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A Study of Genetics Stressing Human Hereditary Factors: Sociobiology

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INTRODUCTION

The study of the following unit on sociobiological genetics is designed to be instructional for those students who have a basic background in genetics, sexual and asexual reproduction and molecular biology. Although the unit will cover all of this information, it is assumed that the additional suggested references are being used.

Each lesson is structured to begin with learning objectives and end with suggested thought questions and glossary words. Within the text the material is explained and special annotations are provided for the instructor.

The level of difficulty of the material and the extent of research and laboratory investigation with each lesson is left to the instructor's discretion.

LESSON I

BEHAVIORAL OBJECTIVES:

1. To understand DNA replication in the process of mitosis
2. To develop an understanding of meiosis for the production of germ cells
3. To understand how proteins are synthesized from codes on the DNA material

The duplication of cells, cell metabolism and cell specialization are also dependent upon the DNA and RNA

within the cells' nuclei.

Mitosis

Cell division known as asexual reproduction takes place in stages and involves a duplication of DNA (double helical) structure in the nucleus before cytoplasmic division occurs.

Annot: The instructor should take the opportunity to use visual aids to demonstrate the differences between mitosis and meiosis and to reinforce that mitosis or cloning is almost a continuous process in most cells. A three dimensional model of the double helical DNA or wall graphs may be used to stress that the DNA/RNA molecules are of prime importance in this study, providing the structure for chromosomes.

Simple asexual division includes the doubling of chromosomes so that each chromosome consists of two chromatids attached in the middle by a centromere. The next phase which is prophase shows each pair of chromatids tightly coiled, visible and paired with its homologue. They form tetrads at the equator of the cell and attach to the spindle. In anaphase the chromatids separate and migrate to opposites ends of the cells. In telophase the cytoplasm pinches off and two new cells are formed called daughter cells. The nuclear membrane disappears after the nucleolus disappears during prophase.

These visible phase changes are the result of some complex molecular biochemistry.

DNA (deoxyribosenucleic acid) consists of a chain of nucleotides, in fact two chains, the chains attached to each other by basis with hydrogen bonding. The double helical structure was determined by several researchers James Watson, Francis Crick and Rosalind Franklin, three of the most eminent.

The importance of the biological function of the DNA in its ability to replicate itself was further investigated by Matthew Meselson and Frank Stahl. Their experiment relied on the ability to differentiate the densities of two isotopes of nitrogen. Using the E. coli bacterial fed on nutrient broth as a source of nitrogen, Crick found that generations replicated DNA with either heavy or light nitrogen determined by the broth.

A nucleotide consists of a 5-carbon sugar called a ribose or deoxyribose, a phosphate and a base. The phosphates link the sugars together to form the outside of a ladder structure and the bases attract complementary bases also attached to sugars and phosphates to form the rungs of the ladder. The four bases are adenine, guanine thymine and cytosine and adenine and thymine always pair as do cytosine and guanine. During chromosome replication, the paired bases separate into two separate strands each one attracting to a new and identical complementary strand.

A number of these bases along the DNA constitute a gene allele therefore replication makes it possible for each new daughter cell in mitosis to have the full genome of a parent cell. In meiosis the germ cells will have only the genes determined by the sequence of bases on one DNA strand.

The sequence of bases in DNA is extremely important in protein synthesis.

The Importance of Bacterium E. coli

Genetic analysis is based on the identification of mutations which are rare DNA changes that disrupt the activity of genes. Since the appearance of mutations is largely a matter of chance, they are most likely to be observed in large populations of organisms which multiply quickly. E. coli is the ideal genetic organism.

E. coli is normal bacterial fauna that inhabit the human colon, where it absorbs digested nutrients. It

propagates asexually by binary fission: the chromosome replicates and splits to form two daughter cells. In a sexual phase, mating involves the flow of genetic material through a cytoplasmic bridge called a pillus.

E. Coli is easily grown in a nutrient medium—such as Luria Broth—that contains carbohydrates, amino acids, nucleotide phosphates, salts and vitamins derived from yeast extract and milk protein. Incubation of the E. coli occurs at 37°C (human body temperature).

E. coli bacteria growth falls into the four distinct phases diagramed below. During the logarithmic phase, the culture grows exponentially and cell number doubles every 20-30 minutes. Death rate exceeds fission rate when nutrients are depleted and wastes accumulate.

(figure available in print form)

Masses of E. coli bacterial cells are grown in a suspension culture and shaking provides the aeration the cells need and keeps cells suspended. Individual colonies can be isolated by spreading the cells on a surface of Luria Broth stiffened with agar. Colonies may be taken off a plate or a stab culture and streaded onto an agar plate using an inoculating loop.

One milliliter of E. coli culture at stationary phase contains approximately one billion cells. A mutation that occurs at a rate of 1/million population should be represented by 1,000 cells. Individual cells are not visible to the naked eye, but colonies of daughter cells are after incubation for 8-12 hours.

E. coli is a prokaryote. It has a single circular chromosome which is unprotected by a nuclear membrane. It contains 5 million base pairs and is therefore only 1/600th the size of the human genome.

Note: Ask students then to compute how many base pairs in the human genome. The chromosomal locations and sequence of a large number of its genes are known.

Because the genetic code is universal, E. coli can accept foreign DNA derived from any organism. A human sequence of DNA inside E. coli is translated and processed in exactly the same manner as the native bacterial DNA.

Hershey experimented with viral phases and determined that it was the DNA which was replicated in bacteria and not the entire phage. Hershey’s experiment also enforced the theory that viral phages have a simplistic structure consisting of a viral protein coat and DNA and that the DNA is the material which enters the bacteria.

Note: Ask students to apply this concept to the diagram of Hershey blender experiment.

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LESSON I

GLOSSARY

Meiosis
Mitosis
Interohase
Prophase
Metaphase
Anaphase
Telophase
nucleotide
Diploid
Haploid

CONCEPT QUESTIONS

1. What occurs at each phase of mitosis?
2. What is the difference in the two meiotic divisions?
3. What is a nucleotide and how does it relate to DNA?
4. What is a double helical model of DNA?

Laboratory:
Students should work with the double helical structured model of DNA.

Secondly, students should utilize models to increase the understanding that PHAGES or bacterial viruses invade bacteria and hijack the DNA of the host.

The instructor should explain the advantages of utilizing the E. coli bacteria because this particular organism has been used for most of the backup laboratory investigations.

The use of simple plasmids or bacterial vectors are utilized as carriers of the DNA molecules into the hosts.

LESSON II

BEHAVIORAL OBJECTIVES

1. To understand protein synthesis as is accomplished by m-RNA, T-RNA and ribosomes.

The DNA unzippers and forms new halves in the process of duplication. When acted upon by certain chemical stimuli a portion of the DNA will unzipper and the order of the bases adenine, guanine, cytosine and thymine is copied in complement by a material known as RNA (messenger) The RNA substitutes uracil for thymine, is a single strand and has a ribose sugar.

The Ability of the RNA to pick up the sequence of bases by forming the complement and then carrying it to ribosomes so that amino acids and proteins can be assembled is known as protein synthesis.

The sequence of three of the DNA bases are picked up at a time and these are called a codon and the process of receiving the code from DNA by RNA is called transcription.

The messenger RNA on the ribosome receives the necessary amino acids from the cytoplasm by a transfer-RNA which attracts the acids from the cytoplasm that are necessary for the polypeptide synthesis coded for by M-RNA.

The m-RNA has a start codon and a stop codon so that the DNA can be transcribed for only certain order of bases.

It is important to remember that each amino acid which is a peptide to form a polypeptide chain consists of the purines and pyrimidine bases in a specific order with only three for any amino acid/peptide formation. Most amino acids can be formed by several different combinations of three bases (codon). The codons are formed by translation from RNA after the codes have been transcribed from DNA.

The significance of knowing how and what proteins can be synthesized is that the proteins and enzymes that are synthesized cause cells to differentiate and specialize giving organisms their respective characteristics.

Genes or paired aloles along the chromosomes are the sequence of bases in DNA which determine the proteins which determine the traits or characteristics.

In 1961 Crick and Brenner performed genetic experiments for the discovery of ‘codons’ and the code was cracked in 1966 by Marshall Nirenberg and H. Gobind Khorana.

All possible mRNA combinations were tried, yielding a genetic dictionary for the translation of RNA into

proteins. All proteins begin with the amino acid methionine, its codon (AUG) represents the start signal and UAA, UAG and UGA are stop signals.

FOR BETTER STUDENT UNDERSTANDING STRESS THESE CONCEPTS

1. From Procaryotes to Eucaryotes

It is thought that all organisms living now on earth derive from one single primordial cell born several billion years ago . . . . The family resemblances between all organisms seem too strong to be explained in any other way. One important landmark along this evolutionary road occurred about 1.5 billion years ago, when there was a transition from small cells with a relatively simple internal structure—

2. There are over 200 different types of specialized cells in the organisms . . . different cell types are transcribed from different sets of genes.
3. Coiling of the DNA helical structure facilitates transcription because the coils permit the exposure of 10 bases. It creates superhelical tension.
4. There is a tight packaging of DNA with histones to form chromatin. Histones become packaged to form the beaded structures known as nucleosomes.
5. A phenomenon known as cell memory figures into the cell differentiation so that certain portions of the chromosomes are opened for transcription.
6. Substances regulate and control
    a. transcription
    b. processing
    c. transport
    d. translation

At this point in the study students should be allowed visitation to a laboratory where an electron microscope is available or/and electronmicrographs of chromosomes should be available or copied from texts.

karyotypes of chromosomes
beaded appearance due to coiling and thickening due to histones
twisting, crossing and splicing of chromosomes

(figure available in print form)

(figure available in print form)

(figure available in print form)

Many changes have been made to the Crick central dogma and it is now known that the flow of genetic information is not one-way. The molecular genetic system (DNA-RNA-Protein) is dynamic; elements exert feedback regulation in ways that could not have been originally known. The genetic material is 'plastic' so that a single 'gene' may, through rearrangement and biochemical editing, be responsible for the production of several different proteins.

(figure available in print form)

THE MECHANISM FOR PLASMID UPTAKE BY E. coli

Work with E. coli has shown that the bacterial cells can take on the DNA of other organisms and then the bacteria replicates that DNA as its own.

By treatment with certain solutions the E. coli become 'competent' or able to take on the DNA which is transported into the bacteria. The mechanism for transport is called a plasmid.

The acidic phosphates of the DNA helix are negatively charged. Similarly these make up the bacterial membranes and permit zones of adhesion.

(figure available in print form)

GEL ELECTROPHORESIS USED TO DETECT RESTRICTION FRAGMENTS

In 1970, Daniel Nathans introduced gel electrophoresis as a means to separate DNA restriction fragments. Gel electrophoresis means, literally, to carry with electricity. When placed within an electrical field, DNA molecules are attracted toward the positive pole and repelled from the negative pole. The process is used to determine the size in basepairs of DNA restriction fragments which have been enzymatically ligated.

Below—Right: This micrograph shows that lambda DNA material can be fragmented by the enzymes EcoRI, and HindII. Fragments of smaller size travel further during electrophoresis.

(figure available in print form)

Below—Left: The charged fragments of DNA make it possible for the binding of reversed charged DNA fragments.

(figure available in print form)

ENZYMES ARE THE MECHANISM BY WHICH BASEPAIRS ARE ACTIVATED OR MANY BASEPAIRS ARE ACTIVATED AS A GENE TO PRODUCE A PROTEIN

Enzymes are produced or synthesized with many amino acids

which are coded for from the DNA-RNA-protein sequence. Certain enzymes can cleave the DNA chain and these are called restriction endonucleases. Some of the endo's cut clearly through the double helix and others such as the EcoRI cut each strand off-center in the recognition site, at two to four nucleotides apart leaving exposed ends. The latter 'sticky ends' are useful in making recombinant DNA molecules.

(figure available in print form)

Lesson II

GLOSSARY

Polypeptide
Codon
DNA
RNA
m-RNA
Transfer-RNA
ribosome
AMINo Kid
Gene

CONCEPT QUESTIONS FOR HOMEWORK AND QUIZZES

1. Describe polypeptide synthesis including m-RNA and transfer-RNA?
2. What is the function of ribosomes?
3. How do bases pair in DNA and in RNA?

LABORATORY DISCUSSION

Research has found that the classical concept of a 'gene' as a unique entity is not as useful. The genetic material is plastic and a 'gene' may be responsible for the production of several proteins.

Protein research has yielded:

1. RNA viruses store genetic information as RNA and the information is converted to DNA by the enzyme *reverse transcriptase* .
2. DNA replication and gene transcription is regulated by DNA-binding proteins which bind directly

to DNA.
3. There are transposable genetic elements that move from one chromosome spot to another. These transposons act as molecular switches to regulate gene expression.

LESSON III

Behavioral OBJECTIVES

1. to understand how genes determine cell chemistry and thus determine cell specialization
2. to begin to understand how cell specialization and individual characteristics in humans vary
3. to begin to understand the laws of heredity as Mendel proposed them

As studied in the previous lesson, specific loci on the DNA an responsible for the coding in m-RNA which puts together peptides for enzyme synthesis in the ribosomes of the cells.

An outstanding development in biochemical genetics was the concept that each gene is responsible for producing a specific enzyme. The theory was proposed by G. W. Beadle and E. L. Tatum. They experimented with the mold Neurospora They found that when Neurospora, Men exposed to radiation, did not synthesize a vitamin which it needed. Destruction of the gene by radiation does not only effect the syntheses of amino acids but of other polypeptides.

In 1976, Har Bobind Hhorana of the Massachusetts Institute of Technology succeeded in synthesizing an artificial gene. . . . The structural part of the gene has 126 nucleotides.

Traditionally biology has studied genomes and accepted variations within genetic material to account for the differences between organisms within a species and between individuals of different species.

Remarkably, the genetic code is the same for all living things, Only the mitochondrial codes are slightly different from the rest. Both protists and humans use GCU as the code word for alanine. This is another example of the unity of life and the relationship of living things.

We are trained by socialization to distinguish individuals belonging to different racial groups.

During the last forty years immunology and protein chemistry studies have identified a large number of genes that code for proteins and specific enzymes. Seventy-five percent of the different kinds of proteins are identified in all human tested.

Human genetic traits are inherited in a mendelian manner. There are over 3,000 human traits and some of them are shown in the table below. There are many others such as sex determination and ABO blood types.

(figure available in print form)
Over 2,000 human disorders are known to be inherited. Genetic counseling and typing are recommended for the recognition of many of these traits. Some are:

Sickle Cell Anem ia where red blood cells are crescent shaped. They last 10-25 days whereas normal cells last 120 days.

Change of one codon recessive

Huntington's chorea incurable insanity after age 35 dominant Tay Sacks destruction of nervous system in children recessive failure of enzyme to eliminate fat from nerve cells

PKU failure to convert enzymes and mental retardation occurs recessive Cystic fibrosis recessive where mucous forms in the lungs and pancreas Prior to genetic engineering which has helped to emphasize the importance of DNA sequencing, Gregor Mendel studied hereditary factors. He knew nothing about DNA, transcription and translation by RNA. His material did know that each parent contributed half the inherited material. Thus many 'hidden' factors produce traits that appear in successive generations.

Like humans, pea plants have certain characteristics such as flower color, blossom placement, plant size and pod color, and shape to name a few. He made thousands of crosses and recorded results from generation to generation. He knew nothing about DNA and genes determining polypeptide synthesis but his findings were:

1. that traits are determined by paired factors
2. that in paired factors one of the pair seems to be expressed more often than its homologous pair and is thereby said to be dominant
3. in gamete formation (germ cell) the paired factors for one trait assort independently from the paired factors representing another trait

The occurrence of traits from generation to generation is predictable by representing the trait appearance in all gametes and then finding the possibilities from crossing all gametes.

GLOSSARY

Factors
Traits
Law of Dominance
Recessive
Law of Independent Assortment
Gamete
Germ Cell

CONCEPT QUESTIONS

1. What is meant by a pattern of inheritance?
2. What is one of the accomplishments of genetic engineering?
3. How are amino acids related to proteins?
4. What did the findings of Gregor Mendel disclose?
5. What were some of the dominant and recessive traits discovered by Mendel?

LESSON IV

Behavioral objectives:

1. to understand what is meant about being able to determine a ratio of occurrence of traits in offspring The expression of traits in offspring can be predicted The expression is determined by paired factors or alleles or genes located at homologous locations on paired chromosomes The exact location of the alleles for many traits has been determined by researchers and the process is called gene mapping.

Mendel did not know about genes andalleles but he did work out ratios representing the expression of traits. He determined that traits are represented by pairs and that in the germ cells of each parent only half of the pair is found because of meiosis where half of the homologous pair or chromosomes is present. For each trait he assigned a pair of letters, for each gamete—a single letter. He then devised a scheme to show all of the possibilities of combinations of germ cells from two parents.

The same scheme can be used for human traits that come in pairs. However some traits are represented by more than a pair of alleles such as blood type which has three loci. In humans there are 22 pairs of autosomes and one pair of sex chromosomes. The twenty-third pair of chromosomes in females show XX in the karyotype and in the male—XY.

The germ cell of the female can therefore only be X but the germ cell of the male can be X or Y. For each mating therefore there is a 50/50 chance that the offspring will be male and a 50/50 chance of a female. To have two of the same sex consecutively the ratio is represented as 1/2 x 1/2 = 1/4 possibility.

Sample problems:

(figure available in print form)

LESSON IV

GLOSSARY

Monohybrid
Dihybrid
Genotype
Phenotype
Probability
Punnett Square
Homozygous
Heterozygous

Hybrid

CONCEPT QUESTIONS

1. Practice writing a pure trait (genotype) homozygous.
   a hybrid " Heterozygous.
   a dihybrid
   a female
   a male
2. What is the result of crossing two pure for opposing traits.
3. Cross two dihybrids for the same traits. What is the ratio phenotypically and genotypically?

LESSON V

***BEHAVIORAL OBJECTIVES* :**

1. To understand how behavior is the result of genetic and environmental f actors
2. To understand that there are genes that affect human behavior

Sociobiology—A new and Controversial Science

Sociobiology is a combination of ethology which is the naturalistic study of whole patterns of behaviors and ecology which is the study of organisms in their environment and of genetics which is the total chemical make-up of the organism.

Socio-biology is the study of the biological properties of entire societies and involves comparisons of the social species i.e. man, apes, ants, and bees. It is based on the premise that a person is molded by interaction of his cultural environment and the genes that affect social behavior. There are similarities in the social behavior between man and monkey which are equated to similarities in gene chemistry. Laughter is a good example of like behavioral patterns.

A postulate of sociobiologists is that “social behavior inc. eases biological fitness”. For instance the social taboo against incestuous behavior is a behavior which discourages inbreeding and promotes substantial variety within the gene pool. The premise is that natural selection of Darwin which acclaims ‘survival of the fitness’ means that good genes are selected for. Social behavior such as altruism does not allow for the selection of the most ‘fit’ genotypes.

Postulating genes for behaviors is the most controversial part of the application of the theory of socio:biology. There is fear of repeating the mistakes of the eugenicists who postulated genes for alcoholism, crime and other unapproved social behaviors.

Eugenics or the determinability of human fitness by genes for behavior was alluded to in many sociological studies. One of the tools used by man against his fellow man in the social environment is a tool to measure intelligence, called the IQ test. The Stanford-Binet test published by Terman in 1916 was used as a means for social and economic exclusion. It was used against the poor as an instrument to verify that those at the bottom economically were genetically inferior. The IQ test has been used by immigration authorities, penal institutes and educators. Its use resulted in putting the mentally deficient, lunatics, poor and disadvantaged all in a social outcasts situation.

To follow the correlation between intelligence and environment has been established as a very close one. Both types of twins, MZ and DZ, have been tested in similar adoptive environments. Estimating the heritability of intelligence independent of the environment is difficult. This is because there is similarity in adoptive environments frequently.

Comparing twins which are monozygotic MZ with the same genetic material with those which are dizygotic results in closer IQ scores for the MZ twins. Still it has not been determined exactly what the heritability of IQ

really is.

Also to be considered is that the expression of a trait may depend almost entirely upon the environment. An analogy is using identical flower seeds grown in different soils.

Studies concerning the differences that arise among individuals of the same species show that most differences are between individuals not among groups.

An obvious question that arises is/ Should genetic typing be allowed as an acceptable evaluation criteria on for the determination of an individual's fitness or suitability?

Note: A class discussion, debate and/or thesis could be assigned to discuss the moral, ethical and legal aspects of the proposal.

(figure available in print form)
Tracing human traits by electrophoresis of the DNA material can produce micrographs similar to the one above, The DNA material or basepairs are duplicated in a ' southern' block using RNA for reverse transcriptase. Note that carriers for the trait in generation II were 1 and 3 and the two types of DNA showed at locations 1 and 5 on graph. This alters the allele theory and substantiates a transposon theory or different reading concept for utilizing different basepairs at different recognition sites.

LESSON V

GLOSSARY

Monozygotic
Dizygotic
Monomorphic
Polymorphic
IQ Test—Stanford Binet
Sociobiology
Ethology
Ecology

CONCEPT QUESTIONS

1. How valid an instrument is the IQ test?
2. Does environment effect the development of IQ?
3. Is there evidence of the heritability of IQ in MZ twins.
4. What have been the difficulties in studying the heritability of traits exclusive of the environment?

SUGGESTED LABORATORY TEACHING

SESSIONS

Laboratory 1
Laboratory equipment and technique practice and safety procedures

Laboratory 2
Preparation of agar culture plates and inoculation with E. coli

Laboratory 3
Demonstration and/or slide presentation of micro techniques and electrophoresis reading culture plates

Laboratory 4
Model reconstruction of DNA and RNA Stepwise simulations of protein synthesis

Laboratory 5
Continuation of protein synthesis from # 5 above Practice reading partial libraries of simple DNA

Laboratory 6
Students practice locating or constructing pedigrees for human traits

Laboratory 7
Crosses of commercially prepared Drosophila can be traced for eye color and wing shape This will require four consecutive days

Laboratory 8
Using rodents such as white mice or hamsters or even gerbils behavioral patterns of siblings can be studied. White mice can be marked with color on their heads and male and female should be used for each test situation.

Objective is to determine whether those from the same parents vary in social behavior or in 'learning ability' when their environment has been varied.

Variances include:

1. Diet

2. Exposure to stimuli such as maze or other learning apparatus
3. Exposure to light or noise for 24 hr.
4. Negative reinforcement situs

STUDENT READING LIST

Dorothea Allen. *Biology Teachers' Desk Book* . Parker Publishing Company, West Nyack, New York, 1979.

Carl D. Glickman. *Supervision of Instruction* . Allyn and Bacon, Inc. Boston, 1985.

L. Kamin. *The Science and Politics of IQ* (1974).

Lewontin, Rose and Kamin, *Not in Our Genes* (1984).

Jamie Murphy. "Tracing Fragile X Syndrome," *Time* , March 16, 1987.

E.O. Wilson. *On Human Nature* , 1978.

S.L. Washburn. "Human Behavior and the Behavior of Other Animals," *American Psychologist* , Vol. 33, No. 5 (May 1978).

BIOLOGY—TEACHERS

B.S. Bloom. *Stability and Changes in Human Characteristics* . John Wiley and Son, Inc., New York and London. 1964.

Donald B. Cheek. *Human Growth Body Comparisons, Cell Growth* . Lea and Febiger, Philadelphia, 1968.

Richard Dawkins. *The Selfish Gene* . 1976.

J. Francis Fletcher. *The Ethics of Genetic Control: Ending reproduction roulette* . Anchor Press, New York, Garden City, 1974.

John L. Fuller. Behavioral Genetics.

Raymond F. Gale. *Developmental Behavior—a human approach* .

G.J. Goodfield. *Playing God—Genetic Engineering, the manipulation of life* . Random House. New York, 1977.

L. Kamin, *The Science and Politics of IQ* . 1974.

Oscar Kempsthorne. *An Introduction to Genetics Statistics* . American Iowa State Press. 1969.

Jonas Langas. *Theory of Development* . Holt, Rinehart and Winston, 1969. (New York).

Lewontin, Rose and Kamin, *Not in Our Genes* , 1974.

R.W. Old. *Principles of Gene manipulation, an introduction to genetic engineering* . Blackwell Science, Oxford & Boston, 1985.

Curriculum Guide by Greg Freyer and David Micklos. *DNA Science—A First Laboratory Course in Recombinant-DNA Technology* . Cold Spring Harbor Laboratory, 1987. (New York).

“What You Do What You Do” *Time* , August 1, 1977.

ADVANCED BIOLOGY PROGRAM

CURRICULUM STUDY BIBLIOGRAPHY

Alberts, Bruce, D. Bray, J. Lewis, M. Raff, K. Roberts, J.D. Watson. *Molecular Biology of the Cell* . (New York: Garland Publishing, Inc., 1983).

Cairns, John, G. Stent, J.D. Watson, eds. *Phage and The Origins of Molecular Biology* . (Cold Spring Harbor, NY: Cold Spring Harbor Laboratory, 1966).

Cherfas, Jeremy. *Man Made Life* . (New York: Pantheon House, 1983).

Commercial Biotechnology: An International Analysis . (Washington, DC: US Congress, Office of Technology Assessment, OTA-BA-218, January 1984).

Fjermedal, Grant. *Magic Bullets* . (New York: Macmillan Publishing Company, 1984).

Gold, Michael. *A Conspiracy of Cells* . (Albany, NY: State University of New York Press, 1986).

Gonick, Larry, M. Wheelis. *The Cartoon Guide to Genetics* . (New York: Barnes & Noble Books, 1983)

Judson, Horace Freeland. *The Eighth Day of Creation: Makers of the Revolution in Biology* (New York: Simon & Schuster, 1979).

Keller, Evelyn Fox. *A Feeling for the Organism* . (New York: W.H. Freeman and Company, 1983).

Maniatis, T., E.F. Fritsch, J. Sambrook. *Molecular Cloning: A Laboratory Manual* . (Cold Spring Harbor, NY: Cold Spring Harbor Laboratory, 1982).

Strickland, Stephen P. *Politics, Science, and Dread Disease: A Short History of United States Medical Research Policy* (Cambridge, MA: Harvard University Press, 1972).

Sylvester, Edward J. *Target: Cancer* . (New York: Charles Scribner’s Sons, 1986).

Watson, James D. *The Double Helix: A Personal Account of the Discovery of the Structure of DNA* . (New York: W.W. Norton & Company, 1980).

Watson, James D., J. Tooze. *The DNA Story: A Documentary History of Gene Cloning* . (San Francisco: W.H. Freeman and Company, 1981).

Watson, James D., N. Hopkins, J. Roberts, J. Argetsinger Steitz, A Weiner. *Molecular Biology of the Gene* . 4th edition, Volume I. (Reading, MA: W.A. Benjamin, Inc., 1987).

Watson, James D., J. Tooze, D.T. Kurtz. *Recombinant DNA: A Short Course* . (New York: Scientific American Books, 1983).