to the light, and the green Algae within carry on photosynthesis, thus feeding both of them.

Still other Protozoa have little "eye-spots", usually red, in one end of the cell. These eye-spots are light-sensitive, although none of them have sight in the sense of seeing an object.

As you know, earthworms have no eyes at all and yet they are sensitive to light as you may learn if you flash a light upon one at night. He will crawl away from your light quickly enough. This is because he has peculiar light-sensitive cells scattered among the epidermal cells of his skin. He cannot see objects, but he "feels" light upon his skin by means of these specialized cells.

There are other worms which have small specks of color on the head. These

ght-sensitive cells into one spot. From the
ls they send nerves to the brain. These
y have the beginnings of an eye. (See page
nce of Life" for pictures and a full account.)

ls, these light-sensitive cells are not only
incurved layer with a bulge on top of it,
apparatus or lens.

evolved both the compound eyes of the Arthro-
ch each light-sensitive cell developed its
eyes of the Vertebrates.

ghly specialized structures in the body.
th the parts of it, but it is worthy of
learned. The retina is a collection of
ough the optic nerve to the brain. The lens

Study XXXVIII

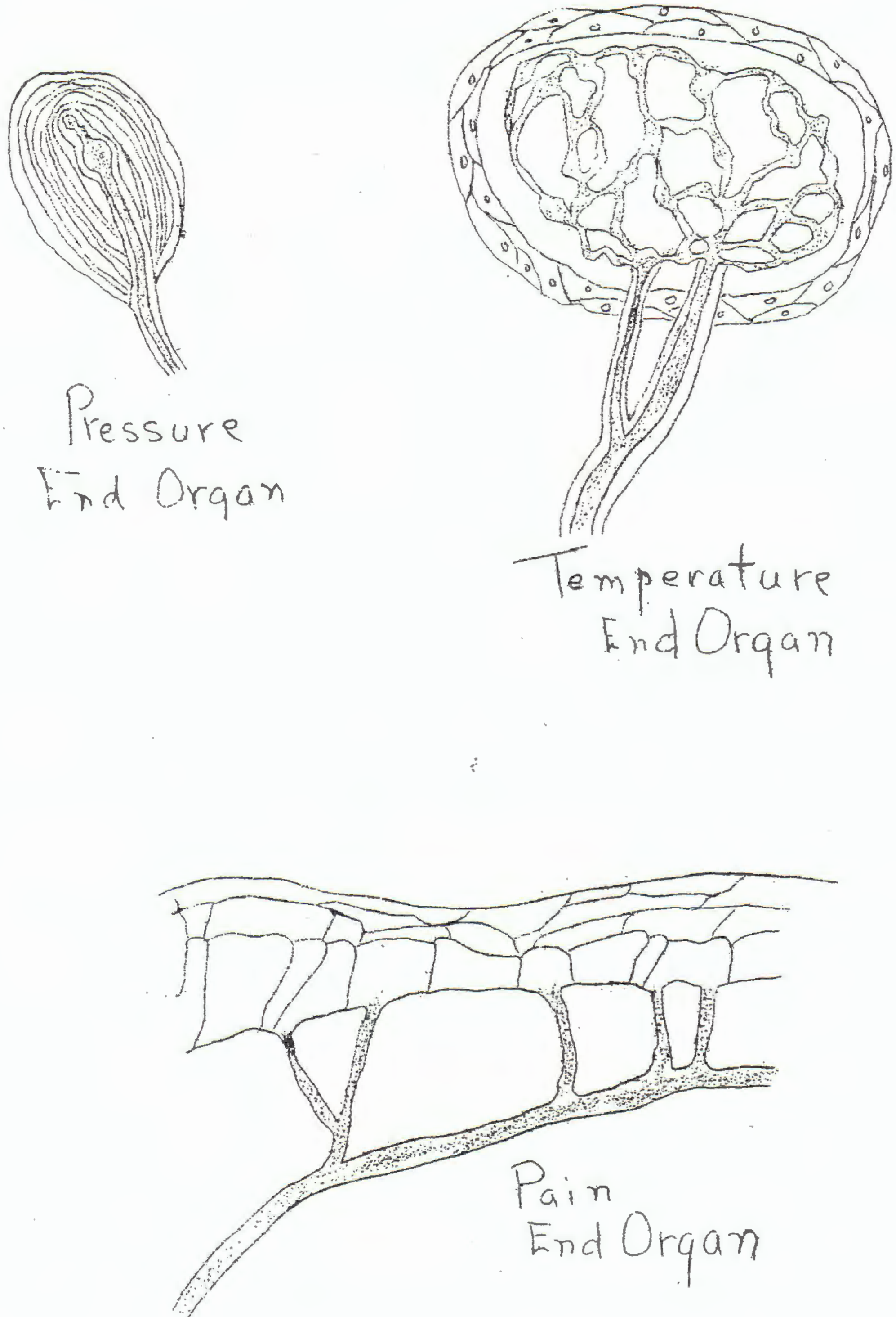
Can you find the lens? ______. What is the

______________________. What color is the

function? ______________________________

f all of the senses. The four types of
adually from generalized irritability or
lled the chemical senses. You may speak
t. The skin contains four kinds of end
kinds are sensitive only to pressure, one
ching various points on the palm of your
at you feel the warmth only at certain
with a cold pin and moreover the points
cold will not coincide. You can locate
in which do not coincide either with the
other. End organs sensitive to pressure
... are also scattered through the muscles of the general body.

The development of the sense of hearing is a more complicated story. The stimulus in hearing is a series of sound waves and there is no evidence that the simple protoplasm of an Ameba is sensitive to sound waves. As a matter of fact, the



Nerve Endings in Skin
Called End Organs

stimulus which excites the auditory cells is not a sound stimulus at all, but a touch stimulus instead. The ear is a structure with the power to convert sound waves into touch stimuli so that any sense of hearing must be lacking in the Protozoa, jellyfish, starfish, and worms, since they have no ears.

The human ear consists of three main parts, the outer ear, middle ear, and inner ear. The inner ear contains the sensitive cells, and the outer and middle ears merely catch and transmit the vibrations to the inner ear which lies embedded in the bone of the skull for protection. The outer ear is a sort of ear trumpet which catches and directs the sound waves. The ear drum separates the outer and middle ears. The middle ear is filled with air and connected to the throat by the eustachian tubes, whose function it is to keep the air pressure equal on both sides of the drum. The drum is a membrane stretched across the canal of the ear. At the inner end of the middle ear there are two more membranes, called the fenestra ovalis and the fenestra rotunda, which separate the middle and inner ears. Three bones, called the hammer, anvil, and stirrup, run from the drum to the fenestra ovalis.

The inner ear consists of two parts, the cochlea and the semicircular canals. Only the cochlea is concerned with hearing. It is embedded in bone and its spiral passageway is filled with fluid. A partition runs the full length of the passageway and on this partition are the sensitive cells. The sensitive cells are long cells with stiff hairs on top of them and nerve fibres joined to them. Above the stiff hairs is a rigid shelf, while the sensitive cells themselves are located in an elastic membrane surrounded by the fluid.

When sound vibrations enter the ear canal, they cause the drum to vibrate in tune with their own rate. The drum starts the hammer; it transmits it to the anvil and thence to the stirrup. This last bone is pressed against the membrane of the fenestra ovalis, which receives the sound vibrations from the stirrup and transmits them to the liquid which fills the cochlea. Thus the sound vibrations reach the elastic membrane to which the sensitive cells are attached, causing it to bob up and down, thus bumping the stiff hairs on top of them against the rigid shelf above them. It is the touching of these hairs against the shelf that causes us to hear. It is believed that certain cells are stimulated by certain vibration rates something the way the string of middle C on a piano vibrates in response to the sounding of middle C on a violin in the same room. There are supposedly individual sensory cells which respond to vibration rates ranging from 16 to 30,000 per second. The auditory nerve carries the message to the brain, and thus we hear.

In the other part of the inner ear, known as the semicircular canals, there is also a liquid, and there are sensitive cells connected by nerves to the brain. It is here that your sense of balance is located.

You have now traced the evolution of all sensation from the generalized function of irritability of protoplasm as expressed in receptivity. The nerves which carry messages of sensation into the spinal cord and brain are called sensory nerves.

The second phase of behavior is called response. Responses are largely motions, and motions are brought about by muscles. Muscles are simply composed of cells which have specialized in the function of contracting, which has evolved from the generalized ability of all protoplasm to change its shape. You have seen how an Ameba is able to move about by the slow flowing of its protoplasm into pseudopodia. There is also a flowing of protoplasm within living plant cells. From this simple beginning all power of movement has evolved. The Paramecium shows a second step, for its cilia have specialized in the function of motion. The evolution of muscles can be traced through a series of animals to our own complex and highly specialized ones.

Responses, however, are not always motions. The smell of food awakens a flow of saliva. This is a response by glandular activity. Other responses are the color changes of a chameleon, or the electric shock productions of the electric eel.

At any rate, sensations awaken responses, such as jerking one's hand away from a hot stove. The sensory nerve carries its message into the central nervous system (brain and spinal cord) and the motor nerve carries the message back to the muscles which jerk the hand away.

By correlation, we refer to the ability of the organism to coördinate receptivity and response. It is accomplished through the central nervous system. The nerves are like telephone wires and the brain and spinal cord are like a telephone exchange.

As you know an Ameba has no central nervous system. You may wonder whether it is able to suit the response to the stimulus and if so, how. Evidently, it can suit its reaction to the stimulus since it moves away from harmful influences and toward food. As you know, the whole surface of the Ameba is sensitive and contractile. Likewise all of its protoplasm can conduct impulses at a very slow rate. Thus it is able to coördinate the stimulus and response very slowly and imperfectly. Just as all protoplasm is irritable and contractile, so it is able to conduct impulses. Just as higher animals have developed special sense cells for reception and special muscle cells for motion, so there have developed special nerve cells for conducting messages. These special nerves are called neurones in man. A nerve is simply a bundle of elongated cells which carry messages from one part of the body to another.

In the higher animals, nerve cells have become highly specialized, while in the Ameba there is no specialization at all. To trace the evolution of the complex nervous system of man from such a simple beginning through all the phyla is possible, but would require a book of its own. We shall here present merely a few of the progressive stages in this evolution as illustrated by Protozoa, starfish, earthworm, crayfish, fish, frog, and bird.

Although the Ameba has no specialization whatever of the conducting function, there are other Protozoa which do have fibrils which branch out from a sensitive area like the points of a star. These fibrils conduct messages to other parts of the cell, thus acting like nerves.

The first true nerve tissue appears in the phylum Coelenterates, of which the jellyfish is a good example. A jellyfish is like a transparent inverted cup with a fringe of tentacles ("arms") around the edge of the cup. The nerve tissue does not have definite pathways as it does in the higher animals but consists of a network of conducting cells scattered over the whole body. There is one definite ring of nerve fibres around the edge of the cup. Here you see there are true nerves but they are not organized since they conduct equally well in all directions. There is no centralized portion like our brain to control the whole organism. You might compare it to a telephone system with no central operator.

Much the same condition exists in the Echinoderms of which the starfish is the most familiar example. A nerve runs the full length of each of the five rays (arms) and joins the main center which is a ring of nerve tissue running around the mouth in the middle of the animal. These nerves are comparable to our spinal cord in that they govern the particular ray in which they are located. But the coördination between the rays is very poor, being brought about by the ring of nerves around the mouth. This is still a highly decentralized nervous system, but there is a beginning of central control.

The earthworm is a good example of an animal with the brain in its initial stage of development. Refer again to your drawing of its nervous system. You will recall the ventral cord, the collar, the "brain" and the nerves branching out into the prostonium and into each segment. Besides there is a collection of nerve cells called a ganglion, on the ventral nerve cord in each segment. The "brain" in the head is a larger ganglion. These ganglia are centers of control with the one in the head dominating all the others.

That these ganglia are really embryonic brains with learning power, as well as centers of control, has been proved by experiments performed by Yerkes, and later by Heck. A passageway in the shape of a T is bored into a block of wood and the worms are made to crawl through this passageway. When they come to the cross on the T, they must turn either to the right or left. If they turn to the right, they will receive a slightly unpleasant electric shock which they will avoid if they turn to the left. In the beginning these men found that all the worms turned to the right just as frequently as to the left but after about one hundred trials, they turned to the left much more often than to the right and after one hundred and fifty trials, they turned to the left ten times as often as to the right. Then the experimenters changed the apparatus so that the electric shock was received on the left branch rather than the right. Gradually the worms unlearned what they had learned and eventually they were turning to the right to avoid the shock.

Then they removed the "brain" from the head and they found that the worms were still able to learn to avoid the shock. They were forced to conclude that all the scattered ganglia along the ventral nerve cord were also endowed with learning power.

The Arthropods, of which you have studied the bee and crayfish, have a nervous system very similar to that of the earthworm. In some of the insects, however, there is still another advance. In the fly, for instance, several of the scattered ganglia have been collected into one central mass in the abdomen and this "brain" rivals that in the head for the dominant control. X

With this type of nervous equipment, so simple in comparison with that of the higher animals, insects have evolved very elaborate systems of behavior. They have developed highly organized communities, such as bee hives and ant hills, within which the details of life at first study would seem to indicate a high grade of intelligence. However such is not the case, for they have small brains with only a comparatively small number of brain cells, thus making it impossible to develop the infinite number of alternative brain pathways which are necessary to intelligence. Rather is the complexity of insect behavior due to instincts, by which we mean those elements of behavior which are inborn. A bee builds the cells of the honey comb by instinct, being able to build just as perfect cells the first time as after much practice. Such inborn behavior is called congenital. Animals in general are born with a certain inherited endowment of congenital behavior; most animals also learn as they live. But in the insect world, the inherited instincts control their lives almost entirely. In fact, they cling so closely to their instincts that the frequently come to harm as a result. For instance, a moth will fly into a light to which instinct attracts it, and even after being burned enough to fall to the ground it will rise and fly straight into the light again, only to be burned to death. This lack of ability to learn from experience is characteristic of insects, being due to the absence of enough brain cells to function intelligently.

Another example of the blind functioning of instinct is found in the case of one of the solitary bees. The mother builds a mud cell, then half fills it with honey and pollen. After laying an egg in it, she proceeds to fill the cell to the top with honey and pollen and seals the cell. One might suppose that she was very intelligent thus to provide food for her offspring. But note the fact that an observer made a hole in the bottom of a half filled cell through which all of the honey ran out. When the mother bee returned, she deposited her honey in the empty cell, laid her egg, and then proceeded to put more honey and pollen into the cell until she had brought the regulated number of loads, then sealed the empty cell, just as though it were full of food, for her baby. This is not intelligence, but only a clock-like working of instinct.

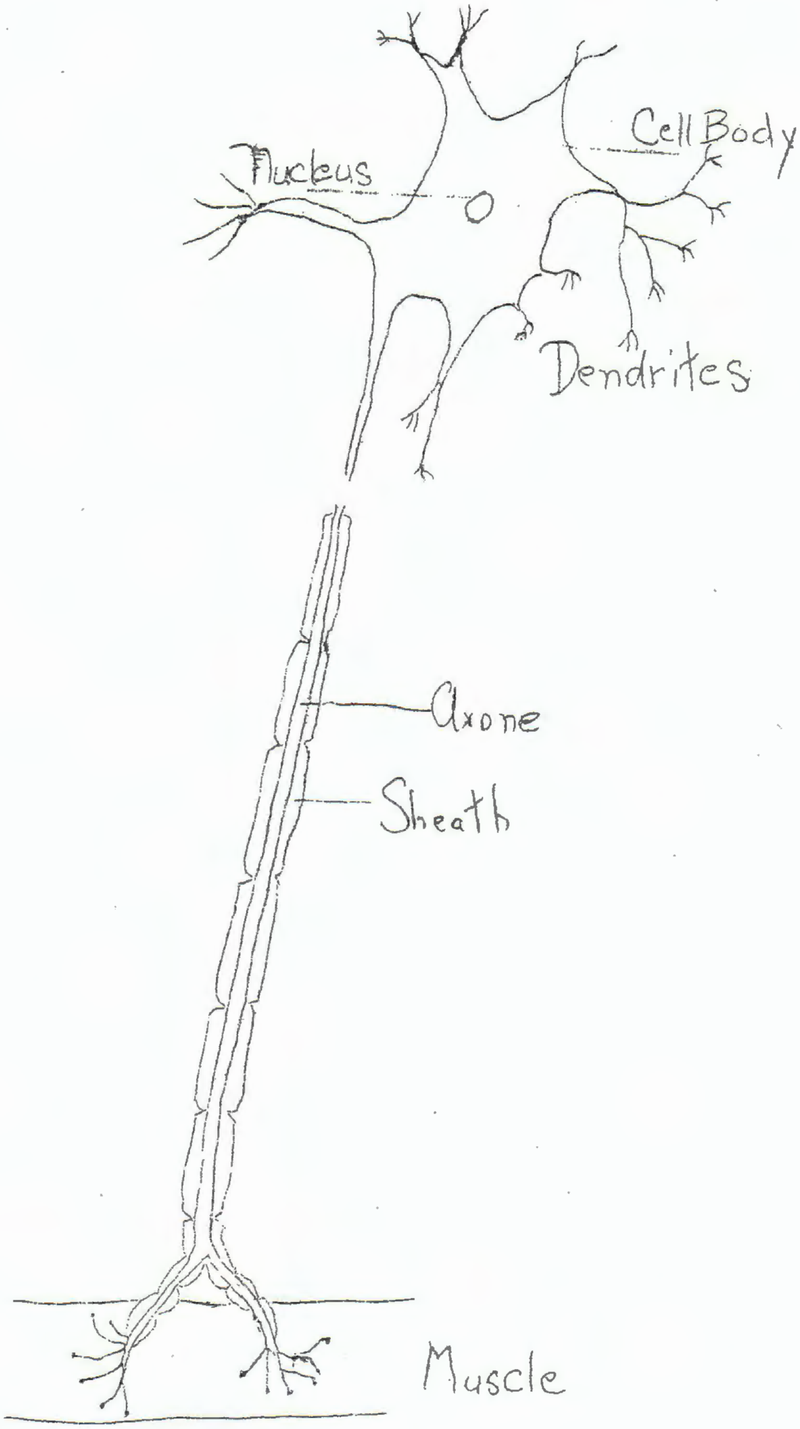
In contrast with the Arthropods, which have evolved to the place they occupy largely by specializing the instinctive functions, the Vertebrates hold their position through their specialization of the learning function. We may trace this evolution very briefly by comparing the brains of the fish, frog, bird, cat, and man. You have already made drawings of the brains of the fish, frog, and bird. Add to your page of drawings a cat's brain.

It is evident from these drawings that the central nervous systems of all of the Vertebrates are built upon the same plan. All of them have the olfactory lobes, cerebrum, optic lobes, cerebellum, and spinal cord. A careful comparison reveals the progressive enlargement of the cerebrum as we pass from the fish to the mammal, until in man the cerebrum constitutes at least four fifths of the total brain.

The brain and spinal cord of the Vertebrates are the centers of control or correlation. They contain enormous numbers of nerve cells called neurones. Nerves branch out from the brain and spinal cord to the sense organs and muscles. In man there are twelve pairs of cranial nerves and thirty-one pairs of spinal nerves.

Here we have a nervous system comparable to a telephone system with a central exchange. The central exchange has specialized parts for control. For instance: the olfactory nerves join the nostrils to the olfactory lobes which receive the messages concerned with smell. The optic lobes receive and transmit messages from the eyes; the cerebellum is the center of balance and of coördination of the voluntary muscles; the medulla is the center of control of the vital organs, such as heart and lungs; and the spinal cord is the center of reflex action, such as jerking the hand away from a hot stove. The cerebrum is over the whole system. Here all messages which reach our consciousness are reported and coördinated, thence all voluntary commands are sent out. The cerebrum is the center of consciousness, intelligence and thought. Its increase in size is accompanied by an increase in learning power and intelligent behavior until we find it is at its climax in man.

The cerebrum of man consists of two portions, a gray layer over the surface called the cortex and a white portion in the center. As you have already learned, the whole nervous system is made up of nerve cells, called neurons in man. In the cerebrum the gray matter is a collection of cell bodies and the white portion consists of the branches from the cell bodies. In the spinal cord we find the gray matter on the inside and the white matter on the outside. The folds, or convolutions on the cerebrum of man greatly increase the amount of gray matter. When a message travels along a nerve, it really travels along the axone of a neuron. Note that the end brush of an axone of one neuron does not quite touch that of a dendrite of another neuron. This junction is called a synapse. Consequently, it is necessary for a message, as it comes to the end brush, to jump across the synapse somewhat as a spark of electricity jumps across a short gap in an electric circuit. As a message travels along an axone into the cell body it may spread through several of the dendrites and thus pass to several other neurons, resulting in a scattered response to the stimulus. An example of such a response may be witnessed when a brightly colored rattle is dangled above a baby's eyes for the first time. The baby kicks and throws his hands and laughs. As he throws his hands about, he may strike the rattle and this gives him pleasure. After some practice, he learns to reach directly for the rattle and the other responses, such as kicking his feet, disappear. Then we know that the impulse has established a pathway from the eye to the arm. When the impulse travels in along the axone, instead of spreading through all of the dendrites



Neurone

from the cell body, it travels only through the one which leads to the arm and stimulates the muscles which reach for the rattle.

Now babies are born with a few pathways already established, such as sucking and crying. These pathways are called reflexes. But most of our pathways are developed during our lifetime. When the opening of a new pathway is accompanied by a sense of pleasure, that pathway will tend to open more easily at the repetition of the same stimulus. When a pathway has been opened several times, the same stimulus will tend to follow that pathway every time. When a pathway that required attention at first in order to be opened reaches the point where the stimulus follows that pathway automatically, we say that we have acquired a habit. For instance, you may recall your own efforts to learn to write. You had to think just how to write an "a" and direct your muscles to that end. But after a while you were able to write an "a" without giving any attention to the way the letter was to be formed. Then you had acquired a writing habit, simply by reopening a certain pathway until it became automatic.

At birth, all of the neurones of the brain and whole nervous system that the individual will ever possess are already present. Nothing you can do will increase the number of cells in your brain. However, the development of pathways between neurones comes about almost entirely within your lifetime. Learning is just such a process. The more neurones an organism possesses, the more alternative pathways can it develop. Thus you see why the increased number of cell bodies in the gray matter of the brain, due to the convolutions, increases the learning power of the organism so tremendously that man stands far above any other animal in learning power and intelligence.

UNIT X
The Theory of Development

A. The Fact

You have undoubtedly yielded at times to the common human tendency to wonder how the earth began, if it ever had a beginning; how life first arose; and how all of the myriads of kinds of living things came into existence. Men have wondered about these things throughout the ages and have arrived finally at a conclusion, which is convincing, because it is based upon scientific evidence. This theory of the origins and development of living things is to be presented in this unit, together with the evidence upon which it is based.

There are only two possible views of the universe. Either it is static or unchangeable, or it is dynamic or constantly changeable. Within the past century and a half, the use of the scientific method of observation, experimentation, hypothesis formation, and further experimentation has produced ample evidence that the second view is the correct one. The universe is dynamic. Its natural condition is change, not rest. Someone has said that change is the only constant thing in the universe. Scientists have coined a word to express this view of the universe as forever changing, and never at rest, and that word is evolution. The word itself merely means change. Do not let the popular opinion that the word evolution means something sinister keep you from reading this unit intelligently, for the popular opinion of the meaning of evolution is far from the true meaning of it.

Evolution means change. In the past the changes have usually been from simple to complex, from simplicity to great variety. Evolution may thus be seen to apply to everything. Changes in rock formation are going on constantly through the action of water, volcanoes, and earthquakes, so we speak of evolution of rocks or geological evolution. Chemical elements and compounds change continually thus constituting a chemical evolution. The shifting of river beds, shore lines, and mountainous areas gives you evidence of physiographical evolution. Living things change before your very eyes, as when a tadpole becomes a frog. The evolution of life is called organic evolution.

Naturally it is organic evolution which interests biologists. As applied to living things, the theory of evolution means that organisms are constantly changing and have always been changing. Just as there are progressive changes in any individual plant or animal from the moment of fertilization until death, so there have been progressive changes in races of plants and animals in past ages. No one knows just how life began, but without a doubt it originated in one-celled forms of life or perhaps even simpler forms. Evolution means that all life has developed from a common origin, that all living things are related, that there is a unity in all the variety of species.

By species, we mean kinds of individual organisms which agree closely in structure, function, embryological development, and are able to interbreed. Cats are a species and dogs are another, according to this definition. When Linnaeus, in 1758, published a classification of all the organisms then known, he described only about 4,000 species. Today we know of 700,000 species of living animals, and 300,000 species of living plants, besides 1,000,000 species of extinct forms which have lived in the past. Thus you see, there are approximately 2,000,000 species known to be or to have been alive. And new species are being discovered constantly.

Yet underneath this tremendous variety in life, we find a fundamental unity. All of the organisms on earth consist of protoplasm, and are composed of cells. All organisms carry on the same universal functions: metabolism, motion, reproduction, and irritability, and all organisms have the same energy source, oxidation. It is this fundamental unity in all of the species of life which lays the foundation for the theory of development known as evolution.

There are many lines of evidence to support this theory. The first line of evidence that began to force itself upon the attention of students is that of the rocks and this was noticed only a little over one hundred years ago. You have probably seen coal which shows the imprint of fern fronds, or you may have found a piece of rock showing fossils of shells. Fossils are simply the remains of plants or animals which have been turned into stone or the imprints of such organisms in stone. Even throughout the eighteenth century, the few known fossils were considered mere freaks of nature or perhaps the remains of organisms killed in the great flood. Toward the end of the eighteenth century a new interpretation began to dawn upon the minds of a few observers.

Everyone knows how rivers deposit sediment along their courses and particularly where they empty into the sea. The example of the Mississippi Delta, which has been built out sixty miles into the gulf, will suffice as an illustration of what is going on universally. Waves and currents in streams, rivers, lakes, and oceans are constantly depositing materials in layers which are gradually compressed into strata of rock. Such rocks are called sedimentary and are distinguished from igneus or volcanic rock by the fact that they always are found in layers or strata while igneus rock is not.

It is inevitable that plants and animals as they die, will fall to the bottom of the body of water where they lived and will be deposited with the other sediment. Thus their bodies will become embedded in the slow-forming rock and some of them will be preserved as fossils. Now as this idea came to human consciousness, men began also to realize that the rate of formation of sedimentary rocks could be estimated, and from it, the age of the earth could be roughly measured. The rate of emanation from radium is another key to the age of the earth. The combined evidence indicates that our earth is a billion years old, more or less. This is a tremendous lengthening of past time, for mankind has believed in the past that the earth was of comparatively recent and sudden origin, while the study of geology (study of the rocks) proves that the earth is old beyond our comprehension and that it has developed to its present state through a long gradual process of evolution.

If you consider that sedimentary rocks have been forming ever since water condensed upon the earth and that these rocks are formed in layers, you will be convinced that the deepest layers of rock are the oldest and the top layers must be the youngest. Consequently, the fossils found in the deepest layers must represent living things from the time when those rocks were being formed. As we come upward through the rock layers, the fossils must represent more and more recent forms of life until the top layer shows the forms now living.

You will understand that the study of life in the past through the study of fossils is not quite so simple as tracing the forms from the lowest layer of rocks to the highest, because the rock layers have been disturbed many times by upheavals, volcanic activity, changes in pressure, erosion, and other earth forces. But there are places where the rock layers are undisturbed for many feet upward and here we read the history of life as written on the rocks.

One of the first men to begin to study the rocks as a record of the past was a surveyor in England, named William Smith. As he went about over the country, he noticed layers of characteristic rock, such as a layer of chalk, colite limestone, red sandstone, or gault clay. Furthermore, he noticed that these layers were always arranged in the same order, with the red sandstone lowest and the colite limestone above it, followed as he looked upward by the green sand layer, the gault clay layer, and the chalk layer above them all. Still further, Smith noticed that the same kinds of fossils occured in the same layer of stone, no matter in which part of England he found that layer outcropping, while the fossils in one layer differed from those in another. In the layer of gault clay, for instance, he never found fossilized fruits of seed plants, but he did find the ammonites, beautifully coiled spiral shells of animals long since extinct. In a higher layer, he found fossil fruits of seed plants, sea snails, and a few mammals, but never any ammonites.

Further observations of this type produced the fact that the oldest and deepest rocks known contain no recognizable fossils at all or mere suggestions of them, while the rocks next above contain fossils of many simple forms of life, including algae, mosses, and ferns, but no seed plants. The rocks of this so-called Cambrian period also contain fossils of all kinds of simple animals such as protozoa, sponges, coral, and mollusks and even animals as complex as worms, but absolutely no vertebrates. As the rock layers are studied progressively upward from the Cambrian, they contain more and more complex forms of life. The first vertebrates to be found are fossilized fishes; above the fishes are found amphibians; still above the fishes and amphibians we find in the rocks of the Devonian and Carboniferous periods, ever increasing numbers of land forms of life until in the Permian rocks we find our first reptiles. In the next higher system of rock layers we find an abundance of reptiles and primitive seed plants such as cone-bearing trees and cycads. This age, the Mesozoic Era, is spoken of as the Age of Reptiles, which, because of their great abundance and size, dominated the life of the earth. "Fish-lizards," dinosaurs, and "lizard-birds" or flying reptiles, lived and flourished in this Era, as proved by their fossilized remains, only to become extinct when they failed to adapt themselves to the changing conditions of life on the earth. Their huge skeletons are found imbedded in solid rock, whence they are excavated, chiseled out of the rock, and mounted for display in museums. Even the fossilized eggs of dinosaurs have been found and sectioned revealing the young dinosaur within the shell.

The uppermost rock layers belong to the Cenozoic Era. In them, we find birds, mammals, grasses, flowering plants, and trees; in a word, the most complex forms of organisms.

Sir Charles Lyell is given the credit for founding the science of geology, and he did not publish his "Principles of Geology" until 1833. In spite of the shortness of the time during which men have been studying the rocks in the light of this interpretation, they have completed very masterful histories of numerous life forms. One of the most thorough and complete records is that of the horse, which has been traced step by step from a little four-toed mammal no larger than a dog. This fossilized horse-ancestor has been named Eohippus. Eohippus lived in the earliest part of the first period of the Cenozoic Era, known as the Eocene Period. Fossils of mammals of the Eocene show that they were very much more generalized than mammals today. By this we mean that none of them had specialized for speed, as have modern horses, or for flesh-eating as have lions and tigers, or for keenness of scent as have dogs, or for any other of the many diversified purposes to which modern mammals are adapted. All of these primitive mammals were small, with four or five toes on each foot, and with short, low rounded teeth. Eohippus was one of these small unspecialized mammals. He had four small hoofs on the front foot and three on the hind foot, with two splint bones on the hind foot, showing where the first and fifth toes had been. His teeth were very short and showed no adaptations for grinding food, such as modern horses have developed.

In the rock layers of the next period the fossilized Mesohippus shows us the advances made toward specialization. Mesohippus had three toes on each foot, all of which touched the ground. The teeth were larger and flatter than those of Eohippus and ridges on top for aiding in grinding food were beginning to show. Mesohippus was about the size of a Shetland pony, so of course the neck had elongated, to

There are several other lines of evidence available, however, of which we shall present a few. One of these may be spoken of as evidences from similarity of structure. If evolution is true, all of the higher organisms have ascended from the lower. As surrounding conditions have changed, plants and animals have changed to meet the conditions of the new environments, thus giving rise to new varieties and species. Organisms descended from common ancestors ought to have similar structures modified by adaptation to new conditions. When we compare the structures of the higher plants and animals, we discover that this very condition is true to a remarkable degree. For instance, the fore leg of a lizard, the wing of a bird, the wing of a bat, the shovel of a mole, the fore leg of a horse, and the arm of a man are all built on the same plan with modifications for running, flying, digging, or grasping, as the case may be. At the tip of the wing of a bird there are remains of finger bones. The fore arm and lower leg and anterior wing joint contain two bones, the ulna and radius. The bones of the shoulder are strikingly similar. This close similarity in structure heaps up even more conclusive evidence that animals have developed from simpler organisms in the past.

Closely related to the evidences of similar structure, we have evidences from rudimentary organs. By rudimentary organs, we mean the remains of organs that were once useful, but are no longer needed in a changed environment. When an organ ceases to be used, it gradually decreases in size something the way an arm in splints shrivels, and eventually it is lost entirely. Such ridimentary organs as the wings of the ostrich, the reduced eyes of cave fish, the hip bones of the whale and snake, and the appendix of man are conclusive proof of the fact that these animals have changed so much that they no longer use these parts and retain them only as rudiments of organs formerly useful. There are over eighty such rudiments in man alone, whose presence we can explain only by the theory of evolution.

One of the most conclusive proofs of evolution is found in the evidences from the domestication of plants and animals. You certainly know that dogs were not always dogs, but are descended from a wolf-like ancestor and have been changed into dogs by domestication. The same thing may be said of cultivated grains, all of which have been evolved from wild grasses. Apples have been developed from the wild crab. Peaches and almonds have both been developed from a wild plant with a thin fleshed fruit with a hard pit and bitter kernel; cabbages, turnips, and cauliflower have been brought into existence by the cultivation of the same wild plant, of the mustard family. Potatoes are the result of the domestication of a wild Solanum with a small, tough, bitter root.

All of Burbank's work is further proof that organisms change, that evolution is true. Burbank developed hundreds of new kinds of plants such as the Burbank potato, spineless cactus, plumcot, white blackberry, improved varieties of apples, peaches, plums, walnuts, tomatoes, petunias, gladioli, carnations, poppies, and lilies. The research of our whole Department of Agriculture is based upon the truth of the theory of evolution, for it is trying constantly to improve our present domesticated plants and animals and to produce new kinds that are useful. Its work would be useless, except for the fact that it is known that plants and animals can be changed. In this controlled evolution of domestic plants and animals, you have absolute proof that organisms do change, that the same organism may produce descendants as different as cabbages and turnips in a few short centuries. Given 500,000,000 years in the past, it is inevitable that gradual changes have come about from generation to generation resulting over a long period of time in new species of living things.

There is still another line of evidence wherein man has actually changed species experimentally. By burning a portion of a chromosome in the egg of the fruit fly, Drosophila, with X-ray, young flies have been caused to hatch showing extreme variation from their parents, even to the extent of having only one eye. These new flies, furthermore, breed true to themselves, producing offspring with only one eye. Here is an actual observed case of evolution.

These and many more lines of evidence all combine to force biologists to the conclusion that life upon the earth as it exists today reached its present variety and complexity by a long slow process of development from simple forms of life. To the biologist, evolution is the most outstanding and fundamental fact in his science.

UNIT X
The Theory of Development

B. The Explanations of the Fact

The fact of evolution is one thing; the explanation of how it works is another. That organisms do change, it is easy to prove, but to explain what makes them change is far more difficult.

One of the first men to attempt an explanation of evolution was Jean Baptiste Lamarck, who lived in France at the end of the eighteenth and beginning of the nineteenth century. Having been convinced of the fact of evolution, Lamarck attempted to explain it by his so-called theory of use and disuse. He knew that structures developed through use and degenerated through disuse. He believed that the young inherited these changes in structure. For instance, he believed that giraffes were once animals with necks of ordinary length. As the competition with other animals for food became keen, these giraffe ancestors stretched up after food higher on the trees. By thus stretching their necks, they caused them to elongate somewhat, and when their young were born, they inherited this somewhat longer neck. They, in turn, stretched their necks a little more, and from generation to generation the neck grew longer until the modern giraffe was evolved, with his ridiculously long neck. This is a beautiful theory, but it contains a fallacy. It is based upon the assumption that changes in the structures of the body of an animal due to outward influences will be inherited by its offspring. This assumption is false. You never heard of a blacksmith's having a son born with an overdeveloped right arm, no matter how well he may have developed his own right arm by using it. Nor have you ever known of a man who had lost a leg, having a son born without a leg. In fact, experiments have been tried repeatedly to test this idea that characteristics acquired by an organism during his lifetime can be inherited by his offspring. For instance, one man bred many generations of rats, and cut off the tails of his rats before allowing them to breed. No matter how long he continued his experiment, the baby rats were always born with full length tails. All of the experimental evidence, of which there is an abundance, denies the inheritance of acquired characteristics. Consequently, Lamarck's theory of use and disuse must be discarded, but it is worthy of note, because his book, "Philosophie Zoologigue" published in 1809, focused the attention of other men upon the problem. Their consequent investigations have led to more acceptable results.

The next notable attempt at an explanation of evolution was made by Charles Darwin, an Englishman, who lived in the last century. At the conclusion of his college career, Darwin was commissioned to sail as naturalist on Her Majesty's ship "The Beagle" on a tour round the world. It was to be his task to seek out new forms of organisms in other parts of the world, and keep records of his findings. The trip lasted five years, during which time Darwin ruined his health by too persistent labor at his assigned task. It was on this trip that Darwin's extensive observations of living things led him to the conclusion that the fact of evolution could be explained by the theory of natural selection. He did not come to this conclusion hastily, nor did he publish his results at once, upon his return to England. Darwin was far too cautious a scientist to rush the publication of an idea with merely fragmentary proof.

In fact, he spent twenty years after his return to England in painstaking research for complete and indisputable proof of his theory.

At length, when he had accumulated sufficient material to satisfy his own judgement completely, he began to make preparations for the publication of the results of a lifetime of work. Just at this time he received a short manuscript from a young enthusiastic scientist, named Alfred Wallace, who was studying the organisms of the East Indies. Wallace had hit upon the very same explanation which Darwin had been forced to accept more than twenty years before. And this happened entirely independently, since Wallace knew nothing of Darwin's idea. Wallace was eager for the publication of his theory in pamphlet form, and Darwin, like the modest, unselfish person that he was, was about to withdraw his own publication entirely, when Sir Joseph Hooker, a friend of both men, discovered the situation and urged Darwin to present his own results at the same time.

A friendly agreement was reached, whereby both Darwin and Wallace published simultaneously. Darwin's publication was the book, "The Origin of Species by Natural Selection", one of the masterpieces of scientific literature of all time. The year was <u>1859</u>, a date worthy of being remembered, since it marks the beginning of modern experimental biology.

Darwin based his theory of natural selection upon five underlying ideas. In the first place, he noticed that all organisms produce more offspring than can possibly survive. Suppose that every one of the million eggs laid by one female fish were to hatch, and all the young fish were to survive, and each female were to produce another million offspring. You can see that one single pair of fishes would soon populate the whole sea; fill it, in fact, so completely that nothing could survive. Or again, suppose that all of the three hundred eggs laid by one female frog were to hatch and grow into adults, half of which were females. Suppose these females also laid three hundred eggs, all of which hatched, grew to adulthood, and reproduced at the same rate. In five years time, one pair of frogs would have produced some one hundred fifty-two billion offspring. Darwin called this fact <u>overproduction</u>.

In the second place, he noticed that there are always difficulties in the environment to be met by the young, as well as by the adults, of any species. Among these difficulties we may mention such things as scarcity of food, enemies, drought, floods, light supply, and temperature. Since there is always an overproduction of offspring, it is inevitable that many of them must perish, because of their inability to overcome these difficulties in the surrounding conditions which Darwin called <u>the exigencies of the environment.</u>

In the third place, Darwin noticed that all individuals vary amongst themselves. No two individuals are exactly alike; not even identical twins. Individuals in the same species vary in every detail of their make-up. It is claimed that two blades of grass cannot be found which are exactly alike, nor two identical leaves on the same tree. Individuals of the same species vary as to length of legs, neck, or tail, amount of fur, color of eyes, or in any other factor you may mention.

His fourth fact was the inevitable conclusion of the first three. Since far more offspring are produced than can possibly survive, since these young must face the exigencies of the environment, and since the individuals among the offspring vary somewhat, it must follow that there will be a struggle for existence amongst the offspring, and those individuals having variations which best fit them for the struggle must survive, while those with less useful variations must perish. Darwin called his fourth and fifty facts the struggle for <u>existence and the survival</u> of the fittest, respectively. Thus, he said, nature is constantly selecting the individuals best fitted for their particular environment to survive and reproduce the race, just as man has selected artificially the ears of corn best fitted to his use for his seed corn. Just as man changed wild grasses into grains by artificially selecting those seeds in each generation which were best suited to his needs, so nature has been changing plants and animals into new forms throughout the long ages past by selecting out of each generation those individuals to survive and reproduce which showed variations best fitted to cope with their environment. Hence he named his theory, natural selection.

Thus Darwin explained the origin of new species from old. His theory of natural selection is still accepted, but only as a partial explanation of evolution.

Modern biologists believe that many other factors enter into the process. One of the most interesting additional explanations of evolution is that of the Dutchman, Hugo De Vries, who published his discoveries in 1900.

As De Vries was walking through his garden of blooming Oenothera Lamarchiana (evening primroses), he came upon one which was quite different from its sisters, although grown from the same seed. He took the flower to his laboratory and tried by every available means to find out just what species it was. Eventually he established the fact that it was unlike any known species. Furthermore, when he planted its seeds, he found that they produced offspring like themselves, and unlike their grandparents and cousins. Thus we observed the origin of a new variety from an old one. He called a new variety which sprang thus suddenly from an old one a mutation. Examples of mutations have been observed frequently, and are popularly called sports. Hereford cattle arose as a mutation.

Thus De Vries added a further explanation of evolution to that of Darwin. Both mutations and natural selection are accepted today as partial explanations of the great fact of evolution. Modern research indicates that additional factors enter into the cause of change, but modern biologists agree that evolution itself is true, however it may be explained.

UNIT XI
Inheritance

A. The Facts

You may plant wheat in one half of a field and oats in the other. The soil is identical, the water supply, sunshine, and air conditions are the same in both fields. And yet the wheat grains always grow into wheat plants while the oats grains just as infallibly produce oats plants. You are so familiar with the fact that organisms always produce offspring resembling themselves that you probably never stop to wonder why this is true.

What is there in the wheat grain to make it grow into a wheat plant? You say that there is an embryo wheat plant in the grain and you are right. You will recall, however, that the embryo wheat plant in the grain grew from a single cell, the fertilized egg, just as the embryo oats plant in the oats grain did. Since the fertilized eggs of wheat and oats appear to be identical, outwardly, obviously there must be some invisible thing within each, which makes the one grow into a wheat plant and the other into an oats plant.

It has already been suggested to you in the discussion of mitosis that it is the chromosomes within the nucleus of the fertilized egg which control the growth of the offspring. Chromosomes only become visible under the highest magnification and were not discovered until an Italian, named Boveri, saw and named them in 1887, only forty-five years ago.

Today we know a great many things about the chromosomes. We know that every cell of every plant and animal contains a set of chromosomes within its nucleus. We know that these chromosome sets vary in different species as to number, size, shape, and arrangement, but within the same species the chromosome sets are alike. We also know that a species having a given number of chromosomes (forty eight in man) in the cells of the general body show only half that number of chromosomes (twenty-four in man) in each gamete (egg or sperm.) We know, further, that chromosomes are composed of units, called genes, which are strung along the thread-like chromosome, as beads are strung on a string. It is these genes which control the growth of the offspring, making the fertilized egg of the wheat produce wheat and that of the oats produce oats.

The specialized science which has to do with the study of heredity is genetics. It is of very recent origin and the story of its rise and development is one of the most interesting chapters in modern biology.

The founder of the science of genetics was a monk, the Abbe Johann Gregor Mendel, who lived in the Monastery at Brunn, Austria, and carried on his experiments in the cloister garden. There in his monastery garden, he carried out extensive experiments on pure breeds of the common garden pea. His discoveries were vital, even epoch-making, but he published them in an obscure scientific magazine, where they attracted little, if any, attention, to his great disappointment, for he felt that he had hit upon very significant facts, as we know now that he had. Their publication in 1865 was noticed so little, that the general world of science never heard of his work until 1900, long after his death, and then only because three different investigators, looking up past literature on their own problems, happened upon this obscure publication of thirty-five years before, and immediately recognizing the importance of it, at once put it before the world. One of these three rediscoverers was the Dutchman, Hugo De Vries, of whom you heard in connection with the theory of mutations. The other two were Correns in Germany and Tschermak in Vienna.

The work which Mendel did sounds commonplace enough, since he was merely engaged in cross-pollinating pure breeds of garden peas, but the results he obtained and his interpretation of those results place the man among the real pioneers of science.

After he had obtained a pure breed of tall and another of dwarf garden peas, he transferred the pollen from the stamen of a tall plant to the stigma of the pistil of a dwarf plant. He planted the seeds which grew from this cross-pollination and found that all of them grew into tall plants, although the female parent had been a dwarf. He reversed the crossing so that the male parent was the dwarf, but the resulting seeds still produced only tall offspring. We call organisms which are crosses between two pure breeds hybrids.

Next, he allowed these tall offspring to produce seeds, which he planted. In this generation, he found that most of the seeds grew into tall plants, but a few of them grew into dwarfs. After many careful countings of the numbers of talls and dwarfs, he found that one plant in every four was a dwarf, while the other three were talls.

If the dwarf plants were allowed to produce seeds after self-fertilization, these seeds produced only dwarf offspring throughout all of the succeeding generations. Likewise one in every three of the tall plants after self-fertilization produced only tall offspring throughout all of the succeeding. However, the other two out of every three tall plants produced offspring partly dwarf and partly tall in the ratio of one dwarf in every four plants. These dwarfs in turn produced only dwarf offspring, and of the talls, one in every three produced only tall offspring, while the other two of every three talls continued as before to produce partly dwarfs and partly talls in the same ratio of one in every four plants.

The diagram on page 169 illustrates these facts.

Mendel interpreted these facts to mean that the egg cell of a dwarf pea contains some unit which will cause dwarfness in the offspring, while the sperm cell from the tall parent similarly contains a unit which will cause tallness in the offspring. When a sperm cell containing a unit-determiner for tallness unites with an egg cell containing a unit-determiner for dwarfness, the fertilized egg must inevitably contain both of these unit-determiners. Since these fertilized eggs grow only into tall plants, it is apparent that the unit-determiner for tallness dominates that for dwarfness. Consequently, Mendel called tallness a dominant and dwarfness a recessive character.

After obtaining the same results from crossing pure breeds of peas showing six other pairs of contrasting characters, such as yellow and green, smooth and wrinkled peas, Mendel drew the following three conclusions, which are usually spoken of as Mendel's laws:

1. Law of dominance.
2. Law of unit-characters or segregation.
3. Law of 1:2:1 ratio between pure dominants, hybrids, and pure recessives.

After drawing these conclusions, which we may call hypotheses, Mendel tested them rigorously by further experimentation. When his experimental evidence proved his laws to be correct, he had completed the steps in the scientific method of attack and published his discoveries, only to have them ignored until thirty-five years later.

Since the rediscovery of Mendel's work, scientists have performed a great many similar experiments and they find that Mendel's laws hold true.

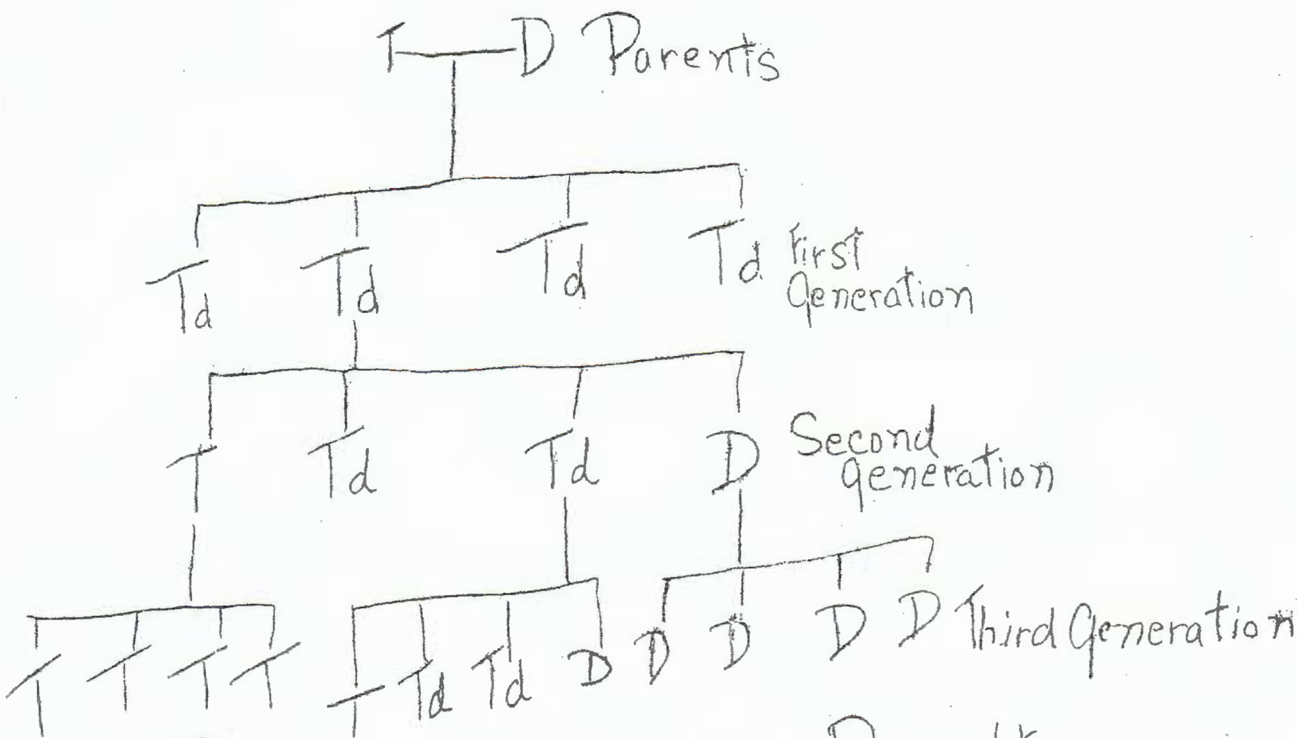
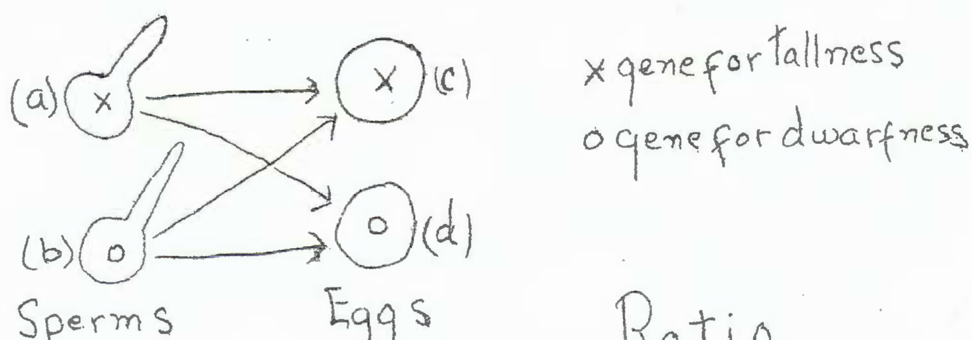


Diagram of Mendels Results



		Ratio
(a) + (c) = (xx)	1 Pure Tall	1
(b) + (c) = (ox)	1 Tall Hybrid	2
(a) + (d) = (xo)	1 Tall Hybrid	
(b) + (d) = (oo)	1 Pure Dwarf	1

Diagram of Possibilities of fertilization in Hybrids

For instance, a pure four-o'clock with a red flower has been crossed with one with a white flower. When these seeds are planted, they produce only pink-flowered hybrids. When the hybrids form seeds, they produce one red, two pink, and one white-flowered offspring. This is a repetition of Mendel's results except that redness does not dominate whiteness completely since the hybrids have pink flowers. Nevertheless the unit-character for redness does not become mixed with that for whiteness, since the second generation sees them being sorted again into pure reds and whites in the normal ratio.

We now know that Mendel's theory of unit-characters is true, and we call his units genes. In the light of the research that has been done since 1900, it is easy to explain why the 1:2:1 ratio appears.

You already know that a sperm or egg of any organism contains only half as many chromosomes as the cells of the rest of the body. It is also known that each cell of the general plant body of a pure tall pea contains two genes for tallness and that each cell of a pure dwarf likewise contains two genes for dwarfness. When the tall plants form eggs or sperms, the number of chromosomes is cut in half thus giving each egg or sperm only one gene for tallness. Likewise each egg or sperm of the dwarf plant receives only one gene for dwarfness. When a sperm containing one gene for tallness unites with an egg containing one gene for dwarfness, the fertilized egg must contain two genes, one of each kind. This fertilized egg will grow into a tall hybrid since the tall gene dominates the dwarf. Each cell in the plant body of the tall hybrid contains two genes, one for each character.

When a hybrid plant produces an egg or sperm, the genes for tallness or dwarfness must be divided since a gamete must contain only one gene for a given character. Consequently, half of the eggs or sperms will contain one gene for tallness, while the other half of them will contain one gene for dwarfness. The diagram on page 169 will illustrate the possibilities of fertilization.

A large part of the recent research in genetics has been carried on with the fruit-fly, Drosophila, because of its convenience. The chromosomes and even the genes within them can be mapped in a diagram so that the gene which determines the shape of the wing, for instance, can be pointed out to you definitely. Many similar genes have been demonstrated to determine such things in the fruit-fly as the size and vein pattern of the wings, the shape and color of the eye, the color of the body, the instinct to fly toward a light, fertility, fatal tumors, and even the length of its life. It was in connection with these genetic experiments that several mutants of Drosophila were produced artificially, by burning out certain genes with X-ray.

Definite knowledge of the control of genes over the growth and form of the bodies of other plants and animals is not lacking. For instance, hornless cattle owe their lack of horns to a particular gene. Beardless wheat is controlled by a single gene. Amongst domestic fowls, the genes determine the color and kind of plumage and the shape of the comb, as well as the egg-laying capacity.

Naturally the most interesting phase of the study of inheritance is that which relates to human beings. Although it is extremely difficult to collect experimental evidence concerning human inheritance, nevertheless we already have proved that a large number of our characteristics are determined by genes or groups of genes and that they follow Mendel's laws. For instance, the evidence indicates that blue and brown eyes are controlled by single genes, blue being recessive and brown dominant. Since blue is the recessive, two blue-eyed parents should have only blue-eyed offspring, because blue-eyed individuals cannot carry the gene for brownness, since if it were present, it would dominate the blue. On the other hand, brown-eyed parents could both carry the recessive gene for blue eyes and might have blue-eyed offspring.

aks by having them adopted into good homes in their very early childhood. These attempts have been wretched failures, except that restraint has lessened the opportunity for criminal deeds. There is not one case to show that training ever improved the mind of one of these feebleminded unfortunates at all.

The other half of the Kallikak story is a happy one. After the War of Revolution was ended, Martin Kallikak returned to his home, and later married a normal woman. The descendants of this marriage total four hundred ninety six of whom not one has ever appeared who was feebleminded. Never has any one of them been guilty of criminal acts, but all of them have been normal, healthy, worthwhile persons, honored and useful citizens.

The eugenist says that feebleminded persons should be prevented by the state from becoming parents, because of the Mendelian character of the trait. He believes that the elimination of this and other undesirable traits in human beings can only be brought about by preventing reproduction among those who are known to be almost certain to give bad heredity to the offspring, and can never be accomplished by simple improvement of environmental conditions. The need for some intelligent solution may be realized if you investigate the cost to the nation both in money and suffering, of these dependents. Able-bodied, normal Americans pay over $100,000,000 a year in taxes to support our criminals, paupers, insane, feebleminded, and diseased. Those individuals already born who show these traits should be cared for properly and sympathetically. But they surely ought not to have offspring. Some states, such as Kansas, have already adopted legislation to this effect.

Another phase of eugenics is that which relates to the number of children per family. At the present time, in general, the families endowed with the best sets of genes are having the smallest number of children and vice versa. This must result in the gradual lowering of the percentage of the finest citizens and the increase in the percentage of the less desirable individuals. Whether any workable remedy for this problem will be forthcoming remains to be seen.

Still another problem in connection with human inheritance is that of cousin marriages. The facts indicate that the marriage of cousins is dangerous only when the family stock carries undesirable recessive genes. For instance, two normal persons who were cousins married and became the parents of a deaf-mute. This family stock carried the recessive gene for deaf-mutism, but as long as these individuals married persons from families without this recessive gene, there would be no deaf-mutes born, since it requires a recessive gene from both parents in order for any recessive characteristic to express itself. On the other hand, when cousins marry, both of whom carry the same recessive gene, there is a chance for them to have children showing the recessive character. These occasional experiences in the past led to the conclusion that all cousin marriages are apt to produce abnormal offspring, which is not true.

For instance, many cousin marriages occurred between the closely related Darwins, Wedgewoods, and Galtons. Charles Darwin himself married his cousin and among his descendants there have been several distinguished persons possessed of the same keen, patient, scientific insight which characterized him and his family stock. Besides, there have been no undesirable individuals.

The eugenist concludes that cousin marriages are in no wise dangerous except when the family germ plasm carries undesirable recessives. In fact, in a fine stock, inbreeding may be highly desirable as productive of more individuals with a high endowment.

There is another common belief about human inheritance which has been proved to be entirely false. Many persons still believe that maternal impressions during the period of pregnancy can "mark" the child. For instance, stories are told on every hand about an expectant mother's being shocked by the sight of a cripple, and giving birth to a deformed child, or being frightened by a fire and having a child with a red birth mark like the fire. Such results are utterly impossible, because there is no possible way whereby the mind of the mother may affect her unborn offspring. Not only is there no connection whatever between her nervous system and that of the child, but neither is there any direct flow of blood from the mother's circulation through the embryo. The child absorbs food and oxygen from the blood stream of the mother into its own blood stream, and likewise eliminates its own waste products into the blood stream of the mother, but their respective blood streams are entirely separate and distinct.

Furthermore, there is ample experimental evidence in the field of animal breeding to disprove completely the belief that maternal impressions can have any effect whatever upon the offspring. For instance, the birth of a number of red calves in a herd of Black Aberdeen-Angus cattle caused the breeder, who knew nothing of Mendel's laws, to conclude that the cows were seeing red color in their surroundings and thus marking the calves. Consequently, he had a high board fence erected around his paddock and painted jet black, so that the cows should see nothing but the black color. To his disgust, he continued to have red calves born, because his herd carried the recessive gene for redness, so that one fourth of the offspring were bound to be red.

This and much more experimental evidence absolutely disproves the belief in maternal impressions. Nevertheless many mothers still hope to make a child beautiful by gazing at a beautiful picture, thus raising false hopes, for no contemplation of a beautiful picture can possibly change her child's features in the least degree.

Closely related to this idea of maternal impressions is another fallacy, which maintains that the sex of the offspring can be determined by all sorts of amusing means. The geneticist knows exactly how the sex of the offspring is determined.

Approximately thirty years ago, geneticists discovered that the female of certain insects has one more chromosome than the male. The female has all of her chromosomes in pairs. Thus she has an even number of chromosomes while the male has an odd number, always one less than she possesses. This extra chromosome of the female has been named the X chromosome and it exists double in all of the body cells of the female. In the male the X chromosome exists singly in each cell.

It must be evident to you that when the female produces eggs, since each egg receives half of each pair of chromosomes, each egg must receive one X chromosome. In the male, however, when the chromosome number is reduced to half in the sperms, half of the sperms will receive an X chromosome and the other half will receive nothing. Thus all of the eggs and half of the sperms will contain an X chromosome, while the other half of the sperms will have no X chromosome.

If a sperm containing an X chromosome fertilizes the egg, the fertilized egg will contain two X chromosomes and will grow into a female, since the cells of females always contain a pair of X chromosomes. On the other hand, if a sperm without an X chromosome fertilizes the egg, the fertilized egg must contain only one X chromosome, and will grow into a male since the cells of the male contain only one X chromosome.

Thus the sex of the offspring is determined by the chromosomes at fertilization. This is the method of sex determination in most animals, including man, and it makes one realize that anyone who believes he can affect the sex of an unborn child to make it boy or girl as he wishes is pinning his faith upon a false premise. This does not mean that biologists may not discover a method whereby they are able to control which a wild American daisy with abundant blossoms but a poor plant body, an English daisy with a dignified plant body but a poor bloomer, and a Japanese daisy with a pearly lustre in the flower. The Shasta Daisy combines the abundant bloom, the dignified plant body, and the pearly lustre.

Burbank also used the method of selection in his breeding. His first attempt was while he was still living in Massachussetts. The people there had been selecting the largest potatoes for seed, thus gradually getting them larger and larger. Burbank began selecting for uniformity of size and succeeded so well that the Burbank Potato became famous.

He made use of selection again after he had gone to California. The Japanese quince was very sour and had a thin flesh, but a very peculiar flavor. Burbank began selecting the fruits with the thickest flesh out of each generation from which to grow the next generation. Eventually, out of thousands of selections, he attained a fruit of desirable thickness of flesh and flavor and propogated it by grafting.

Burbank also used mutations occasionally. For instance, in an enormous field of dahlias, he happened to find one with the scent of arbutus. He pedigreed it, thus preserving the mutation. Other mutations which he discovered and preserved were the Bartlett plum which tastes like a Bartlett pear, and the scarlet California poppy.

Although Burbank was applying Mendel's laws constantly, he never knew anything about them. We know that the variety of new types which he produced by hybridization was due to recombinations of genes contributed by both parents, but Burbank himself knew nothing of genes. Just as a chef may cook delicious food without any knowledge of organic chemistry, so may a practical man produce results without understanding why.

On the other hand, we shall now relate several incidents in which the conscious application of Mendel's laws has benefited mankind more than the most of us ever appreciate.

For instance, a serious disease attacked the cotton crop of the Southern States. Three government experts were sent out to try to solve the problem. When they arrived, they found the cotton fields devastated by this disease as though they had been swept by fire. The youngest of the three experts noticed that individual cotton plants were still standing here and there in the fields and were apparently in perfect health. He reasoned that these individuals were immune to the disease, and, knowing that disease-resistance had been proved to be an inherited characteristic, he set to work to breed offspring from these plants. He proved that their immunity was inherited and thus he produced a race of cotton immune to this particular disease. Thus, by applying his knowledge of genetics, this man was able to save the cotton industry.

Another interesting example of the practical value of genetics is found in the story of coffee in East India. The Germans had introduced Coffea arabica into East India, where a local parasite attacked it and destroyed the coffee plantations. A German named Appel set about to solve this problem. He sent Coffea liberica to the colony, and it proved to be disease-resistant only for a short time. Then he tried Coffea robusta which came from the forests of Africa. It proved to be perfectly and persistently disease-resistant, but it produced only an inferior grade of coffee. It remained to cross Coffea robusta with Coffea arabica, thus obtaining amongst the hybrids a plant combining good quality and disease-resistance. Thus the coffee industry of East India was saved from ruin.

Still another similar case is that of the chestnut blight in the United States.

This disease was introduced in some nursery stock from Asia about 1880. In Asia, the variety of chestnut is highly immune to the blight, but the American chestnut proved highly susceptible. The blight spread rapidly over the eastern part of the United States, killing every tree it attacked. By 1911, the damage was estimated at thirty million dollars. An effort is being made to cross the disease-resistant Asiatic chestnut with the American variety and some promising hybrids have already been produced.

The problem of wheat rust was one of the worst confronting the wheat growing nations. Wheat rust is a Fungus which lives part of its life as a parasite upon the wild barberry. The earliest efforts to combat this crop enemy were aimed at the disease itself, without great success. Later, when the fact that disease-resistance was inherited was established, breeders saw the possibility of a new solution to the problem of wheat rust. Wild wheat was discovered in Palestine and it proved to be highly resistant to the rust, but had small grains, a poor yield, and other undesirable characteristics. Wild wheat was crossed with a wheat of good quality, but highly susceptible to the disease. The first generation proved to be one hundred percent susceptible, showing the breeder that susceptibility to wheat rust is caused by a dominant gene. To a Mendelian, this result was no discouragement, since he knew that it is the second generation which shows the recombinations of genes. Consequently, a vast number of wheat plants were grown from this first generation of hybrids by self-pollination. Fortunately for our food supply, two strains of wheat appeared which combined rust-resistance and the desirable features of the susceptible ancestor.

One more example will suffice. In 1921, the Dutch in Java undertook to create an improved strain of sugar cane in order to combat disease and increase the sugar yield. First, they crossed a high-yielding variety of cultivated sugar cane with a wild Javanese cane which was very resistant to disease, but contained no sugar at all. From the descendants they selected the most desirable individuals and crossed them again with other cultivated varieties, until by 1924, they had produced the new variety of sugar cane which they named P.O.J. 2878. This new cane yields approximately twenty percent more sugar per acre than any other known variety and at the same time is highly resistant to the diseases that the plant is heir to.

It is interesting to note that the improved sugar cane contains one hundred twenty chromosomes in the nucleus of each cell instead of the forty found in its cultivated ancestor. Likewise, the best varieties of cultivated wheat carry forty-two chromosomes instead of the fourteen of the primitive wild wheat.

Java ranks only second to Cuba in the production of sugar. While it is smaller than England, it has a greater population. The problem of feeding such a dense population has thus been partly solved by applied genetics, just as applied genetics is helping in the solution of practical problems all over the world.

UNIT XII
Plant Successions

A. Rocky Uplands

If you have spent any of your time in the woods of this region, you have probably noticed that the trees are largely beeches and maples. When you have stood in the midst of a beech-maple woods, it has probably seemed to you as though that woods had always been there and would always continue there. Such is far from the truth. Where the beeches and maples now grow, the soil was once a rocky upland with no vegetation at all. The story of the evolution of the woods as you see it is both long and interesting.

The first plants which are able to grow on a rock surface are lichens. You have often seen them as a grayish-green smear on rocky cliffs or granite boulders. These lichens are Thallophytes, half Alga and half Fungus. They are able to live on a bare rock surface because they can actually bore into the rock by giving out carbon dioxide. The Alga is able to carry on photosynthesis and the Fungus obtains and retains the water for the lichens. Plants which are adapted to live in very dry, light conditions are called xerophytes, of which lichens are a splendid example. An example of a lichen is the reindeer moss which keeps the reindeers alive during winter, since they are able to paw the snow away and eat it.

As these lichens live and grow, they actually loosen a little of the rock surface, and as some of them die and decay, there begins to appear a very thin layer of soil. The spores of such mosses as Grimmia lodge in this thin soil layer and grow there so that mosses gradually crowd out the lichens on the rock surface.

If you have ever peeled mosses from a rock, you know that they have a considerable soil layer. As the soil layer gradually increases by the dying and decaying of the mosses and the further addition of rock particles, it will be able to hold more moisture, so that fern spores of such ferns as Woodsia, the walking fern, and the bracket fern are able to germinate. Thus the mosses and ferns gradually replace the lichens entirely.

As the mosses and ferns reach a thriving condition they gradually increase the soil layer and, by shading it somewhat, they keep more moisture in it. As the soil layer grows thicker and more moist, certain kinds of seedling herbs begin to appear. Alum root is particularly adapted to these conditions. Yarrow, cinquefoil, Kentucky bluegrass, dandelions, and mullein are also xerophytic herbs which appear in these conditions.

As these xerophytic herbs gradually crowd out the mosses and ferns, even so do they enrich and shade the soil still further, thus preparing the way for the next stage which will be the xerophytic shrub stage. Chokecherries, junipers, poplars, and aspens are pioneer shrubs which succeed in establishing themselves among the xerophytic herbs, thus again increasing the richness and moisture of the soil.

The first trees which grow on such a rocky upland as we are studying must be very light-tolerant and they must be able to get along with a comparatively small amount of moisture. Poplars and birches are the most successful trees under these conditions.

As these trees establish themselves, their groves become too shady and too moist for their own seeds to grow. Young poplar trees do not come up in a poplar grove, but the seedlings will be found to be evergreen seedlings such as spruce or jack pine. Evidently the shade and moisture in the poplar grove are just right for the germination of the seeds of these evergreens. Consequently the old poplar trees will gradually die out and the young evergreens will take their places, so that in the course of time, the area once occupied by a poplar grove comes to be occupied by an evergreen woods.

Probably you are wondering where the seeds of the new kinds of plants come from. Seeds are so successfully scattered by their adaptations for seed dispersal that they are sure to appear in far greater abundance than is desirable. There are always many kinds of seeds present in any area, but only those seeds grow which are suited to the surrounding conditions.

Nor does the succession end here. Just as the poplars prepared the way for their own downfall by producing too much shade and moisture for their own seedlings, even so do the evergreens prepare for their downfall. The seeds of the evergreens are unable to germinate in their own soil because it is too acid for them. Acorns, on the other hand, like an acid soil, and you will find young oak trees growing up beneath the old and dying evergreens. In due course of time, the oak woods will have succeeded the evergreens.

Nor is the oak woods to be permanent. The soil in the oak woods is rich, moist, and shaded so that the conditions are now described as mesophytic. In an oak woods, the acorns are unable to germinate because of these mesophytic conditions. The seeds of beeches and maples need just these conditions for germination. In any mature oak woods, you will find that the young seedlings are beech and maple, rather than oak.

Naturally enough, the oak trees eventually become old and die and the young beeches and maples grow up to take their places. Thus is evolved a beech-maple climax forest, which is more or less permanent since the beech and maple seeds can still germinate in their own soil.

A beech-maple forest grows only in a rich moist soil and all the plants which like these conditions are called mesophytes. Growing in these woods in some regions we also find hemlocks and yellow birch. Underneath the trees we find many plants, such as dutchman's breeches and squirrel-corn, trillium, mayapple, violets, dwarf dogwood, various mesophytic ferns, and many fungi.

The next time you are tramping in a beech-maple woods, try to realize the long story back of its development. The very area it now occupies has passed through the following stages:

a. Rocky upland
b. Lichens
c. Xerophytic mosses and ferns
d. Xerophytic herbs
e. Xerophytic shrubs
f. Poplars
g. Evergreens
h. Oaks
i. Beech-maple climax

These stages succeed each other in order, as the soil conditions change from extremely dry to moist and from extreme light to shade. We speak of these stages as plant successions from xerophytic to mesophytic conditions.

Any given group of plants which grow together in one habitat we call a plant association. The beech-maple association includes all the plants which grow in the beech-maple woods. Plant associations exist because certain plants thrive in certain conditions and not in others. Thus you see that plants are adapted to particular kinds of environments. The relation of plants to their environments is studied in plant ecology.

B. Swamps

In swamps, you have undoubtedly noticed that we have entirely different plants from those on an upland. In a swamp succession, we begin with extreme moisture. Plants which like extreme moisture are called hydrophytes, in contrast with xerophytes and mesophytes. In the swamp succession, we start with hydrophytes and gradually evolve toward the mesophytic conditions.

Swamps develop in rather shallow water. The first plant association in a swamp succession includes only floating Algae. As the lake fills up somewhat, ground vegetation will appear, including chara, cut-leaved seed plants, bladderwort, tape-grass, pond weed, and white buttercup. All of these plants live entirely submerged. These plants tend to fill up the lake still further, thus preparing it for the third stage, wherein surface plants will be able to grow. In this association we find water lilies with their roots in the soil and their leaves floating.

The reed swamp or rush vegetation crowds out the water lilies to form the fourth stage. Bull rushes, cat-tails, pickerel weed, iris, lizard tail, and arrow-leaf are common plants in this association.

Sedges will succeed the reeds or rushes, and shrubs including willows and buttonbush will succeed the sedges.

As these plants live and die, they gradually fill up the lake until conditions become less hydrophytic and begin to approach the mesophytic conditions. The shrubs will be followed by evergreen trees, including larch, white cedar, pines, poison sumach, winter holly, and the tall blueberry. The evergreens are succeeded by the hydro-mesophytic forest in which we find willows, birches soft maples, black ash, elms, and sycamores.

The climax forest of this succession will be beech-maple when the conditions become truly mesophytic. Thus the lake and the rocky upland have both evolved into the same mesophytic conditions.

C. Bogs

Bog successions are among the most interesting in the world. A bog begins with a deep lake instead of a shallow one. The first plant is Decadon, which creeps out over the surface of the deep water something the way a strawberry runs over the ground. Then the spores of sphagnum moss lodge in the Decadon vines and germinate. This sphagnum moss grows thicker and thicker until it produces a floating mat on top of the water strong enough for one to walk upon. If you have ever been fortunate enough to visit a real bog, you know that this floating mat, three or four feet thick, shakes beneath your feet, giving you the sensation similar to that produced by an earth tremor in an earthquake. Hence the name "quaking bog".

Growing in this mat of sphagnum, you may find plants which grow nowhere else in the world. The pitcher plant is very characteristic of a bog. It has its leaves shaped like pitchers with a canopy over the top of the pitcher. A ring of nectar inside of the canopy attracts insects, which are caught and drowned in the water in the pitcher. The plant supposedly digests these insects, thus obtaining some of its food supply. Sundew is another insectivorous plant found only in a bog association. Cranberries, buckthorn, bog violets, and several kinds of ferns are found in the same association.

As the mat grows thicker and less moist, tamarack trees, poison sumach, and alder appear. These are gradually succeeded by black ash, gum, buttonbush, and other hydro-mesophytic plants which later give way to the beech-maple climax.

In Ireland, peat is cut from the peat bogs and used as fuel. During the World War, sphagnum moss was dug from bogs, sterilized, and used instead of absorbant cotton in dressing wounds.

D. Sand Dunes

You have now traced three successions, those starting with rocky uplands, with shallow lakes, and with deep lakes. Another unusually interesting succession is that of the sand dunes. The story of the sand dune succession was first worked out by Dr. H. C. Cowles of the University of Chicago, who has attained an international reputation as the father of plant ecology in the United States.

On the southeastern shore of Lake Michigan, the waves are constantly depositing the sand which they have eroded from the western shore line. As you stand at the water's edge, southeast of the lake, you may see the offshore bar, a ridge of sand a few feet out in the water, being built up by the deposition of sand at the point where the waves break. This offshore bar grows higher and higher until it comes above the surface of the water thus forming a lagoon behind it. A new offshore bar again forms farther out in the lake, so that a new shore line is constantly appearing farther and farther out in the lake. In most areas, the lagoon is gradually filled by the blowing of the sand but at Buffington, Indiana, the series of old offshore bars and lagoons can be traced back a mile or more inland.

At most points along the lake, as for instance, at Miller, Indiana, the bars and lagoons are soon lost sight of, but the soil is sandy for as much as three or four miles inland, showing that all of this land has been built up by the depositing of sand along the ever-advancing shore line.

As you stand at the present shore line, it is easy to observe three beaches, the lower beach which is constantly washed by summer waves, the middle beach which is washed only by the higher winter waves, and the upper beach which is no longer washed by waves at all.

There is no vegetation at all on the lower beach, for no plants have yet evolved which are adapted to live in the rapidly changing wet and dry conditions of the lower beach. On the middle beach a few annuals such as bug seed, sea rocket, and Russian thistle live and thrive in the summer, only to be destroyed in the following winter. On the upper beach where wave action cannot reach them, we find sand cherries, sand reeds, smooth willows and a few seedling cottonwoods. We also find scattered bunches of two kinds of grasses, Ammophila and Calamovilfa, both splendidly adapted for growth in sand.

Immediately back of the upper beach we come to the foredune, where these two grasses have succeeded in growing quite successfully. It is on the foredune that we first see the sand beginning to pile up about these bunches of grass, and thus we have the first step in the formation of dunes. Unless the wind-swept sand found some obstacles about which to collect, sand dunes could never develop. These bunches of sand grass offer just these obstacles. The sand piles up around a bunch of Ammophila which has a splendid adaptation to prevent its being choked out by the piling sand. Ammophila is able to spread by means of rapidly growing root stalks just a little faster than the sand piles up. As the grass spreads the sand piles around it still more until we find little heaps of sand three or four feet high overgrown with grass. Calamovilfa has the same power to outgrow the pile of sand by growing taller. Thus on the foredune we may observe two kinds of small dunes, low spreading ones formed around Ammophila and tall conical ones formed around Calamovilfa.

Coming in among these grasses on the rear of the foredune, we may find a few seedling cottonwood trees and as we walk back away from the lake, we come next into the true cottonwood dune. The cottonwood is another plant remarkably adapted to grow in the region of blowing sand. The small cottonwood tree offers another obstacle about which the sand piles up. Any other tree would soon be choked out by the sand, but not the cottonwood. As the sand piles up around its trunk, it simply sends out new roots from the part of its trunk which has been covered and shoots up new branches into the air. These new roots are called adventitious roots because they originate at an abnormal part of the plant. Old cottonwood trees have been uncovered in a dune area with adventitious roots growing out from the trunk for many feet upward, while only the top of the uncovered tree shows normal green branches. In the cottonwood dunes we find other plants growing, such as red osier dogwood, sand cherry, Equisetum, smooth and glandular willows. The cottonwood dunes attain considerable height, sometimes as much as fifty or seventy five feet.

Just back of the region of cottonwoods we come into the dune-complex belt. In the dune-complex, huge hills of sand have escaped from their restraining vegetation and gradually blown away from the lake as huge moving dunes. The wind sweeps up the gentle lakeward slope of the dunes and drops the blowing sand down the steep leeward slope. It is real sport to climb the windward slope of a moving dune and gently fall down the leeward slope with the sand. Such a moving dune travels only a few feet each year. At one point in Indiana a moving dune so completely blocked the mouth of the Calumet River as to change its course and cause it to flow in the opposite direction.

Fortunately, these dunes do not continue to move forever, for eventually a new dune blows up back of an older moving dune, thus cutting off the wind supply. As the dune stops moving, the bunch grass spreads rapidly over it, thus helping to stabilize it. Milkweeds, Equisetum, and sand rushes are associated with this bunch grass. Seeds of evergreens germinate readily among the bunch grass so that we find a belt of evergreens just back of the dune complex. The jack pine is the dominant tree and with it we find associated cedars, junipers, sand thistles, poverty grass, bearberry, and an occasional white pine.

The pine dunes eventually prepare the way for their own downfall by rendering the soil too acid and too moist and by producing too much shade for their own seeds to germinate. As in the rocky upland succession, the pines are gradually replaced by a typical oak woods. The oak woods seems at present to represent the dune climax in Indiana and the belt of oak dunes is found fartherest from the lake. In the oak woods, there is an abundance of plant growth, including lupins, sand violets, New Jersey tea, and silvery cinquefoil.

As we stand in these oak dunes, we realize that this was once the lake shore, that it was once an offshore bar, that the beach was succeeded by the foredune, and this in turn by the cottonwood dune, dune complex and pine dune. The beauty of the dune succession is that we have all the preceding stages preserved for our observation as we walk out toward the present shore line.

In these stories of plant successions, you have further evidence that life is dynamic, not static; that change is the universal law. The evolution from xerophytic or hydrophytic conditions toward mesophytic conditions is going on everywhere. Plants change as the environment changes, association succeeds association until the climax is attained.

If you ever have the opportunity to take a course in physiographic plant ecology, do not miss it, for it will enrich your appreciation of nature a thousand fold.

As Tennyson has said in his "In Memoriam" so we also say,

"The hills are shadows and they flow
From form to form and nothing stands."

Field Trip

Visit a beech-maple woods. Record all of the kinds of plants which you see and know. Try to learn the names of any plants you find and do not know, and add them to your list.

Look for a rocky ledge in a ravine, in order to observe the early stages in the rocky upland succession. Do you see any lichens? _______. What color are they? _______________. Can you peel them from the rock? _______.

Look for a moss layer growing upon a rock surface. Peel some of it loose. How thick is the soil layer? ______________________________. Are there any ferns among the mosses? _______. What xerophytic herbs usually succeed the moss and fern stage? ____

____.

Can you find examples of any of them? _______. If so, which? ___________________

____.

Visit any swamp and record the kinds of plants which you find. Which stage of the swamp succession seems to be cominant in this particular swamp? __________

_________________________. If possible, pull up some submerged plants. What kind of leaves do most of them have? ___________________________________.

Review of Unit XI

Enumerate the stages in the evolution of a beech-maple climas forest on a rocky upland.

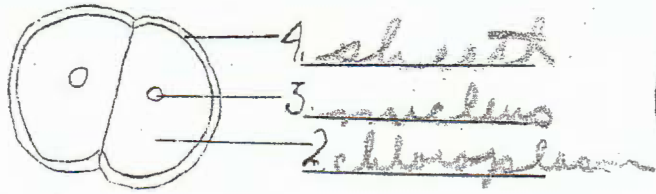
Enumerate the stages in a swamp succession.

Enumerate the stages in a bog succession.

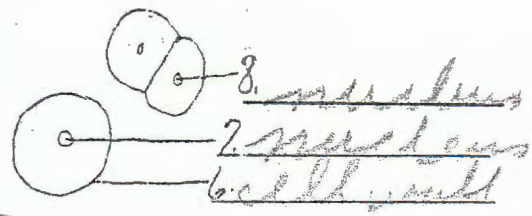
Enumerate the stages in a dune succession.

What do we call a plant which is adapted to very dry, light conditions? ______________. To very wet conditions? ________________. To conditions of medium moisture and light? __________________.

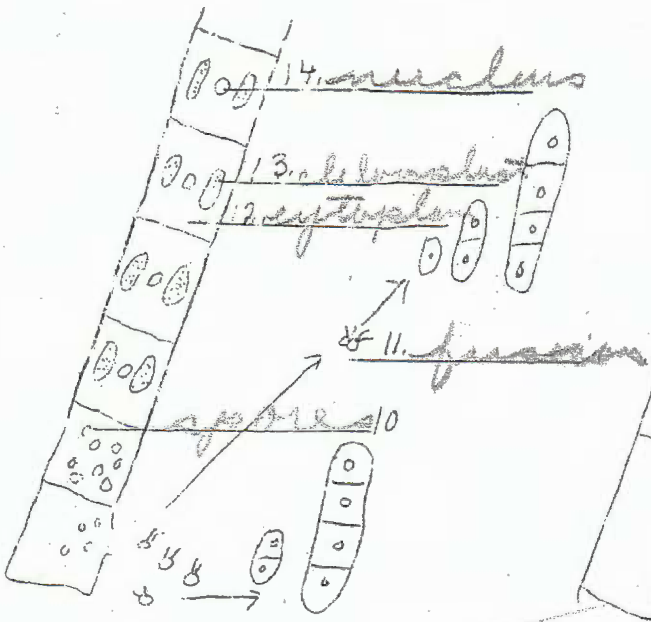
What do we call a group of plants which grow together in the same habitat? ____________________________________. What do we call the study of the relation of plants to their environments? ______________________________.



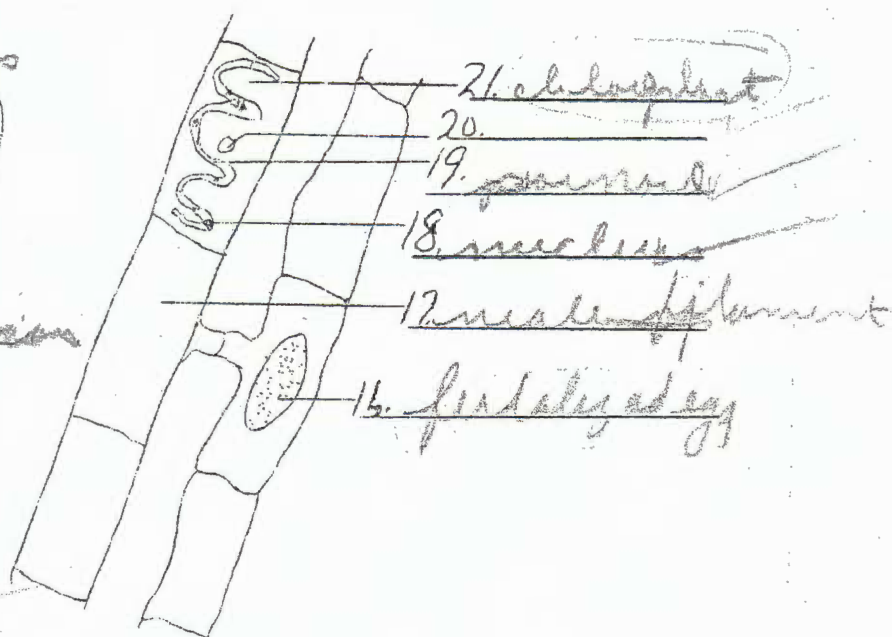
1. Gloeocapsa



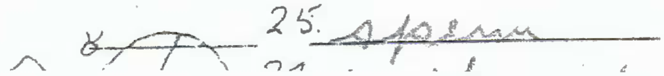
5. Pleurococcus



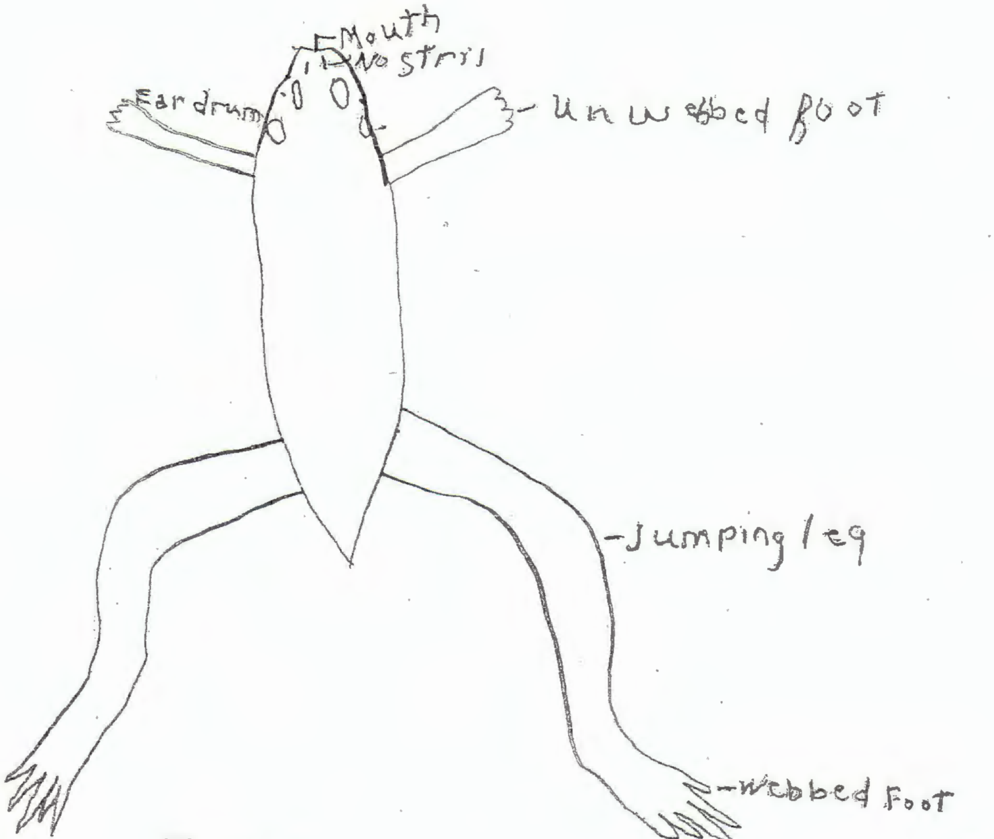
9. Spirogyra



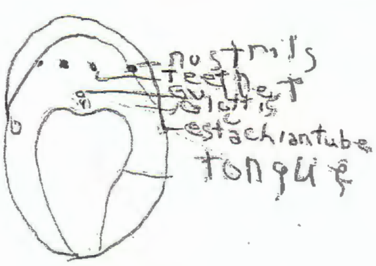
15. Spirogyra conjugation



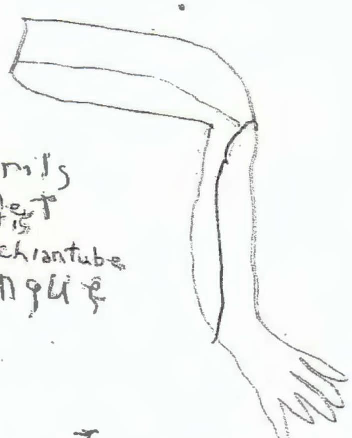
	Food Getting	Digestion	Absorption	Circulation	[illegible]	Excretion	Respiration	Mo[illegible]	[illegible]	[illegible]
Earthworm	mouth [illegible]	esophagus crop gizzard intestine	villi of intest.	5 hearts [illegible] blood	oxygen	[illegible]	moist skin	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] mandibles	esophagus [illegible] intestine	villi of intestine	heart 7 arteries blood	oxygen	[illegible] green [illegible]	gills	[illegible] walking legs	[illegible]	[illegible]
Fish	Mouth	Stomach intestine	villi in intestine	veins arteries heart blood	oxygen	[illegible] kidneys	[illegible]	fins tail [illegible]	lateral line [illegible] nostrils	[illegible]
Frog	mouth tongue	Stomach Intestine	villi of intestine	veins arteries heart blood	oxygen	bladder? kidneys [illegible]	2 lungs glandular skin	legs	eyes nostril [illegible] ear	[illegible]



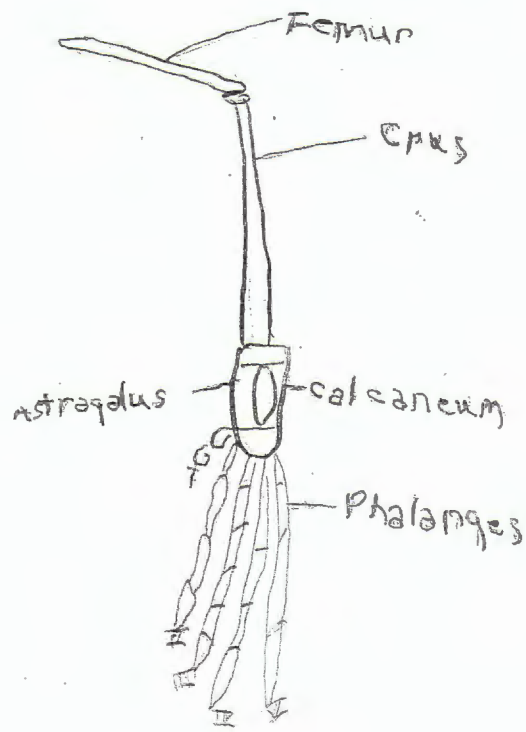
Frog

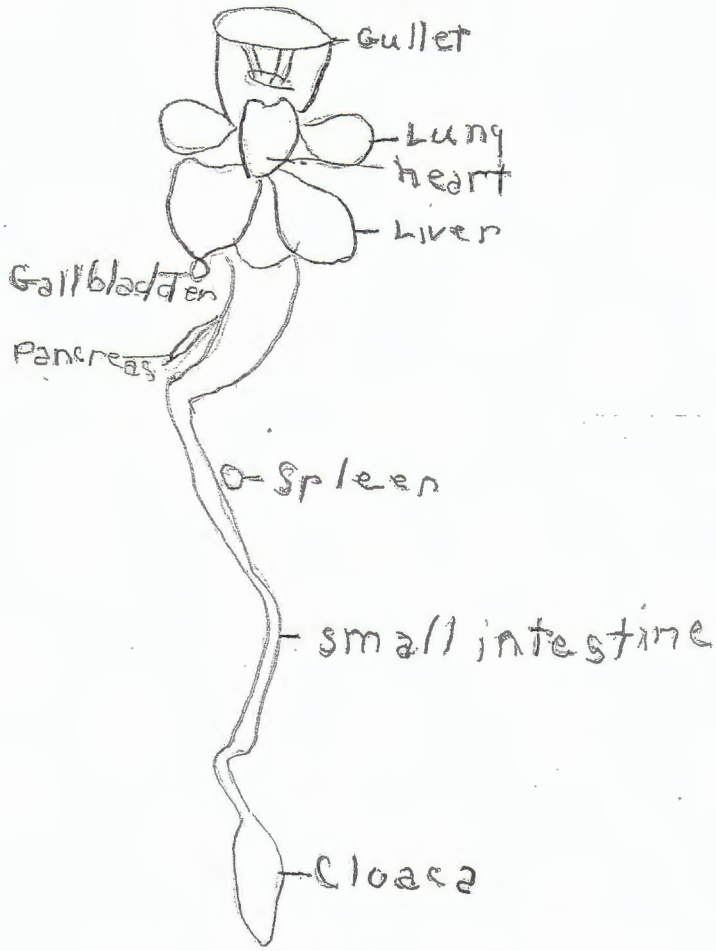


Mouth of frog

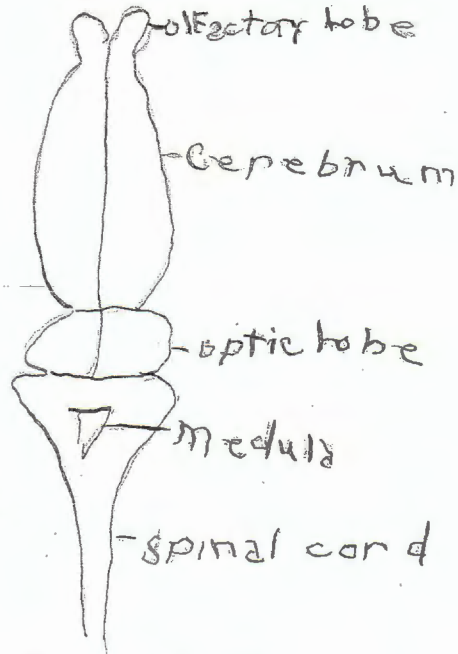


Jumping leg

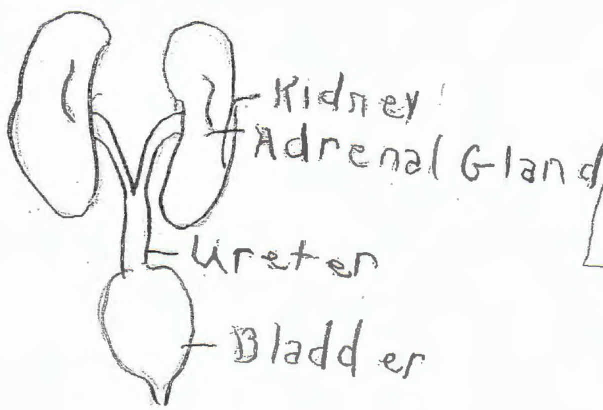


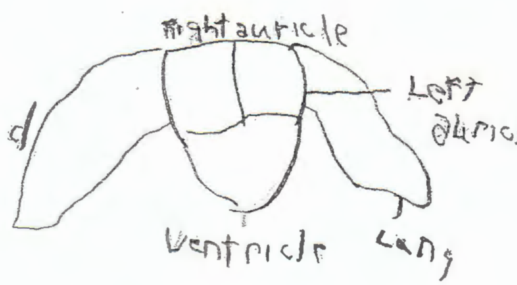


Food Tube of Frog

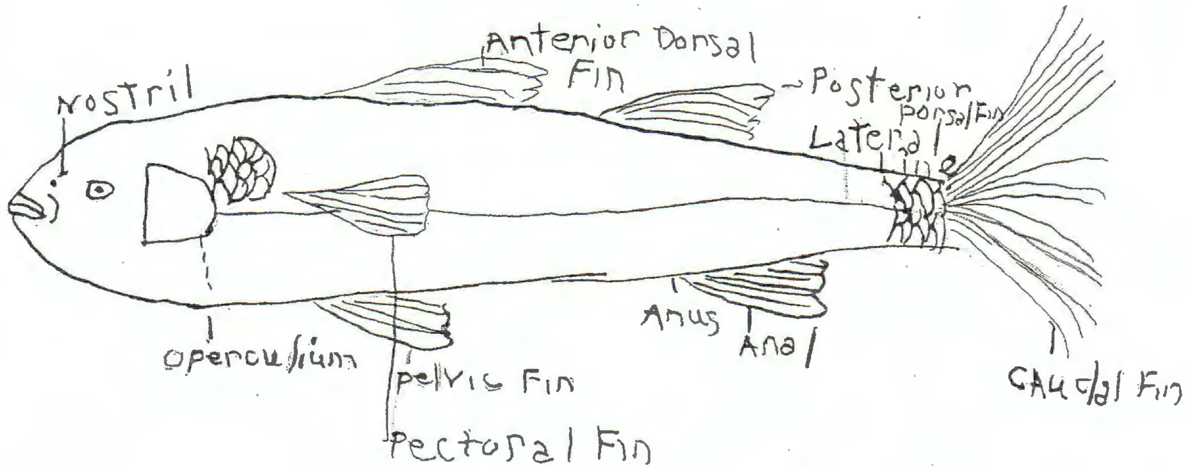


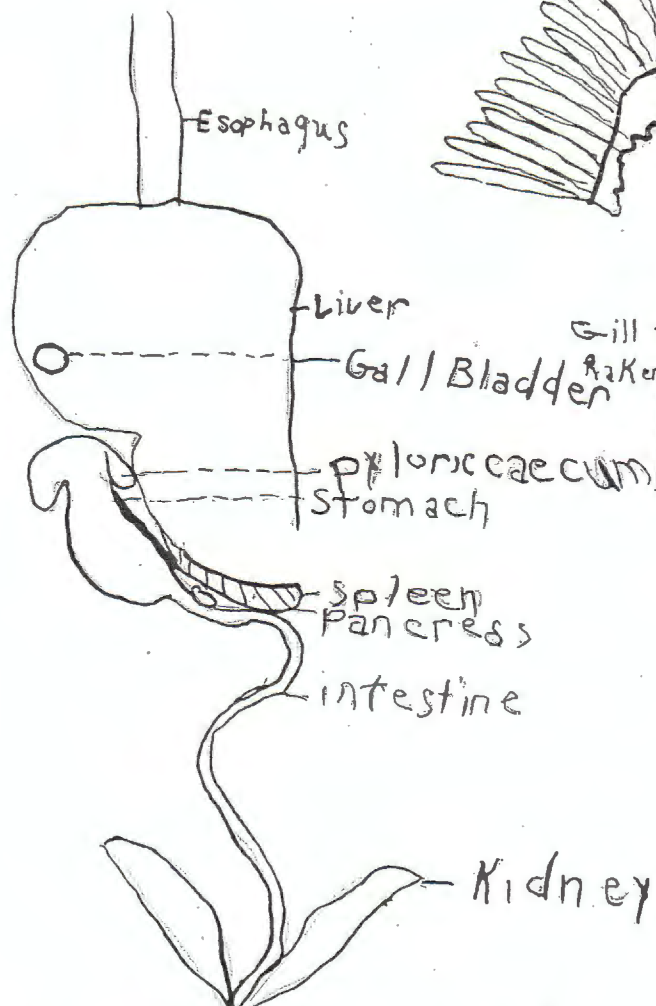
Brain of Frog

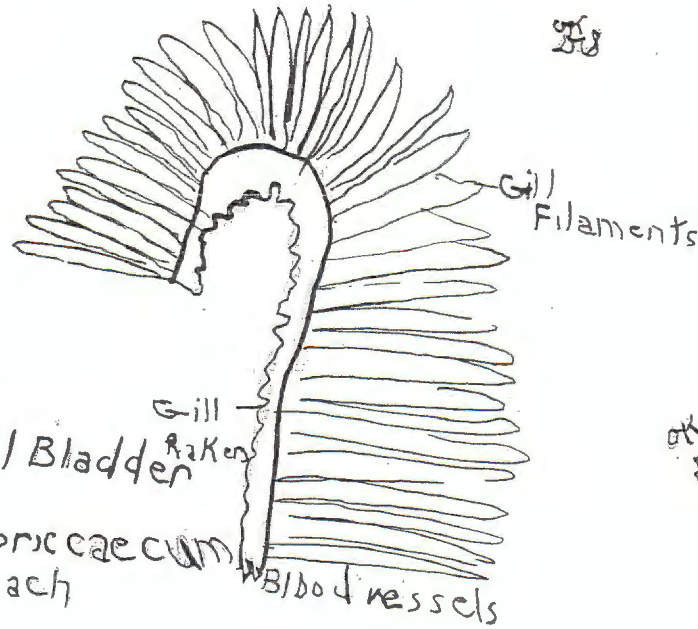




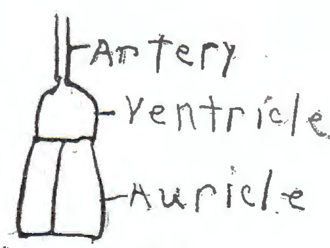
Heart and Lungs



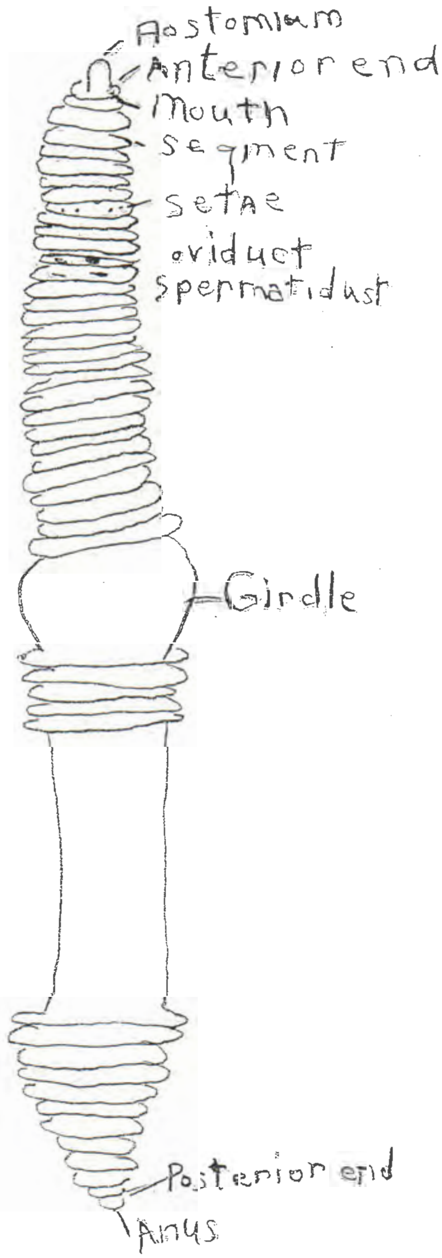




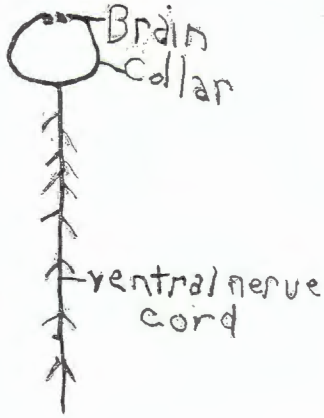
Internal structure of fish



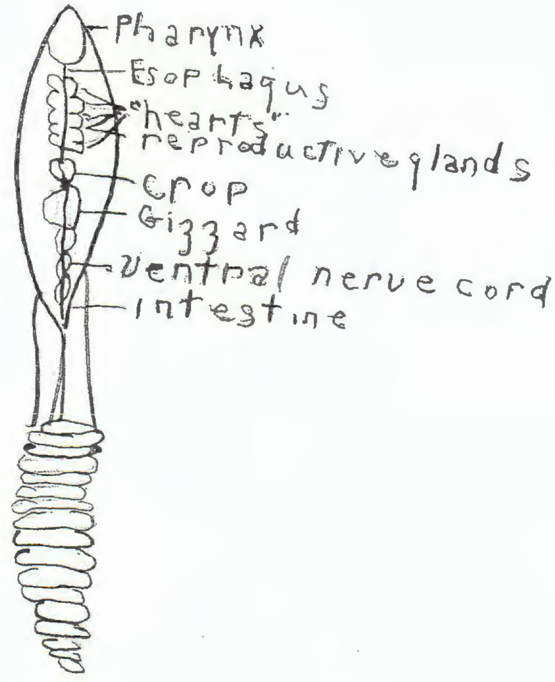
Heart of fish



ventral vein
of an Earthworm

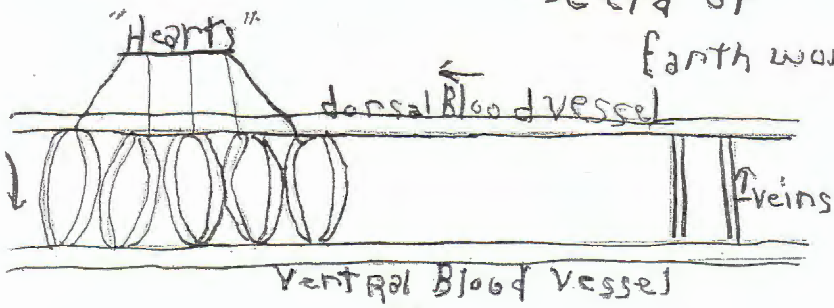


Nervous System



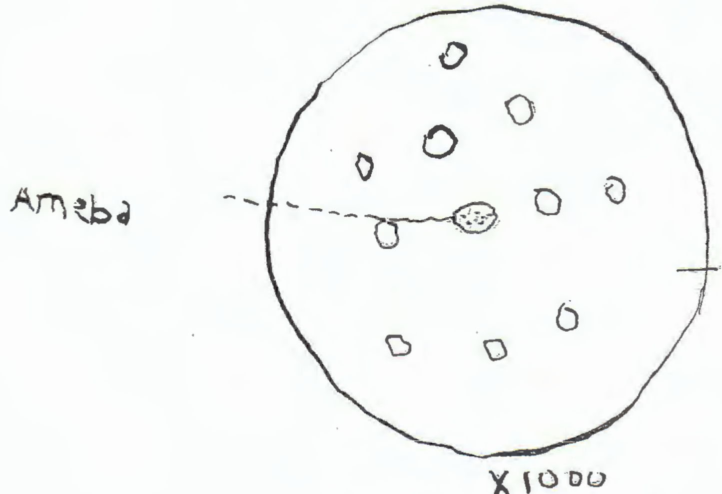
Viscera of Earth worm

OK DCS

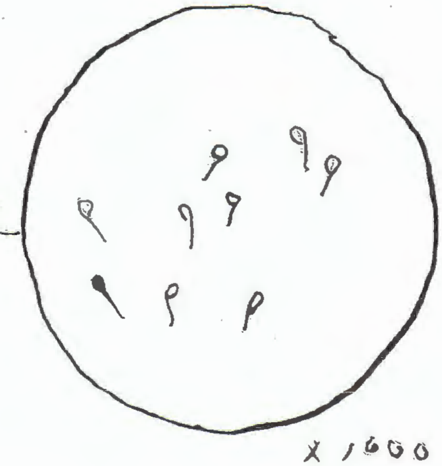


Circulation of Earthworm

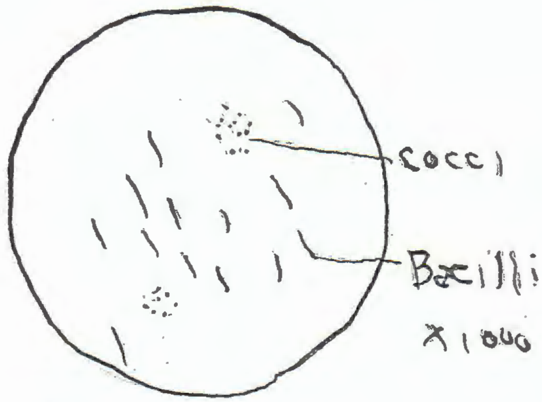
Betty Hofmann



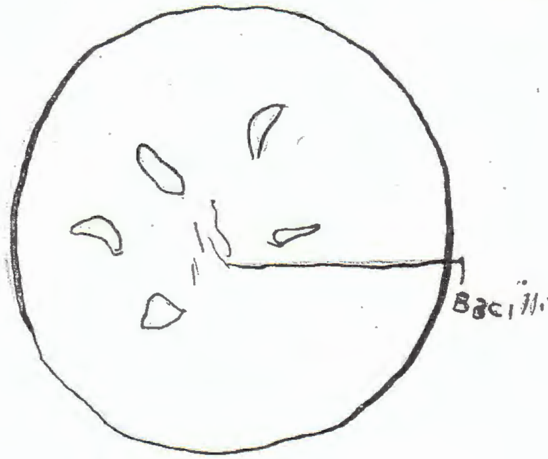
Human Blood showing malaria



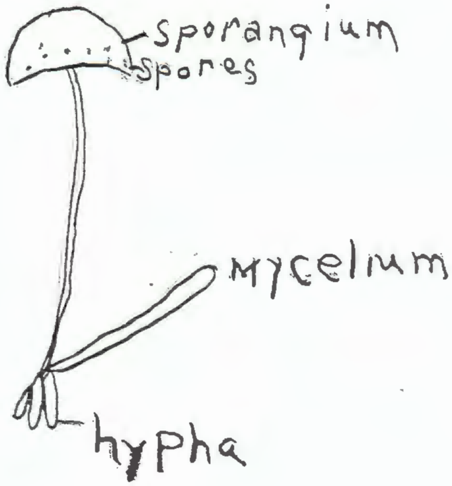
Gas Bacilli



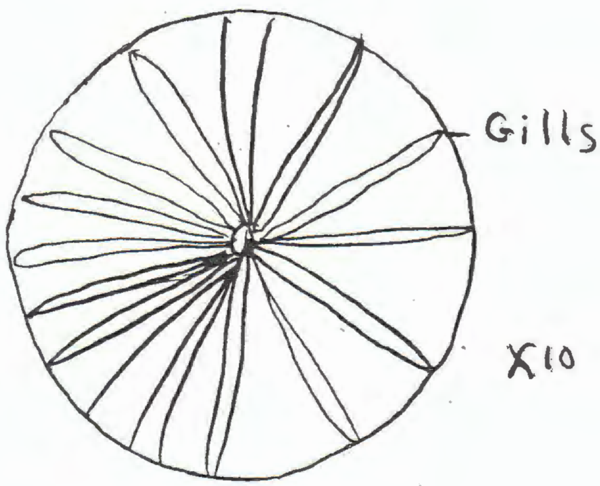
Smear From Mouth



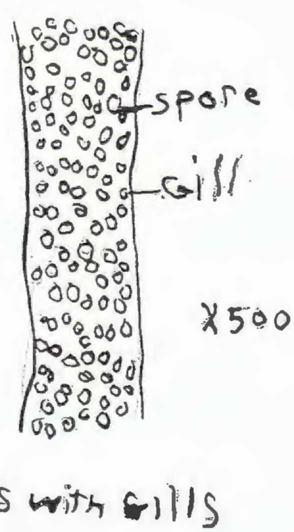
Trench mouth



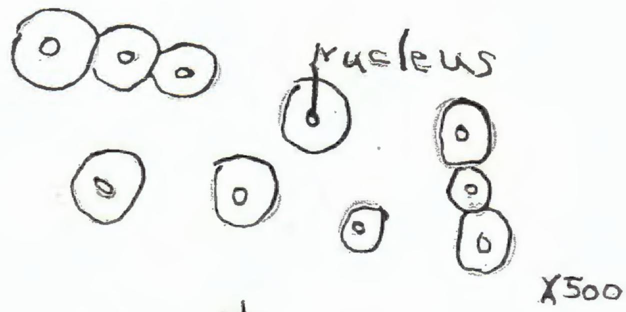
Mold



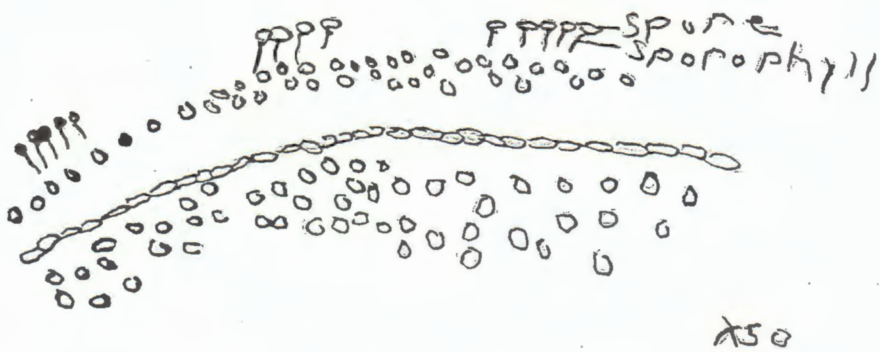
Mushroom



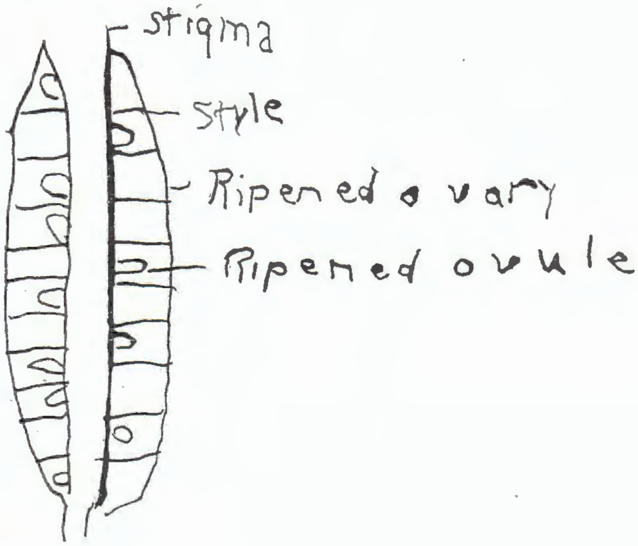
Mushrooms with gills



yeast

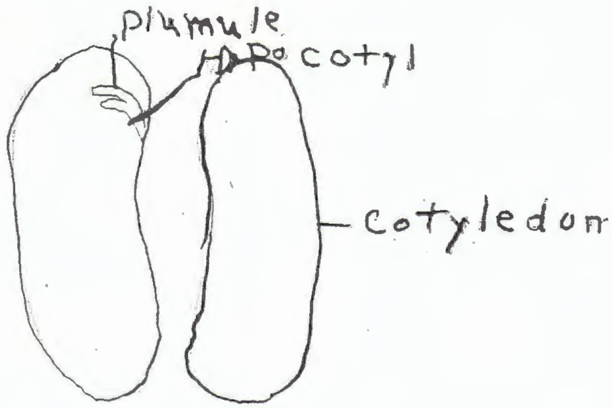


Wheat Rust



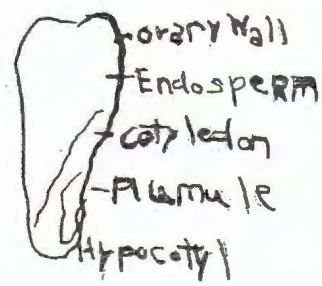
Locustpod

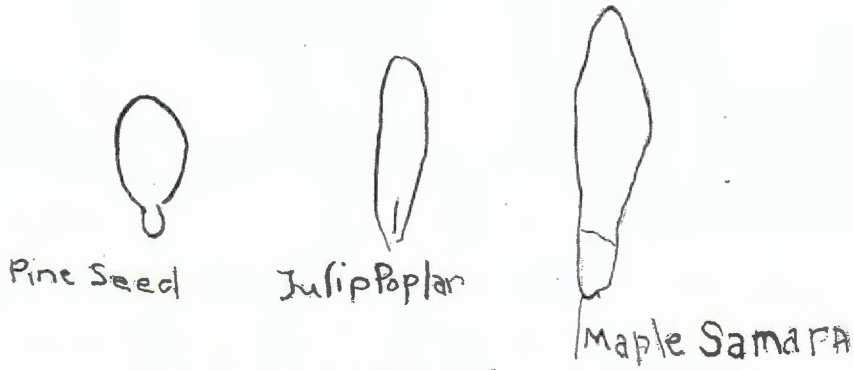
Bean



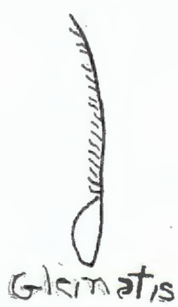
Embryo of Bean

OK



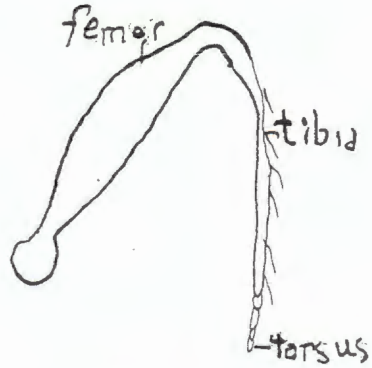


Seeds With Wings



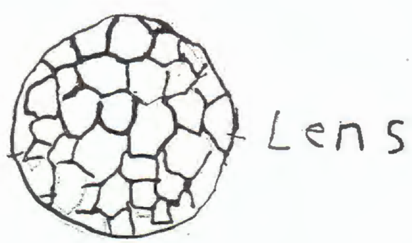
Seedswith feathery Attachment

Seeds with Hooks



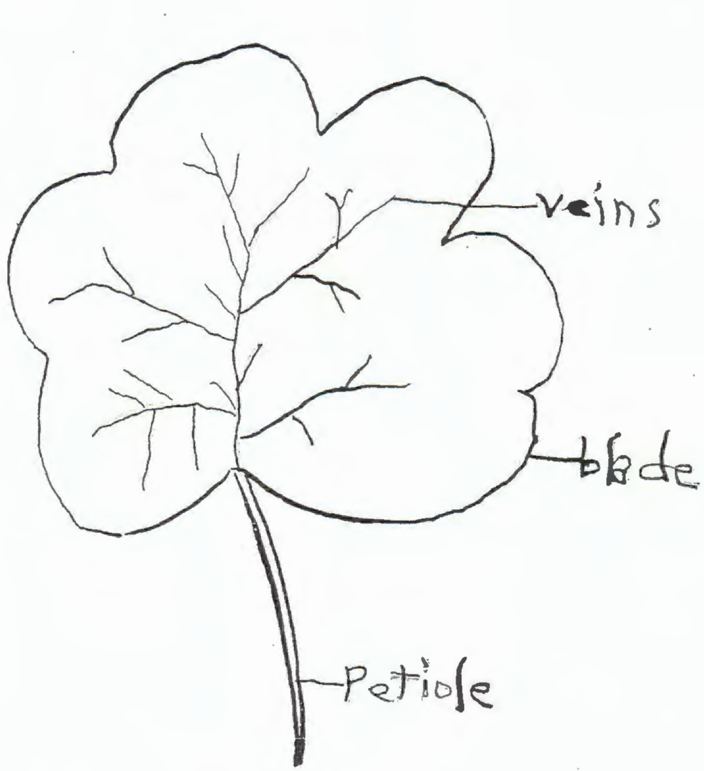
Jumping Leg


Lower wing

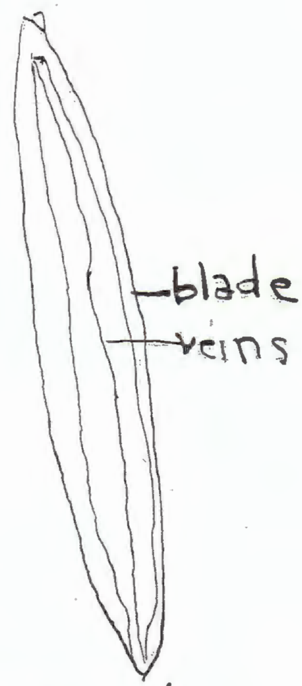



upper wing

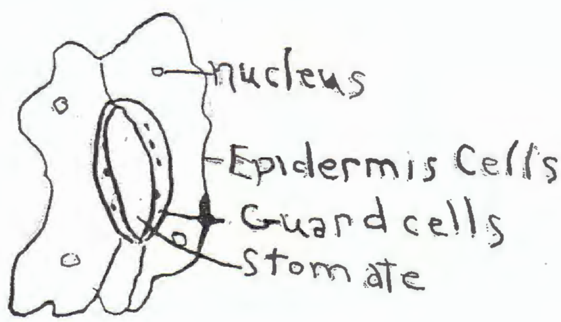
Side of GrassHoppers Head



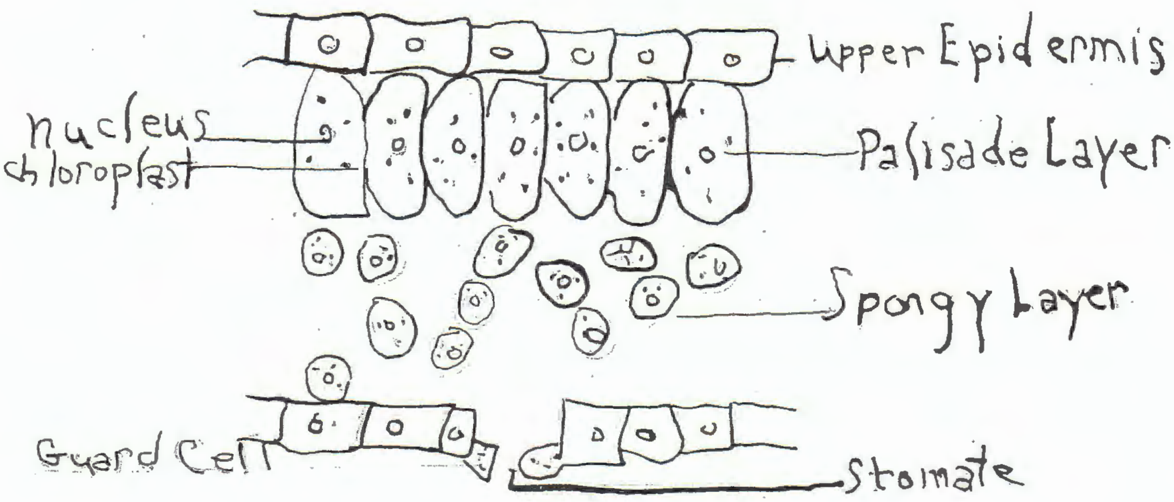
Dicot Leaf



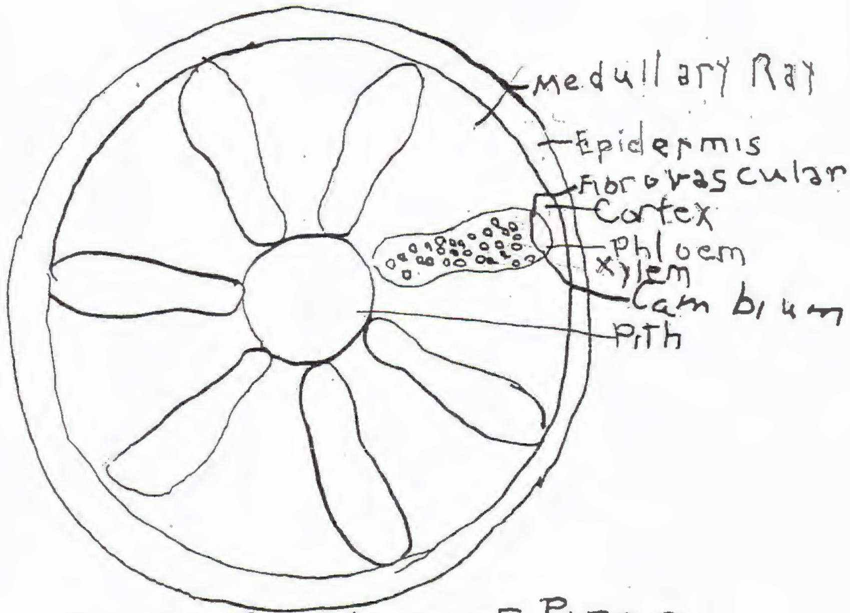
Monocot



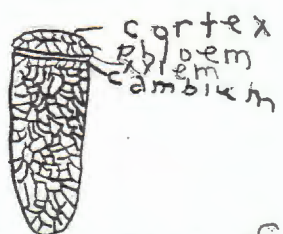
Lower Epidermis
of
Geranium



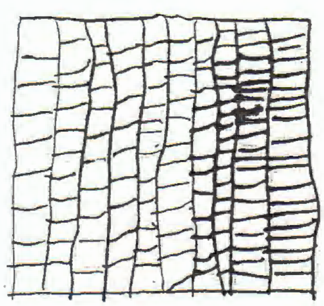
Cross Section of Leaf



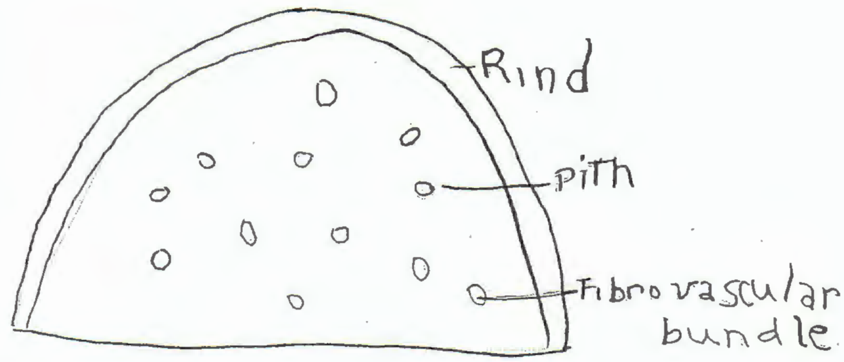
cross Section of Piper



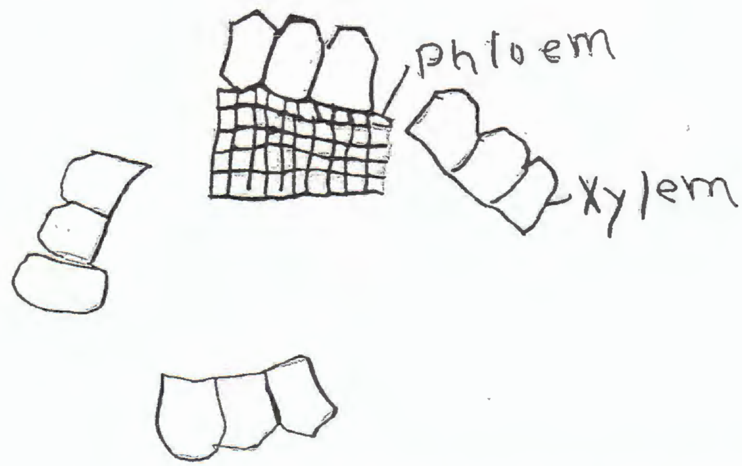
cross Section of stem of Piper



Annual wreath of pine

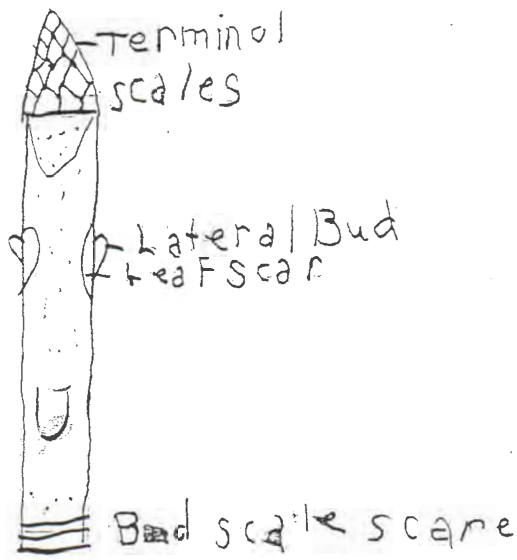


cross Section of Monocotyledon Stem.



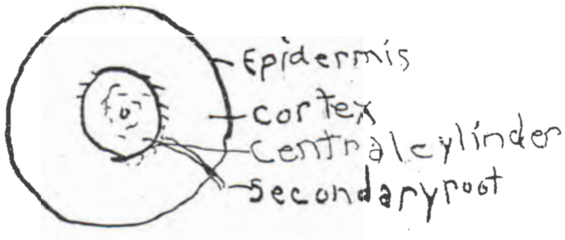
Fibrovasculan bundle

OK
Dcs

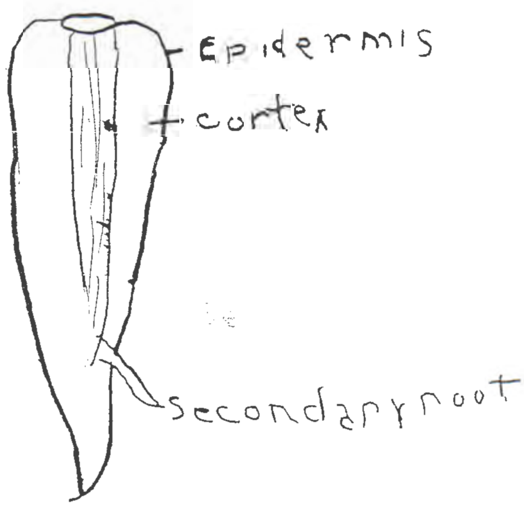


Twig of Horse Chestnut

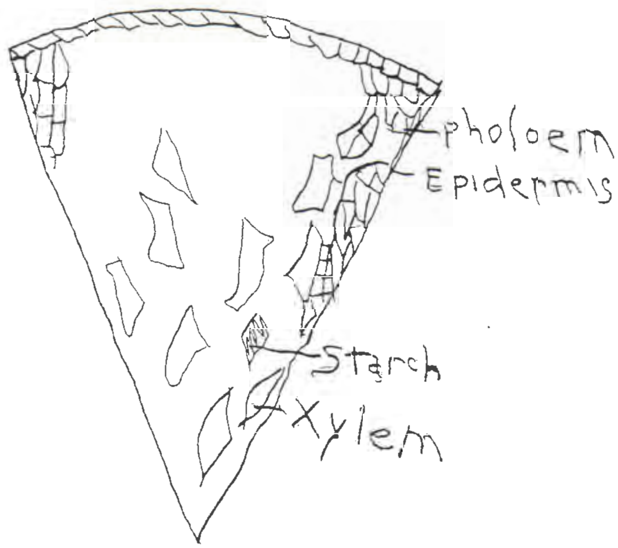
Ks



Cross Section Of Carrot

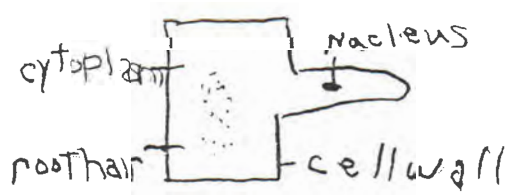


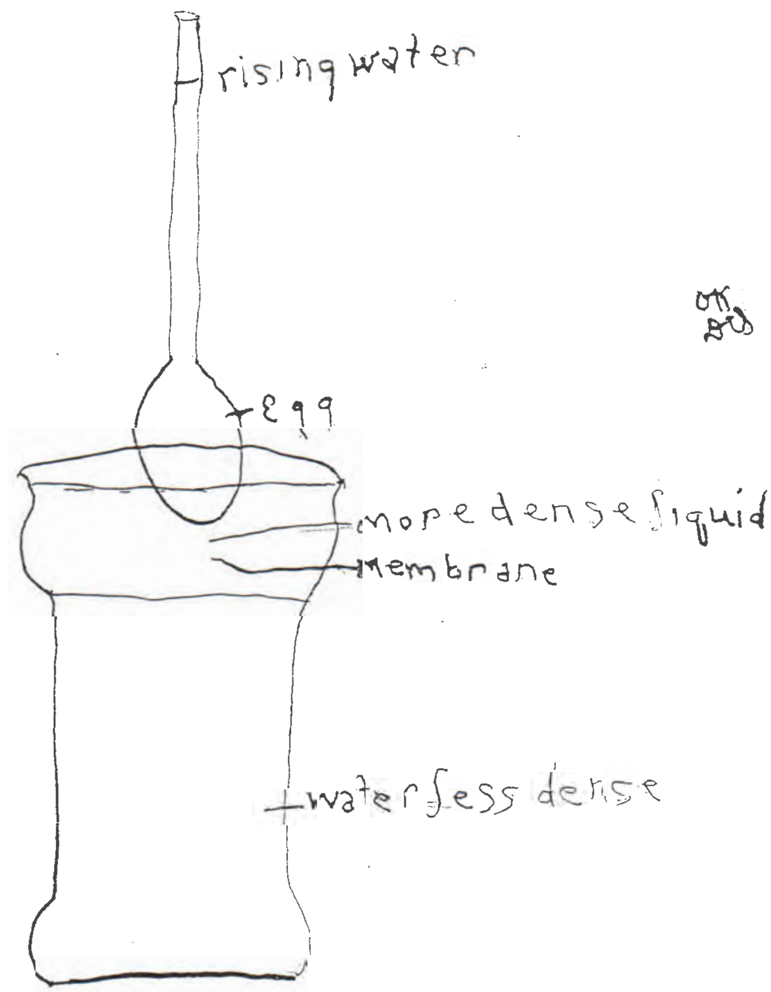
OK
DS.



Cross Section root

OK

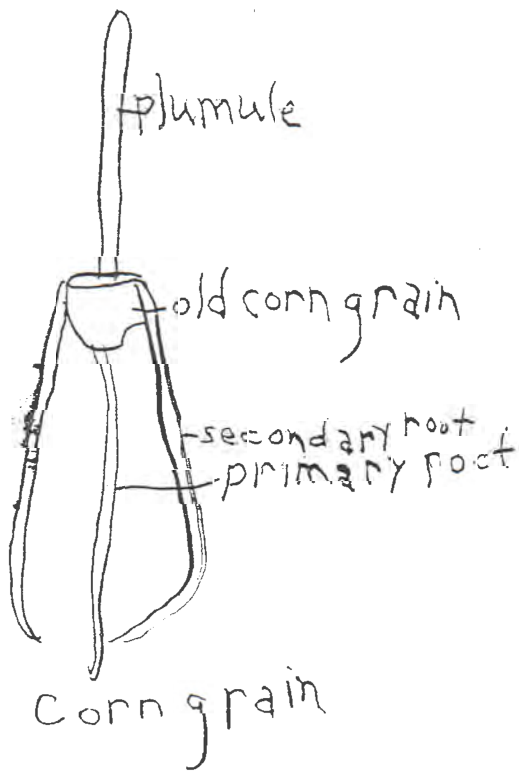




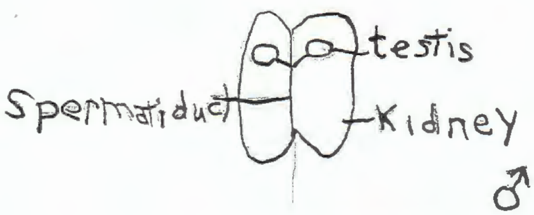
rising water
egg
more dense liquid
membrane
water less dense

Osmosis

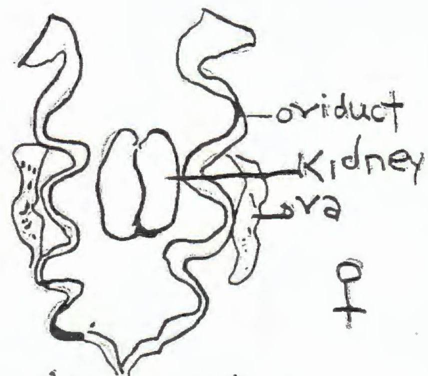
Germination of a bean



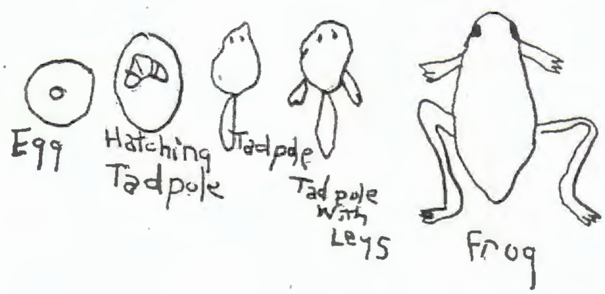
Corn grain

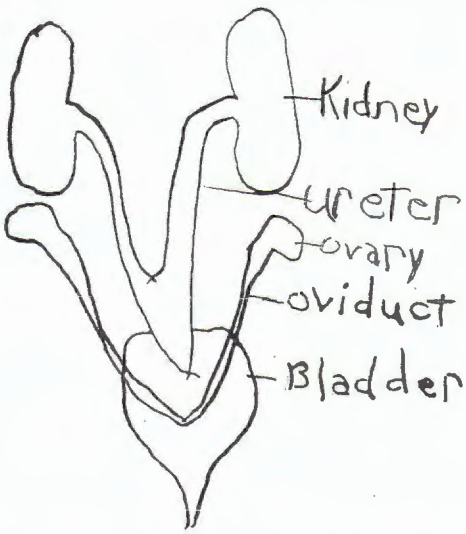


Urino-genital System of a Frog



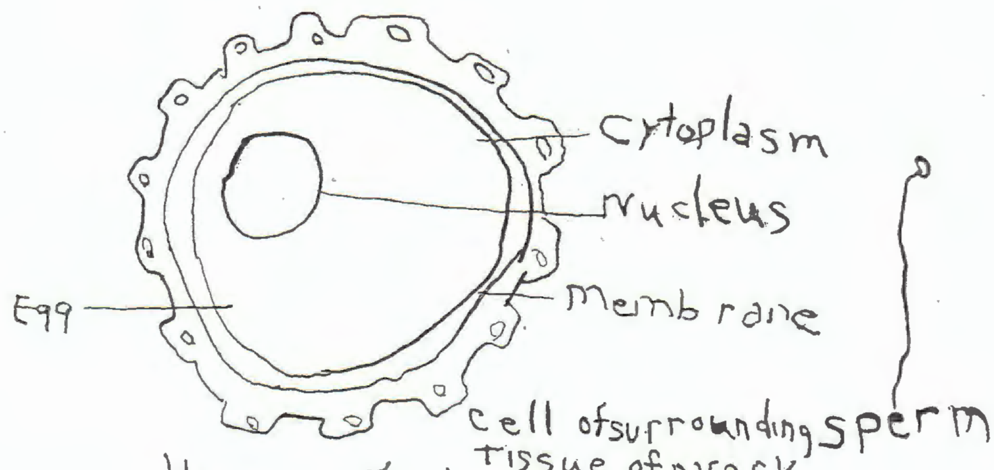
Urino-genital System of a Frog





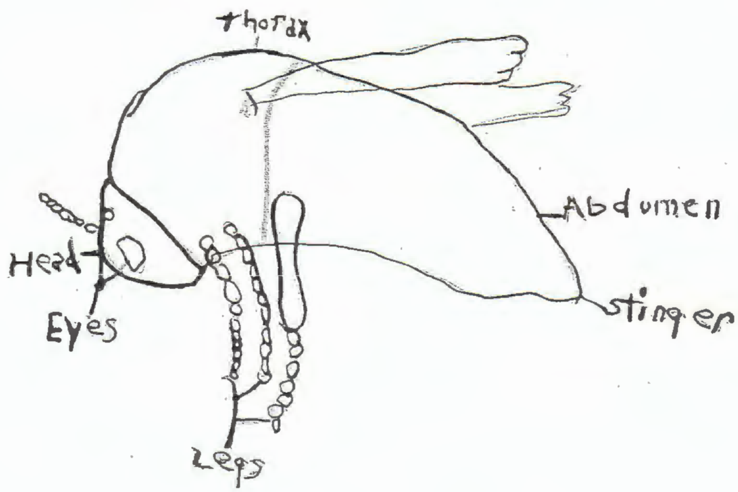
Urino-genital System of ♀ Cat

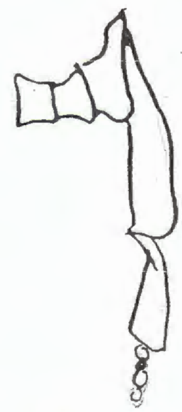

Chick Embryo



Human Embryo

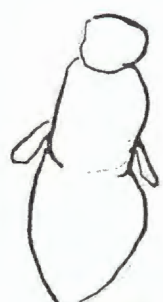
from Prentiss Arey



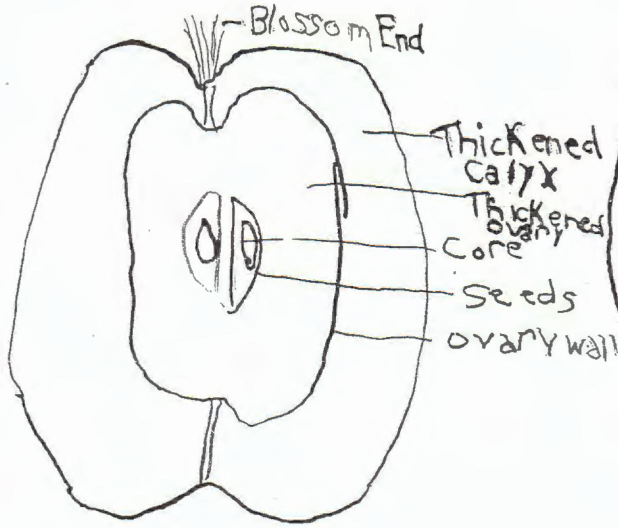


Bees
Hind Ley

Larva



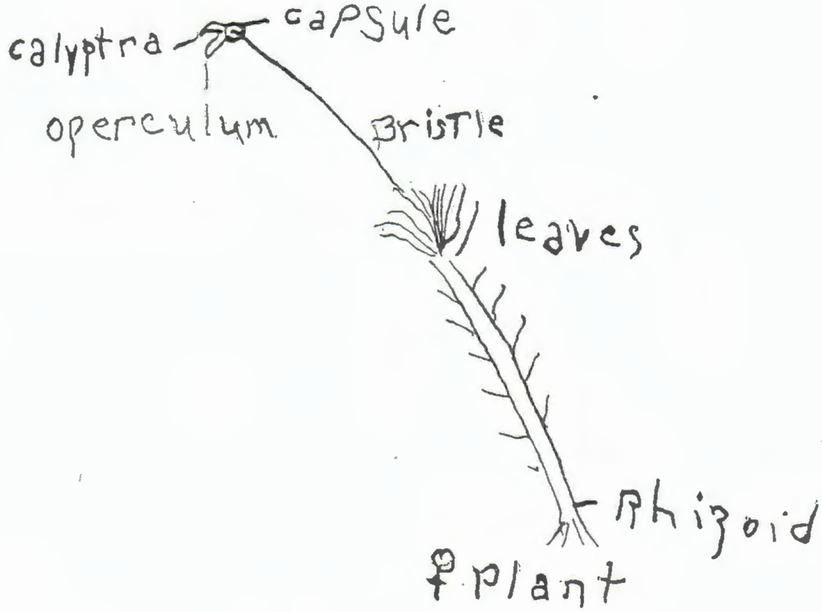
Pupa


Blossom End
Thickened calyx
Thickened ovary
Core
Seeds
ovary wall

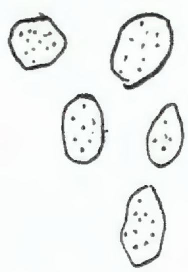
Apple


Seeds
Core
Thickened ovary
Thickened calyx

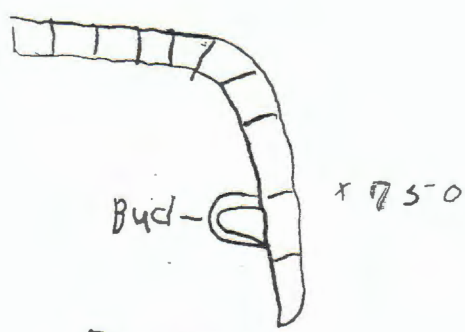
Apple



Moss Plant



Spores



Protomema

Archegonium
moss X50

Antheridium

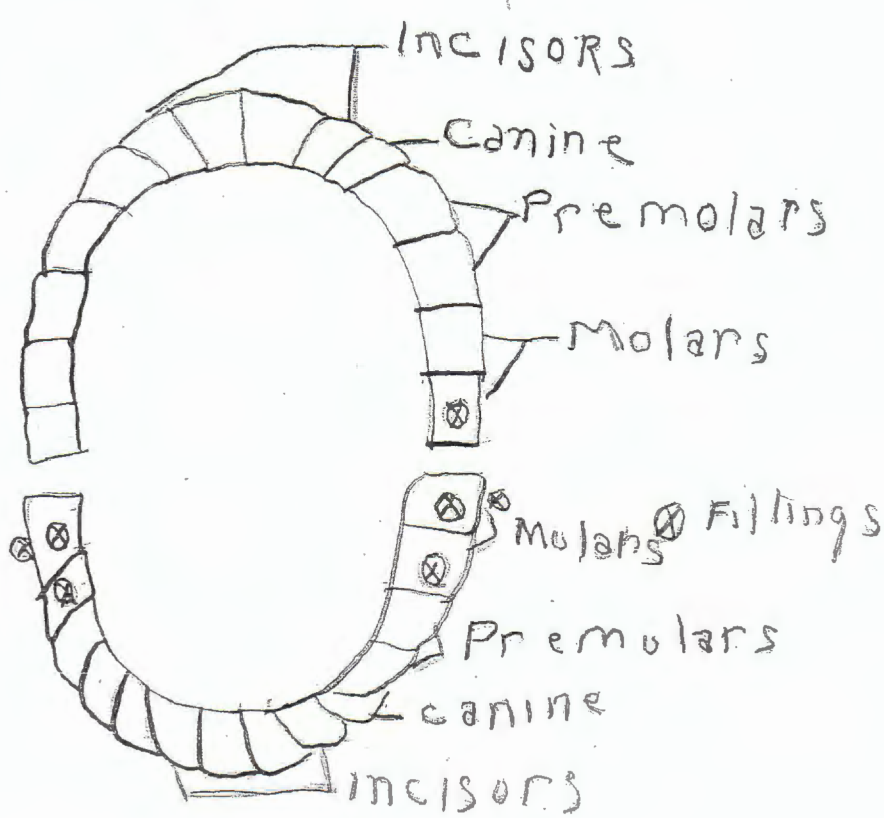
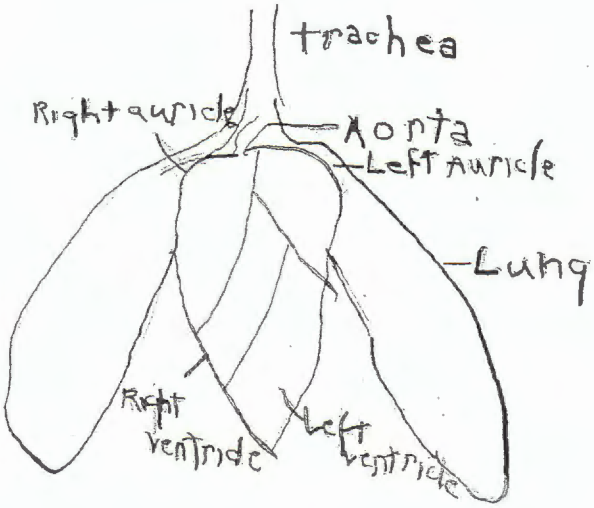
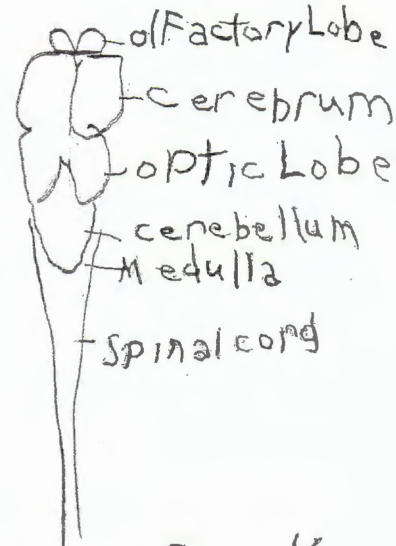
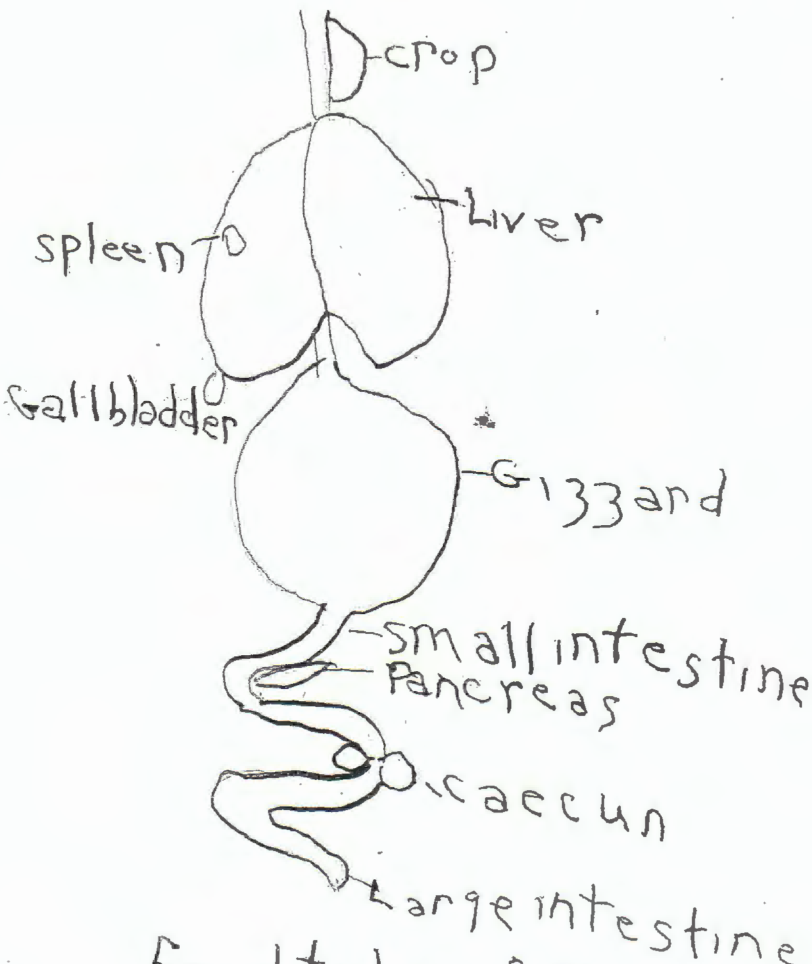


Diagram of Mouth

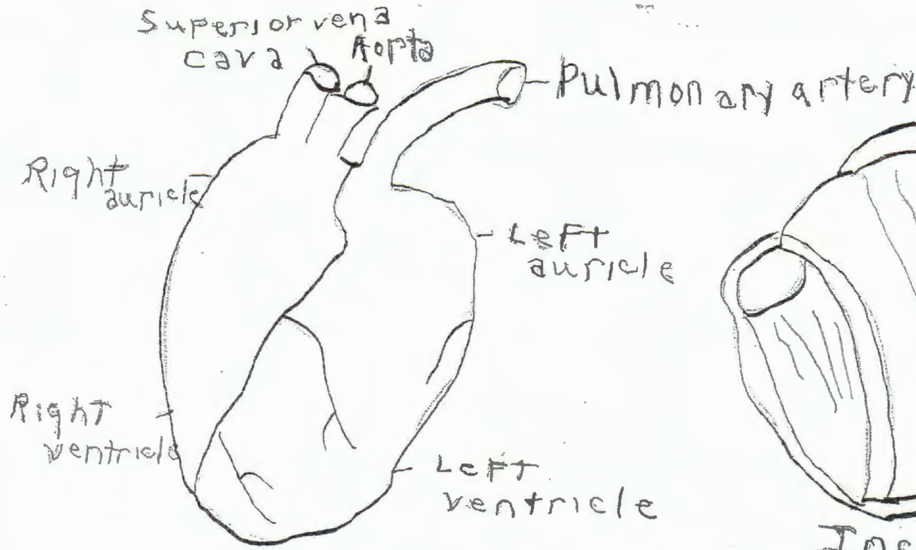


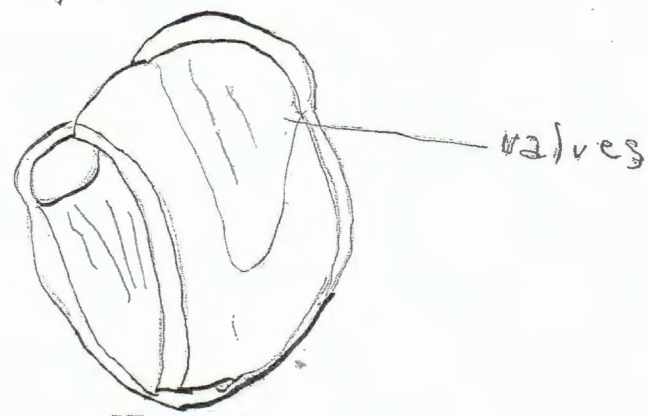


Brain of Chick



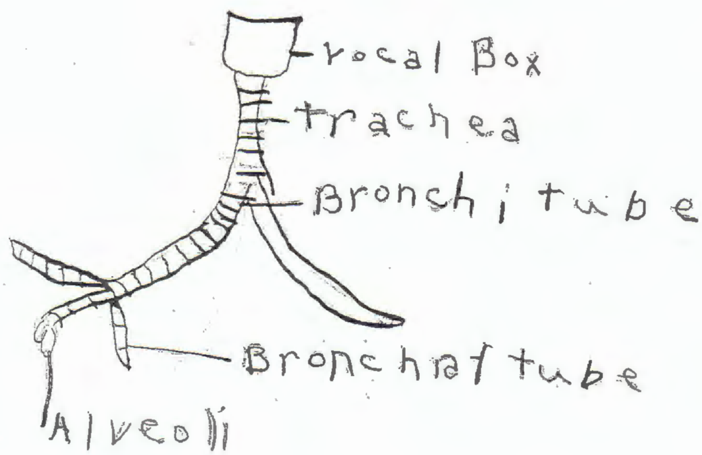
Foodtube of Chick



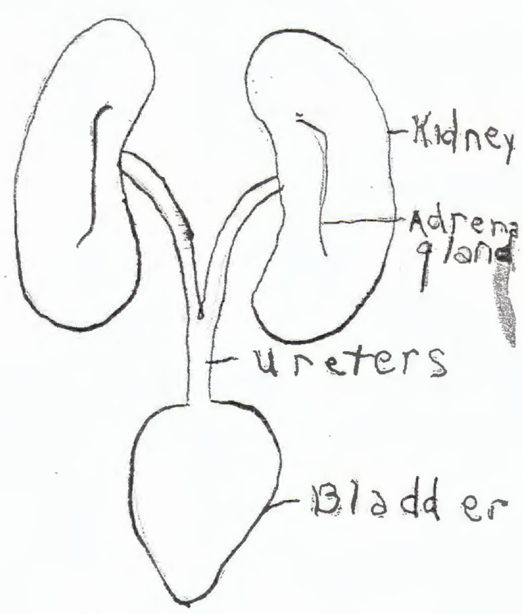


Insideveiw

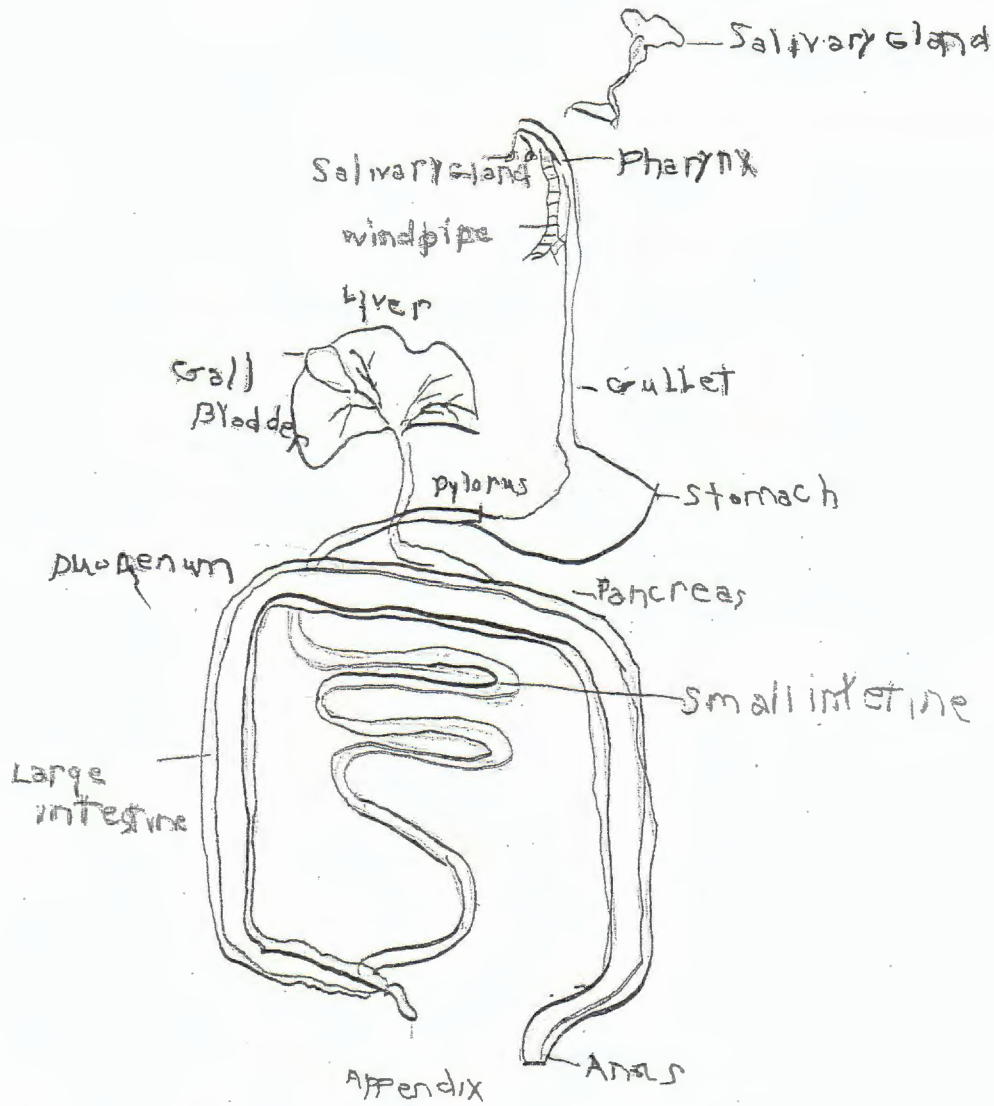
Heart of Human



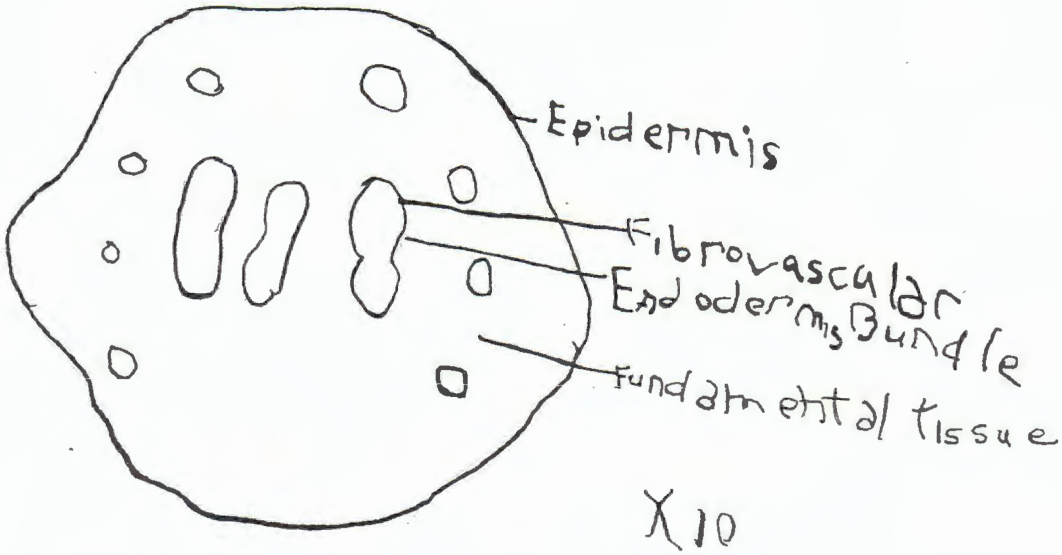
Lungs of Human



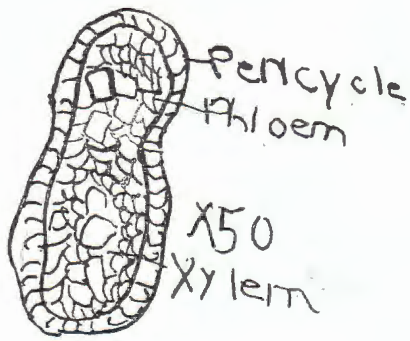
Kidneys of Human



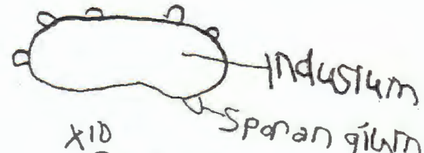
Alimentary Canal of man



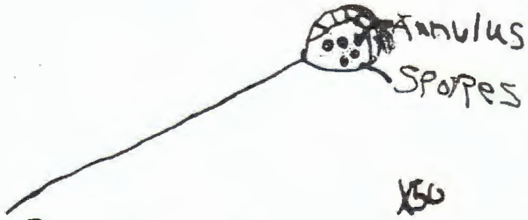
Cross section of fern Stem



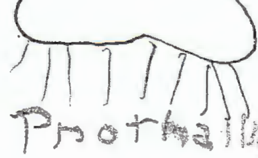
Fibrovasculal Bundle



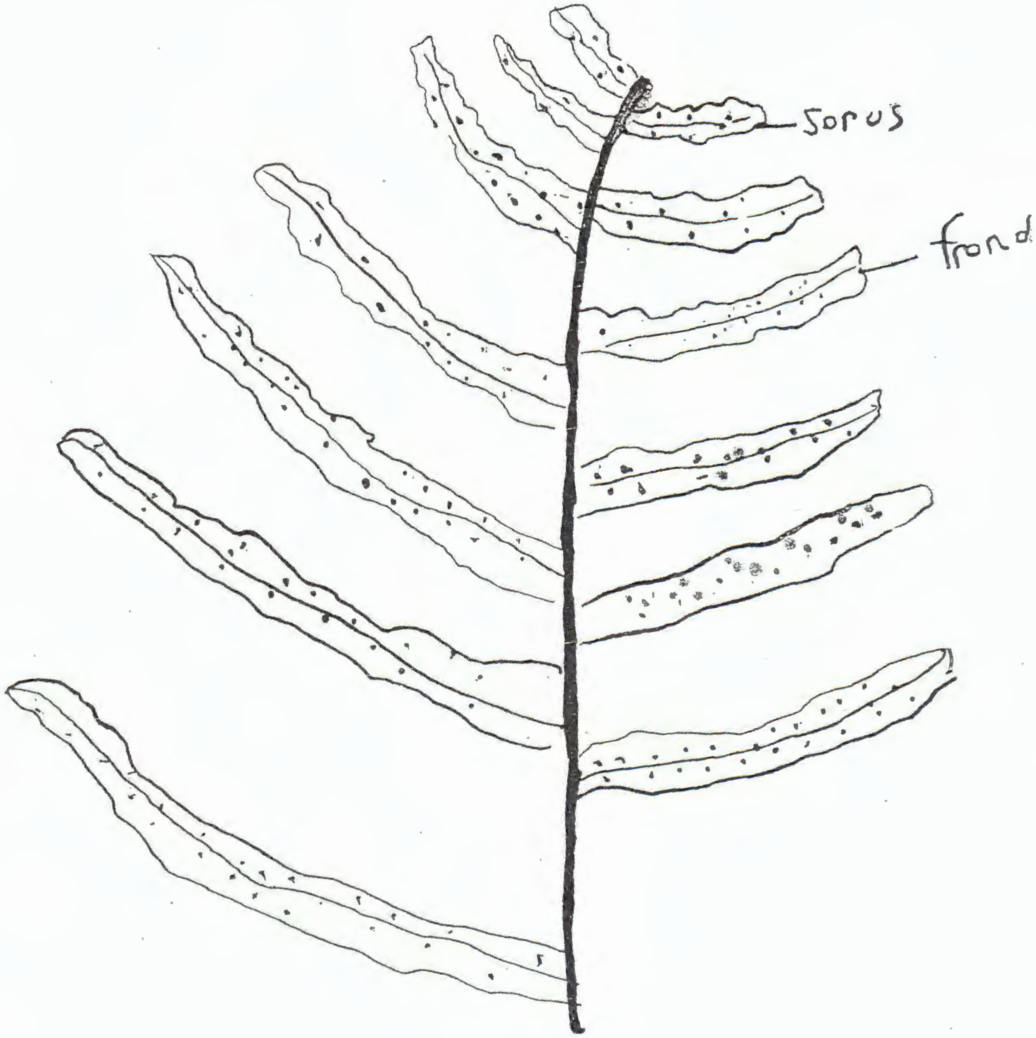
Sorus



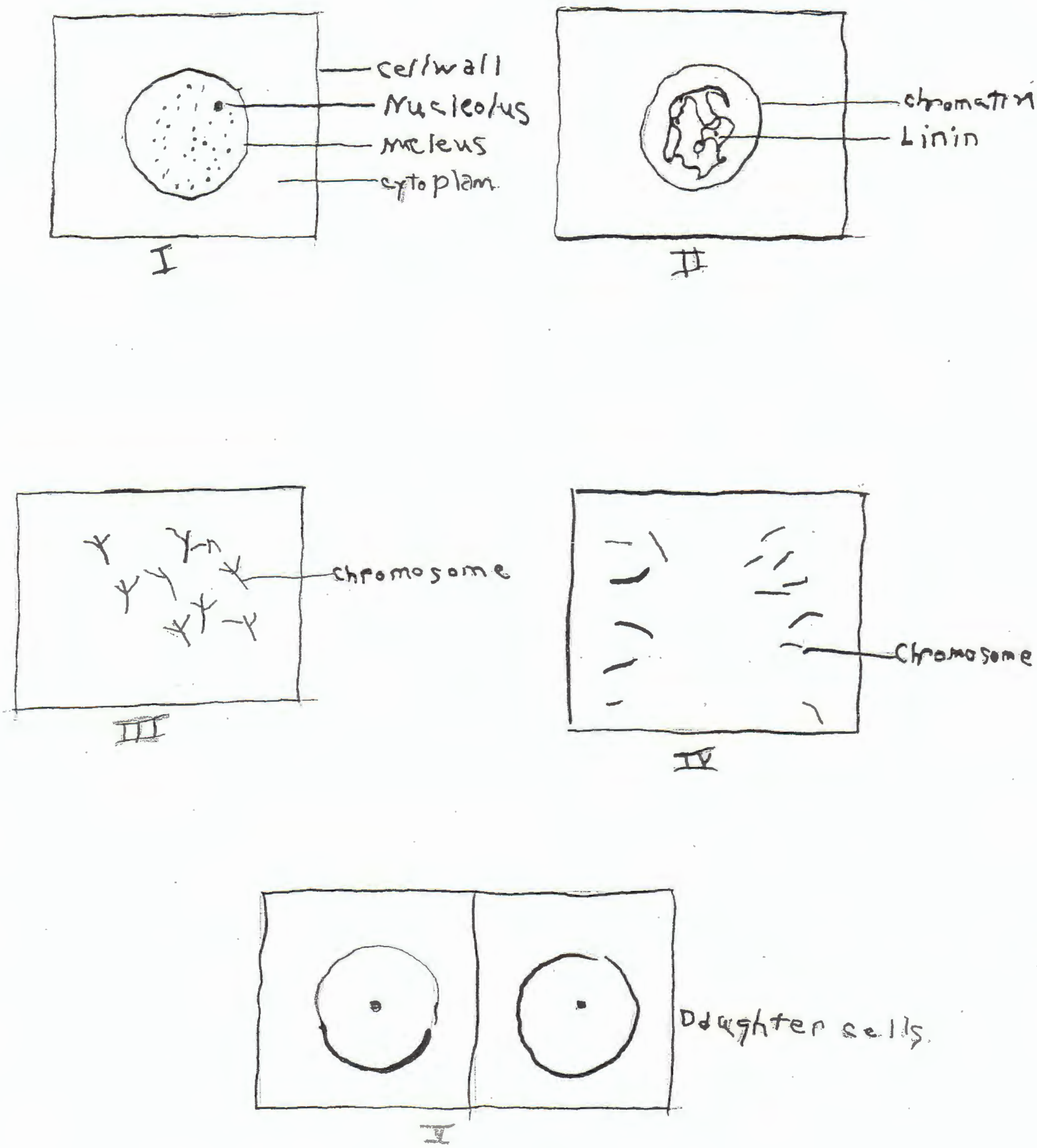
Sporangium



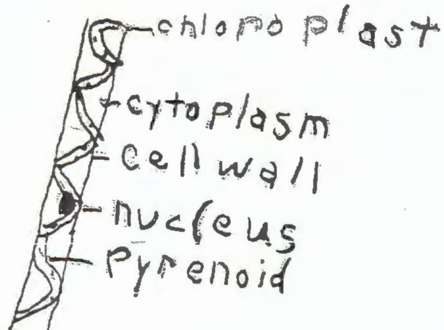
Prothalla



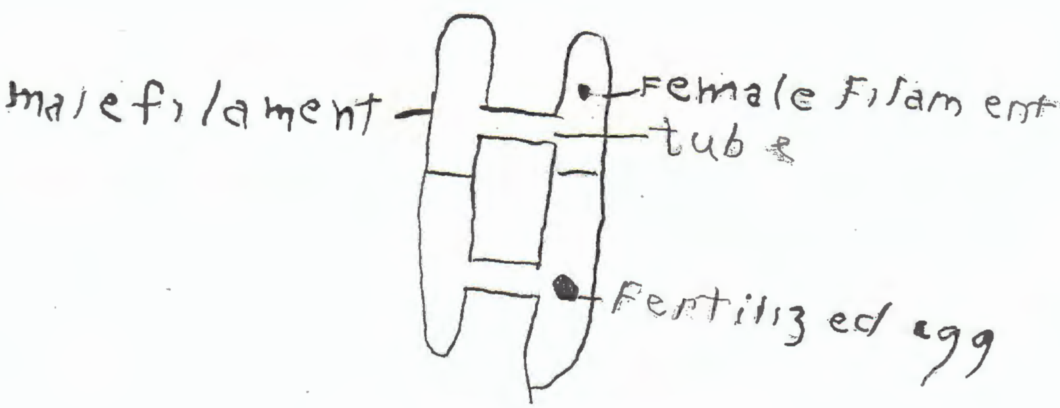
fern



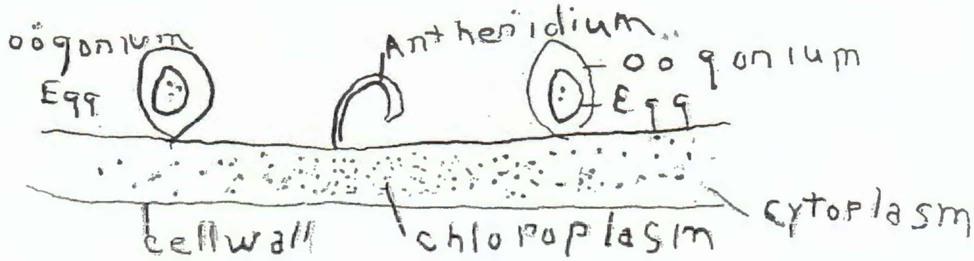
Mitosis in Onion Root tip. X1000



filament of a
Spirogyra Cell.
X50



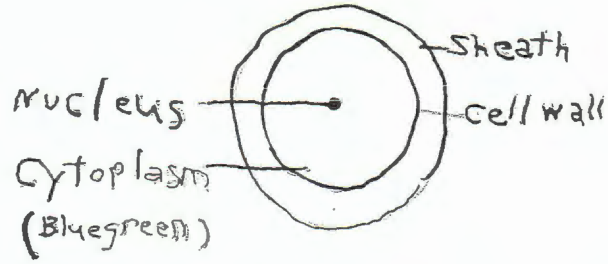
Conjugation X50
Spirogyra



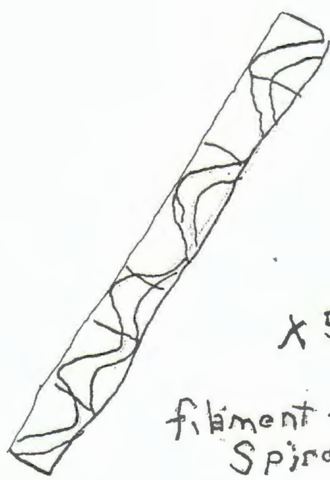
Vauchepia x50

ok
88

Betty Hof



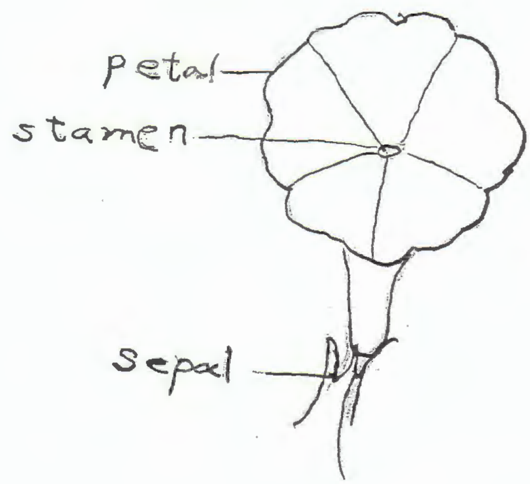
Gleocapsa
from Smith



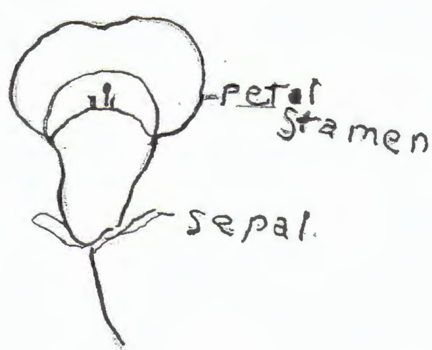
x50

filament from
Spirogyra

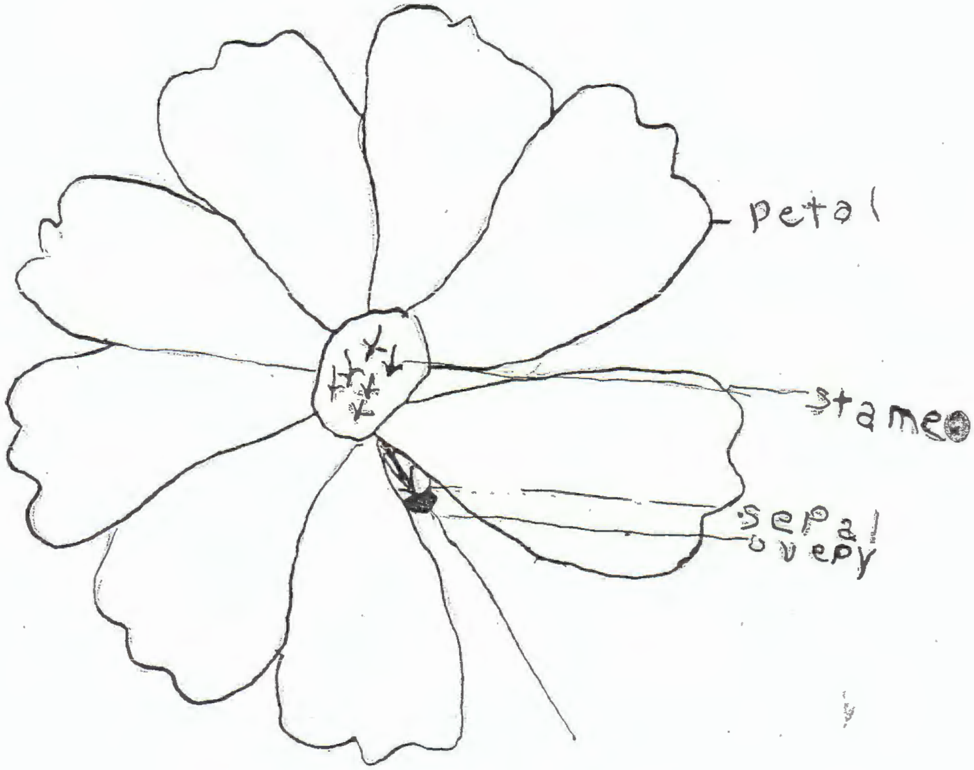
OK



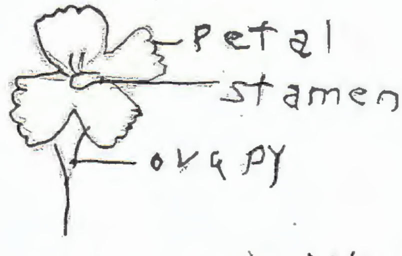
Petunia



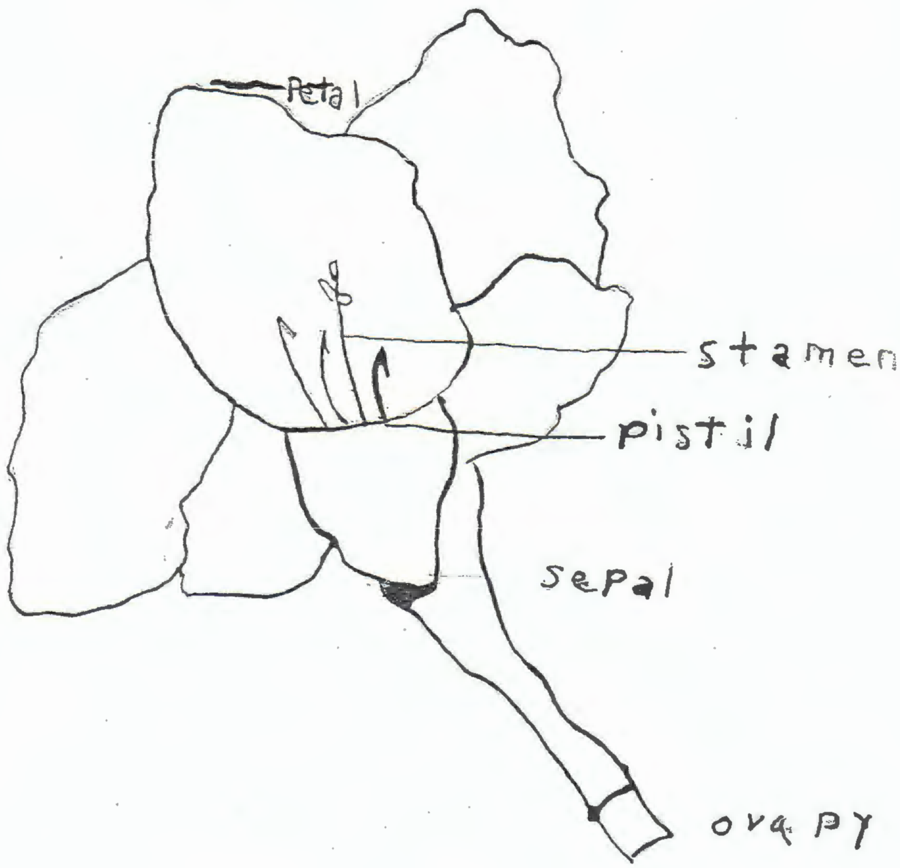
SnapDRagon



Cosmos



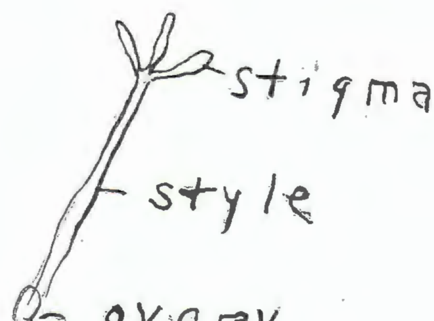
Sweet William



Gladiolus.

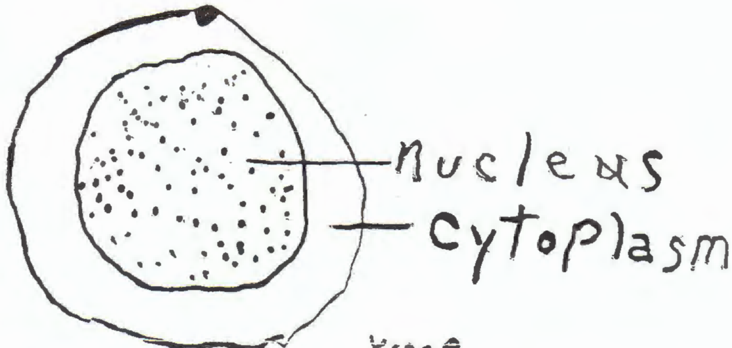
OK

Pistil



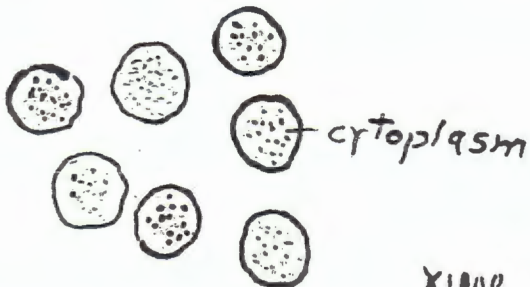
Stamen.

Human Blood



X1000

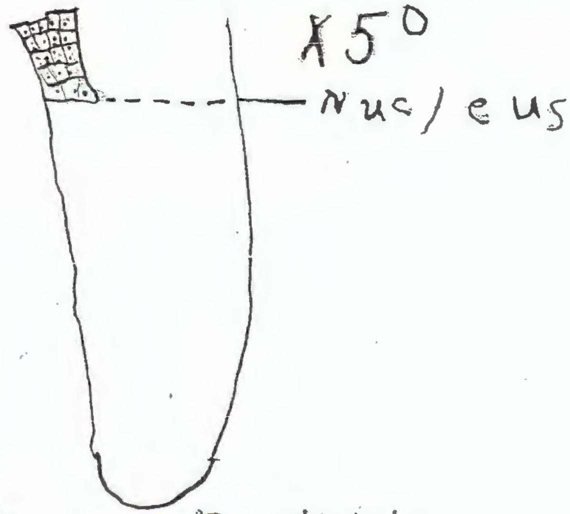
White Blood Cell



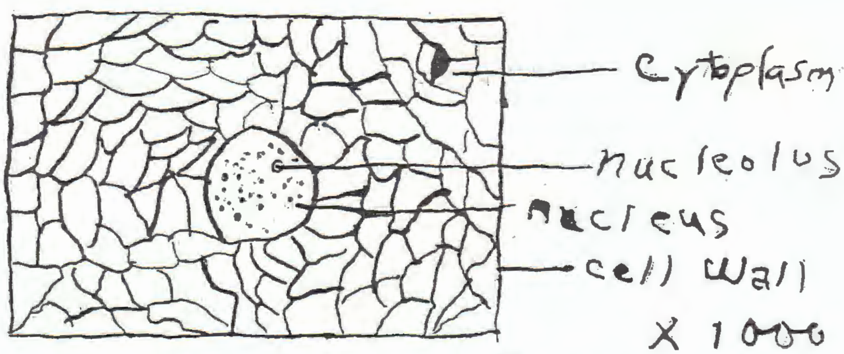
X1000

Red Blood Cells

OK DB

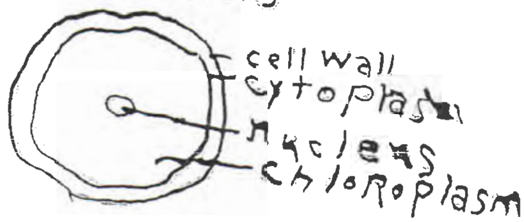


Onion Root tip

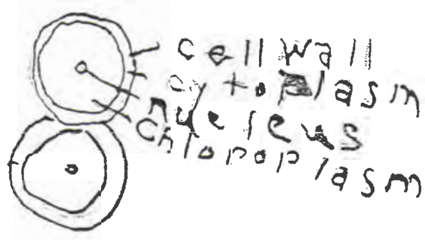


cell in Onion Root

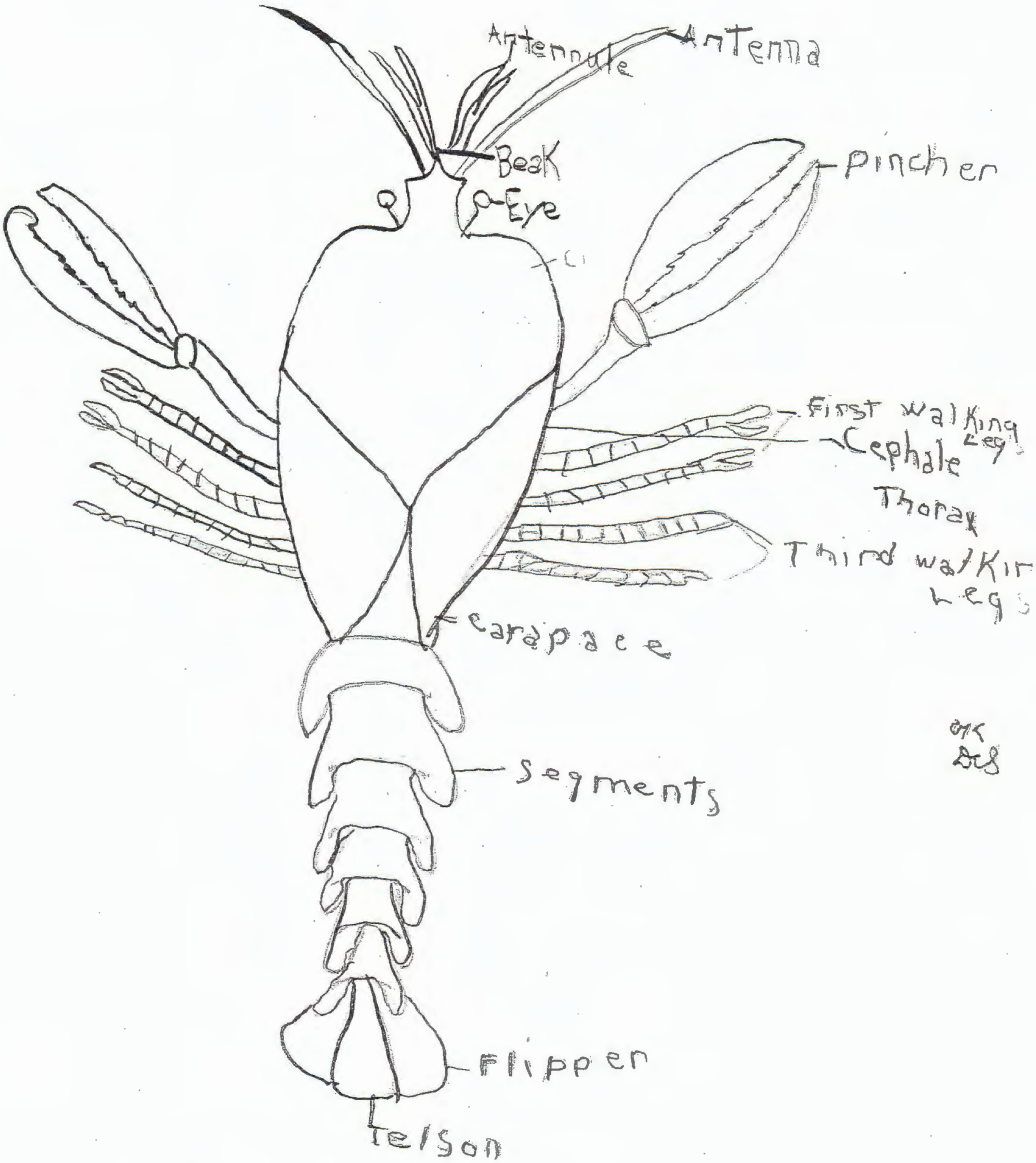
Pleurococcus



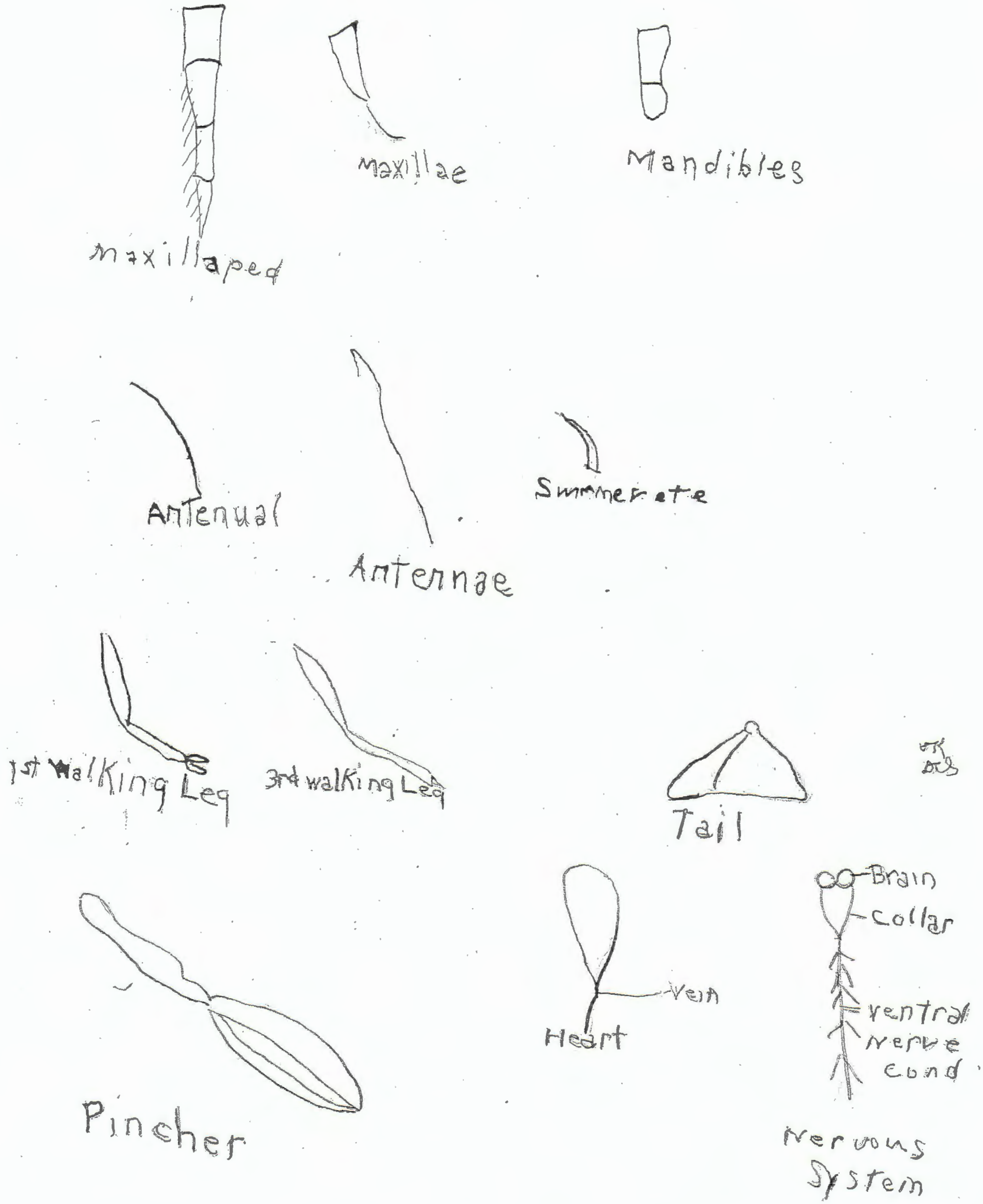
X1000

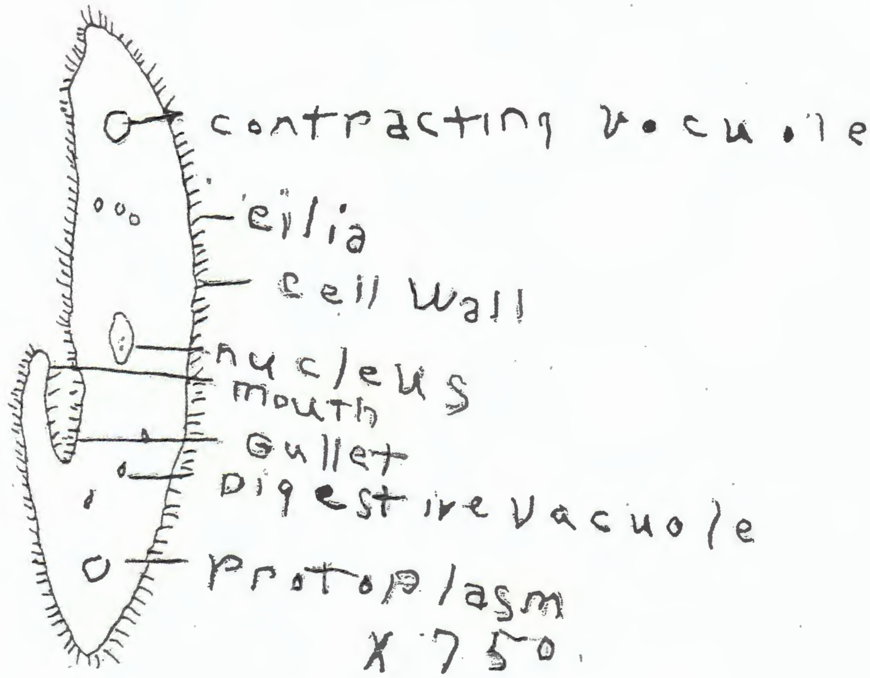


Colony


Antennule
Antenna
Beak
pincher
Eye
First walking Leg
Cephale
Thorax
Third walKin Legs
carapace
Segments
Flipper
Telson

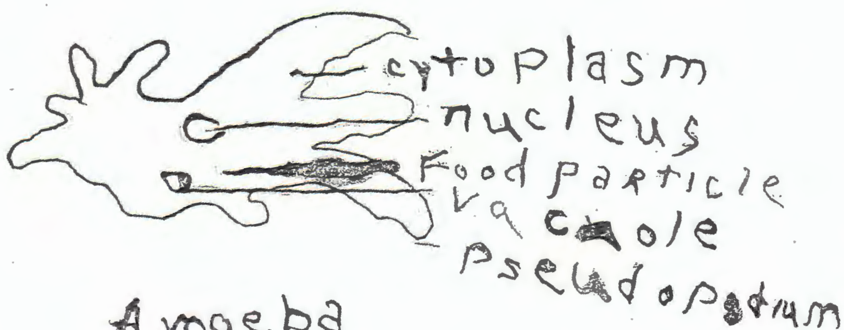
CrayFish


maxillaped
Maxillae
Mandibles
Antenual
Antennae
Summerete
1st walking Leg
3rd walking Leg
Tail
Pincher
Vein
Heart
Brain
Collar
ventral nerve cond
Nervous System



Paramecium

from
Everyday
Problems
in Biology



Amoeba