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Basic Introduction to Foundation of Life: Genes, Genetics and Genetic Diseases

Curriculum Unit 87.05.07
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This curriculum unit is designed to teach 9th or 10th grade students at the high school level. Every effort is made to motivate the students by attracting them to the many marvels of genetics, demonstrations and models of applied genetics, genetic engineering, genetic disorders, detecting genetic diseases thereby invoking their curiosity.

The teachers in the Junior High Schools can also use these plans directly or modify to the students' levels and needs.

The aim here is to attract students initially and to hold their interest, while slowly introducing the terms, vocabulary and thought-provoking discussion questions without turning them off.

Genetics is only one section of biology and can be prEsented within a week or two and the curiosity of students are brought into focus in the development of this unit.

The search for Nature's secrets can be an exciting story if presented in an orderly manner. The subject can be introduced with a sequence of events that builds on mendel's experiments with Pea Plants, leading to an understanding of basic, genetic mechanisms—sex determination, gene function and mutation. The students learn that Mendel concluded from his experiments that traits from both parents are passed on to the next generation of offsprings and that there are dominant and recessive factors for each trait.

What Mendel noted as factors are now called genes. These genes are located on the chromosomes which are found in the nuclei of the cells.

With the aid of models and hands-on experience, students are taught that the chromosomes are made up of long, coiled chemical chains known as DNA. During meiosis and mitosis, DNA is duplicated to make it possible for chromosomes and their genes to be transferred to new reproductive cells and body cells.

Vocabulary and genetic terms can be introduced slowly-heredity, genotype, phenotype, homozygous, heterozygous, sex determination. (xx and xy chromosomes) sex linked traits in humans, etc.

The curriculum unit is divided into 5 capsule lessons; each of which is introduced with the aid of some

attention-getting pictures, models, photos, diagrams, slides, videos, demonstrations or activity.

This will turn the students on so that motivation can be generated by relating the information from the lesson to the students' self-interest. The students' natural curiosity about how human heredity works should be discussed fully. Further discussions and prepared debates on topics such as *environment* versus *heredity* should be encouraged.

Teaching Suggestions **:**

1. Probing students' knowledge of identical twins, lively discussions can be initiated.
2. Using various color-blindness charts, projection slides or diagrams, color-blindness can be surveyed and discussed.
3. Blood typing kits may be available from some biological supply houses. These can be used to determine blood types of students.

Capsule Lessons **:**

Each lesson is designed in the form of a capsule lesson which includes objectives, activity, check up questions for classwork or homework and sometimes a crossword puzzle or vocabulary.

Objectives **:**

Objectives for each lesson plan are set forth in the beginning of that lesson.

List of References **:**

A list of references for reading and addresses of videos, films and biological supply houses are given at the end of the curriculum unit.

Appendices:

Appendices at the end of this unit can be used to supplement the capsule lessons to initiate interest of students by incorporating diagrams, case-studies and graphs.

CAPSULE LESSON I—HEREDITY

Objectives:

At the completion of this lesson, students should be able to:

1. List the heredity factors that influence the traits of an organism.
2. Explain the terms heredity, genes, genetics, dominant and recessive.
3. Explain what a Punnett Square is in relation to Probability.

4. Give an analogy of heredity factors in an animal and in a human being. (ex. Animal-Short—horn Cattle, rr=Pure Red. ww=Pure White(p), rw=Hybrid Roan(F); incomplete dominance in Short—horn Cattle). (ex. Human being-Show picture or photo or slide of twins and explain that identical twins develop from a single egg and sperm; they have the same genetic make-up. Fraternal twins develop from the different eggs and sperms and are more like brothers and sisters).

Activities: (N.B. Supplement with AV-1)

1. Mendel's selection of garden peas for his experiments must be emphasized. The varieties he chose had many clear-cut traits; for example, red versus white flowers, green versus yellow seed pods, etc. The students can then write essays on why Mendel chose plants rather than animals for his experiments.
2. Pea seeds bred for dominant and recessive factors can be obtained from a biological supply house. Students can grow their plants and simulate Mendel's experiments in class.

Check Up-Questions:

1. What terms do scientists use for the heredity factors that determine the traits of an organism?
2. Why were there no short plants in the first generation?
3. Mendel found that there were tow heredity factors for each trait in pea plants. Give a few examples.
4. In mendel's experiments when he crossed tall and short pea plants, what resulted in the first generation of plants?
5. How did Mendel decide which traits were dominant?

PUNNETT SQUARES AND PROBABILITY

When you study genetics, just like in a game of chance, gambling, lottery numbers or magic wheel, etc., you take chances to predict certain results. There is a definite formula, chart or calculation to predict these results. In Genetics, special charts resembling checker boards are used to find the possible results of various crosses. This type of chart is called Punnett Square and is named after the inventor-R.C. Punnett.

The *Chart A* below is an example of Punnett Square for an organism. The paired genes for a trait may be identical as with TT or tt. If both genes are same, the organism is *homozygous* , or pure for that trait.

(figure available)
(figure available)
In Punnet Square A, the possible gene pairs that result from crossing different pea plants are represented as *alleles* -T for tall t for short. (Alleles are contrasting effects on a trait).

The results of pollinating an egg of a homozygous tall pea plant is shown in the Punnett Square A. Everyone of the resulting pea plants will be heterozygous tall. In a similar process, other forms of crossing can be followed or calculated. (ex. crossing Tt x Tt or TT x Tt or Tt x tt).

These charts or Punnett Squares can also be used to show the probability of each resulting phenotype. For example, in the following chart B, the probability of producing tall plants from a cross between heterozygous tall pea plants are three out of four. (3:4) This means there is one chance in four of producing a short plant from such a cross.

CAPSULE LESSON 2—CELL-DIVISION, CHROMOSOMES AND DNA

***Objectives* :**

After completing this lesson, students should be able to:

1. Explain that the factors studied by mendel are now called genes, located in chromosomes in the nuclei of cells.
2. Explain with the aid of diagrams that the chromosomes are made up of long coiled, chemical chains known as DNA.
3. Demonstrate and describe the fact that during meiosis and mitosis, DNA is duplicated to make it possible for chromosomes and their genes to be passed on to new body cells and reproductive cells.
4. Define and explain with examples the terms genotype and phenotype, homozygous and heterozygous and variations in inheritance.
5. Explain the sex chromosomes (xx for females and xy for males) that determine the sex of the offspring.

***Activity* : (Supplement with AV-2)**

Modeling Chromosomes

For many of the average students, modeling of chromosomes is necessary to understand the difference between mitosis and meiosis because they lack the facility to understand abstract concepts. Hence, they will find the models very helpful.

Each student is given some clay of various colors, with enough of each color to make pairs of “chromosomes”. The students can then draw circles on sheet of paper, to represent stages of the cells. The students then place the right number and kind of chromosomes in each kind of cell as it undergoes mitosis and as it undergoes tow divisions in meiosis. It is hoped that this will help clarify the difference between the two processes. This activity can be combined with exhibition of movies or video tapes describing DNA.

***Check Up Question* :**

1. In what part of a cell are DNA, chromosomes and genes found?
2. List the parts of the DNA and describe how they are arranged.
3. Explain in your own words why DNA replication is necessary for meiosis and mitosis to occur.

CAPSULE LESSON 3—FACTORS OF INHERITANCE AND CHANCE

***Objectives* :**

After completing this section, students should be able to:

1. Explain that double helix DNA model provides an adequate explanations of the duplication, mutation and transmission of genetic material.
2. Describe what scientists have learned from mapping genes.
3. Explain what is meant by homozygous genotype.
4. State how many genotypes and phenotypes are possible when tow heterozygous individuals mate.
5. Explain with diagrams how to use the Punnett Squares.

Activities **: (N.B. Supplement with AU-3)**

1. Students can construct models of the Double Helix DNA as conceived by Watson and Crick. Using colored construction paper. (As an alternative, students can draw diagrams of DNA as shown in prior studies, drawings or models). (See Appendix 4; p. 18, 18a, 18b)
2. Students can also use tongue depressors and strips of stiff plastic to form a double helix and to show the arrangement of the bases.
3. Slides, films and video tapes can be shown.
4. Some human genetics problems can be given to students to solve. For example, blond hair in humans is recessive to darker hair;, right-handedness is dominant to left handedness, etc.
5. Students can be instructed to make a family inventory of traits that have been passed from grandparents to students.

Check Up Questions **:**

1. What do you think the scientists have learned from mapping genes?
2. What can you tell about the differences in genes of a boy having dark hair and a girl who is light-haired?
3. How are their genes similar?
4. What genotypes are produced from a heterozygous cross?

5 Knowing the phenotype of a flower what can you determine about its genotype?

CAPSULE LESSON 4—VARIATIONS IN INHERITANCE

Objectives **:**

After completing this section the student should be able to:

1. State on example of incomplete dominance.
2. Name three factors that may cause genes to mutate.

3. Explain why plant breeders sometimes try to breed polyploid plants.

***Activities* :**

1. Students can be instructed to make a list of breeding examples in which breeders have taken advantage of incomplete dominance of traits to produce variations. (ex. cats, roses, cattle, breeding dogs, race horses, etc.).
2. Students can be asked to research and prepare reports on diseases like sickle-cell anemia, cystic fibrosis, diabetes and tay sacks disease.

(N.B. Activities can be supplemented with AU-4) *Check Up Questions* :

1. What is an incomplete dominance? Give an example.
2. The colors of flowers in a flower garden are varied. What might you assume in the genotype of each of the differently colored flowers?

CAPSULE LESSON 5—SEX CHROMOSOMES CHANGES, GENE CHANGES

***Objective* s:**

After completing this section, the students should be able to:

1. Describe when the sex of a child is genetically determined.
2. Name which gamete, male or female determines the sex of a child.
3. Give an example of a sex-linked characteristic in people.
4. Explain Down's Syndrome, mutations, polyploidy.

Activities **:**

1. Sex linked traits have long been studied in the common fruitfly-Drosophila. Traits for red/white eye color, normal/small wings and others can be studied by obtaining cultures of this fly from biological supply houses.
2. Red-green color blindness can be studied in class.

Check Up Questions **:**

1. When is the sex of a child determined?
2. Which gamete, male or female, determines a child's sex?
3. What is an example o a sex-linked characteristics in people?

(N.B. Activities can be supplemented with AU-4)

Also show charts of color blindness.

Appendix I—MARFAN SYNDROME

The Marfan syndrome also has been known as arachnodactyly, from the Greek works for "spider" and "fingers." Abnormally long, slender, tapering fingers are often a feature of the disorder that Dr. Antoine Marfan first described in 1896. Symptoms may be severe or mild, and may be present at birth or show up in adult life. The disorder sometimes causes sudden death in adults who were unaware that they had it.

The Marfan syndrome affects some 20,000 persons in this country, including males and females of any race of ethnic group. The March of Dimes supports research on this and related disorders, and cooperates with other concerned organizations to keep the public informed.

Significance of Marfan Syndrome

It is a variable pattern of abnormalities that may affect the heart, blood vessels, lungs, eyes, bones and ligaments. It is one of many inherited disorders of connective tissue (material that holds tissues of the body together). Affected individuals are often tall, slender, and loose-jointed. Arms and legs may be unusually long in proportion to the torso. The spine may have a spiral curve (Scoliosis). And the breastbone may protrude or look caved in. The face may be long and narrow, with a high roof of the mouth and crowded teeth.

Heart and blood vessels nearly always are affected. Heart valves—pairs or trios of flaps that keep the blood flowing in one direction through the heart— usually are oversized and floppy. Their action during heart-beats

may allow brief reverse blood flow and cause a heart murmur (an abnormal sound heard through a stethoscope). The body's largest artery, the aorta, is nearly always affected to some extent by the Marfan syndrome. Sl blood pumped from the heart passes forcefully into the aorta, which branches out to carry oxygen-rich blood to the entire body. A defective aorta can split in places and allow blood to leak into the chest or abdomen.

In some 50% of persons with the Marfan syndrome the lens of an eye is off-center. Nearsightedness is another common symptom, whether the lens is in place or not. The light-sensing inner lining of the eye (retina) may become detached. Persons with the Marfan syndrome are more prone than others to sudden lung collapse,

Figure 1 VISIBLE SYMPTOMS OF MARFAN SYNDROME

(figure available in print form)

Causes of Marfan Syndrome

It results from a single abnormal gene. It cannot be "caught" from another person. Although it may be diagnosed at any age in a person's life, it doesn't occur unless the abnormal gene is present. The gene is believed to cause the disorder by producing a weaker form of one of the proteins that normally make connective tissue strong and resilient. In some families the syndrome may be the result of different mutations (changes) in this same gene, or in other genes. But, in general, the cause seems to be some single gene.

The gene is usually inherited from on parent. It is a "dominant" gene, which means that each child of a parent with the gene has a 50-50 chance of inheriting it. In about 15 percent of cases, a genetic accident (new mutation) occurs in a sperm of egg cell of an unaffected parent and so in passed on to an offspring.

A person who has such a gene and doesn't know it may overdo physical activity which might harm vital body structures that are made up largely of connective tissue.

Test for the Marfan Syndrome

There is no single, conclusive test for the condition. A doctor or team of doctors familiar with the condition may diagnose it after examining the heart, aorta, eyes and other body parts and functions. Symptoms (problems perceived by a patient) and signs (clues that are not part of a patient's complaint, but evident to an examiner) may be very different in different people with this condition. All the possible symptoms and signs rarely appear together in one affected person.

Treatment for Marfan Syndrome

The condition usually is treated by a team of specialists, but a single doctor who knows all its aspects usually is in charge. The greatest danger is death from a sudden split in the aorta. This may happen from the normal pumping of blood through a weak aorta or from extreme physical or emotional activity that sends the blood rushing at high pressure. Marfan patients are warned to avoid heavy exercise, contact sports, and lifting heavy objects. Regular check-ups, heart tests, and examination of the aorta using ultrasound can alert a specialist before problems become serious. Heart problems may be treated with drugs to calm heart activity.

Because of heart value abnormalities, most Marfan syndrome patients are prone to infections in those valves. They must be treated with preventive antibiotics before any kind of surgery, including tooth-pulling, to keep bacteria out of the blood stream.

An artificial heart valve, can be implanted surgically to replace a weakended valve. Afterward, the patient is given anticlotting medication on a lifelong basis, because blood tends to clot in contact with artificial valves.

Although little can be done about the outward appearance of a person with classic Marfan syndrome, physical therapy, a brace, or surgery can often correct spinal curvatures that may arise. Crowded teeth can be adjusted by an orthodontist. Early and regular eye examinations may lessen eye problems common to these patients. Detached retinas can be restored by “bloodless surgery” with lasers. A hormone specialists may help with control of spinal curves and overall growth. Psychological attention may be necessary.

Appendix 2—CLEFT LIP AND PALATe

Some 5,000 children (one out of every 700 births) are born with cleft lip or palate in the United States each year. “Cleft” describes a split where parts of the upper lip or palate (roof of the mouth) fail to grow together. Some have only cleft lip, also known as “harelip,” while more have only cleft palate. About 40 percent have both cleft lip and palate. The defect appears more often among Orientals and certain tribes of American Indians than among white Americans. It occurs less frequently among black Americans.

Figure 2

(figure available in print form)

Causes of Cleft Lip and Palate

There is no one cause for all clefts. Scientists believe that any number of factors such as drugs, disease, heredity, malnutrition, and adverse environment may act on each other to disturb normal growth. Many infants with cleft palate are premature and have other defects.

Heredity appears to play a role in about 25 percent of cases. In other 75 percent there is no family history of the defect, even among distant relatives. It is known that if both parents are normal and have a child with a cleft,the chances that subsequent babies will have a cleft increase progressively. If either parent has a cleft, there’s a four percent chance that their first baby will have a cleft, and the chances increase with each time they have an affected child.

Figure 3

(figure available in print form)

Cleft Lip Affecting Baby’s Face

Cleft lip may involve only one side of the upper lip or both. The split may be only in the upper lip, or may extend up into the nostril. Usually the split goes through the outer skin, muscles, and inside of the lip. Cleft palate may involve only the soft part of the palate toward the back of the throat, or it may extend forward through the hard palate.

Treatment of Cleft Lip and Palate

Treatment usually combines surgery, speech therapy, dental corrections and psychological help. Depending on the type of cleft and the infant’s general condition, corrective surgery can be started within the first few

months. It may be a simple stitching together of the separated edges of the lip; or with a cleft palate, several operations may be necessary. Sometimes tissue grafts are needed. Temporary dental splints or plates are used to keep the upper jaws in proper alignment before and between operations. Braces may be needed later because teeth usually grow in crooked and some may remain impacted in the jaw.

Problems related to Cleft Lip and Palate

Feeding is the first problem to be overcome. Since a split in the roof of the mouth makes it difficult for a baby to suck, foods backs up through its nose and may cause choking. Parents are taught to feed the baby in an upright position, in small amounts, using a nipple with a large hole or syringe.

Defective speech is one of the most serious results of cleft palate and, to a lesser extent, cleft lip. Psychological problems may result from speech difficulties and the child's unusual appearance before clefts are repaired,a nd require a professional counselor's help. Clefts have no relation to mental ability or retardation.

Ear infections are common. Difficulty in swallowing affects air pressure around the inner ear, spreading infection directly through the nose to ear. Frequent or severe ear infections may lead to hearing loss.

Prevention of Cleft Lip and Palate

If there is any history of cleft palate or lip in the family, or a history of any other condition of which the cleft is a part, a genetic counselor can determine the chances for passing on the defect. Since certain drugs may influence structural growth, it is important for an obstetrician to know if the pregnant patient is taking such medications as anti-convulsant, sedatives, insulin, etc., or if she is on a special diet. Early and regular prenatal care and good health habits are important for prevention of many birth defects, but cannot guarantee that all babies will be normal.

Appendix 3—DOWN SYNDROME

Down Syndrome

Down syndrome is a combination of birth defects including mental retardation. Formerly, it was called mongolism because most infants with this birth defect have a somewhat oriental appearance. "Mental retardation" means that the child does not learn as quickly as other children, due to abnormal brian formation.

A Child With Down Syndrome

The child may have oval-shaped eyes, a tongue that seems big for the mouth, a short neck. The head may be flattened in the back and the ears small and sometimes folded a little at the tops. The nose is also flattened and wide. The child or adult with Down syndrome is often short in stature and has unusual looseness of the joints.

Significance of The Mental Retardation

The degree of mental retardation varies widely, from mild to moderate to severe. Most fall within he moderate range, but all are retarded to some degree. There is no way to predict the mental development of a child with Down syndrome from the physical appearance.

Symptoms of a Child with Down Syndrome

A child with this birth defect can usually do most things that any young child can do, such as walking, talking, dressing and being toilet-trained. However, they do these things later than other children. As with other children, you never can know exactly at what age these developmental milestones will be achieved.

A Child with Down Syndrome and Studies

There are special programs beginning in the preschool years to help each child develop skills as fully as possible. These programs continue through the school years and there are special work programs designed for adults with Down syndrome. The extend of achievement is determined by the development of the brain and the social environment in which the child lives.

Children with Down Syndromes and Special Health Problems

Many have heart abnormalities and frequently, surgery can correct these problems. A child with Down syndrome may have many colds, bronchitis and pneumonia. These children, like all others, should receive regular medical care including eye and hearing tests as well as regular immunizations.

Many adults with Down syndrome age faster than their normal age group. Life expectancy among Down syndrome adults is about 50 years of age, but this varies widely.

Causes of Down Syndrome

A baby is formed when the egg from the mother and the sperm from the father come together. Normally, egg and sperm cells each have 23 chromosomes. Chromosomes are the hereditary information “packets” of every living cell. In the usual case of a child with Down syndrome, either the egg or the sperm cell contributes 24 chromosomes, instead of 23. The result is that the chromosomes present total 47, instead of normal 46. The extra chromosome causes the mental and physical characteristics of Down syndrome. This cause of Down syndrome is called trisomy 21, because of the presence of three #21 chromosomes. Certain other accidents involving chromosome #21 in egg, sperm or very early embryo also cause Down syndrome, but account for less than 4 percent of cases.

Figure 4

(figure available in print form)

Treatment of Down Syndrome

There is unfortunately no cure for a child born with this birth defect. Although many claims are made, science has yet to develop the means to prevent the cause of Down syndrome.

Marriage and Down Syndrome

Some young people with Down syndrome have married, but this is unusual. A man with Down syndrome had never fathered a child. A woman with Down syndrome has a 50-50 chance of having a child with the same condition. Many people with Down syndrome require someone to care for them.

Possibilities and Greater Chances of Having a Down Syndrome

Parents who have already had a baby with down syndrome, a mother or father who as a chromosome rearrangement as mentioned above, a mother who is over 35 years old. The chances of an older woman

having a baby with Down syndrome are the same whether it is the mother's first pregnancy or not. Down syndrome is the most common genetic birth defect. It affects all races and economic levels of society equally.

Diagnosis Before Birth

There is reason to be concerned about the possibility, a test called amniocentesis can be done in the fourth month of pregnancy. Any family who has a mentally retarded child or a child with other birth defects can discuss the test with a doctor or other health professional who may refer them to a genetic counseling center. The test cannot guarantee the birth of a normal child, but it can indicate whether Down syndrome is present in the fetus.

Mental Retardation

This is moderate to severe in most patients, but some can be trained to the eighth grade or an even higher level. It is important to have the child seen regularly by a physician so that he can judge growth and development and aid in making decisions about appropriate education and training.

Leukemia and Heart Defects

Acute leukemia is 20 times as frequent in children with Down's syndrome as in normal children. About half of all infants with the syndrome have congenital heart defects.
(figure available in print form)
(figure available in print form)

Appendix 4— *Structure of DNA-Activity*

Present concept of DNA structure activity can be encouraged to be drawn by students with different color pens or pencils. The sugar-phosphate backbones of the double helix are represented as ribbons and the steplike base pairs are connected as planks. In (A) DNA, the student can draw the base pairs which are tilted and are pulled away from the axis of the double helix.

In (B) DNA, on the opposite side, the base pairs sit astride the helix axis and are perpendicular to it.

This activity is ideal for Capsule Lesson 3.

Annotated References-Genetics

AV-1. Genes and Protein Synthesis.
17Mins. 16mm. film.
Hereditary diseases caused by aberrant hemaglobins, such as hemaglobin S, and especially sickle cell anemia. Also explains allelism and non-allelism.

AV-2. Genetic Activity and Chromosome Chemistry. 29 Min. B&W. 16 mm.
Reviews the contribution of Mendel, nucleic acids, chemical composition of chromosomes. Compares cell activity of DNA & RNA.

AV-3. Genetic Chance 60min., color l6mm.

Starts with problematical question: Suppose you were told that your unborn male child stood an even chance of being born with a crippling disease! You had the choice of terminating the pregnancy or allowing it to continue. Would you run the risk of aborting the healthy fetus or of bringing into the world a child crippled with a paralytic disease for the whole life.

-very real chance of mothers who are carriers of hemophelia.

-technique of diagnosing the sex of fetus.,

AV-4. Genetic Defects: the broken code

87 mins. color

Features several revelations explaining the medical advances ocurring in the field of genetics; counseling to families having genetic problems, cystic fibrosis, Huntington's Chorea,hemophilia, combined immune deficiency, Down's Syndrome, sickle cell anemia, discussion of genetic screening finding potential parents, and ethical, moral and legal questions are raised.

N.B. All the above can be located and loaned at Yale Audio Visual Center.

AV-5. Basis of Birth Defects

16mm about 5mins.

Exposes the different types of birth defects of children.

Above film available at March of Dimes.

List of Laboratory and Biology Supply Houses

1). Carolina Biological Supply Co., Burlington, North Carolina 27215.
2). Fisher Scientific Co., 1259 Wood St., Chicago, Il. 60622.
3). Wards' Biology, Ward's Natural Science Establishment Inc., 5100 West Henrietta Road, P.O. Box 92912, Rochester, N.Y. 14692-9012. 1-800-962-2660.

List of Audio-Video Suppliers, Distributors Etc.

1). Contemporary/McGraw Hill Films, 1221 Avenue of the Americas, New York, N.Y. 10020.
2). Encyclopedia Britannica, Educational Corporation, 425 N.Michigan Ave., Chicago, Il 60611.
3). March of Dimes, 18 Elm Ave., Norwich, CT. 1-203-889-3883.
4). National Geographic Educational Society, Services, Dept. 79, Washington, D.C. 20036.
5). Yale Audio Visual Center, Educational Film Locator, 59 High St., New Haven. Tel. 1-203-432-2650.

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2. Genetic Counselling, March of Dimes Birth Defects Foundation (1985)., New Haven County Chapter, New Haven, CT. 1-203-397-5008.

3. Huntington's Disease , Huntington's Chorea, (1976), National Institutes of Health, Bethesda, MD.20014.

4. March of Dimes Birth Defects Foundation, Public Health Education, Information Sheet, Genetic Series, 1275 Mamaroneck Ave., White Plains, N.Y. 10605.

5. Morholt, Brandwein & Joseph, *A Source Book for the Biological Sciences* (1966).

6. Otto, J.H.; Towle, A. & Bradley, J.V., (1981)., *Modern Biology* Holt, Rinehart & Winston Publishers, N.Y.

7. Tuberous Sclerosis, National Tuberous Sclerosis Association, Inc., (1984), P.O. Box 612, Winfield, Il. 60190. 1-312-668-0787.