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The Origin of Life:Ahistory of Ancient Greek Theories

Curriculum Unit 80.05.11
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This unit presents a history of scientific thought relating to the origin of life as explained mainly by early Greek scientific philosophers. The unit begins with Greek science during the eighth century B.C. and proceeds quickly into the seventh century B.C., concluding with the fourth century B.C. Since the scope is limited to this time period the unit will end with information that is presently, for the most part, outdated. The teacher must constantly remind the students of this fact. The purpose of this unit is not to impart scientific knowledge for its own sake. Rather, it is to show how scientific thinkers came to their conclusions based upon how science was viewed in the scheme of history.

There are various high school courses taught, yet no specific course has been designed to relate the development of the academic disciplines to each other. Many science textbooks include the names of scientists who contributed valuable information upon which specific ideas were developed. Yet, most textbooks provide a minimum amount of information relating to the scientists themselves. It is my feeling that students will better understand the development of scientific thought if an opportunity can be provided in which a connection can be made between science and history.

There are four general objectives for this unit. Upon completing the unit students will: 1. be familiar with the ideas of early scientific minds, 2. recognize the relationship between Greek science and Greek history, 3. realize the importance of observation and drawing conclusions, and 4. appreciate the development of science.

Approximately one month before beginning this unit the teacher should require each student to read one book which in someway deals with the Greek period covered in this unit. Selections may be made from an historical or scientific aspect. Before the unit is begun students should have completed a book report and be required to present a short oral report. This will insure that all students have some common frame of reference from which to work. Lesson one at the end of the unit should be started the first day the unit is taught.

An excellent laboratory activity which should be done early in the unit is the biogenesis of microorganisms, i.e. producing microorganisms from hay infusions. This will arouse student interest and help them to understand how incorrect conclusions were drawn. Later, a laboratory activity based upon the experiments of Spallanzani, Pasteur, or Redi should be performed to show how spontaneous generation was disproved. For the advanced students, the development of fertilized chicken eggs could be done in the classroom throughout the unit. All of these activities are readily available in most laboratory manuals. A very complete guide to egg incubation is provided in the 4-H Manual listed in the teachers bibliography.

In Hellenic (Greek) antiquity cosmogonic ideas originated in the eighth and seventh centuries B.C. These were religious and legendary descriptions of the origin of the world. There was a belief in the cosmic egg from which all things were said to have been produced at the beginning of the world. Most of these ideas began to establish themselves at the end of the seventh century.

Before the teacher pursues these scientific ideas it would be best to provide each student with an early map of the Greek land. This will help students to understand the colonization of the Greek land, allowing them to visualize the areas in which the scientific men originated. The map should be referred to throughout the unit.

The first Greek tribes to become civilized were the Ionians and the Dorians. The Ionians were fond of math, philosophy, and astronomy. The Ionian colonies were in the eastern part of the Agean Sea, off the West coast of what we now call Greece and off the coast of Asia Minor. These colonies sprung up on the many tiny islands located in this region. The two greatest colonies which were developed were Miletus and Cos. The latter was located at the southeastern corner of the Aegean Sea. Road travel was extremely hazardous and these sea colonies were of great importance to all Greeks. Ionian descendents also settled and formed the Greek city-state of Athens. The Dorians were less civilized but more practical people than the Ionians. Sparta was the chief city-state, settled by the Dorians, on the peninsula in the land south of Greece called Peloponnesus, which means “Land of the Pelops.” This area was probably the last area, along with Athens, to be settled by the Greeks.

The word “Hellas” means Greek. Anyone who did not speak the Hellenic language was considered to be a barbarian because they spoke languages which, to the Greeks, sounded like “Bar, Bar, Bar.” These people were considered to be unintelligible and inferior by nature. This included the people we know now to be the Egyptians and the Persians.

To the Greeks, philosophy meant a love of wisdom. Philosophy and science were identical. The Greeks were concerned with the origin of things and from that knowledge they wanted to build up a right way of life. Their answers were sometimes inadequate and often wrong. It was the quality of their minds which they brought to their inquiries that was of great importance. They had a passionate desire to know the truth about living things. They had the power of going beyond superstitions and of seeing things as they truly were. These scientific philosophers were open-minded and willing to accept new truths and were patient students and observers. They had a strong desire to learn the unknown through reasoning from the known, which was acquired through experience. It was not enough to know that something existed; it was also necessary to find out why it existed.

What is Man? What is the world? These questions had always been pondered by the ancient Greeks. For this reason, many of the myths which centered around Zeus, Poseidon and Hades were told in early Greek history. The myths were usually quite concrete and specific, explaining both natural and human phenomena by reference to particular supernatural events or actions which in themselves were unaccountable. Thales was the first of the Greeks to try to generalize the questions and propose general, more rational answers which did not specifically involve the Greek Gods. He tried to separate theology and science.

Thales the Milesian (639-544 B.C.), was one of the Seven Sages of Miletus. He was fond of “physis,” the Greek word meaning nature. He was a self-educated man who had learned a great deal by traveling. He was a wealthy man, as most studiers of science were, with a very high social standing. Because of this high social standing he collected many disciples. What is today called science was born over two thousand years ago in this Ionian colony with this Ionian descendent. Thales questioned the real meaning of things he saw in his world and he had a great desire to go beyond the facts and try to find out the reasons for their existence.

One of Thales' contributions was based upon his observation that water was the most abundant material on the Earth and all plants and animals needed it for life. He postulated that life originated from water and that everything died when deprived of it. This concept, although based on reason, still had a magic aura about itself since Thales did not attempt to explain how or why the birth and death actually occurred.

To the modern student of science, this concept and some of the others to follow, may seem ridiculous. It is important for the teacher to point out that none of these early thinkers had any scientific instruments to help in their work. Thales was the first person to base thought on observable facts. We know today that observations made without scientific instruments often prove to be something different when made with highly specialized equipment.

A student of Thales, Anaximander of Miletus (611-547), helped to free Thales' concept from magic and helped the elevation of science into pure reason. This was the pattern to be followed by future Greek thinkers. Anaximander spoke of the germ of the fetus of the world. He gave more of an explanation as to how life originated. He believed spontaneous generation had taken place in the residue of mud and mist on the Earth while the water was being evaporated by the heat of the sun.

Anaximander did not believe, as his teacher had, that water was responsible for creating life. He did feel that water, along with earth, played a part in developing life, but he felt there was something else. He theorized about an unknown substance or force which he called "apherion." He felt that this was the original material which was not one of the recognizable elements, but a neutral matter, indefinite and unlimited, out of which all other elements were formed. He further explained that apherion existed in two different principles, hot and cold. Intermixes of these two types of apherion had given rise to the four major elements of which the Earth was made, namely, earth, water, air and fire. The etheral substance, apherion, was unlimited and endless and not subject to decay or old age and constantly yielded fresh substance for new beings that issued from it.

Anaximander observed that Man was helpless for a long time after birth and he needed special protection, Man was unlike many of the other creatures of the world, most creatures soon became self-supporting, Man did not acquire this skill until long after birth. For this reason he postulated that Man would not have survived for long if this had been his original form. He felt that the first life must have consisted of creatures with a thorny bark which were generated in the warm slime and it was from their successors on dry land that Man first hatched. He felt some type of fish-like creature, in the original semen, had grown, inside themselves, embryos which were retained inside until they reached puberty. At this time the creatures burst open depositing men and women who were already able to nourish themselves.

Anaximander's student, Anaxagores of Clazomenae (570-500 B.C.), from northern Ionia, shed a different light on the subject. He felt it was not water nor apherion but air which was the main force of life. It was air which enveloped the earth and penetrated into the body of all living things. He felt air was strong and had body. His proof for this was often provided when he would tie up empty wine skins and then squeeze them to show the presence of the air. Air represented life giving and life preserving principles.

In Anaxagores' view, in the original state of the universe, before the separating off process began, air must have prepondered to such an extent that the minute particles of all other substances would simply not have been perceptible. This question of the perceptionality of particles was fundamental to his thought. His theory of matter stated that everything contained minute particles of everything else in varying proportions and one changed to another as food changes during digestion.

Anaxagores was concerned with the origin of life on a universal level. It is not surprising to find that he taught (one of his students was Pericles who was to rule during the Golden Age of Greece) and concerned himself most with the area of astronomy. This eventually led to a charge against him for his blasphemous assertions about the heavenly bodies. In order to escape prosecution he was forced to flee to Lapsacus where he was received with honor.

A contemporary of Anaxagores, Diogenes of Apollonia, felt that the life giving force was fire. He accepted the view of Anaximander as true, but he felt it was not apherion but the heat it created that gave rise to life. He related this to heat inside the uterus and talked in terms of a living embryo. He felt there was a fire inside the embryo which set the parts in order as they developed. He stated that a mass of flesh formed first and bone and nerve were formed next. He was the first to recognize the placenta as an organ of fetal nutrition. He also theorized that the male embryo was formed in four months and the female in five. This error was probably due to the fact that in the early months of pregnancy the abdomen does not protrude and, more importantly, that fetal movement is not felt until later months.

For a time, Empedocles of Acragas (504-433 B.C.), brought these long standing arguments to a close. He based his beliefs on what he called the four humors, which were of course, fire, earth, water and air. These basic components of the world originated from a combination of four fundamental qualities which were hot, cold, wet and dry. He postulated that all the world changes were associated with different mixes of the four humors. Plants and animals arose through the functioning of fire which cast up out of the earth's interior shapeless lumps that formed into Man. He declared that growth in infancy depended directly on an increased warmth of the body while decreased warmth produced aging.

Empedocles described the embryo as deriving its composition from four vessels, two veins and two arteries, through which blood was brought to the embryo. Sinews were formed from a mix of equal parts of earth and air, nails were formed from congealed water, while bones were formed from a mixture of water and earth. He also speculated about the causes of monsters and twins. Empedocles was sure that these strays from the normal pattern occurred because of the influence of the maternal imagination upon the embryo, which was so very great that it interfered with the guiding fire during formation.

Empedolces' ideas marked the end of the archiac scientific Greek thinkers from the Ionian Islands. In the next two centuries which were to follow, there was a switch in the location of the great thinkers from the Ionian islands to the city of Athens. Students should be reminded that although there is a geographic change, the men who are next to contribute are still of Ionian descent.

During the fourth and fifth centuries B.C. the city-states of Athens and Sparta flourished and cultural achievements increased and reached their greatest heights. This was sometimes referred to as the Golden Age of Pericles, or the Classical Greek Period. During the fifth century Athens became an empire; the school of Hellas appeared, and the center of all Greek learning was founded in Athens. Unfortunately, by the end of the fifth century Sparta became wary of the power that Athens had gained and the Peloponnesian War broke out between these two great city-states. Sparta conquered Athens and Spartans began to rule. During the fourth century the plague broke out and one third of the Greek population died as a result of both of these catastrophes. During the high point of this period philosophy ruled in the academic world.

Probably one of the most well known men of Greek science may have already been familiar to students, Hippocrates (460-370 B.C.). Historians are uncertain about who actually set down in writing the ideas of this famous physician but evidence seems to indicate that the Hippocratic writings may have actually been done by Polybus, Hippocrates' son-in-law. These writings included three books which dealt with obstetrics and gynecology. It was in these books that Hippocrates described his *Doctrine of Four Humors* (which was the foundation for his medical practice) and described suggestions to be employed by the physician at the time of child birth. Hippocrates recognized the importance of methodology and he was the first advocate systematic daily observations of the fertilized chicken egg.

In his time men who were physicians usually had a father who had been a physician, so it was with Hippocrates. In approximately 600 B.C. the Ionian's had established a medical school at Cos. This was one of the oldest scientific institutions from which records have come down to modern times and Hippocrates is the most famous graduate of this school. After completion of his studies Hippocrates traveled a great deal and made keen observations of people who were ill. He is credited with curing the great plague in Athens. Throughout his life he continued to study the available medical works because he was greatly concerned with trying to find new ways to decrease human suffering.

The Hippocratic *Doctrine of Four Humors* is probably the most famous of ancient ideas. Although it seems to have been based on the ideas of Empedocles, Hippocrates took it one step farther and used it in his work with patients. He related these ideas directly to the fluids in the human body. Earth was synonymous with phlegm, air with blood, fire (hotness and coldness of the body) was exemplified with yellow bile, and water (moisture and dryness of the body) was exemplified in black bile. A balance of all of these fluids yielded good health.

Hippocrates felt the two major constituents of all living bodies were fire and water or yellow and black bile. He said that each of these were in turn made up of three primary natures which were only separable in thought and could never be found isolated. They were heat, dryness, and moisture and each had the power of attracting their like, a very important feature of the system. Life itself consisted of the moisture being dried up by the fire and being rewetted again by the moisture. Nourishment coming into the body was consumed by the fire, so that more was required to continue life.

His Treatise, *On Formation of the Embryo* , related the proceeding ideas to the origin of life. In it he stated that the sex of the offspring was produced by chance, being set into motion by the fire. Fond and breath were introduced via the mother's body. At first the embryo's body was the same throughout, porous, but because of the fire it dried up and solidified, creating a dense outer crust so that the fire inside could no longer draw in a sufficient amount of nourishment nor expel air. Therefore, the fire began to consume the interior humidity. Parts of the embryo which are naturally solid (hard and dry) were not consumed to feed the fire. Rather, they condensed and solidified as the moisture disappeared creating the bones and the nerves. In this manner, the fire continued to burn up the humidity, forwarding the development towards the natural disposition of the body.

Since the fire could not make permanent channels in the solid and dry parts it was forced to do so in the soft and wet parts, where it would receive its nourishment. The fire created air pipes and pipes for delivering and receiving food. It then made three circulations through the embryo and what were the humid parts became the blood vessels. The remainder of the water contracted to form the flesh. Hippocrates explained the formation of the embryo on machine-like principles, related to the observed properties of fire and water. The embryo drying up during development was an observation anyone could easily make by comparing a fourth day chick to a fourteenth day one.

Different lengths of gestation time, depended for him, upon when the embryo met with the fire. The birth resulted when the embryo showed itself to the light after having completed the blending of water and fire and there was a lack of food. He recognized the umbilical cord as the means of fetal respiration and nourishment. He believed that in the later stages of development the embryo was able to nourish itself by sucking from the placenta. His proof for this was based upon the observation that the intestine contained meconium at birth.

Also, he theorized, if this were not true then how would the newly born life have learned to suck?

A lesser known contemporary of his, Democritus of Abdera, (470-380 B.C.), who was also a descendent of Ionian Immigrants from Teos at Abdera in Trace, popularized what became known as the Atomic Theory. Democritus theorized that the universe was made of atoms which moved in space and all physical changes were due to the union and separation of these atoms. Life was dependent on these atoms and death came when these life giving atoms departed from the body and went back to the sky from where they had originally come.

This theory had originally been postulated by a Milesian named Leucippus but it was Democritus who developed it as an alternative theory for the development of life. He continued the theory by saying that space was infinitely indivisible and the atoms, of which matter were composed, were also indivisible and impenetrable bodies. Thus, the atoms were the indivisible minimum units of physical substance. All atoms were made of the same materials but they differed in their shape, position, and arrangement. These differences were responsible for the multiplicity of phenomena which occurred in the world.

According to this theory the creatures of the world started with large numbers of atoms breaking from the infinite mass and going into a huddle in a patch of empty space. Larger groups of matter were built upon these center atoms. What started this process was never clearly identified but once begun the process was automatic and the driving force was necessity. This view was more universal and less specific than that of Hippocrates. It tried to describe how original life forms had been created and made no attempt to explain these ideas in terms of an embryo created inside the body. Plato (427-347 B.C.), the famous Athenian philosopher and teacher, applied a semi-atomic theory to the development of life. His ideas seems to have taken their origin from those of the two previous men.

Plato believed, as did Hippocrates, that the body was composed of four humors and that development progressed in a manner similar to that described by Democritus, Plato felt the embryo had triangles of new materials which were locked tightly together while still remaining soft and delicate. When triangles of meat and drink were brought in from without, and were absorbed into the body of the new form, being older and weaker than the triangles already present there, the frame of the body would get the better of them and then its newer triangles would cut them up. So the animal would grow, being nourished by a multitude of simple parts.

Plato’s most famous student, Aristotle (384-322 B.C.), was the last to make worthy scientific contributions before the decline of Greek science was to take place. Aristotle’s observations and conclusions were to be unsurpassed until the time of the Renaissance. His analyses and interpretations of embryogenesis raised all of the most important questions of developmental biology. He developed a collection of knowledge which became the foundation on which all of embryology was built. Two thousand years passed before it was equaled or surpassed. Comparative embryology came in to its own as Aristotle observed the development of different animals.

Aristotle’s basic beliefs followed the Hippocratic treatises which he expanded through active observation and deduction. He also made daily observations of fertilized chicken eggs and was the first to consider that the chicken embryo was formed from the white and not the yellow. He also asked why it was that eggs of a particular species develop only into beings of that group. He may have been the very first scientist to have worked on a dissection of a human embryo which had been aborted.

Aristotle spent most of his early life as a student to Plato, remaining Plato’s student at the Academy for some twenty years, until the time of Plato’s death. Aristotle’s father, Nicomachus, had been a physician who died while Aristotle was still a child. Although his father did not live to see his son grown, his status as a physician was to affect Aristotle’s later years. His father had been the court physician to Amyntas, father of King Phillip of Macedonia and grandfather of Alexander the Great. This situation was to lead Aristotle into unhappy times before his death.

Aristotle felt the world of experience was what needed to be understood, not empiricism. One third of all of his work was done in the area of biology and his biological interests were satisfied only when he understood the purpose, function, and final causes of living things. Aristotle did not go on to provide practical application of his knowledge, probably because Greek science and philosophy were very aristocratic, developing in the leisured classes for whom the only acceptable practical pursuits were war, statecraft, poetry, and oratory. To look for practical applications would have been, in essence, a lowering of his social status.

During Aristotle’s time scientific philosophers were beginning to divide into two opposing groups that were to exist into the 1600’s. One group, called the Preformationists, felt that the embryo existed in a miniature form before fertilization occurred. This group further divided itself into two opposing groups, the Ovists and the Spermatists, depending on where the miniature was thought to exist. Aristotle belonged to the group which was to eventually be proven correct, the Epigenesists. To these thinkers the individual began life in a simple, undifferentiated state and all of its necessary structures developed as the process of embryology progressed. Development consisted of a change from simple to complex, not merely an increase in size as the Preformationists believed.

Within both of these groups there also existed another two groups, the Vitalists and the Naturalists. The difference between the thinkers of these two groups centered on the nature of life itself. Naturalists believed that all the actions, movements, and activities of living things could be expressed as the outcome of forces which could be investigated in matter that was not living. Aristotle was a Vitalist, believing that living organisms contained some principle of a quite particular nature different from anything that is found in matter that was not living. “Pyche” was the Greek word he used to describe the difference between living and non-living things. He theorized that different organisms had different kinds of psyches. Most of Aristotles’ ideas were presented in his treatise, *On Generation of Animals* . This was the very first complete embryological work ever written but by modern standards it was not well arranged, was repetitious and haphazardly put together. This may have been due to the fact that he was without scientific nomenclature. Fortunately, he was the first to illustrate his treatises, which helped to clarify his writings.

In the first section of this work, *Pangenesis* , he refuted the popular idea that the semen took its origin from all parts of the body, so as to be able to reproduce in offspring the characteristics of the parent by coming together in the reproductive organs at maturity to represent the parts from which they had originated. In the second section, *Epigenesis and Preformation* , appeared a most noteworthy contribution to embryology. Within this section he stated his *Doctrine of Menstral Blood* , where he expanded his theories about formation. He stated that the menstral blood was the structure giving principle, the semen, which shaped the embryo as a sculptor shapes stone, providing an energy-giving force which guided development. He refuted the preformationist concept and explained how the embryo formed from homogeneous matter.

Aristotle did not believe that the sex of the embryo was produced by chance alone. He felt it was determined at coagulation (fertilization) depending on which, the male or the female, contribution was the most dominant. His complete theory of fertilization provided a specific mechanism for sex determination. He stated that the formation of the embryo was a kind of clock-work mechanism which, once set into motion, continued until the entire embryo was formed.

Aristotle believed that a negative or nutritive soul existed in the unfertilized material. Generation first produced more specific parts, later less specific. Different types of souls existed and entered the embryo at different stages of development. These souls were not breathed in from an external source but were, instead, internally generated when necessary. Parts were formed, according to Aristotle, by being softened by the fire but not melted, bones became insoluble by fire as does pottery. The upper part of the body was first marked for development and the lower later. This occurred in an outline fashion with form, color, hardness and softness being acquired at a later stage. On the development of the original life forms Aristotle postulated that higher organisms had existed from eternity just as they do now. Only more primitive forms of life, such as plants and invertebrates were derived from non-living matter.

During the time in which Aristotle lived, King Philip ruled in Macedonia and became the father of a son named Alexander. When the boy was young, King Philip recognized the need for a good tutor to develop Alexander's intellectual and observational powers and so the king summoned the son of his father's physician, Aristotle. Aristotle remained in Macedonia for several years. What caused the end of the relationship is uncertain. All that is known is King Philip was murdered, Alexander took over the empire, and Aristotle went back to Athens.

Once back in Athens, Aristotle set up a school called the Lyceum. As Plato had taught in a grove at his school, the Academy, so did Aristotle. The name of the new school was derived from the Greek word "lykeides" which was a familiar word for luminous or light-bearing. Through the gardens with his students Aristotle walked and talked. In the Greek language "peripatos" meant to walk and so his followers became known as "Peripateics."

In those thirteen years while Aristotle was at his school Alexander's empire grew. However, in the year 323 B.C. at Babylon, at the age of thirty-three, Alexander died. Military powers which were opposed to Macedonia seized power in Athens and Aristotle, who had lived in Macedonia as Alexander's tutor, was under suspicion of having Macedonian sympathies. An accusation of impiety was brought against him and he was charged with having instituted a private cult in honor of his friend and uncle of his wife, Hermias, who had been a former member of the Academy and was the Tyrant of Assos and Atarneus in Mysia and Asia Minor. The charge was brought about because Aristotle had created a statue and poem honoring Hermias. He was forced to flee from Athens leaving his school in charge of a former student of Plato and his favorite student, Theophrastus. He sought refuge under the protection of Antipatec, Viceroy to Alexander, in Chalcis in Euboea, where he died one year later in 322 B.C.

Greek scientific learning also seems to have died with Aristotle. The Greeks were no longer a free people and with the conquest of Athens, first by the Spartans during the Peloponnesian Ware, and later by outside forces, all creativity seems to have left the Greek people. What began next in Greek history has come to be called the Hellenic Age. During this time the seat of learning shifted from Athens to Alexandria, Egypt. Through the following centuries, up to 100 A.D., some minor advances were made but none equaled the contributions of the early Greeks. By the end of the second century A.D. science was virtually dead and the Dark Ages began.

Lesson One—Creating a Life Comparison Bar Graph

On the first day of teaching the unit give students graph paper. Explain to the students that they are to begin to construct a bar graph that will be used throughout the unit. Along the left side students are to number the lines using divisions of twenty. Starting from the year 640 B.C. at the bottom and working up until the year 300 B.C. Along the bottom students should skip every other column. (Note the paper should now be turned so the names can be written inside the column rather than across.) The following names should be copied in this order: Thales, Anaximander, Anaximenes, Empedocles, Hippocrates, Democritus, Plato, and Aristotle. As each scientist is introduced students should be given their life span dates and the graph can be filled in. This on going activity will be useful in helping the students to visualize the time relationships between these men and their ideas.

Lesson Two—Culturing Frog Eggs

This activity can be done with a few simple materials which include: fertilized frog eggs, small finger bowls, dissecting needles, microscopes-dissecting and or compound.

Eggs should be maintained in pond water, with sprigs of Elodea if possible, at a temperature of 18 to 20 degrees Centigrade. Eggs which become cloudy should be discarded. Each day students are to remove a few eggs and examine them. Using a textbook, students should make daily labeled diagrams to show the observed developmental changes. Hatched tadpoles may be transferred to a large bowl or aquarium containing pond water. The young tadpoles will survive nicely on baby food spinach.

Lesson Three—Observing an Egg

The following 3 pages may be duplicated and given to students. This lesson should take 25 35 minutes. Answers: 1. No embryo, 2. I, 3. F, 4. H, 5. G, 6. C, 7. B, 8. A, 9. D, 10. E, 11. Shell, 12. Outer Shell membrane, 13. Vitelline membrane, 14. Inner shell membrane, 15. Chalaza, 16. Albumin, 17. Blastodisc, 18. Yolk, 19. air space.

OBSERVING A FERTILIZED UNINCUBATED CHICKEN EGG

I. Materials-Egg, fingerbowl, scissors, cotton, forceps, dissecting needle.

II. Procedure and Observation

1. Prepare a bed of cotton in a fingerbowl. Place the egg down so it is held in position by the cotton.
2. Observe the shell which is composed of calcium carbonate and provides a protective covering. Although it is hard, it is also porous. Observe the larger end of the egg for the small pores which are the largest here. The pores allow for an exchange of gases and moisture.
3. Open the shell by inserting the scissors and cutting out a small circle. If you cannot easily get

your scissors inside try gently breaking a small hole with the dissecting needle. If you have an accident transfer the inside of the egg to a fingerbowl filled with water. (Note: If the yolk has been damaged you will need another egg.

4. Look for an *air space* at the larger end. The air space acts as a cushion and will be the place where the chick draws its first breath. The space results when the egg is laid. The hen's body temperature is higher than the outside environment causing the inside of the egg to shrink due to the cooling which occurs.

5. Near the air space you should be able to observe a membrane surrounding the white or *album* in of the egg. This is the *inner shell membrane.* The *outer shell membranes* may be observed on the pieces of shell which were removed in step 3. It is attached to the inside of the shell. The membranes function to protect the inside from evaporation and bacterial invasion.

6. Observe the albumin. The albumin provides protein for growth. Notice the opaque cords located in the albumin which connect to the yolk. These are composed of a special protein and function to hold the yolk in place. They are the *chalazae* (singular=chalaza).

7. Observe the large yellow *yolk* which contains protein, fat, carbohydrates, minerals and vitamins. When combined with oxygen which has been taken in the yolk provides food for the embryo. An invisible membrane, the *vitelline membrane* , surrounds the yolk and embryo.

8. On the upper surface of the yolk look for a red "blood" spot. This will identify the position of the embryo which can be seen as a small white spot. The area where the embryo develops is called the *blastodisc* . Examine this area with a dissecting microscope if possible.

III. Summary

1. How does a fertilized egg differ from an unfertilized egg?_________________

Match the following terms with their descriptions.

_____2. shell A. greatest amount of protein
_____3. blastodic B. provides embryo with nourishment
_____4. chalaza C. surrounds embryo and yolk
_____5. air space D. surrounds the albumin
_____6. vitelline E. attached to the shell membrane
_____7. yolk F. area in which the embryo develops
_____8. albumin G. located at the large end of the egg
_____9. Inner shell H. thicken portion of albumin membrane

10. Outer shell I. hard protective covering membrane

Using the above terms label the diagram found on the following page by placing the correct term on the line proper number.

11 ______________

12 ______________

13 ______________

14 ______________

15 ______________

16 ______________

17 ______________

18 ______________

19 ______________

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* These three books are highly recommended for the high school student. There are a total of twenty-five biographies in this series. Each provides an excellent account of the lives of scientific thinkers whose contributions have most advanced science.

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