Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Basic Human Genetics

Curriculum Unit 90.06.06
by Anita G. Santora

This interdisciplinary set of mini-units on basic human genetics is designed to be taught during the course of a school year as a theme of focus for integrating curriculum in a self-contained sixth grade class where one teacher is responsible for all curriculum areas. Alternatively the various components of the unit could be shared by single-discipline teachers working with the same groups of students. The introduction to the unit, "Similarities and Differences," may begin early in the school year. It can be developed over a period of time as the mathematical skills needed to carry out the activities are taught. The balance of the mini-units are intended to enrich the life sciences normally covered in the curriculum. Much of the teaching will, of course, take place in science classes. However, an extensive student bibliography is provided so that reading and report writing activities can be assigned. Social studies content includes career exploration and current event interest.

I intend to use the unit intermittently during the year as a continuing theme. However, the mini-units adapt readily to being taught separately as interest and need dictate.

Mass media reporting of advances in the field of genetics has become an almost daily occurrence. In one recent week, national television news shows were announcing a probable genetic link to alcoholism and another to the susceptibility to tuberculosis. *The New Haven Register* highlighted a Yale study to "target genetic flaws . . . before a woman is even pregnant". *My Weekly Reader* reported the genes from firefly-like beetles being placed in bacteria.

The resultant glowing bacteria are being used to study patterns of inheritance. A recent advertisement appearing in *Parents Magazine* offered genetic "fingerprinting" of children as a means of positive identification in cases of kidnapping. The current interest in the topic takes human genetics out of the realm of advanced biology classes in high school and college and places it with a background of general knowledge necessary to comprehend reading and current events.

Human genetics is, above all, the study of human diversity. There are, of course, those common traits that define human beings as a species; but, the variations that occur within those parameters are innumerable. A class photograph of any sixth grade class would certainly point out a wide variety of physical characteristics within the group.

The variety of development found in any group of eleven to thirteen year olds is probably wider than at any other age. As children are entering adolescence, their own rapidly changing bodies and different rates of

growth they observe in their classmates causes them to question their own normalcy. Investigating these similarities and differences and exploring the causes of individuality should be a high interest introduction to the unit.

Most science books in use today cover reproduction of plants and animals. This unit reviews sexual reproduction from a genetic point of view, with emphasis placed on the genetic material passed from each parent to the offspring. Although the scientific explanations are simplified to serve only as an introduction to the topic, the exchange and restructuring of the chromosomes within each parent prior to the production of the sex cells is explained. The role of the chromosomes and structure of DNA are introduced. The continuing role of the genes (within the chromosomes) in life-long development, and patterns of inheritance are explored. The usefulness of genetic technology is illustrated by citing applied examples of genetic engineering and introducing the role of the genetic counselor. Other careers in the science of genetics are introduced.

Many of the principles covered in the unit are ideal vehicles for practicing mathematical concepts taught in the sixth grade. The structure of DNA and the pairing of the chromosomes can be illustrated with lessons in symmetry. The frequency of the mirror-image relationship of two halves of living things was cited by Dr. James Watson in *The Double Helix* , his personal account of the discovery of the structure of the DNA molecule.

Practice in measuring and recording the attributes of simple geometric figures introduces children to the scientific practice of writing detailed descriptions to record observations before they begin the more complex task of observing and recording human physical characteristics. Metric tape measures are later used to gather physical data on students; with subsequent recording, graphing, establishing ranges and determining averages.

In studying patterns of inheritance, probability and ratios come into use. The mathematics activities should be planned as group endeavors to accommodate the wide range of abilities found in most classes.

Similarities and Differences

Every individual within a species, similar living things potentially able to produce fertile offspring, has traits or observable characteristics that are shared with all other members of that species. One knows immediately that long, floppy ears can belong to a rabbit, donkey or dog, but not to a bird, snake or fish. Pigs have curly tails but chickens and alligators do not. These traits inherited by all members of a species are known as defining traits. Some species display an enormous variety of characteristics and no two living things are exactly alike. It is interesting to note that, according to Sargeant Robert Lillis, Supervisor of the Identification Division of the New Haven Police Department, a fingerprinting expert can almost always detect differences in the fingerprints of identical twins. A bulletin board in the classroom displaying a group picture, preferably a poster-size enlargement, of the class is an excellent illustration of the physical diversity exhibited by the students. This can be supplemented by individual photographs of the children. Pictures brought in from home depicting the children when younger will illustrate growth and change.

A fingerprinting activity done with the class is a vivid demonstration of the uniqueness of every person. This activity is made even more interesting if preceded by a trip to the identification division of the local police department. The children’s fingerprints can be displayed or kept with data sheets or booklets to be developed.

Detailed data should be accumulated over a period of time on each child. This can begin with obviously observable traits such as eye and hair color and progress to more subtle observable traits such as attached/detached earlobes, cleft chin/smooth chin, ability to roll tongue/ unable to roll tongue, etc. In addition to being recorded on children's individual record sheets, the data can be displayed on illustrated class charts.

As proficiency with metric measure (the scientific standard) is developed, children can work in pairs and add various body measurements to the accumulated data. All of this data can be used to construct frequency and distribution tables displayed in both bar graph and line graph form.

The graphs can then be used as the basis for word problems dealing with range, mean, median and mode. Word problems can also be formulated using the concepts of ratios and percentages (also expressed in fraction form).

These activities should help to establish cohesiveness within the group and, while pointing out individual differences, establish a wide range of "normalcy".

Sample lesson plan To be done in two sessions.

We're Scientists!

Objectives

To give practice in recording precisely what is observed. To illustrate that the ability to observe and record is influenced by having appropriate measurement tools and vocabulary.
To expand mathematical vocabulary.
To practice using metric rulers.
To introduce protractors.

Materials needed for each pair of students Metric rulers

Lined paper
Pencils or pens and crayons
Protractors
Simple geometric shapes such as those found in *Attribute Logic Blocks* (see list of resources) or cut from colored paper. If making your own geometric figures, they would include at least two different sizes, 6 inches and 3 inches at the largest dimension works well, and three different colors of each shape such as a triangle, rectangle, square and circle.

Method (first session)
Explain to class that they will be working in pairs and that they are going to be laboratory scientists, recording in as much detail as they possibly can all the information about the figures that will be passed to them. Distribute paper, pencils or pens and one geometric figure to each pair of students. When most children have completed the activity, question to encourage the group to share their written observations. Ask if anyone drew a picture of their figure to include with their written observations. Collect observations.

Pass new paper, crayons, rulers and protractors. Rave children now do new observations and record them. These observations will probably include colored drawings of either the traced or drawn-to-size figures. Do not explain the use of protractors to those children who have not used them before. When children have completed second observation, again have some share what they were now able to record with the rest of the class. Encourage discussion about why the second set of observations are superior to the first. Collect papers and other materials.

Method (second session)
Display a circle from the set of geometric figures used in the previous lesson. Draw a circle on the chalkboard and label the radius and diameter; indicate measurement by writing in actual measurement rather than drawing the figure to size. Leave drawing on the board and do the same for a square. Label sides, indicate measurement and demonstrate the use of a protractor to measure the angles. Repeat with the rectangle labeling width and length. Repeat again with triangle, labeling base and height. Leave all drawings on the chalkboard so children can refer to vocabulary.

Group children in pairs as in previous lesson. Pass geometric figures, two sheets of paper, pens or pencils, rulers, protractors and crayons to each pair. Instruct children to refer to the chalkboard as needed in order to complete a new observation of their figure. Discuss observations when completed. Return observations completed in previous session to students and discuss progression of observations.

Have students write a few paragraphs to tell about what happened to their powers of observation in the course of the two lessons. Display some sets of observations with children’s remarks about lessons.

A Genetic View of Reproduction

All matter is composed of atoms. Atoms combine (join) to form molecules of elements (made up of just one kind of atom or compounds (made up of more than one kind of atom. Because of the unique structure of each type of molecule it can only join to certain other molecules and will only bond at specific points in its structure. The basic structure for all living things is the cell. The simplest living things are composed of just one cell or one type of cell. In more complicated living things the cells are specialized according to function and band together to form organs and systems within the body. Microscopic examination of a human cell will readily identify it as a skin cell, muscle cell, nerve cell, etc.

All living things grow and develop by means of cell replication and division; the process of mitosis. Through mitosis the cell’s growth is culminated by its splitting into two identical cells, which in turn divide into two identical cells, and so on. The additional cells account for the growth of the organism; however, cells are constantly being shed from the body and must be replaced as well.

Within the nucleus, or control center, of each human cell (with the exception of the mature sex cells) are twenty-three pairs of chromosomes. These forty-six chromosomes are made up of protein structures supporting DNA, deoxyribonucleic acid; complicated chains of molecules whose structure has been described as a double helix. Dr. Margretta Seashore beautifully (in its simplicity) demonstrated this structure during one of our seminars by suspending an elastic band between two pencils and twisting the pencils in opposite directions. If we compare this structure to a twisting zipper, the outer ribbons are composed of molecules of sugar and phosphates with each interlocking tooth representing a molecule of one of four nitrogenous bases: adenine (A), thymine (T), guanine (G), or cytosine (C). The structure of the adenine (A) molecule will only allow it to bond with the thymine (T) molecule and the guanine (G) molecule similarly can only bond with the cytosine (C) molecule.

The order of these bases forms a code to be passed from one cell to the next generation of cells. This code is arranged in sets of chemical sentences referred to as genes. Genes carry the traits, or characteristics, passed on by the parents.

Traits passed on by the parents are not necessarily the traits that they themselves exhibit. When the sex cells are produced, the ultimate result of cell division is a reduction in the number of chromosomes within the cell; so that the offspring will receive twenty-three single chromosomes from each parent. These haploid cells (cells with half the usual number of chromosomes) will fuse at fertilization forming a new cell with the full number of chromosomes (diploid cell).

This process of cell division and reduction of the number of chromosomes in the production of sex cells is called meiosis. In the first phase of meiosis the full set of forty-six chromosomes duplicate and line up, pairing with their counterparts, and exchange DNA (breaking off, crossing over, and exchanging genetic material). The forty-six duplicated chromosomes now within the cell contain all the original genetic material recombined so that they are no longer identical to the original paternal and maternal chromosomes; they are a mixture of both. In the crossing over process the DNA may break in such a way as to change some of the sentence structure of the chemical code specifying one or more genes. These changes contribute to the diversity found within a species.

In the male, the original germ cell then divides into two cells with twenty-three duplicated chromosomes which in turn divide into two cells with twenty-three single chromosomes; thereby producing four sperm cells, each containing twenty-three chromosomes carrying the newly recombined genetic material from each completed meiotic division.

In the female, the process is slightly different. The female produces only one egg cell containing twenty-three recombined single chromosomes from each completed meiotic division. While most of the cytoplasm is retained by the developing ovum after each division, the rest of the genetic material is sloughed off in the form of polar bodies.

When the resultant ovum is penetrated by a sperm, the twenty-three chromosomes carried by each now pair up, again chromosome by chromosome and gene by gene, forming the first complete cell of the new life. This cell will now undergo mitosis, the replicating and splitting that forms new cells, following the orders contained in its own chromosome pairs.

The male and female will each contribute one sex chromosome; the ovum always contributes what is designated as the X chromosome and the sperm contributes either an X chromosome or a Y chromosome. Therefore, the sex of the offspring is determined by the sperm. A male offspring is the result of an egg being

fertilized by a sperm carrying a Y chromosome. A female offspring if the result of an egg being fertilized by a sperm carrying an X chromosome.

Sample lesson plan Passing on Genes to the Next Generation

Objectives

To review the process of meiosis in the production of sex cells.
To visually simulate the variations in genetic material passed on by the same parent.

Materials needed One copy of the following two pages for each student. Pencils, sets of crayons.

Method Pass worksheet one and the rest of the material. Go over the instructions with the class. They should complete the first worksheet before you pass worksheet two.

Passing on Genes to the Next Generation

Worksheet one: Replication

Every human cell (except for mature sex cells) has twenty-three pairs of chromosomes. This drawing represents one pair of imaginary duplicated chromosomes. They are drawn in a shape (Tetra) they assume after replication. Each numbered section represents an imaginary gene.

Using the colors indicated by the letters, lightly color in each section that has a capital letter. Use your crayon to outline the sections with small letters.

(figure available in print form)
CHROMOSOME FROM FATHER
(figure available in print form)
CHROMOSOME FROM MOTHER

New copy the letters and the coloring from the left side of the chromosome diagram to the newly replicated right side.

During meiosis the chromosomes cross over and exchange genetic material before making the sex cells that are passed on to the next generation.

Passing on Genes to the Next Generation

Worksheet two: New Chromosomes

After two cell divisions, a single chromosome (for each of the twenty-three original pairs) is passed to the newly produced sex cell.

To form a new chromosome that may be the final result of this exchange, choose any letter from each numbered section to complete the new single chromosome below. You may choose to copy an entire strand or

one complete chromosome (right or left side of either) instead of selecting letters section by section. You cannot replace a capital letter with a small letter if the original chromosomes both have a capital letter in that section. You cannot replace a small letter with a capital letter if the original chromosomes both have a small letter in that section.

Using the indicated color, lightly fill in all sections that contain a capital letter.Outline all sections that contain a small letter.

(figure available in print form)
Using the indicated color, lightly fill in all sections that contain a capital letter. Outline all sections that contain a small letter.

Comparing our new chromosomes with others in the class will illustrate why offspring, even with the same parents, are not exactly alike.

Patterns of Inheritance

Just as chromosomes are paired, the genes on those chromosomes are also paired; so that we have two genes for every genetically influenced trait or function. One of those genes came from within the sperm contributed by the father and one from within the egg contributed by the mother. A dominant trait will be expressed (show, or take control) even if only one copy of the gene is present.

Dominant Inheritance

(figure available in print form)
If one affected parent has a single faulty gene, D, which dominates its counterpart d, with each pregnancy there is a fifty percent chance of the child inheriting the dominant gene D. A recessive trait is only expressed when two copies of the gene for that trait are present. But a gene for the recessive trait remains part of the chromosomal structure that may be passed on to offspring even if it is not observed in the parents. Both parents may exhibit the same normal trait, however, if either or both are not pure for that trait (e.g. the unexpressed recessive gene is also a part of their genetic makeup) either, or both may pass the unexpressed gene and not the normal gene to their offspring.
Recessive Inheritance
(figure available in print form)
In a recessively inherited genetic disorder, both parents carry a defective gene, “g”, but are protected by the presence of a normal gene, G. The condition caused by g is not observed in either parent. However, each child has a twenty-five percent risk of inheriting a g gene from each parent and exhibiting the trait, a twenty-five percent chance of inheriting two normal genes; and a fifty percent risk of inheriting a Gg combination and being a carrier. The genes located on the X chromosome (the sex chromosome passed by mothers to both male and female offspring, and passed by fathers to their female offspring) are called X-linked genes. The genes located on any of the other twenty-two pairs of chromosomes are referred to as autosomal. In an X-linked recessive condition, if a female has a defective gene on one of her two sex chromosomes, she is protected against the defect because her normal sex chromosome, X, compensates for the defect on the other X*. A male with a defective gene on the X(*) chromosome inherited from his mother would not be protected because he only has one X chromosome.

X-linked Recessive Inheritance

(figure available in print form)

If the mother has a defective gene on one of her two X chromosomes and the father has a normal X chromosome and a normal Y chromosome, each male child has a fifty percent risk of inheriting and being affected by the faulty gene on the X(*) chromosome, and a fifty percent chance of inheriting the normal X chromosome. Each female child has a fifty percent risk of inheriting the faulty X(*) chromosome and becoming a carrier like her mother, and a fifty percent chance of inheriting two normal X chromosomes. Genes located on the Y chromosome (the sex chromosome passed by the father to his male offspring) are called Y-linked genes.

Mutations are genetic characteristics that were not part of the original genetic makeup of either parent. They may occur because of the rearranging of the chemical code into new sentences that occurs in the production of sex cells. However, there are many, many other causes that can contribute to mutation.

Pedigree charts are used for tracing known patterns of inheritance in a family. The diagram that follows is a pedigree chart showing three generations of one family

(figure available in print form)

Mary and Paul are symbolized by a square for a male and a circle for a female. Their marriage is shown with a connecting line. On the next line, their children are indicated in order of birth. Tom, a son, is the oldest; followed by fraternal twins, Ann and Bob. Twins are marked with symbols attached to lines beginning at the same point. The diagonal line through Bob's symbol indicates he is not living. Mary and Paul's youngest child is Sue. Tom is married to Joan and they have three children; identical twins Bill and Ed are noted by attaching their symbols to lines beginning at the same point as for Ann and Bob; and, because they are identical, joining the symbols with a horizontal line. Their younger brother is Joe. Sue married Tim and they have three daughters, Kim, Jen and Liz. Jen has a disease that did not previously appear in the family. A filled in symbol in this drawing shows that a person is affected by the trait being traced. A half-filled symbol shows a carrier. Through testing, it was determined that Jen's parents are both carriers of the disease even though neither actually had the disease. Jen's mother, Sue, had inherited the gene from her mother, Mary. When she married Tim, who also unknowingly carried a gene for the disease, it meant that it was now possible for some of their children to receive a double dose of the gene and have the disease.

Sample lesson plan Pedigree Charts

Objective To introduce pedigree charts.

Materials needed

One copy of the previous page explaining pedigree charts for each student.

Crayons

Pencils or pens

Rulers

Paper

Method Pass introduction sheets and give children time to silently read them. Working at the chalkboard, recreate the chart one line at a time as the children take turns reading aloud. After

you have worked through the sheet with the class, ask questions such as: Who is Joe's father? Who is Joe's aunt? Who is Liz's cousin? Name all the grandchildren of Paul and Mary. Name Sue's sister and brother.
When children are comfortable determining relationships, pass the crayons, pencils or pens, rulers, and paper and allow time for children to draw a pedigree chart descriptive of a family through one set of grandparents.

Collect and display pedigree charts.

Extension Childrens' familiarity with pedigree charts will enable you to use information sheets on inherited diseases available from the March of Dimes Birth Defects Foundation. (See resources.)

The Usefulness of Genetic Technology

Genetic technology is being used today in agriculture and forestry to improve plants; increasing disease resistance, increasing the yields of crops, and adapting nonnative plants to a new environment where it has been determined they will be of benefit to the ecosystem. Animal breeders have been using genetic principles for many years to develop characteristics within a species that they feel are desirable. This has improved the quality and quantity of food production in much of the world. A review of the many and varied dog breeds that have been developed over the years is a very good example of the diversity that can occur within a species.

New technology involving recombinant DNA has proven beneficial in medicine.

Hemophilia is a disorder of the blood that interferes with clotting. Some victims of this disease in the past bled to death after very minor injuries. Hemophilia is an X-linked genetic disorder. The trait is not passed from father to son because fathers only pass on Y chromosomes to their sons. It is rarely manifested in females because they have a second X chromosome which has a normal gene. Females become the carriers of this recessive gene, with a fifty percent risk of passing it to their sons and daughters.

In more recent years, the clotting factor in blood has been isolated and it was possible for a person with hemophilia to survive with transfusions of this clotting factor extracted from normal human blood. However, the recent emergence of AIDS has given these patients a new possible death sentence. Some were transfused with contaminated blood before testing was available; and,even with new screening methods, it is questioned whether all blood supplies are safe. The recent death of Ryan White, a teenager who had hemophilia and who acquired AIDS in this way, captured the sympathetic attention of the country and beyond.

Recombinant DNA technology has made it possible to produce bacteria with a human gene for manufacturing the clotting factor needed by patients affected by hemophilia. This clotting factor is harvested in vats where great quantities of genetically altered bacteria work to produce clotting factor that has never been in the body of another human being; therefore, it is completely disease free.

Bacteria have also been altered to produce human growth hormone which was previously available only by processing material from the pituitary glands of dead humans. The problems of disease transmission were similar to that faced by hemophiliacs.

Insulin to alleviate diabetes can also be produced by genetically altered bacteria.

Expanding knowledge of genetic factors as the cause of many diseases and handicapping conditions have led to test procedures that can identify carriers of many of these conditions. There are also tests that can be done early in pregnancy to determine if the fetus is affected by certain deleterious genetic conditions.

A genetic counselor works with prospective parents to help them make difficult decisions when faced with the probability of a genetic disorder in their children. Genetic counselors also act as patient advocates for people with genetic disorders and do community outreach in genetic education.

It is possible to arrange for a genetic counselor or a physician specializing in medical genetics to work with you as a resource person when dealing with genetic topics in the classroom by calling The Department of Human Genetics of Yale School of Medicine. Dr. Seashore may even be able to arrange for a laboratory visit for some groups.

A classroom visit by a plant geneticist can be arranged by calling the Biochemistry and Genetics Department of the Connecticut Agriculture Experiment Station.

Because of the rapid development of breakthroughs in the science of genetics and the frequency with which they are reported, students should be encouraged to assist in accumulating articles for discussion and display in the classroom.

Resources

Attribute Logic Blocks can be borrowed from the office of New Haven's Supervisor of Mathematics, Mr. David Howell; or can be ordered from New England School Supply, P.O. Box 1581, Springfield, MA, 01101. 1-800-628-8608

Clark Color Labs, P.O. Box 96800, Washington, D.C., 20090 Poster-size enlargements of photographs.

Connecticut Agriculture Experiment Station, 123 Huntington St., New Haven, CT 789-7227

Resource for consultation or in-classroom visit by plant geneticist.

March of Dimes Birth Defects Foundation, Community Services Department, 1275 Mamaroneck Ave., White Plains, New York, 10605. (914) 428-7100.

Local chapter: 31 Bernhard Road, North Haven, CT, 777-4030. Request *Catalogue of Public Health Education Materials* . Available publications include *Genetic Counseling* , information sheets on many inherited diseases, BSCS developed curriculum including teachers' guides and reproducible masters for grades K through 6. Excellent selection of 16 mm films, video cassette and film strip/audio cassette sets for free loan, rental and purchase.

National Institute of General Medical Sciences, Bethesda, MD (301) 496-7301.

Publications list includes The *New Human Genetics, How Gene Splicing Helps Fight Inherited Diseases* .

National Maternal and Child Health Clearinghouse (NCEMCH), 38th and R Sts. NW, Washington, D.C., 20057.

(202) 625-8400/8410

Request publication catalogue.

New Haven Police Department, 1 Union Ave., New Haven, CT. A field trip to police headquarters for a fingerprinting demonstration and explanation of classification.

Yale University School of Medicine, Department of Human Genetics, 333 Cedar St., New Haven, CT 785-2660 Resource for consultation or in-classroom visit by genetic counselor or medical geneticist physician. Possible laboratory tour.

Bibliography for Students

Asimov, Isaac. *How Did We Find Out About Genes?* . New York: Walker and Company, 1983. Traces the history of genetics from Mendel through some genetic engineering. An excellent source for identifying scientists who made significant contributions in genetic and cell theory.

Boy Scouts of America. *Fingerprinting* pamphlet in Merit Badge Series, BSA, New Brunswick, N.J.

Dunbar, Robert E. *Heredity* . New York: Franklin Watts, 1978.

Includes projects for self-discovery of genetic principles. Large type and good diagrams.

Engdahl, Sylvia. *Tool for Tomorrow, New Knowledge About Genes* . New York: Antheneum, 1979.

Illustrated.

Facklam, Howard and Margery Facklam. *From Cell to Clone* , *Story of Genetic Engineering* . New York: Harcourt, Brace, Javanovich, 1979.

The history and techniques of cloning. includes material on genetic research.

Goldreich, Gloria and Esther Goldreich. *What Can She Be- A Scientist* . New York. Lathrop, Lee and Shepard Company, 1981.

One of the Lathrop series of *What Can She Be* books. Careers in genetics.

Higgins, Jane H. *Discovering Genetics* . New York: DOK Publishers, 1983.

Introduces the principles of genetics in an interesting and easy-to-understand manner.

Hyde, Margaret O. and Lawrence E. Hyde. *Cloning and the New Genetics* . Hillside, N.J.: Enslow Publishers, Inc., 1984.

Includes chapters on recombinant DNA and its uses in medicine.

Lerner, Marguerite Rush, M.D. *Who Do You Think You Are?, (A Story of Heredity)* . New Jersey: Prentice-Hall, 1963.

Old, but nice illustrations.

Morrison Velma Ford. *There's Only One You* . New York: Julian Messner, 1978.

Good book which describes family trees. Introduces basics of genetics and DNA coding. Glossary.

Rowland, John. *The Insulin Man* . New York: Roy Publishers, Inc., 1965

Sir Frederick Banting's search for a diabetes cure.

Showers, Paul. *Me and My Family Tree* . New York: Thomas Y. Crowell, 1978

Very easy. Introduces ancestors, heredity, family trees; Mendel. Great illustrations.

Shymansky, James A., Nancy Romance, Larry D. Yore. *Journeys in Science / 6* . River Forest, IL: Laidlaw Educational Publishers, 1988.

Chapter 18: "New Generations".

Silverstein, Alvin. *The Genetics Explosion* . Four Winds Press, 1980.

Illustrated. Good bibliography.

——— and Virginia Silverstein. *The Code of* Life. New York. Antheneum, 1972.

Coding of DNA.

Webster, Gary. *The Man Who Found Out Why* . New York: Hawthorn Books, Inc., 1963.

Mendel and his work.

Wubben, Pamela G. *Living Genealogy for Children* . Boulder, CO: One Percent Publishing, 1981.

Provides an introduction to genealogy; the tracing of one's family tree.

Bibliography for Teachers

Biological Science: a Molecular Approach . 6th edition. The Biological Sciences Curriculum Study (BSCS). Boston: D.C. Heath, 1989

Gardner, Eldon J. *Human Heredity* . New York: John Wiley & Sons, Inc. 1983.

Genetics for non-science college majors. Descriptions of human genetic syndromes.

Mange, Arthur P. and Elaine Johansen Mange. *Genetics: Human Aspects* . Philadelphia: Saunders College, 1988. Rules of inheritance and pedigree well covered in Chapters 1-3.

Milunsky, Audrey, *Know Your Genes* . New York: Avon Books, 1979.

Readable. Covers genetics, inherited disorders, genetic counseling, etc.

Shymansky, James A., Nancy Romance, Larry D. Yore, *Journeys in Science / 6* . Teacher's Edition. River Forest, IL: Laidlaw Educational Publishers, 1988. Chapter 18: "New Generations".

Swertka, Eve and Albert Stwertka. *Genetic Engineering* . Franklin Watts, Inc., 1982.

Introduction to “new” and most-controversial developments in genetics and genetic engineering.

Thompson, J.S. and M.W. Thompson. *Genetics in Medicine* . Philadelphia: Saunders Co., 1986.

Watson, James D. *The Double Helix* . New York: Mentor Book, 1968.

A personal account of the discovery of the structure of DNA.

COMPUTER COURSEWARE

Chromy Bug, Apple II, II= and IIe, T.I.E.S., St. Paul, MN, 55113.

Heredity Dog, (Apple II and Commodore 64) HRM Software, Pleasantville, NY 10570.

AUDIOVISUAL MATERIALS

The Chromosomes of Man , color film, Encyclopedia Britannica Educational Corporation, Chicago, IL, 60611.

Generation Upon Generation , Episode 12, *The Ascent of Man* series. Aired on PBSS, *NCVA* . Inheritance examined from Mendel to modern laboratory research. (52 minutes). Producer: BBC / Time-Life Films.

Available in some public libraries as a part of the MacArthur Foundation Collection of video tapes.

Decoding the Book of Life , episode of *NOVA* . (57 minutes). History of genetics.

Produced by Jon Palfreman

Coronet Films, Deerfield, IL 60015 1-800-441-NOVA

Note: See additional resources listed at the end of this volume.