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Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: BIOLOGICAL GENERALIZATIONS: A METHOD FOR INTEGRATING THE SUBJECT MATTER TO BE TAUGHT IN AN ADVANCED HIGH SCHOOL BIOLOGY COURSE

Pages in Study: 82 Candidate for Degree of Master of Science

Major Field: Natural Science

Scope of Study: Very few, if any, high school biology textbooks have been written in such a manner that the material is well integrated. Most of the textbooks are sectioned into plants, animals, heredity, human biology, and other topics. Thus, the student comes away from such a course with very little insight as to the connections and commonness in almost identical phenomena found in all living organisms. This paper was prepared in order to show how the subject matter taught in an advanced high school biology course can be integrated. The chapter titles are broad biological generalizations. Subject matter for each chapter, which can be connected with each generalization, was collected from articles found in the more recent natural science publications. The different topics to be included were, of course, selected before the literature was examined. The material included under any one particular generalization may be taken from all the major, and special, fields of the natural sciences. In many chapters this is the case.

Conclusions: This paper is not all inclusive. It was found that the material which could be included under each of the generalizations was overwhelming. Therefore, the material which appears in each chapter is that which could be used in a textbook written on the same plan as this paper. Much of the subject matter included could also be used to help bring the high school biology teacher up to date on the more recent developments in the field. Many old beliefs can now be discarded and new knowledge can replace them.

ADVISER'S APPROVAL Kenneth F. Lamb

BIOLOGICAL GENERALIZATIONS: A METHOD

FOR INTEGRATING THE SUBJECT MATTER

TO BE TAUGHT IN AN ADVANCED

HIGH SCHOOL BIOLOGY COURSE

By

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Bachelor of Arts

University of Wichita

Wichita, Kansas

1958

Submitted to the faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1961

BIOLOGICAL GENERALIZATIONS: A METHOD
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PREFACE

Very few, if any, high school biology textbooks have been written in such a manner that the material is well integrated. Most of the textbooks are sectioned into plants, animals, heredity, human biology, etc. Thus, the student comes away from such a course with very little insight as to the connections and commonness in almost identical phenomena found in all living organisms. To the students plants are plants, animals are animals, and there are no connections between the two. Identical terms used for both plants and animals seem to impress the students not at all.

In recent years many high schools throughout the United States have added an advanced biology course to their curriculum. A prerequisite for such a course is General Biology taken either at the junior high or at the sophomore level. In most cases this prerequisite course is taught on a "piecemeal" basis as described above, and, in most cases, the advanced course, at the senior level, is also taught in the same way. This has distrubed me very much and I will attempt to do something about it. This paper represents a start on what I hope will be my answer to the problem.

I am deeply indebted to the following people who have contributed in some way to the preparation of this paper: to Dr. James Zant for his patience, encouragement, and willingness to help with every problem; to Dr. L. Herbert Bruneau for having encouraged me, and for his guidance and the taking of time from his busy schedule to read and correct the paper; to James Sumner who gratiously consented to prepare the illustrations for the paper; to my wife, Marilyn, for her great patience and encouragement, without which I could not have succeeded; and to Dr. Robert Mac Vicar, Dean of the Graduate School, and all the faculty members at Oklahoma State University for being kind, helpful, and encouraging people.

John D. Ransom

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CHAPTER I

INTRODUCTION

The purpose of this paper is to show how the material for an advanced course in biology can be integrated and, thus, become more meaningful and worthwhile. This has been accomplished by using broad biological generalizations as chapter titles and then collecting, and including, various materials on phenomena which appear to have some connection with the generalizations. In many cases the reader may be required to stretch his imagination in order to see the connection. For those who are well prepared in the field, the connections could be more obvious.

This method has been employed, by the writer, as a test of its usefullness, and it was found to be very successful. The discussion elicited from the students, and the interest shown by them, was overwhelming. This was the clue which indicated that much more work along this line would be worthwhile.

This paper will not be all inclusive, nor is it intended to be the entire subject matter material for an advanced course. If a teacher took it to be all-inclusive then the writer would consider it more worthwhile not to present the paper at all. Laboratory exercises must be considered as an entirely separate part of the course. It is intended that the material presented here will be greatly added to in the future.

This paper is presented merely as an idea which has generated in the mind of the author. The idea, if it is a good one, should be shared with others. The larger part of the work has been done. It merely remains for any interested person, or persons, to expand upon it.

Biologists can be classified as being vertical or horizontal in their interests. Some areas of biology, such as genetics or evolution, function as a unifying study. The vertical biologist studies specified points of organisms while the horizontal biologist studies an organism in all respects.

	EMBRYOLOGY	PHYSIOLOGY	PARASITOLOGY	ECOLOGY
BIRDS		V		
AMPHIBIANS		V		
FISHES	H	HV	H	H
REPTILES		V		

Fig. 1 Vertical and Horizontal Classification of Biologists

In high school the study is horizontal. This is rather undesirable if there is to be complete understanding. There is a lack of unity in high school biology. "Look at biology as a whole, not through a keyhole." (T.E. Chamberlin).

As many of the references as possible were taken from the author's own library. This was done because such references will always be available to the teacher's students. Much of the material has come from the lecture notes taken by the author during his years as an undergraduate and as a graduate student.

CHAPTER II

SOMETHING HAS NEVER BEEN BORN FROM NOTHING

Quite familiar to all biologists is the statement that everything that is living is connected with everything else living, or that has ever lived, by an unbroken chain of protoplasm. (Weismann, 1902). The continuity of the germ plasm clearly stipulates that every living thing is related and connected by an unbroken stream of protoplasm. Somatic cells arise from germ cells but germ cells do not arise from somatic cells. It often seems that the body's only function is to make more germ cells.

Any interested person would surely wonder about the origin of life after considering the above statement. There are four possibilities of the origin of life: One possibility is that life has no origin, it has always existed. This is quite difficult to conceive and surely is not reputably held. Another possibility is that life originated from a supernatural event. A little consideration here will reveal that since life is natural, then its origin could not have been super-natural. A third possibility is that life originated by a series of ordinary chemical reactions. This statement implies that life was almost sure to have been caused and that it may have been initiated in many places at many times. A fourth, and last, possibility is that life originated as a result of a very highly probable event, implying that life's beginning was just a barely possible chance event.

The last two possibilities are the choices of most biologists today. Evidently these biologists are aware of the Parable of Occam's Razor which states that the most probable explanation is the one with the least number of "ifs."

A further consideration of the origin of life would lead one into the chemistry involved. For instance, the question of how organic compounds can be created from inorganic compounds might arise.

There appears to be four methods by which this event might take place. One is that the influence of ultra-violet light from the sun on simple carbon compounds can result in the formation of simple amino acids. Another method could be that carbides were derived from carbon compounds as the earth cooled. Then, carbides plus water will produce acetylene ($H-C \equiv C-H$) and from acetylene large chain molecules can easily be obtained. A third method, revealed by organic chemistry study, proves that carbon dioxide and water, when exposed to high energy radiation, will yield formic acid. This one-carbon acid can in turn be changed into a two-carbon oxalic acid and then into the four-carbon succinic acid by the same means. A fourth method could be the formation of simple organic molecules from certain substances with electronic charges which increase the possibility of interplay between organic compounds.

One definition of autocatalysis states that this is the ability of one chemical unit or compound to make other different compounds change into itself. For example, one cupric ion with a single positive charge and in the presence of many cupric ions with two positive charges can reduce the doubly charged cupric ions to single charged ions.

Such autocatalysized molecules can be considered as naked genes. Here is where the competition of life begins, each type of molecule trying to make other molecules into itself.

The cell theory, as propounded by Schleiden and Schwann in 1839, states that all organisms are composed of like parts, the cell; and that all cells come from pre-existing cells. The Gestaltists have challenged the central idea of the cell theory. They state that the cell is just a part of the unit and that it is the unit organism that is the basic entity, not its component cells. The cell is only a part of the whole.

It must be understood that specialization by a cell is a sequence of the nature of a cell. Cell protoplasm shows a definite continuity and organization that is a climax of a continual increase of molecular complexity.

When discussing or considering the above, the old argument of just what death is may arise. When is a cell dead or alive, and how would the death of a single cell affect the organism?

It seems that there are two types of death. There is clinical death and this is the death of the organism as a whole. Then there is physical death which must be the death of the individual cell. It is quite difficult to define the point at which life or death begins or ends. One can draw a straight line whose ends represent the definitely living and the definitely dead. But somewhere along this line one ends and the other begins.

Death -------------------~~Viruses here?~~---------------------Life

Fig. 2 Line Between Life and Death

Are Viruses living or not? This question cannot be answered until we define the terms "life" or "living." Viruses, outside of a cell, are incapable of any metabolism as an individual. Yet, when they get into a cell in the presence of protoplasm they can do all of the above. A virus is actually a complex protein material.

One must remember that all life processes are the same as those which apply to non-living things. Life processes are just a series of chemical and physical processes in a living cell.

CHAPTER III

ALL ORGANISMS GROW

All organisms grow, in that they increase in size, control and organization.

The Biogenetic Law is a statement that "ontogeny recapitulates phylogeny." (Haeckel, 1903). This says that the embryo passes through the ancestral stage to reach the present form. This idea in embrology is false in that no embryo passes through the stages of development of another organism. An embryo is never anything but itself. An embryo will show its relationship with other kinds of organisms at some particular stage in its development. An organism does not pass through lower stages in the process of embryonic growth.

The difference between species is primarily in adults even though the embryos may look alike. A pig embryo may at some particular stage look exactly like a human embryo but, regardless of its appearance, it is never anything but a pig embryo. Every species is that species right at the beginning. Development within a species is to create a new individual, not to repeat history.

The Biogenetic Law is partially correct in that every species shows relationship to other species. The gill pouches in the human embryo look like the gill slits in the fishes. All organ systems in a species must be alike at birth. Some stages of development are occasionally omitted in a species. For example, the tongue and teeth appear at different comparative stages in the embryos of birds and mammals.

At this point one may wish to compare the environments of the embryo and the adult. The environment in which an embryo develops is very stable, but the environment of the adult form changes rapidly and often. Therefore, any rapid change in the environment of a fetus can prove lethal, particularly if the change occurs in an early or crucial stage of development. Biological material is stuck with what it has. Every organism must learn to function with what it has inherited.

Which came first, mitosis or meiosis? Mitosis preceded meiosis because meiosis is a part of and involves the process of mitosis. Mitosis, being the simpler process, must follow the axiom that simplicity precedes complexity. Even though meiosis could be performed more simply, the cell must follow its inherited ways and go through the more involved method.

Recapitulation is defined as occurrence in the embryonic development of an individual of stages repeating the structure of ancestral adult forms. Successively later embryonic stages correspond to successively more recent stages.

Recapitulation, as such, depends in its final analysis on the gene sequence taking place under genetic control. It is very likely that a successful genetic sequence will be perpetuated. Successful methods always tend to remain. A cell that could learn to undergo meiosis in a simple manner would have no advantage over those cells that undergo the traditional cumbersome meiosis; therefore, the new method would be swamped and lost by the system already established.

Some tissues grow slowly, others must develop quickly; such as the early appearance and growth of the heart on which other tissues will so shortly depend. Many large organisms grow at irregular rates in its different parts. Change in the horse skull has come about as a result of different rates of growth of organs within the skull.

One point which is common knowledge in biology is that growth of almost all organisms is in the manner of a sigmoid curve. (Odum, 1959). Growth starts slowly, then it increases to very rapid growth and at maturity it levels off to where the rate of growth becomes stabilized.

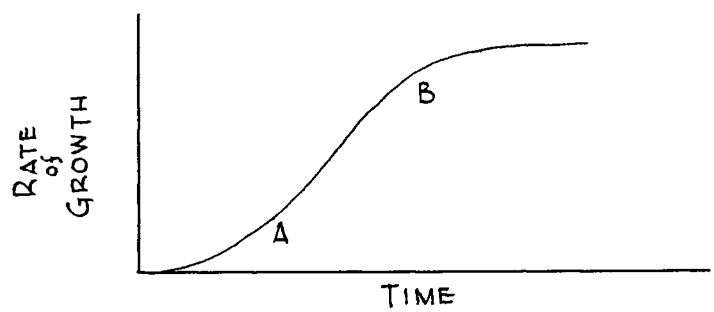


Fig. 3 Growth By A Sigmoid Curve

It can also be pointed out that hemoglobin receptability to oxygen is by a sigmoid curve. Hemoglobin will carry oxygen up to point "A" but will not release it. The rate by which it is released from there on is obvious.

When on considers the rate of growth by the process of geometric increase (1-2-4-8-16-32-64, etc.) in cells, the sigmoid curve is again easily applied. If a single cell divides every twenty minutes, at the end of twelve hours there would be sixty-eight billion cells and at the end of twelve hours and twenty minutes there would be twice that many.

Growth in organic organisms is not just the process of getting larger but is instead the internal reproduction and growth of the protoplasm within the cells.

Differentiation also occurs with growth. Daughter cells which are the same in their genetic makeup will still differ. This may be explained by differential functioning of nuclear genes, differential substrates upon which the animal or organism subsists, the failure of genes to function in the daughter cell, and by differential environment. The cell may respond to the new environment in which it finds itself. This problem has been well explained by experiments on nuclear transplants (Briggs and King, 1952).

The control of growth is probably hormonal. It has been found that the direction of plant growth is in part controlled by certain growth hormones called auxins, which are elaborated in the growing tips of plants. (Leopold, 1955). The auxins filter down into nearby cells resulting in a faster rate of growth of those cells containing them. The unequal growth causes the growing stem to turn in the direction away from these cells. A stem laying on its side will turn upward because the auxin has trickled down, by gravity, into the lower cells causing more rapid growth there. Sunlight destroys auxins. Therefore, plants will turn toward light in a manner which is generally referred to as phototropism. The side of the plant opposite the sunlight actually grows more rapidly.

Auxins cause elongation of the stems. They also inhibit growth and opening of the buds. This is the reason for the start of growth of lateral buds if the auxin producing terminal bud is cut off. In roots auxins produce elaboration, proliferation and thickening, rather than elongation. (Audus, 1953). The following figure demonstrates the comparison between growth rate and auxin concentration. Very little auxin is required for the stimulation of growth. An increase in auxin concentration will not increase the rate of growth.

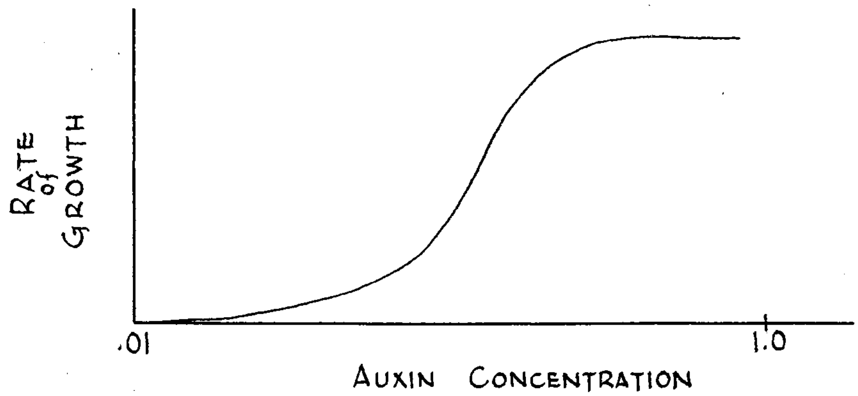


Fig. 4 Growth Rate of Plants Due to Auxin

If part of a tissue of an organ, or the organ itself, is removed, there will be an increase in size of the reamining organ or tissues. This is called compensatory growth and it may be a response to a function overload. If a kidney is removed, the remaining kidney increases in size.

Sometimes there is no logic in this, such as when the lacramal gland of one eye is removed, the glands of the other eye do not enlarge.

Compensatory growth can possibly be explained by a constant effort in an organ system to maintain a balanced state of function. This is described as a "chemical community system." There is chemical communication through the blood by which tissues are able to communicate and coordinate. (Weiss, 1950).

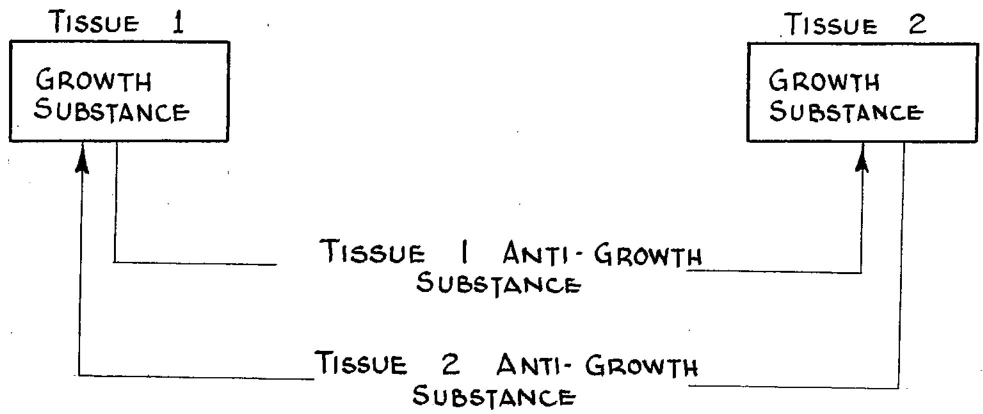


Fig. 5 The Relationship of Growth and Anti-growth Substances

Removing one tissue removes it as a source of anti-growth substance. This allows the other tissue to increase in size. However, it will not grow forever. The growth stimulus and its own anti-growth substance reach a balance to determine its final size.

Environment plays a big role in growth just as does heredity when environment is stable. An organism will vary as a result of genetic inconsistancy. Maintaining the genetic makeup and varying the environment will affect growth. A plant growing at sea level will certainly not grow well when transplanted to an elevation of ten thousand feet. If the plant is again moved back to sea level it will grow very well again. (Odum, 1959).

Species in competition grow the best under conditions different than those optimum for it when alone. If plants number 1, 2, and 3 when grown alone, require a ph of 5, 6, and 7 respectively, it can be shown that when plants 1 and 3 are grown in competition the optimum ph of plant number 3 becomes 4, etc.

A basic biological principle is that growth and the capacity for growth is a fundamental capacity of all living organisms.

CHAPTER IV

ALL ORGANISMS DEVELOP A CHARACTERISTIC FORM

Form is used as the basis for tracing relationships. This is not the best way to show relationships but it is the most established method.

The above statement leads to a consideration of phylogeny and some of its difficulties. All of the developing tissues of an organism are contributing factors in the development of the form. Form alone is unsatisfactory for basing relationships because it is often too generalized as a result of adaptive functions, such as the fusiform body of fishes. Other phenomena such as behavior and behavioral mechanisms, and the antigen-antibody relationships must be used to trace relationships.

Convergence often causes error when one uses form as a basis for relationship. Convergence is the development of close resemblance of forms whose ancestors were not alike. This is an evolutionary phenomenon.

Organisms may be polyzygous. That is, they may have two shapes, or different shapes at stages of their life cycle. Some investigators have mistaken two sexes for two separate species.

Balanced polymorphism and hybrids often lead to difficulty in showing relationships. Balanced polymorphism is a balance between the various morphological types of an organism as is found in a beehive or in an ant hill. Hybrids are often more successful forms than either parent. They show heterosis or hybrid vigor. Therefore, the hybrid, when inbred, will often revert back so it is not used as seed. The parent plants must be re-bred each year.

Some authors have postulated that a colony is a single organism. The individuals within the colony are the cells. Each individual has given up something as a contribution to the good of the colony. A colonial form, Volvox, for instance, regenerates just as does an individual. This also applies to the social colony. (Emerson, 1954).

Specialization of cells permits organization of the individual. The same applies to organization of colonies; once cells specialize within a colony, they are no longer able to turn the clock back and exist separately. They must continue to remain in the colony. Colonies show a characteristic form whether considered as single organisms or not.

Anatomy and the study of its comparison in varying forms developed into the idea of evolution. Functional anatomy, the question of how organisms operate as they do, is a relatively new idea. It has altered some long held ideas about the use to which anatomical structures are put.

A recent study has been done on the circulation within the frog's heart. (Foxon, 1951). The conclusions reached indicate that the previously held notions of the frog's cardiac circulation are not valid. That is, both auricles filled the ventricle equally. When the ventricle contracts, it fills all the outgoing vessels equally and with equal pressure. There is no change in heart structure or selective filling of arteries. From these findings it became necessary to establish new theories regarding coronary circulation. Foxon suggested that the trabeculi absorb oxygen directly from the blood and do not depend on the cardiac arteries which apparently cannot be found.

Changes in the system are made known by a mechanism in the circulatory system itself. Systemic circulation in frogs is as likely to be as completely oxygenated as is the blood that goes through the lungs because of the frog's ability to exchange gases through its skin and membranes.

Therefore, there is a necessity for differentiating between old belief and new theory derived from new investigation. It must always be kept in mind that all of an organism's anatomy is there for a purpose. Form alone should not be the basis for anatomical doctrine. Function is just as important. The complete study of the frog's heart reveals how easy it is to forget this.

There are a great many different structures in the animal kingdom which perform the same general function. This is exemplified by the insects. All animals have the same basic problems to solve in remaining alive, but they solve them in different ways. One problem which must be solved by all animals is the problem of respiration.

Respiration is often thought of as breathing. Some go further to say that it is the exchange of gases between the cell and its

CHAPTER V

ALL ORGANISMS HAVE A CHARACTERISTIC LIFE HISTORY

The life history of single-celled organisms is quite simple. The organism's life ends when fission takes place and it becomes more than one organism.

The life history of the multicellular organisms is considerably more complex than that of the single-celled organisms. The life history of multicellular organisms includes a number of areas, such as embryology, morphology, behavior patterns, and reproduction.

Sexual reproduction is actually more widely spread in nature than is usually thought. It is actually almost a universal phenomenon. If the alternation of generations, metagenesis, is presented in a different way than it usually is, one finds that it is much more common than formally believed. This is mainly because of the broad definition which can be applied. The following are three different ways of expressing an identical process:

By structure ------ Gametophyte ----- Sporophyte ---- Gametophyte

By Chromosome ----- Haploid ----------Diploid ------- Haploid

By sexes ---------- Sexual ---------- Asexual ------- Sexual

Fig. 6 Ways of Expressing Alternation of Generations

Parthenogenesis is the development of the ovum without fertilization. The ova which develop are diploid, in which case all the offspring are genetically identical to the parent. Parthenogenesis is fully sexual without involving both sexes. The Rotifer life history actually demonstrates the alternation of parthenogenesis and fully sexual reproduction. (Buchsbaum, 1939).

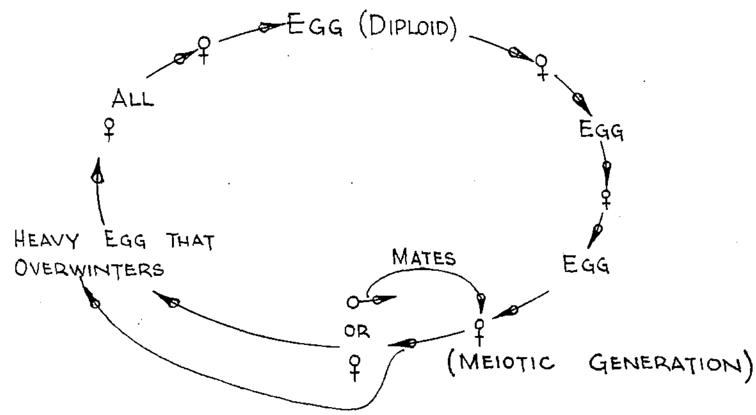


Fig. 7 Life Cycle of the Rotifer

Some say that the alternation of generations is the most important difference between metazoans and multicellular animals. One must keep in mind the alternation of the haploid-diploid condition.

In some of the lower plants the zygote is the only diploid phase. A comparison of the different forms of life can be represented by the following diagram which actually shows the relationship between alternation of generations and the length of time the organisms spend in each condition.

This diagram demonstrates visually that alternation of generations is involved in most life forms.

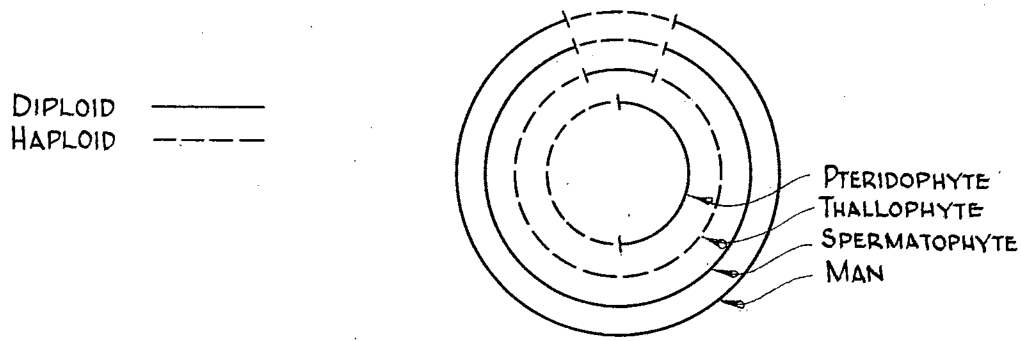


Fig. 8 Alternation of Generations in Different Life Forms

The concept of life history can be used to shed light on many of the problems of evolutionary relationships. A few examples will be presented below. One must recall that behavior patterns are a definite part of any life history and, furthermore, they offer a rich area of investigation for anyone.

The first example has to do with the nest building by the English Sparrow. This bird constructs its nest in such a way that it must be classified with the weavers. Unless the nest building habits of this bird were known, it would not be classified with the weavers.

A generalization which is quite well known among biologists is that which has to do with the development of parental care. There is a direct connection between the amount of parental care and the number of eggs produced. In almost all cases the greater the amount of parental care shown the number of eggs produced is less. This care may be in the form of personal attention or protection provided for the hatchlings. In mammals often only one egg is produced. Usually this is just enough to propagate the species.

There are many amphibians which do not lay as many eggs as a result of changes in the amount of care given the young. They often do not fit the described behavior pattern of having to return to water to lay their eggs.

A frog in South America builds a dam around a small pool in which it deposits its eggs. The young develop with no competition. Some frogs carry the tadpoles on their backs. One species of frog has an abdominal pouch where it carries its eggs and the developing tadpoles until they become frogs. In another species, the male places one or two eggs in his vocal sac until the development is complete to the adult stage. There is a European salamander which produces two offspring per year, one from each ovary. The eggs are retained in the body. There is a strong evolutionary trend toward an increase in parental care.

CHAPTER VI

ALL LIVING THINGS CAPITALIZE ON CYCLIC PHENOMENA

If organisms are to become a part of the cycle of energy, they must attach themselves to the cycle. This is what is sometimes referred to as cyclic biology. Once an organism is attached to the energy cycle, they must change, many times, to maintain their place with changes which take place in the cycle. Once solar energy is captured by organisms it becomes a cyclic phenomenon.

One of the simplest types of cycles is for one organism to utilize the waste products of another in its own metabolic processes. The classic example of such a cycle would be the oxygen and carbon dioxide cycle of plants and animals. The first step in this cycle can be designated as the utilization of carbon by plants in photosynthesis and photosynthesis is the key to making solar energy available.

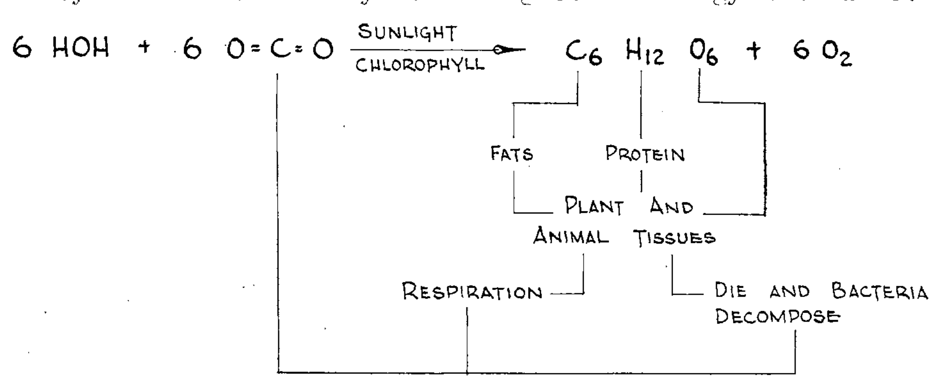


Fig. 9 Waste-Products Cycle

The above diagram can be used to demonstrate the oxygen cycle, the carbon dioxide cycle, and the carbon cycle as they are sometimes differentiated. In the carbon dioxide cycle, the free carbon dioxide must be incorporated into organic compounds (compounds of carbon) ending up as glucose, complex sugars, fats, or proteins. Many processes must occur in order to create protoplasm and to release free carbon dioxide back to the air.

There are many cycles within cycles in the broad energy cycle. The primary cycle involves photosynthesis and cellular respiration. One often encounters the statement that respiration is merely the reverse of photosynthesis or that photosynthesis is a reversible process. This is false and should not be presented in this way. The photosynthetic and respiratory processes are both very complex series of enzymatic processes which cannot possibly be reversed. In many cases, contrary to some reports, photosynthesis and respiration are not carried on in the same cells of a leaf.

If one gives the process of respiration a closer consideration, it will be found to be quite complicated. In the first place the chlorophyll traps radiant energy of the sun to split the water molecules into hydrogen and oxygen. The de-energized chlorophyll no longer takes any part in the process but does start a new process. The released hydrogen is now available for combination with carbon dioxide to form sugar. The glucose then breaks down in the cell to release energy. This is actually respiration and it is not quite so simple a process as it sounds. Perhaps a brief stepwise presentation of the respiration process will dispose of any doubt concerning its complexity.

Glucose (6 carbon molecules) $\longrightarrow$ glucose phosphate $\longrightarrow$

pyruvic acid (3 cabon) $\longrightarrow$ H_2 Z (high energy bond of phosphate molecule)

$\searrow$ Acetic acid (2 carbons) $\longrightarrow$ $H_2 + CO_2 + Z$

$\downarrow$ Krebs Cycle

Fig. 10 Respiration

The Krebs cycle is the process whereby much of the energy stored in glucose is removed. It breaks molecules down from six carbon to five carbon to four carbon and the four carbons then combine with acetic acid (2 carbon) to produce six carbon molecules again. The final products of the entire respiration process are water, carbon dioxide, and ATP (energy).

The energy receptors in the respiration process are AMP (adenosine monophosphate), ADP (adenosine diphosphate), and ATP (adenosine triphosphate). ATP is the form which is regularly stored in the body. When its bonding is broken it releases much stored energy.

One might now ask what happens to the oxygen or how it is used. It is used to oxidize the glucose and by so doing it becomes a hydrogen acceptor to take away the excess hydrogen in the form of water. Respiration is actually the release of energy by the stepwise dehydrogenation of glucose. It must be remembered that glucose is also used to synthesize fats and proteins as well as to furnish energy.

There are many other cycles which could be presented here. The nitrogen cycle, the mineral cycle, and the water cycle are worthy of consideration, but the lack of available time and space demands their omission. A good reference concerning these cycles is Simpson, Pittendrigh and Tiffany, 1957.

CHAPTER VII

ALL LIVING THINGS EXPEND ENERGY TO MAINTAIN BIOLOGICAL EQUALIBRIA

Homeostasis is a term used for the maintenance of a constant internal environment regardless of the external environment. The nervous system's function is to maintain a dynamic equilibrium in order to preserve the status quo. Organisms receive, transmit, and communicate a stimulus into a change so that the animal can return to a comfortable environment or steady state.

The above can be illustrated by the temperature regulation of thermostatic animals such as birds and mammals. This action is carried on by the thalmus, which is the sensory coordinating section of the forebrain. If the temperature is lowered, the following reactions occur to reduce heat loss and hence return animals to a state of no discomfort. This is often termed biological feed-back. There is capillary vasoconstriction in the skin, goose pimple (follicle muscles which hold hairs contract) are formed, shivering occurs to increase muscular activity and the release of heat, and the sweat glands are inactivated. If the temperature is raised and causes discomfort, then the skin capillaries dialate, the muscles relax, the sweat glands become active, and panting occurs in some forms. The Thalmus gets its message from the skin and blood messengers. It then acts to counteract the annoying stimulus.

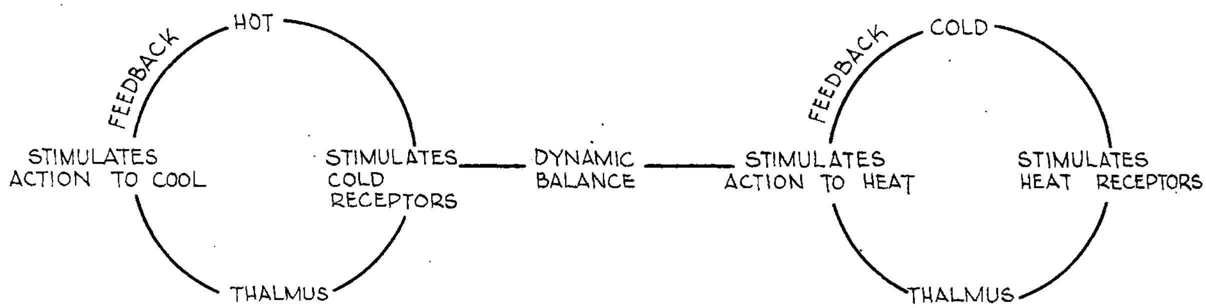


Fig. 11 Temperature Regulation by Thermostatic Animals

A good example of how the endocrine system operates to maintain a state of equilibrium is the twenty-eight day ovulation cycle of the female human being. (De Coursey, 1955).

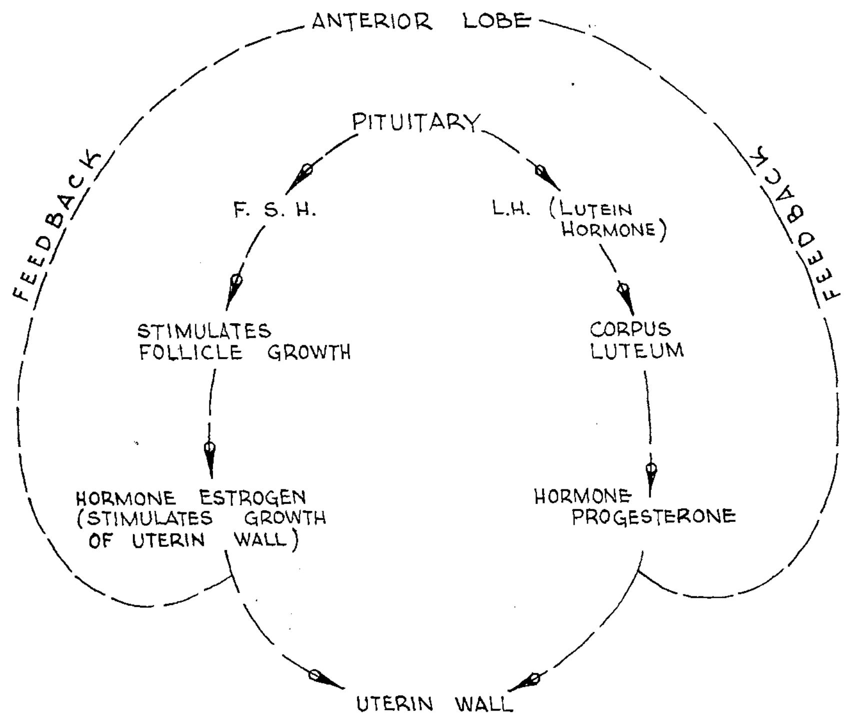


Fig. 12 The Female Ovulation Cycle

Estrogen causes the pituitary to cut down on its secreation of L.H. and FSH. When the slowing up takes place, then ovulation occurs, the production of estrogen and progesterone is slowed down, and menstruation takes place with the shedding of the inside wall and blood of the uterus. The cycle is stopped when the egg is fertilized and progesterone is secreted by the placenta. The corpus luteum and the follicle continue to secrete their hormones.

There are many other examples found in nature where energy is expended to maintain the steady state. From the plant kingdom an example can easily be found. This is the process of succession and the establishment of a climax.

Succession is the series of changes that takes place in any region as any one species replaces another species in its habitat. The first species prepares the area for the next and it, in turn, prepares for the next and so on. Furthermore, there will be a succession of animals due to their close association with certain plant species. Eventually a species appears which does not change the environment but maintains the situation, and the species continues to reproduce. This state is known as the climax or the steady state. An equilibrium has been established between the species and its environment.

The records of the Hudson Bay Company has furnished other examples of the maintenance of equilibrium. One is concerned with the ten year cycle of the Lynx. The Lynx is a predator of the Hare. It was found that when the population of hares went up the population of lynx, with a lag, would go up. The hares would be eaten and lynx pupula would decrease from lack of food. (Elton and Nicholson, 1942).

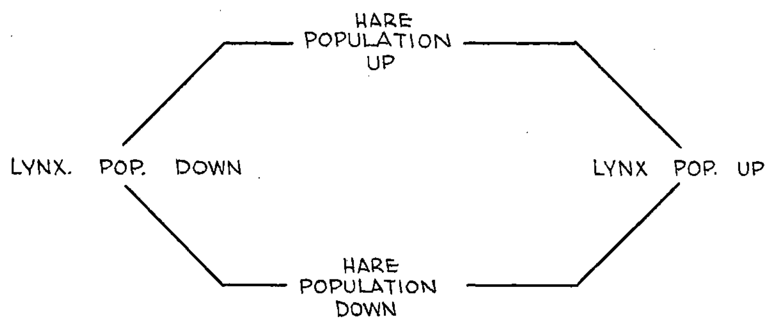


Fig. 13 The Lynx-Hare Cycle

A study of the opening and closing of the stomata of leaves will furnish another example of this sort.

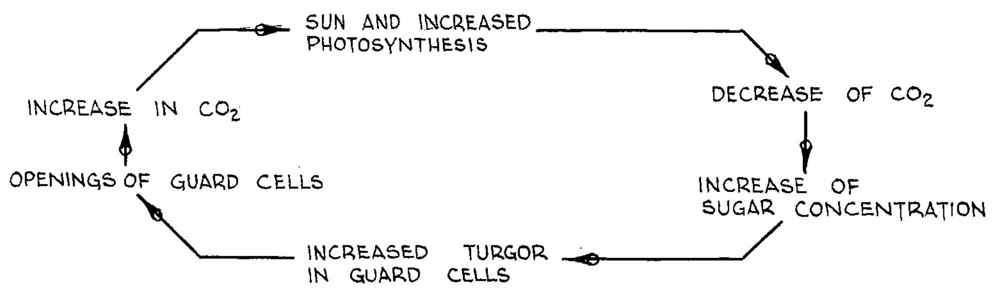


Fig. 14 The Opening and Closing of Stomata

All metabolism is in a dynamic state of equilibrium. There is a balance between anabolism (build up) and catabolism (break down).

As a final example the simple thirst cycle can be used.

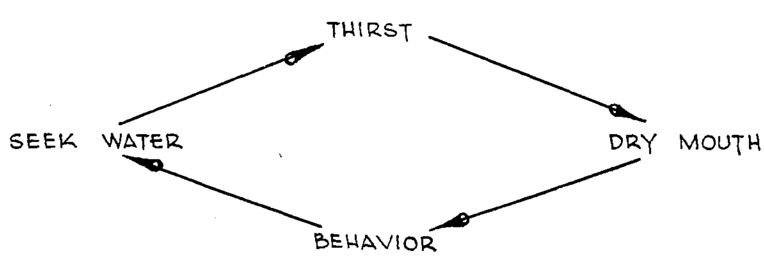


Fig. 15 The Thirst Cycle

Homoeostasis is a general phenomenon. It can be found in every area of biological thought and it is the kind of thing which should be learned.

CHAPTER VIII

ALL ORGANISMS ARE ADAPTED TO THEIR ENVIRONMENT

There are two major kinds of adaptation. One is the adaptation as an individual or aclimatization. These are the changes that take place within an organism in response to its environment. An organism aclimatizes itself to its environment. A good example of aclimatization would be the increase in the number of red blood cells of an individual which goes to, and remains, at a high altitude. The other type of adaptation is the adaptation of a species. These are changes which take place within a species. This involves the changes in genetic makeup over many years in order to adapt to a new environment.

Practically every organism has adapted itself to the use of water, oxygen, carbon, and phosphorus. Many fail to realize the importance of phosphorus. They fail to realize that it is necessary in every known metabolic process. It was very essential in an important process given in another chapter of this paper. It is important as a phosphate linkage in DNA found in chromosomes. It is important in regulating the permeability of the cell membrane. The brain will not function in the absence of phosphorus.

Life is adapted to the nature of the planet on which it is found, as far as the elements and conditions there are concerned. Organisms adapt in many and various ways to fit into the environment of a particular planet, or more specifically, to a particular habitat.

Water diffuses into the cells of fresh water fishes. They excrete much urine and in the process much salt is removed. They reabsorb salts into the kidneys and gills. This process requires a great expenditure of energy as this is going against the diffusion gradient. These fishes retain less slat in the urine and in the cells.

The water diffuses from within the cells of salt water fishes. These fishes take in great quantities of water and it takes considerable energy to excrete the included salt through the gills. This process is also going against the diffusion gradient. The salt content of the urine and the cells is quite high.

As an organism becomes more specialized it loses its ability to adapt to changes. Actually it has adapted to special conditions and it cannot survive in the absence of these special conditions. An anteater must have ants or it will perish.

The size of a population depends on its ability to withstand the extreme conditions. The population must adapt to the extremes of the environment in order to survive. If it can merely adapt to the average, this is not sufficient. If there were a heavy freeze in Florida (this has actually happened), the tropical fish would be killed while those many fishes which are adapted to extreme conditions would survive. There are certain species of birds which subsist almost entirely on nothing but berries. During the years when there is a shortage of berries many of the birds perish. During years of good production most of the berries go to waste. This is merely another example of the lack of ability of an organism to adapt to extreme conditions.

There is a term in the biological sciences called adaptive radiation. Charles Darwin found it well demonstrated when he visited the Galapagos Islands. Adaptive radiation can take place primarily only when there is no competition from other species. An animal will adapt to an environment and then it can further adapt itself to meet many new environmental situations. Darwin found that a species of Finch had migrated to the Galapagos Islands and had taken up permanent residence there. From this one species there were many differences shown by these birds. Some were predators, some were vegetarians, some lived in the trees and some lived on the ground. There was no evidence of these adaptations on the mainland and it is believed that the reason is due to excessive competition.

Sense organs provide for coordination and the ability to move about. Every known sense and every known stimulus has its sense organ. The use of an organism's sense organs in adapting and dealing with its environment cannot be overemphasized. The author was unable to locate the source of information he has on the following experiment. If some very small steel balls are made available to a crayfish, it will put them in its statocysts. If a magent is placed above the crayfish, he will lay on his back in order to place the steel balls next to the sensitive hairs in the statocysts. This is an example of how a crayfish uses sand grains to maintain his equilibrium.

Another example of how organisms have adapted their sense organs to deal with their environment can be found in the pit vipers. They have infra red receptors so that they can see and strike in the dark or when they are blinded.

The author of this paper felt the urge to include a statement on E.S.P. (Extra Sensory Perception). Perhaps this would be as good a place as any to include it.

There is no known biological basis whatsoever for extra sensory perception. It depends upon no known sense organ or stimulus. It appears to be found in only a few individuals within a species. Now, if this were a good trait, and it would be if it were true, then why would not it be found throughout the species? If there is one one-hundredth of one percent selection advantage in any gene, then in twenty-five generations every individual in the species will possess the selected gene. The author can apply to the believers a statement made by one of his professors one time. The professor said, "This is what I believe, don't confuse me with facts."

CHAPTER IX

THE WHOLE IS GREATER THAN THE SUM OF ITS PARTS

When two things are combined, the product will be the two things plus what binds them. It must be admitted that this is not so in mathematics.

When a series of things is summed up and used, something else is added. The parts are definite and arranged, and it is the same for all members of the species; that is, orderliness prevails.

Cells have become specialized; but if a part is removed the remaining cells can lose specialization, form a blastomere, and start growth of the missing organ. The regenerating tissues exhibit polarity. All of this is an exhibition of intergration and coordination of the whole.

The whole is integrated through chemical and nervous stimuli. The chemical stimuli are caused by hormones. They are elaborated in one place and used in another. Hormones control sugar metabolism, growth, and reproduction. In many ways the nervous stimulus is a chemical process. It may be a chemical process as a result of the part played by acetycholene which is elaborated in the synapse area of nerve cells. There is a difference in the method of transfer. Hormones are transferred by the blood while in the nervous system the transfer is by cell tissue.

Organization insures the operation of the organism as a whole. Organization of systems assures the continuation of the organism. None of the parts of a system is completely independent.

The levels of organization are submicroscopic, microscopic or cellular, organism or multicellular, and population or supraorganism.

Organization of organisms is evident at many levels and stages of life. Each level can be characterized and in such cases they exist as an organizational whole. Each level has a unifying, integrating force so it will behave as a unit. The organization of this whole is not changed by taking in new materials or by the discharging of old. The higher levels of organization incorporate the lower levels. The lower levels are subordinate to the higher levels. There is division of labor among the parts and each level exists as an open system.

After the organism, the next highest level of organization is the population. A group very often acts like an individual and can acquire character of its own. The individuals no longer act as individuals but only as part of the group. Reactions very often happen to populations, rather than to the individuals. Polymorphism shows a tendency to subordinate individual action to that required by the particular form of that individual at that stage of its development. This is also shown by segregation of responsibilities of the social insects.

The maintenance of a steady state of numbers is also an indication of the above. Lemmings will destroy themselves when they become too numerous. The lowering of a squirrel population one year will result in an earlier breeding season and earlier sex maturation the following year.

In a herd of feeding animals, one or two individuals will subordinate their own interests in feeding to stand guard for the herd while it feeds. How or why this occurs is not known.

The slime mold, Dictyostelium discoideum, demonstrates an amazing example of individuals acting in concert to the point of the group behaving like a supra-individual. (Bonner, 1949).

The mold is a spore former and these individuals ordinarily feed independently and have amoeboid movement. If there is enough food, they will produce a large population. If the food supply becomes short, several of the individuals will produce a chemical called acrasin which acts as an attractant to the others. The remainder of the individuals will gather to form a colony and then will elaborate their own acrasin. Within two to four hours, all of the individuals have gathered. After convergence into a colony, each cell forms its own small amount of acrasin.

The animal colony now begins to assume a new shape, similar to that of a fish. As it moves or wanders, it leaves a trail of slime behind. The anterior end elaborates more acrasin than does the posterior end. This excessive production by the anterior end is apparently an effort to coax the rear end to keep up. Movements of the colony seem to be coordinated in its search for food and dim light. The colony is extremely sensitive to temperature differences.

While the migration is going on, the colony begins to differentiate. It shows variation in its parts when stained and also in shape. At the end of the migration, the colony forms a ball with a segregation of larger and smaller cells. The larger cells push down through the mass and on reaching the bottom the other cells pile on top of them so that the entire mass is perched on a cylindrical stalk of large cells. The colony soon takes the shape of a mushroom and space capsules are formed in the cap portion. The base cells have sacrificed themselves for the colony and they do not sporulate.

The above description merely illustrates how independent individuals are able to come together to form a completely different organism. It no longer acts as a group of individuals but as an individual of an entirely different nature.

The next higher level of organization is a group of populations, the community, such as will be found in a forest. A community can often regenerate lost parts but a few lost parts can also destroy the community. (Odum, 1959).

Obviously, there is no hard and fast line between population and the community. Both represent what may be considered levels of organization above that of the individual. Some have suggested that the community be considered a sort of "super-organism," and its populations be considered the organs and organ systems of the super-organism. The super-organism concept is probably a useful analogy but not a true homology. Nevertheless, the important point is that the population and community are real entities, even though one cannot usually pick them up and put them in the collecting kit as one would collect an organism. They are real things, because these group units have characteristics additional to the characteristics of the individuals composing them. The forest is more than a collection of trees.

Some refer to two closely associated organisms as an inter-species organism. This organism would come about because of the mutual relationship between two different species. The Yucca plant and the "Yucca" moth furnish a good example here. The moths gather Yucca pollen, drill a hole in the ovary, deposit the pollen through the hole, then deposit their own eggs on top of the pollen. The deposited pollen fertilize the Yucca plant eggs and they develop into seeds. The moth eggs develop onto larvae and these larvae feed on the seeds of the Yucca plant. The larvae leave some seed undamaged so as to insure propagation of the plant. This is an example of complete and total interdependence of two organisms. Another example is the lichen. However, the components of a lichen may exist separately.

Social relationships are quite common in nature. Socio-biology, as it sometimes called, is demonstrated by the order of dominance existing in many kinds of creatures. For instance, the pecking order in certain birds is based on fighting or bluffing and/or physical contact. The social order among common chickens is discussed below. (Masure and Allee, 1934).

The order is established very quickly in a flock and is very difficult to disrupt. Sometimes there are sub-orders in one part of the chain. There are also other exceptions to the rule of a straight sequence. Roosters usually show a more complicated pattern than do hens. The following diagram may be a case where twelve roosters are penned and the order of dominance is established. Each rooster is given a number after the order is established.

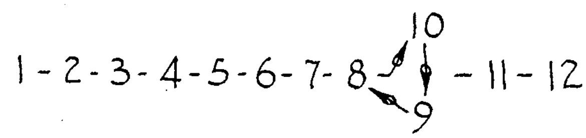


Fig. 16 The Peck Order of Twelve Penned Roosters

Dominance results from the first meeting of any two birds. The simple diagram illustrates that rooster number 8 can peck rooster 1, but not 2 through 7. Rooster 8 may peck rooster number 10, rooster 10 may peck number 9 and rooster 9 may peck 8 but not 1 through 7. Rooster number 10 cannot peck rooster 1 through 8.

When two roosters, who have established a relationship with each other, are released on a runway, they will approach each other. The distance each will travel before they meet is in exact proportion to their relative scale in the order. If, for instance, rooster A is number 2 in the order and rooster B is number 9, then A will travel nine-elevenths of the distance and B will travel two-elevenths of the distance. This is the point at which they will always meet.

Hens vie to select the roosters of highest rank. A hen will assume that poisition among the other hens in accordance to the rank of her rooster. Any hen is dominant in the area of her own nest, and any hen will usually win a battle against a stranger in her own yard.

Birds which are removed from the flock have to re-estabalish their position when they are returned to the flock. Even though a bird's previous position may have been high, it may be completely rejected the second time. The order is never permanent. Re-ranking occurs whenever one member challenges any one of his superiors. If roosters 2 and 7 fight, rooster number 2 will win 7 contests and rooster number 7 will win 2 contests.

When the order is subjected to daily artificial tampering, by the removal of members, the flock continues to fight for re-establishment of the order. Thus an organized and established flock gets along better, eats better, and produces more eggs. Stability and peacefulness prevail.

The lowest member of the order is deprived of many comforts. This member may even be kept from mating. The number 1 rooster has additional responsibilities as well as additional privileges. Thus, it appears as though the lower animals show the same desire for power and dominance as do human beings.

Pigeons do not follow the same pattern or relationships as do the common chickens. One cannot predict the ratio of contests with pigeons because with them the order is much more variable.

There is safety in numbers. Many biological processes are accelerated by the formation of a large group. The cooperative process is well demonstrated in a group by the division of labor and by the process of sexual reproduction. Social organization occurs in many different kinds of animals and in all the phyla. Therefore, natural cooperation is a selective force that confers survival value on the individuals using it. Life is not always a "tooth and claw" struggle

CHAPTER X

ALL LIVING THINGS OPERATE IN ACCORD WITH THE KNOWN LAWS OF CHEMISTRY AND PHYSICS

One of the strongest trends in modern biology is to attempt to explain most biological phenomena by chemistry and physics. When the biologist is capable of knowing what is going on, it can probably be explained in terms of chemistry and physics. The science of physiology is reaching the point of being the biochemistry of living things. Physiology is becoming a subject in chemistry.

Functional properties of living systems are determined by the structure of the living system. Cellular functions must be explained in terms of structure as function depends on structure. Again, physics and chemistry become a basis for understanding biology.

The twitching of a muscle results from the release of ATP, and the fibers coil and shorten in a physical way. The substance which causes the contraction in a muscle fiber is actionomysin. Nerve activity is nothing more than a change of potential that exists on the surface of nerve fiber membranes, and this potential can be measured by physical and chemical techniques. Other common reactions which can now be explained on a chemical and physical basis are catalytic activities, amino acid changes, respiration in cells, and the buffering processes in the cells and the blood.

Originally catalysts were thought to function only in the living cell. Biological catalysts are known as enzymes. All the activities of these enzymes can now be demonstrated in the laboratory. At the present time, all known biological catalysts are thought to be composed of complex proteins. The idea that enzymatic actions are found only in living tissues has now been completely discarded.

A catalyst is never consumed in the course of a chemical reaction. When the reaction is complete, the catalyst's surface is freed so that the catalyst may act again. A minute amount of a catalytic agent can do a great deal of work. It speeds up a chemical reaction without itself being used up in that reaction. It must be understood that it can take part in the reaction, but at the completion of the reaction it will recombine.

Enzymes are catalysts but they do not always fit the definition given for all catalysts. Enzymes always react with the original substance. Later the constituents of the enzyme are released by the chemical reaction and they react to again produce the enzyme in its original state.

Enzymes play a part in practically every living process. They often need additional parts in order to function. These additional parts are called coenzymes and they are not always manufactured by the body itself. They are added from outside the body. Niacin, a vitamin, is a coenzyme which is needed before certain other enzymes will perform their functions in the body.

Many enzymes are common to several events. Contraction of muscle and fermentation of sugar by yeast each require fourteen steps.

Eleven of these steps are identical in both processes. The end products are quite different as one is an alcohol and the other is lactic acid.

Enzymes are generally highly specific. Often they work on but one substance. When a change occurs in a substance, then the substance must have a new and different enzyme to further change it. The molecules of two compounds can contain exactly the same elements with the atoms arranged differently in each. Such compounds are called isomers. The same enzyme will not react with both compounds. Lactic acid is often referred to as being "left handed" or "right-handed" depending on which structural formula one considers.

The reaction of an enzyme with its particular substrate is often referred to as a lock and key function. The enzyme is the lock and the substrate has to be the key which will fit directly into the enzyme so that the reaction can be unlocked. There is a particular enzyme which catalyzes acetic acid. This enzyme will not catalyze mononfluoro acitate or monochloro acitate. This is due to the difference in size of hydrogen, fluorine and chlorine atoms. There are specific enzymes for monofluoro and monochloro acetate. These reactions can be observed with a spectroscope and one can see the enzymes as they are freed when the reactions are complete. A diagram of the reactions is presented below:

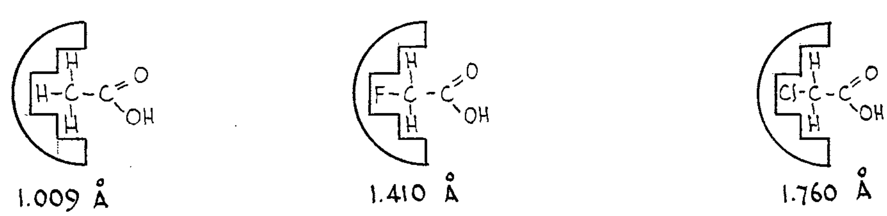


Fig. 17 How Enzymes are Specific

One specific enzyme which has been of great concern is the one found in the head of the sperm of all mammals. This enzyme is called hyaluronidase. The egg is covered with hyaluronic acid and the enzyme reacts with it to break down the egg membrane. Many sperm are necessary in order to produce enough hyaluronidase to break down this barrier. Sterility in some males is caused by an insufficient amount of this enzyme.

The one reason that sulfa drugs have worked so well is that they are similar in structure to a particular vitamin necessary for bacteria to function. The sulfa drug enters the bacterium, functions as a coenzyme, and occupies the space ordinarily taken by the needed vitamin. Eventually the bacterium is destroyed. It has been found that a genetic change, along with a vitamin change, will produce strains which are resistant to sulfa drugs. This same principle is in effect when flies are treated with DDT.

One can see the principles of a first, second, and third class lever demonstrated anytime that an animal is observed while making some type of movement. None of these classes is unique and the laws of physics are followed exactly. An example of the third class lever in operation would be the action of the muscles and the femur when a man comes to a standing position from a sitting position. The disadvantage is actually found to be ten to one. In other words, it would take a force equal to fifteen hundred pounds to lift a one hundred and fifty pound body.

When physical and chemical phenomena are applied to biological use the term osmosis must be considered. The term osmosis is used almost exclusively in biology. This need not be the case. In the first place a few questions must be presented concerning the term. Is osmosis worth the emphasis it receives? Just what does the word mean? Is it any more than simple diffusion with or without a membrane? If something passes through, then the membrane might as well not be there. If something is excluded from passage, the membrane might just as well be a solid wall. Osmosis has been too confused with big word vocabulary when it is actually just a simple idea. The selective passage of materials through a membrane has nothing to do with osmosis.

To leave the discussion at this point would be foolish. The word diffusion, which is usually included in a definition of osmosis, must be considered also. Diffusion is the random assortment of molecules tending toward random distribution. It is an inactive transport across a membrane which might be non-living. But a living membrane of cells can actively pass, or reject, material attempting to pass through it, with, or against, gradients. Thus a living membrane requires energy. The reader may recall the case in which sea fishes expel excess salt and retain the water.

There are three types of movement made by molecules which must be taken into account when consideration is given to their movement across a cell membrane. The first is diffusion and this is the random assortment of molecules toward uniform distribution. There is nothing selective about this movement. The driving force is thermal application and this could possibly be inherent heat energy. The next is facilitated diffusion which is powered by thermal application and the thing which is moving moves more rapidly due to the structure of the membrane. The last is active transport. This includes all transport and transport mechanisms involved in the passage across a cell membrane.

There are changes that take place in the membrane to facilitate the movement of molecules. Insulin does something to a cell membrane because when it is present more sugar is allowed to pass through. It must be recognized that insulin can cause the membrane to exclude some sugar from passage. Galactose must have its structure changed before it can pass through. In another case galactose is the source of energy needed for the passage of sodium and potassium salts into and out of red blood cells against the concentration gradients. Thus, large molecules can pass through a membrane, but their passage depends on structure and an activating agent.

Only living cell membranes possess the energy to pass materials against the concentration gradient. A dead membrane can still pass materials but not against the concentration gradient. There is no longer any energy to make the membrane an active participant.

The cell runs the body. It takes what it wants, rejects what it does not want and passes out what it no longer needs. The idea of the material passing independently through the membrane by diffusion is not true. Growth of this field of study has changed the thinking concerning permeability. Movement is not by diffusion, but is by active transport of the cell. The cell can do this because it has a definite structure designed for this process. It is seen to be a polarized structure with two layers of protein with a layer of lipoid material between.

A more correct definition of osmosis can now be given. It is the passage of materials through a membrane from a region of higher concentration to regions of lower concentration of the material doing the passing. Osmosis has nothing to do with the ability of the membrane, or what is going on in the cell.

CHAPTER XI

ALL ORGANISMS ARE CONSTANTLY ENGAGED IN THE CAPTURE, TRANSFORMATION, AND TRANSFER OF ENERGY

Every living organism has two basic problems to solve. One is reproduction, and the other is the maintenance of a constant energy supply. Every living organism possesses structures for the capture of energy. Some of the organisms are static or sessile forms and some are dynamic or holozoic forms.

The most primitive form of life must have been a high energy organism. It surely had to use some of its own energy as well as use that supplied by the environment. The first use of energy was for the manufacture of one molecule of energy exactly like the one which made it.

Every living organism is constantly faced by the loss of energy and its degradation into useless heat. Energy cannot disappear, but it is always less likely to be transformed into some usable form. One could say that this is a result, or comes from, the second law of thermodynamics. The molecular structure of all living organisms is constantly in a state of destruction or degeneration. The organisms must continually take on energy to replace degenerated or destroyed tissues.

Energy utilization first requires the pursuit and capture of the energy. Three body systems are always used in this function. They are the coordination of the muscular and skeletal systems in locomotion, use of the nervous system, and the use of the sensory organs as a coordinating system. It is interesting to note that organisms which do not pursue and capture food have lost the use of the body systems, or have lost the body systems altogether, which are normally used for this purpose. The plants, sponges, and tunicates are prime examples.

The utilization of energy also requires that the food be prepared and transformed into usable forms. These functions include digestion, circulation, respiration, and excretion. Then in order to assimilate the captured energy, the organism's intracellular activities, respiration or the Redox processes, endocrine system, and body enzymes must take part. The study of all these functions working together as a unit would yield a great appreciation and understanding of the biological phenomena.

Energy, in a sense, can be viewed by its flow. It begins with the capture of energy in the process of photosynthesis. Oxygen and other compounds are released in this process. The energy is transformed into carbon compounds. Utilization of the energy comes after the carbohydrates have been transferred to phosphates in the form of high energy bonds. The materials are actually used as metabolistic energy during the function of organs such as muscular energy, electrical conductivity in the nervous system, or in the transfer of food.

The energy from the sun which is actually used might be compared to holding a bucket under a large waterfall. When the bucket is full, enough of the water to fill a small saucer is the amount which is used. All the water which has passed in the meantime is no longer available for use. The used and unused energy must now be replenished.

There are quite well established beliefs concerning the concepts of using energy. One such belief is that different intracellular activities are based on differential priorities. If a cell is placed in an adverse environment, the following activities occur, in the order named. All cell division discontinues, cell growth discontinues, and all cell maintenance stops. Cell maintenance appears to have the highest priority for all needs, and when this activity stops the cell dies. (Wilson, 1908).

There is considerable research being done on investigating the factors of energy and energy relations. The expenditure of energy is a basic concept in the study of human nutrition and cellular replacement.

One can find a small bit of understanding on the concept of energy by doing some study on the growth and behavior of the human fetus.

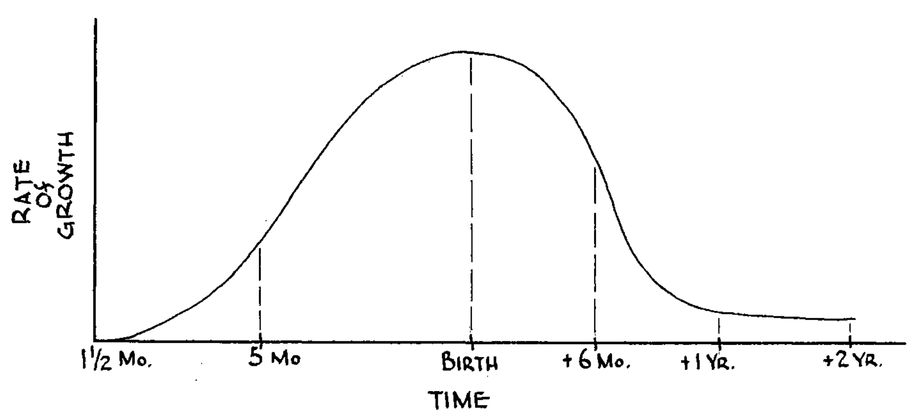


Fig. 18 Growth of the Human Fetus

The maximum rate of growth occurs during the five month to eight month period. The reflex pattern is established during the development from the one and one-half to five month period. From five months prenatal to six months postnatal there is very little development of reflex action. From five months to birth the development is somatic. After birth, the energy concepts change to behavior type concepts. At about one and one-half years, the problems become behavior type problems. There is an assignment, by the organism, of the energy supply to certain growth factors.

CHAPTER XII

ALL ORGANISMS INHERIT AND TRANSMIT BIOLOGICAL POTENTIALITIES

There are three basic concepts which serve to unify, biologically, the understanding of principles. These three concepts are energy transformation, evolution, and the genes

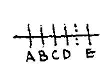
The concept of genes is based on one's understanding of the following points. Genes are the primary bases for the continuity of life. The genes are the chief controllers of the events which lead to most of the general principles previously discussed in this paper. They are the supervisors of cellular metabolism. The functions of many cellular units are characterized by a certain form. Genes can function as autocatalyzers. They can catalyze a second unit exactly like themselves. A gene is probably the origin of life itself.

Perhaps it would be well to first consider the laws of Gregor Mendel before taking a closer look at the gene. The Law of Dominance is actually not a law, but is just an observation. The Law of Dominance is not too important anyway, as ideas are changing rapidly due to the formation of new theories and to new discoveries being made. A study of inheritance will show that which is often described as dominance, or recessive, is actually an exhibition of the lack of dominance.
The Law of Segregation is also a matter of observation, but these observations do require conclusions. A masking of one character by

another does not affect the hidden character in any way. Each parent contributes equally to every characteristic. Mendel had to use a mathematical concept to be able to explain the results of his crosses. Herein lies one of the important factors of his work. The results of his monohybrid cross to get a three to one ratio is not so significant. The significance of it is that there are four possibilities. The same can be said for the 9:3:3:1 ratio of the two pair cross. By the Law of Chance it is found that if two different items are varied and are completely independent then they can be combined in as many ways as for the previous variants times four. In other words, every time one more variant is added, the number of possible combinations is four times the number of combinations possible without the added variant.

It would not be proper to infer that Mendel was quite lucky when he performed his experiments. (Peters, 1959). However, one can recognize the following facts. Mendel had no linkage to deal with. He experienced no lack of dominance. His ratios were not complicated by genes interacting one upon the other. Due to his shrewdness, he looked for about three points on his peas, thus his problem was limited.

The idea that genes were placed on the chromosomes like beads on a string was thoroughly shaken by the position effect concept. This can be better understood by reading a certain classic paper which deals with just such a case. (Peters, 1959).

The appearance of the bar-eyes in <u>Drosophilia</u> is actually due to the presence of oblong shaped eyes. The ultra-bar eye is actually more bar shaped than the bar-eye. The ultra-bar eye will revert back to the bar-eye, and the bar-eye will revert back to the normal eye. The chromosome which carries the genes for eye shape appear like this: 

The chromosome for normal eye requires genes A through E. For bar eye the genes are duplicated A-E, A-E. For ultra-bar eye they are triplicated A-E, A-E, A-E. Where these units are, on the chromosomes, has an effect on the appearance of the eye. Nothing has been changed in the gene except the position of the gene on the chromosome. Therefore, the gene is not completely independent. They can be affected by both their position and their association.

The chromosome appears to have a much more important position in heredity than merely as a carrier of genes. A gene is subject to the laws of the nucleus even though it itself controls nuclear activities. Particular regions of the chromosome have particular results in the organism. Specific units must be present to be arranged.

The gene has always been defined by its mode of action or by what it does. This depends on the way in which its protein molecules are put together to form the gene. This is the way in which genes differ in individuals and in their effects. Since the gene is a protein molecule and is also capable of self reproduction, it can be viewed as the basic building block of living things.

The mode of action, how the gene does what it does, comes from the study of biochemistry. Black urin, (alkaptonuria), has been found to be caused by an enzyme deficiency in the blood. (Muller, 1922). This particular enzyme deficiency is in turn due to a single recessive gene. The disease is inheritable. This knowledge leads to the idea that the gene has a particular function, and to a "one gene, one enzyme" conception instead of the idea that many genes control one enzyme.

An experiment with Neurospora, a mold, proved that when the mold was irradiated to the extent of only a single mutation resulting, only a single enzyme was affected. The inference is that each gene produces a single enzyme which regulates but one step in the biologic synthesis of a chemical substance. Neurospora was selected for this experiment because it has but one life cycle, many offspring with easily recognized characteristics are produced, and for other reasons. (Beadle and Tatum, 1941).

The nature of the gene as a controller of biochemical reactions is quite different from the previous ideas of gene function. The study of Neurospora is the basis of the "one gene, one enzyme" hypothesis. This idea can also be demonstrated by other means.

The gene is a substance which has the ability to reproduce itself. It must have definite and specific connections with a synthetic machine of the cell. It must have the capacity for changing its mode, or method, for affecting that synthesis. The gene must be able to maintain its ability to reproduce while achieving the above. It must be able to maintain linear connections with its neighbors, and it must be able to establish specific relationships with its homolog.

A gene that is dominant in one respect may be recessive in another, when it has an effect on two characteristics. The gene for yellow coat, in mice, will be lethal if it is homozygous. When it is heterozygous, the bearer will not be killed but will have a yellow coat. (Snyder and David, 1957).

CHAPTER XIII

SUDDEN CHANGES CAN AND DO OCCUR IN THE HEREDITARY POTENTIALITIES OF ALL ORGANISMS

A mutation is a sudden inheritable change occuring in living things. Mutations often duplicate themselves. Dislocation of organs and many other such conditions are not considered mutations. They are not passed on. The author of this paper once captured a five-legged frog. His students immediately decided the cause for the appearance of the extra leg to be a mutation. The teacher concluded that this was merely a biological mistake and proceeded to gather some support for his conclusion by mating the frog to several females. None of the off-spring appeared with five legs. The crosses were actually carried beyond the first filial generation.

There are two main catagories of mutations. One is a chromosome mutation. A chromosome may be considered here as an assemblage of genes. In a chromosome mutation, some of the genes may be lost, some may change position, or some may change themselves. These will quite likely result in a change in genotype. The other category is actually called a gene mutation. These are point changes where the structure of a gene, or genes, is changed. Such changes can either be chemical or physical. In such cases the gene, or genes, must continue to reporduce itself; or it will no longer function.

There are two possible ways of explaining point mutation. The first way would be to explain the mutation by a molecular change in the gene itself. The other way would be to explain it as a consequence of its mutagenic effect or inaccurate self duplication. Many of the effects of atomic radiation are on somatic cells and as such are not passed on. Genetically, radiation damage is cumulative because damaged genes reproduce themselves. The per cent of people to whom some mutation will occur, because of radiation, can be accurately predicted as the level of radiation is increased. Mutations occur about once in every thirteen thousand opportunities or about once in every individual. However, these changes usually are restricted to somatic cells. There is no threshold for genetic effects. There is a threshold for somatic effects. Many generations are required before the effect of damage to genes can be detected. (Genetics Conference, 1947).

A very clever method, known as the ClB method, was devised by Muller for the detection of a lost gene or for recognizing lethal mutations. The ClB technique involves the X chromosomes of the fruit fly, Drosophila. (Snyder and David, 1957). The effect of radiation on a gene can be shown by using sex genes. A lost gene will show up with an offspring ratio of two females to one male instead of the normal one to one ratio.

CHAPTER XIV

EVERY SPECIES IS THE PRODUCT OF ITS OWN EVOLUTIONARY HISTORY

Natural selection is not the same thing as evolution. The terms are not synonymous. The process of natural selection depends on some mechanism that can provide a pool of raw material for genetic changes. This mechanism must be available in every generation in order for continuous changes to occur in the species.

Natural selection is based on an increase in the species by a geometric mathematical multiple, on variability occuring among the species, and on the survival of the fittest. This is a passive force and those organisms which pass the test survive and those which do not will die.

Gene mutation accompanied by segregation and survival as a result of the mutation must be universal in living organisms. The mutations must be active enough to produce change in every organism. Evolution is defined as descent with change. All organisms are constructed to function efficiently in their environment and have been derived from simpler forms.

The following experiment can be performed by any person who has been exposed to the simpler techniques or microbiology. The experiment will serve the person with a better understanding of what has been discussed above.

The experiment is done on the bacterium, Escherichia coli. Plates of E. coli can be exposed to streptomycin and all of the organisms will not be killed. Those which remain alive will give rise to resistant generations. If streptomycin is provided often, the bacteria will actually become dependent on the antobotic in order to survive. If the streptomycin is withheld from a succeeding generation, then practically all of the bacteria will perish. After a few generations the experiment can be repeated by killing off the population again.

Polymorphism is the term applied when there is more than one kind of clearly, distinctive individuals within a species. This is an important evolutionary aspect as there are two kinds of chromosome structure.

The fruit fly, Drosophila, has two kinds of chromosome structure (A and B), but the phenotype is identical. A and B are both present in a fruit fly population. During the spring there are more of the B type present, and during the summer there are more of the A type. If these flies are collected in the ratio of about thirty-three per cent A to sixty-seven per cent B, and they are allowed to freely interbreed, at the end of about six months there will be about seventy-five per cent A and twenty-five per cent B. The AB flies are much more vigorous. When two AB flies mate, then more AB, plus AA and BB, will be produced. The AA and BB types can never be done away with completely. The AB flies, as mentioned before, seem to possess a hybrid vigor which enables them to survive over adverse conditions. Polymorphic populations can adjust to a more adverse habitat, and will always have both homozygous individuals (AA and BB), the more poorly adapted genotypes. The greatest adaptability comes when there is the greatest proportion of the AB type. (Dobzhansky and Epling, 1944).

There is a disease, found mostly in the African and American negro, called the sickle-cell disease. An infected person's red blood cells will actually be sickle shaped. In the homozygous condition the person will have severe chronic anemia, pains in the joints, muscles, and abdomen, and it is fatal almost without exception. A heterozygous individual will have some sickle-shaped red blood cells, but can live a normal life. (Snyder and David, 1957). It has been recently discovered that the heterozygotes are very resistant to malaria. In other words, the heterozygous condition has survival value.

Sexual reproduction is primarily important for the recombination of genes that can take place. If one assumes there are one thousand genes in a human and that each reacts with two variables, then there will be two to the one thousand power possible combinations. This figure is larger than all of the combined number of protons and electrons in the whole universe.

It must be reiterated that the population is much more important than the individual. The genetic ratios present in any population can be figured with no importance given to the individuals involved in the population. The number of alleles can be accurately predicted for any population. (Hardy, 1908).

Evolution is sometimes considered as the change in the frequency of genes in the gene pool as against the total number of genes present. If the reproductive capacity of an individual is great, then a greater number of its genes will be present in the gene pool.

Perhaps the idea of "struggle for existence" is not important and should not be strongly considered. The only time that it really becomes important is when the "struggle" results in a loss of reproductive capacity. If a battle (the idea of "struggle for existence" is not meant to include only actual physical struggles) does not end in death, then the battle is not a factor in evolution. There is no change in the gene pool unless the animal loses the capacity for reproduction. Most people are familiar with the fact that male seals fight for a harem. The unattached young males will challenge the older males which are attached to a harem. This is not significant unless one of the males is killed. Eventually the young seal will win and his genes will then enter the gene pool. One should also note that man does not give up in the selection of a mate if he is refused the first time. This helps point up the fact that selection has little importance in evolution.

Many aspects which are thought to be sexually selective in nature really are not. The bright color of male birds has nothing to do with reproduction. Usually the bright color is a factor in laying out the nesting and feeding territory as it is used to scare off other males. The female merely chooses a territory and takes the male that goes with it. If all the males obtain a mate, then the struggle for territory is no longer an important factor in evolution. It must be pointed out that the above statements are by no means universally accepted by all ornithologists.

CHAPTER XV

ALL BIOLOGISTS SHOULD CONTINUALLY RECONSTRUCT THEIR IDEAS

Some biologists feel that evolution takes place from the simple to the more complex. In other words, they say "from Amoeba to Man." This is not true, and it further demonstrates a poor use of terminology. The idea of evolution is often put forth in the form of a phylogenetic tree. This tree is so constructed that man and those animals most like him appear towards the top. Then the biologist will state that these animals are more complex, because they are constructed of more parts. Complex should not be taken to mean more parts, nor should simple be taken to mean less parts. The Amoeba is just as complex to describe as any other organism. It just uses fewer parts to do what other organisms need many parts to do.

One often hears that man is the most successful organism living today. He controls his environment and thus the statement must be true. The person who makes such a statement must be completely overlooking the fact that other species control their environment too. Bee discovered air-conditioning long before man appeared. The beaver is quite successful at controlling his environment.

When one speaks of success, it depends on what he is using as his measurement. The criteria often used are those that are devised to measure only the capabilities of man. Actually, every organism alive today is a success. Probably the most successful organism is the virus. It requires less energy, has less environmental pressure, and less parts which it must maintain to carry on in the environment it has selected.

Going from simple to complex might mean going from dependence to greater independence of the environment. If this criterion is used and stated, then it can be said that man is more successful in altering his environment than any other organism. Man has become a better adapted organism as a result of his independence of the environment.

Perhaps the phylogenetic tree as generally constructed should be considered a little further. The construction of such a tree is the direct consequence of thinking in the line of simple to complex. This is a most misleading simplification of how the phenomenon took place. Too often the location of an organism on the tree is used as a basis for deciding whether an animal is higher or lower than another.

This tree as generally constructed is small at the bottom and large at the top just as a tree really is. The branches get smaller nearer the top. This indicates that evolution was very great at the bottom and much slower at the top. Again, this is not true. Evolution is now going as fast, if not faster, as it has in the past. This tree also leads one to subscribe to macromutation. Naturally occuring mutations are all micro. Macro infers that any phylum could give rise to another. The tree ignores time entirely. Furthermore, it indicates that the higher an organism is on the tree, the more it has evolved.

The evolutionary history of any species may have been shared in part by any other species. The similarities between these species is an indication of their same evolutionary history. Perhaps, then, it may be more nearly correct to present the evolutionary history of organisms in the form of a phylogenetic wheel. Such a wheel is presented below. The circles on the wheel represent time. The dot in the center is the origin of life, perhaps a naked gene. One species on the wheel is no more important than another. Every single living species will be represented at the edge.

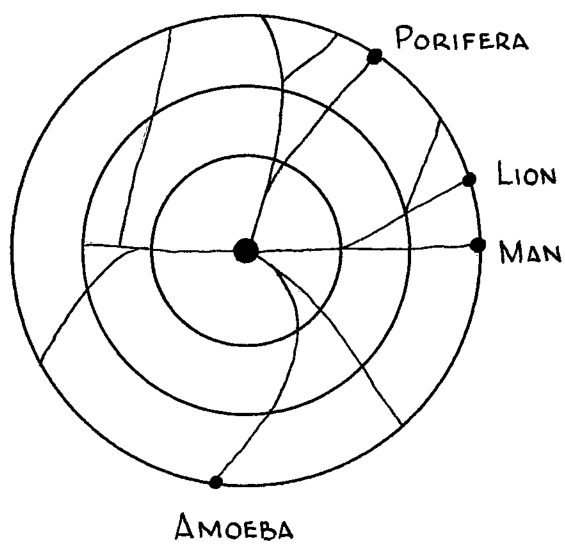


Fig. 19 Phylogenetic Wheel

A fitting climax to this paper would be a condensed version of "The Strangest Story Ever Told" as it was written by James C. Reattie for the March, 1951 issue of Coronet Magazine.

Imagine a movie which runs continuously from New Year's Eve to New Year's Eve of the next year. This movie was taken at the rate of one picture frame per year for seven hundred and fifty million years. The movie could be run at the rate of twenty-four frames per second or in other words, one second equals twenty four years. At this rate one can view the history of the earth pass before him as follows:

January, February, March------------------------No sign of life

Early April-------------------------------------Single-celled life appears

Late April--------------------------------------Muticellular organisms appear

Late May--First vertebrates appear in the ocean

July 15---The first land plants appeared

August 20---------------------------------------First amphibians left the water

September 15------------------------------------The first reptiles appeared on earth

September 15 - November 15----------------------Age of the reptiles

October 15--------------------------------------The first birds and mammals appeared

November 25-------------------------------------The Rocky Mountains appeared

December 1--------------------------------------The mammals began to dominate the earth

December 25-------------------------------------The Colorado River began to cut the Grand Canyon

December 31 at noon-----------------------------The first man appeared on earth

December 31 afternoon---------------------------Glaciers came down and receded over North America four times

December 31 - 6:00 P.M.-------------------------No new man has appeared

December 31 - 11:00 P.M.------------------------Stone-age man appears

December 31 - 11:45 P.M.------------------------Stone-age implements appear

December 31 - 11:55 P.M.--------------------------The dawn of modern civilization

December 31 - 11:58 P.M.--------------------------The Christian Era begins

December 31 - 11:59 and 40 seconds----------------Columbus discovers America

December 31 - 11:59 and 43 seconds----------------The Declaration of Independence

The above can be summarized by presenting the following points. Life has existed on earth for some eight months of the movie year. Man has been here for twelve hours of that year. The Dinosaurs dominated the movie for seventy days. Man has been in existence for twelve hours of the movie, but for only five or six minutes has he had any civilization worth mentioning.

Really, man is just barely getting started on this earth. Someday he may learn to live without war, crime, and drudgery.

The lack of time has now become a factor in the preparation of this paper. The material presented here merely represents a start on what the writer hopes someday will be a more complete work. There is a world of material which is available and can be used to make this paper more complete. Someday the reader may see that material presented, along with what has been presented here, in a textbook.

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VITA

John Dean Ransom

Canidate for the Degree of

Master of Science

Thesis: BIOLOGICAL GENERALIZATIONS: A METHOD FOR INTEGRATING THE SUBJECT MATTER TO BE TAUGHT IN AN ADVANCED HIGH SCHOOL BIOLOGY COURSE.

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