

SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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National Science Education Standard—Life Science

The Cell

Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.

Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues and organs that comprise the final organism. This differentiation is regulated through the expression of different genes.

Cell functions are regulated. Regulation of cells occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division.

Teacher Materials

Learning Sequence Item:

1050

The Watson-Crick Model of DNA Structure

May 1997

Adapted by: Diane Schranck

DNA, RNA, and Genetic Engineering. Students should understand the universality of the DNA molecule. They should become familiar with the Watson-Crick model of DNA structure, recognizing the significance of the nucleotide sequence in that it directs the activities of cells and determines the traits of the organism. Students should examine the relationship between DNA, genes, chromosomes, and inheritable traits. (*Biology, A Framework for High School Science Education*, p. 92).

Contents

Matrix

Suggested Sequence of Events

Lab Activities

1. Where Do Genes Begin?
2. It's Not Hamburger Anymore
3. It's in the Genes
4. It's on the Chromosome
5. Let's Make a New Critter

Assessments

1. How do We Express Ourselves?
2. The Same But Not the Same
3. Can We Pollute Too Much?
4. Why Do We Have to Be Good to Ourselves?

1050

Learning Sequence

DNA, RNA, and Genetic Engineering. Students should understand the universality of the DNA molecule. They should become familiar with the Watson-Crick model of DNA structure, recognizing the significance of the nucleotide sequence in that it directs the activities of cells and determines the traits of the organism. Students should examine the relationship between DNA, genes, chromosomes, and inheritable traits. (*Biology, A Framework for High School Science Education, p. 92*).

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
<p>Where Do Genes Begin? Activity 1</p> <p>It's Not Hamburger Anymore Activity 2</p> <p>It's in the Genes Activity 3</p> <p>It's on the Chromosome Activity 4</p> <p>Let's Make a New Critter Activity 5</p> <p>How Do We Express Ourselves? Assessment 1</p> <p>The Same But Not the Same Assessment 2</p>		<p>Can We Pollute Too Much? Assessment 3</p> <p>Why Do We Have to Be Good to Ourselves? Assessment 4</p>	

Suggested Sequence of Events

Event #1

Lab Activity

1. Where Do Genes Begin? (55 minutes)

Event #2

Lab Activity

2. It's Not Hamburger Anymore (55 minutes)

Event #3

Lab Activity

3. It's in the Genes (45–55 minutes)

Event #4

Lab Activity

4. It's on the Chromosome (55 minutes)

Event #5

Lab Activity

5. Let's Make a New Critter (45 minutes)

Event #6

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Readings to be assigned by teacher.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple-choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.
2. Open-ended questions asking for essay responses.
3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Where Do Genes Begin?**What is going on inside your cells?****Overview:**

In this activity, students construct a model of deoxyribonucleic acid (DNA) and investigate nucleotide structure, including base pairing and sequencing.

The teacher will need to cut the construction paper to the sizes noted below. Construction materials should be placed in an area where student teams have direct access to them.

Materials:**Per lab group (2):**

construction paper, yellow strips, 1/2" × 9", 2

construction paper, white squares, 1/2", 6

construction paper, green, blue, orange, and red strips, 1/2" × 3"

(to serve as the four types of amino acid bases; the amount will vary for each team depending on the DNA code for their amino acid)

glue

glue applicator

ruler (12 inches)

scissors

Procedure:

Have students select an amino acid and a corresponding triplet code. Some amino acids have more than one triplet code. In such cases, advise students to select only one triplet to work with. Two long yellow strips will represent sugar molecules; white squares will represent phosphate molecules; and red, orange, blue, and green strips will represent the four types of bases.

Students should first mark sugar (yellow) strips at 1", 4", and 7" points. These will be the locations for the white phosphate squares. Next have them shape one end of each of the orange and blue strips—round for orange and pointed for blue. Red and green strips should remain the same. Base strips should be glued perpendicular to the sugar strips at points just below the phosphate squares, with the uncut ends of the base strips behind the sugar strips. After verifying the correct sequence of bases in the molecule, students tape the free ends of the base strips to their corresponding bases so that the shaped ends are in the front.

Encourage accuracy of measurement. The finished product should look like a ladder with the paired bases forming the ladder rungs. The ladder should be retained for Activity 2 in this micro-unit. If time does not permit continuation to Activity 2, then the DNA ladders made by each student group can be linked to each other to form a giant molecule. It is recommended that the molecule be twisted and mounted on a wall for display.

Background:

Deoxyribonucleic acid (DNA) is a large molecule located within the cell nucleus of living organisms. This molecule is shaped similarly to a twisted ladder or double helix. The uprights of this ladder are composed of phosphates (PO_4) and sugar units (deoxyribose sugar $\text{—C}_5\text{H}_{10}\text{O}_4$). The deoxyribose sugar has one less oxygen atom than the normal five-carbon sugar, hence the name "de-oxy." Each of the many thousands of rungs on the ladder, called bases, along with the phosphate and attached sugar, are the building blocks of nucleic acids—nucleotides. Nucleotides are joined in the center of the ladder by weak hydrogen bonds that join the base pairs.

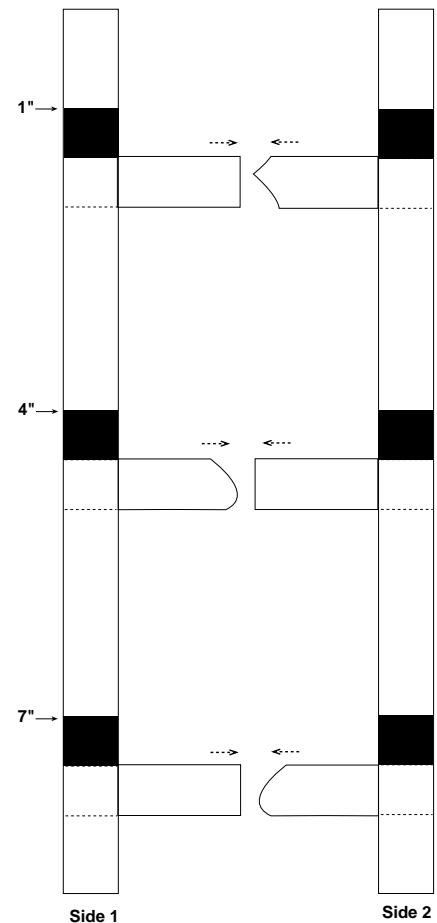
There are four different bases found in DNA. Two are purines—adenine and guanine—and two are pyrimidines—thymine and cytosine. Adenine binds always and only with thymine while guanine binds always and only with cytosine. The pairings may occur in either order (A-T, T-A, C-G, G-C). The bases are thus in only four different combinations in relation to their connections with the ladder uprights, although they form many different sequences along the DNA uprights.

Each base represents a "code letter ." A "code word" or codon is formed by a combination of three "code letters." These triplet codons become instructions from the DNA for the synthesis (making) of various types of proteins (a chain of amino acids) for the cell's use. Identical "letters" and triplet codons have the same meaning in all living things.

DNA molecules have two basic functions to perform:

1. They reproduce exact replicas of themselves at the time of cell division and pass the heredity information from generation to generation. Just prior to cell division, the DNA molecules unwind and separate along the hydrogen bonds, leaving two strands of phosphates and sugars, each with a series of half-base pairs, for each DNA molecule present in the nucleus. Immediately, free floating purine and pyrimidine nucleotides unite with their complementary partners along the half molecules to form two new molecules, one for each new cell being formed and each identical to the original molecule. This process is called replication and immediately proceeds the beginning of mitosis, which is the splitting of the cell's nucleus.

2. They direct and control protein synthesis in a cell by unwinding and splitting along the hydrogen bonds. Not all of the DNA splits at the same time in this function—only the sections necessary to send the code that is needed to make a specific protein molecule. Complementary free-floating messenger



RNA (mRNA) nucleotides (with uracil replacing thymine) quickly form a single strand along one of the split DNA strands. The mRNA strand is started by an initiator codon (methionine) that signals that a protein is about to be coded. When the coding is complete a stop codon ends the mRNA chain, and the mRNA molecule is then released. The split DNA sections then rejoin.

Answers to Student Questions:

4. If you were to make a DNA molecule with six amino acids, do you think that any other team in the room would make the identical molecule? Justify your answer.

Answer: No. With 25 triplet codes for amino acids to choose from, the chance of two teams choosing the exact same six and placing them in the exact same order to form the exact same protein is highly unlikely.

5. Many of the amino acids have more than one triplet to code for. Some will have as many as six different codes. Why do you think that it may be to the advantage of the organism to have different codes for the same amino acid?

Answer: Those amino acids with a higher number of triplets to code for them are in all likelihood very important to the general protein structure of the cell. If a cell miscodes for an amino acid which has six different codons, it is likely that particular amino acid will be coded for anyway, thereby giving the cell the amino acid for the protein it needs.

6. If your DNA molecule was joined with all the other molecules made in your teacher's classes it would form what might be only a small DNA segment of one gene in a real chromosome. If the order of the DNA triplets was changed through mutation, what do you think that would mean in terms of the heredity of the cell and its ability to make the proteins it needs?

Answer: It may mean that the cell will be unable to make the types of proteins that it needs in order to carry on its life functions and therefore it may die. It may also mean that a different code could trigger uncontrolled mitosis (cancer) by telling the DNA to replicate more often than cytokinesis occurs (giving the cell multiple nuclei).

Variations:

Soda straws may be substituted in place of long yellow strips of construction paper. Plastic pieces may also be used to construct the model.

Adapted from: none

Science as Inquiry

It's Not Hamburger Anymore**How do food molecules get turned into useful cell molecules?****Overview:**

In this activity students investigate how new proteins are made by making a model and simulating how cellular DNA directs the synthesis of a new protein. Though students create only a single amino acid of a protein chain, they should be able to put the protein synthesis steps into the proper sequence.

Materials**Per lab group (2):**

DNA model from Activity 1
construction paper, 18" × 12" sheet
construction paper, dark purple strips, 1/2" × 3", 3
construction paper, light purple strip, 1/2" × 9", 1
yarn, 1 skein of each of 3 colors (per class)
scissors
glue
glue applicator
ribosome cutout (template included here)
ribosomal RNA cutout (template included here)
amino acids (template included here)
envelope (to store model pieces)

Procedure:

Before class cut apart the ribosome and ribosomal RNA cutouts so that each team will obtain only one. To conserve paper several sheets of the amino acids can be cut out and teams can pick up only the one that they need or they can be encouraged to return any they do not use.

Students start by drawing the nuclear membrane and endoplasmic reticulum on construction paper and attaching yarn according to instructions. Next, have them cut out and glue down the ribosome and rRNA. Have them place all small parts in an envelope and attach the envelope to the back of the model they have constructed.

Recalling the bases used in the previous activity, students should use this information to construct models of mRNA. They should then cut the amino acids needed to attach to the tRNA.

The distance that the nuclear membrane is placed from the edge of the construction paper must be sufficient to accommodate the existing DNA model. They may trim the bottom of the DNA molecule to a length of 8". Their final model should show the DNA molecule within the nucleus, arranged as a ladder; the mRNA nucleotides should be separated from each other and scattered in the cytoplasm and nucleoplasm; the tRNA triplet, without an attached amino acid, should be in the cytoplasm; the amino acid should be attached near the ribosome. Encourage students to place a few of the unused amino acids around the cytoplasm.

Background:

Ribonucleic acid (RNA) is different from DNA in both structure and function. Structurally, RNA has ribose sugar instead of the deoxyribose sugar found in DNA. RNA is only a single strand and resembles half of a ladder. Uracil replaces the pyrimidine thymine, which is found in DNA. About 90% of RNA molecules are located outside of the cell nucleus.

Functionally, RNA falls into three categories:

1. Messenger RNA (mRNA) originates in the cell nucleus created by the nucleolus. The mRNA nucleotides consist of ribose sugar, phosphoric acid, and one of the four bases found in RNA. These nucleotides, free-floating in the nucleus and in cytoplasm, will form the complementary base pairs for the sections of DNA that have unzipped, exposing the bases to be coded to make new protein. After the code for the protein has been completed, the new mRNA strand will leave the nucleus. The sequence of bases along the messenger RNA, forming three-letter triplet codons, codes for specific amino acids. The message is delivered to the ribosomal RNA (rRNA). Since there are only about 20 different amino acids, some of the 64 possible codes will code for the same amino acid. Some amino acids have up to six different codes. The 20 amino acids combine in different sequences in order to synthesize the thousands of different types of proteins needed by the cell, tissue, or organ that requires them. If a single displacement of a nucleotide changes the amino acid, then the protein that is being made will be different than the one needed by the cell to carry on proper functioning. This mishap may result in the cell's death, a mutation in the cell that could cause cancer, a mutation in the organism, or a similar mishap. One such mutation in humans is phenylketonuria, which is a genetic disease in which babies are unable to utilize metabolic products of phenylalanine (an essential amino acid). This disease is caused by a single mutation on a single chromosome. If left undiagnosed, the child will starve to death.

2. Ribosomal RNA (rRNA) is very stable and stays in a fixed position in the ribosomal membranes. Most RNA molecules are in this category. Their function is to help synthesize amino acids into proteins. Ribosomal RNA reads the code triplets and "tells" the transfer RNA which amino acid to look for and bring back to the ribosome. Ribosomal RNA is responsible for seeing that the amino acids are coded properly and in the correct sequence.

3. Transfer RNA (tRNA) consists of three-letter nucleotide chains that pick up only the amino acids for which they are coded, which are floating in the cytoplasm, and deliver them to ribosomal RNA for synthesizing into proteins. The rRNA may accept or reject the tRNA on the basis of whether the needed code is correct. A rejected tRNA will return to the cytoplasm. An accepted tRNA will briefly affix itself to the mRNA and attach the amino acid it carries, continuing the protein chain. After the tRNA delivers its amino acid, it is free to go back to the cytoplasm for additional amino acids. After the stop order is issued the completed protein chain proceeds to carry out its function.

Answers to Student Questions:

1. Why is the sequence of amino acids important to the production of proteins?

Answer: The sequence of amino acids is one determiner of the kind of protein that a cell synthesizes. Even if the exact same amino acids are used, if the sequence of amino acids is changed so is the protein that is made.

2. What do you believe would be the result if a cell could not make the proteins it needs?

Answer: It may mean that the cell will be unable to carry on its life functions and therefore it may die.

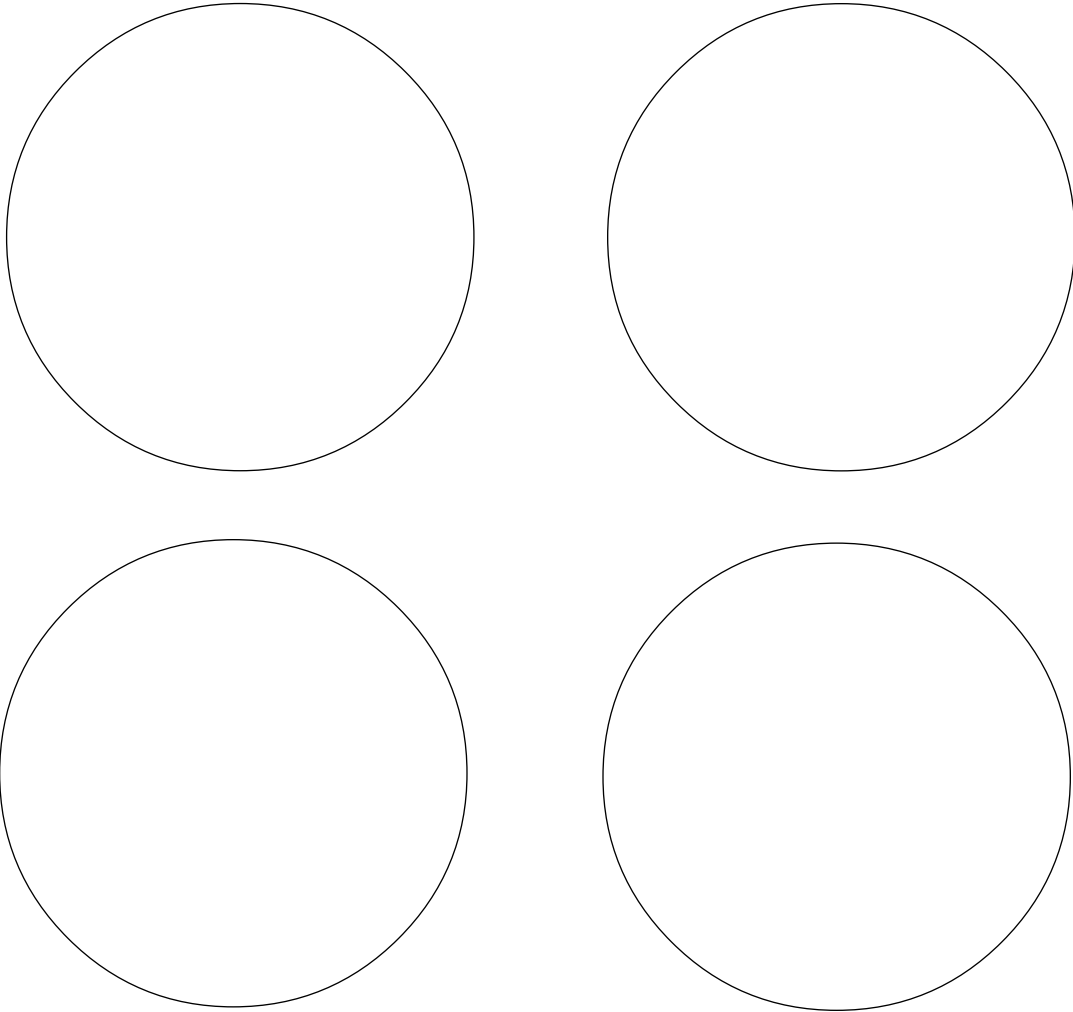
3. Briefly describe the steps of protein synthesis.

Answer: The nuclear DNA unwinds, unzips, and exposes its bases in the section that will code for the protein that the cell needs. The messenger RNA nucleotides pair with the DNA, then leave the nucleus and take the code to the ribosome. At the ribosome, ribosomal RNA reads the code and maintains the mRNA nucleotides in proper sequence. The transfer RNA picks up specific amino acids with matching codes and moves them to the ribosome. If that particular amino acid is needed, the tRNA drops it off and returns to the cytoplasm for another amino acid. If that amino acid isn't needed, it stays attached to the tRNA until it is. After the amino acids are joined, the new protein chain leaves the ribosome to perform the job for which it was made. The DNA rezip and recoils. The process is repeated as needed.

AMINO ACID TEMPLATES

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RIBOSOME TEMPLATE



RIBOSOMAL RNA TEMPLATE



Science as Inquiry

It's in the Genes**What determines what we look like?****Overview**

How can traits on a particular chromosome be determined? How can these traits determine the characteristics of an organism? In this activity students determine genetic traits of a fictional creature by translating DNA codes to the amino acid sequences that are responsible for the traits.

Materials:**Per student:**

penny

blue or yellow pencil

Procedure:

Review with students the roles of DNA, mRNA, tRNA, nucleotide sequencing, and amino acids, and the inheritance of characteristics. Remind them that the creature they are going to make is fictitious. First have them look at the observation tables on the following page (Table A) and flip their pennies to determine which of each pair of traits their organism will have. This will give them the DNA code for the rest of the table.

Students should next record the complementary mRNA and tRNA codes in the proper spaces. Using Table B, they should then determine the amino acid number and record the amino acid sequences in the spaces provided. Using Table C they should determine which trait is controlled by a specific amino acid sequence and record it in the proper space. Finally, have students draw their organisms according to the controlling traits.

Background:

Genes are lengths of DNA molecules responsible for the personal characteristics that an organism inherits, such as hair, eye, and skin color, height, and blood type, as well as species characteristics that all humans have in common, such as two arms, two legs, bone structure, organ structure, and nervous system structure. But how does the DNA code get transferred into a code for a trait? Genes are lengths of DNA molecules that code for particular proteins. Genes determine the structure of polypeptides that our cells make. The sequence of the DNA nucleotides determines the sequence of amino acids in polypeptides and thus also in proteins.

In the process of *transcription*, which takes place in the cell nucleus, messenger RNA (mRNA) reads and copies the section of DNA that has opened itself. It is important to note that DNA usually only completely opens and unzips when replication takes place prior to mitosis. During transcription, DNA unzips only that portion of the helix that involves the specific protein to be made. The mRNA code is formed as a complementary (opposite) code to the DNA. The mRNA code is carried to the ribosome where the synthesis of the protein begins. The code specifies the exact order in which the amino acids

are to be joined together in order to form the needed polypeptide. The code words from the mRNA are not directly recognized by the corresponding amino acids. Transfer RNA (tRNA) is needed to bring the amino acids to the correct mRNA triplet. As the code carried by the mRNA is read in the ribosome, the tRNAs bring the proper amino acid to the site and attach them to the growing polypeptide chain. The process by which the information from DNA is transferred into the language of proteins is known as *translation*. The polypeptide sequence determines which characteristic is activated.

Not all sections of each chromosome or DNA segment are active in each cell. There may be slight bulges in the chromosomes that indicate the active chromosome parts for that cell. Gene regulators appear to turn on and turn off the parts of the genes that are necessary for that particular cell, and this probably accounts for why muscle cells act as muscle cells and not as liver cells. In eukaryotes, the control of genetic expression is not well understood. There appear to be several levels at which control could occur: gene arrangements, the process of protein synthesis, and protein modification.

During the cell cycle, chromosomes form the chromatin found in interphase. They become packed and folded to form the visible chromosomes during prophase. A gene's placement and the manner of folding may determine a gene's expression. DNA methylation causes DNA to be inactive. Methylation of the nucleotides occurs during replication. In specialized cells of higher organisms, not all the genes are needed; therefore, the unneeded genes are more methylated than those that are active.

Because most genes of eukaryotes are inactive, systems for activating the needed genes are important. Regulator genes have been discovered that produce molecules that may act as activators or repressors. Promotor regions associated with eukaryotic genes interact with these molecules. Gene multiplication has also been observed. Whole sections of DNA have been found in which a gene is repeated over and over. Interestingly, only about 1% of a cell's DNA is typically expressed.

For the purpose of this investigation, the fictitious animal will have twelve genes and they will be located on only one chromosome. Each of the genes will be controlled by two or more amino acids.

Please refer to the diagram below to show students how to read the gene squares in Table A.

GENE X (Tells the gene letter)
DNA (indicates the DNA code)
 (Check ___ **H** **AAA-GGG-CCC** (nucleotide sequences)
 heads or tails.) ___ **T** **CCC-GGG-AAA**
mRNA: UUU-CCC-GGG (complementary from DNA)
tRNA: AAA-GGG-CCC (complementary from mRNA)
Amino Acid sequence: 8 - 5 - 1 (see Table B)
trait: The name of the trait goes here (see Table C).

TABLE A

GENE A

DNA

__ H TAC-AGC-CGA

__ T TAC-AGC-CGA

mRNA : _____

tRNA: _____

Amino Acid sequence number:

trait: _____

GENE C

DNA

__ H ACC-ATA-TCC

__ T TAT-ATA-TCC

mRNA : _____

tRNA : _____

Amino Acid sequence number:

trait: _____

GENE E

DNA

__ H TTT-AAA

__ T TTT-AAC

mRNA : _____

tRNA: _____

Amino Acid sequence number:

trait: _____

GENE G

DNA

__ H ACC-GGT-TAT-GAG

__ T ACC-GGT-TAT-CAG

mRNA : _____

tRNA : _____

Amino Acid sequence number:

trait: _____

GENE B

DNA

__ H ACC-GGA-TAT

__ T ACC-GGT-TAT

mRNA: _____

tRNA: _____

Amino Acid sequence number:

trait: _____

GENE D

DNA

__ H GGT-AGG-AAA-CCC

__ T GGG-AGG-AAA-CCC

mRNA : _____

tRNA : _____

Amino Acid sequence number:

trait: _____

GENE F

DNA

__ H TGA-ACG

__ T TGA-ATA

mRNA: _____

tRNA: _____

Amino Acid sequence number:

trait: _____

GENE H

DNA

__ H TGA-GGT-GGT

__ T TGA-GGT-AAA

mRNA : _____

tRNA : _____

Amino Acid sequence number:

trait: _____

TABLE A (continued)

GENE I

DNA

__ H CAC-AGG-AAA

__ T CGT-AGG-AAA

mRNA : _____

tRNA: _____

Amino Acid sequence number:

trait: _____

GENE K

DNA

__ H GGA-CGC-TCC

__ T GGA-CGC-TAG

mRNA : _____

tRNA : _____

Amino Acid sequence number:

trait: _____

GENE J

DNA

__ H GGA-CGC-CGA

__ T GGA-CGC-CGC

mRNA: _____

tRNA: _____

Amino Acid sequence number:

trait: _____

GENE L

DNA

__ H CTA-ATC

__ T TTA-ATC

mRNA : _____

tRNA : _____

Amino Acid sequence number:

trait: _____

Table B

tRNA Triplet	Amino Acid Number	tRNA Triplet	Amino Acid Number
ACC	20	AAA	8
ACG	22	AAC	4
AGG	7	AGC	16
AUC	6	AUA	21
CAC	24	CAG	23
CGA	2	CCC	1
CGC	3	CGU	25
GGA	11	CUA	10
UAC	26	GAG	19
UAU	13	GGG	5
UCC	15	GGU	12
UGA	18	UAG	17
UUU	9	UUA	14

Table C

Amino Acid Sequence	Trait	Amino Acid Sequence	Trait
26-16-2	four-legged	20-11-13 20-12-13	long hair short hair
20-21-15 13-21-15	plump skinny	12-7-8-1 5-7-8-1	long nose short nose
9-8 9-4	no freckles freckles	11-3-2 11-3-3	blue hair yellow hair
10-6 14-6	male female	18-12-12 18-12-8	long eye lashes short eye lashes
18-22 18-21	large eyes small eyes	24-7-8 25-7-8	large ears small ears
20-12-13-19 20-12-13-23	bushy eyebrows fine line eyebrows	11-3-15 11-3-17	plaid coat striped coat

Answers to Student Questions:

1. In how many gene pairs does a single difference in nucleotide sequence make a difference in the characteristic that the organism has? Make a statement concerning the importance of nucleotide sequence.

Answer: Five sequences: Genes B, D, E, G, and J. If even one nucleotide is changed the order is changed and the trait might be different.

2. Why do you think that there was no difference in the two DNA alternatives for Gene A?

Answer: Some genes are species specific; that is, they give a species its shared characteristics (for example, humans have two arms, two legs, hair on head, and so on). They are things that all normal members of the species have in common. Gene A is a species characteristic because all of these critters have four legs.

3. Why do you think that so many of the sequences have some of the same amino acids in them, and in the same order?

Answer: Because alleles of the same trait are likely to have nearly the same genetic structure. Widely varying amino acid sequences would more likely indicate different genes rather than different alleles for the same trait.

4. Do you think that anyone else made a critter exactly like yours? Explain your answer.

Answer: No. Since a flip of the coin determined which of 12 genes were inherited, it is unlikely that two people in the same class flipped their coins exactly the same way for all of the same genes. This supports the notion of variation within a species.

Adapted from:

Miller and Levine, *Biology, Laboratory Manual*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1991.

Gene expression adapted from: *Cliff Quick™ Review: Biology*, pp. 62-63, by David N. Knowlton.

Lincoln, Neb.: M.A., Cliff Notes, Inc., 1993.

Science as Inquiry

It's on the Chromosome**How are amino acids translated into traits?****Overview:**

This activity, an extension of the previous activity, illustrates how genes are a part of chromosomes. Here students will create the chromosome for the creature they created in "It's in the Genes."

Students should understand that amino acids are the controlling factors of the trait and that the nucleotide sequence is very important because it determines which amino acids are made. They should be aware that the order of the amino acids determines the heredity of the gene. If an amino acid is miscoded a mutation may occur. In addition, students should understand that genes are located on specific sections of a chromosome and that gene sequence is also important.

Materials:**Per student:**

- paper, pink or blue strips (for male or female), 17 cm × 5 cm, 4
- paper, colored squares, 1/2", 105
- glue squares (waxed paper on which to put glue)
- glue
- wood splints, craft sticks, or toothpicks to spread the glue

Procedure:

Prelaboratory preparation: Each student will need enough 5-cm-wide paper strips (about 4) to create his or her critter's chromosome. For your convenience, a template for the paper chromosome strips has been included following this activity. The strips are to be cut along the solid lines. It is suggested that you use two different colors of paper to simulate male and female. This will be helpful for the final activity of this micro-unit.

In addition to the paper strips, each student will need colored paper squares (approximately 105) to glue down to form the nucleotide chains. These need to be available in four different colors (one to represent each DNA base), in a quantity to match the number of T's, G's, A's and C's in the student's previous simulation. Use the same color scheme that was used in the "Where Do Genes Begin?" and "Its Not Hamburger Anymore" activities. It may be helpful to have containers of these squares and to encourage students to replenish their supplies periodically rather than to try to count out the exact number of each color they will need.

Have students flip a coin to choose the DNA code for each of the 12 genes in Table A from the previous activity. This will help them determine the corresponding mRNA and tRNA codes and the amino acid sequence. Once the amino acid sequence is found for the gene, the next step is to look up the trait in Table C from the previous activity.

Students then glue base strips together to form a paper chain. Using the DNA code for each of the genes selected in the previous activity, students glue down the nucleotide bases in the order in which they appeared in the gene squares of Table A, separating amino acids with a single line and genes by a double line. They should label the parts of the chromosome as indicated in the figure.

Extension Activity:

It may be interesting to do some research on the Human Genome Project at this point.

Answers to Student Questions:

1. Is gene order important? Justify your answer.

Answer: Yes. Gene order is important to ensure that alleles appear in the same place and in the same order on each chromosome.

2. Is amino acid order important? Justify your answer.

Answer: A different amino acid order will give a different amino acid sequence (protein) and may produce a different gene.

3. Is nucleotide order important? Justify your answer.

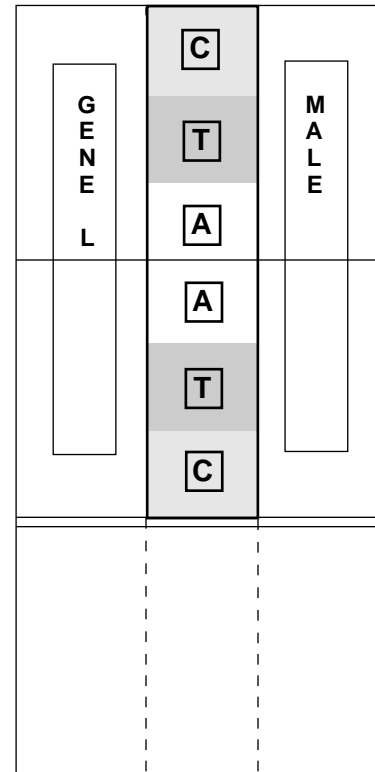
Answer: A different nucleotide order will code for a different protein. A different protein may mean a different gene action.

4. In your own words, explain the relationship among DNA, mRNA, tRNA, amino acids, polypeptides, and genes.

Answer: The nuclear DNA unwinds, unzips, and exposes its bases in the section that will code for the protein that the cell needs. The messenger RNA nucleotides pair with the DNA, then leave the nucleus and take the code to the ribosome. At the ribosome, ribosomal RNA reads the code and maintains the mRNA nucleotides in proper sequence. The transfer RNA picks up specific amino acids with matching codes and moves them to the ribosome. If that particular amino acid is needed, the tRNA drops it off and returns to the cytoplasm for another amino acid. If that amino acid isn't needed, it stays attached to the tRNA until it is. After the amino acids are joined, the new protein chain leaves the ribosome to perform the job for which it was made. The DNA reziips and recoils. The process is repeated as needed.

In addition, it appears that proteins may turn on and turn off certain sections of genes, making them active and inactive. Proper coding must occur so that the correct gene sections are activated at the proper time.

Adapted from: none



Example of a Chromosome Segment

CHROMOSOME TEMPLATE

Science as Inquiry

Let's Make a New Critter**Creating a new critter from chromosomes****Overview:**

In this activity, a continuation of the previous two activities, students examine the inheritance of traits as well as the roles of genes, chromosomes, and amino acids in that inheritance. Students should get the idea that some genes are expressed physically and some are not. They should also understand that there is variation within the species.

Materials:**Per lab group (2):**

chromosome strips made from the previous lab

"It's on the Chromosome"

pencil, blue or yellow

Procedure:

Review with students the difference between a dominant trait and a recessive trait. Discuss variation within the human species and the characteristics humans share, and extend the discussion to their critters. For the purposes of this activity, all traits that were chosen previously by the flip of the penny in "It's in the Genes" will be designated as dominant traits. The only exceptions are on Gene A, which is a species trait, and Gene L, which designates the sex of the critter. Students should be made aware that the inheritance of this critter has been determined by a simple flip of the coin. They should also note that neither of the alternatives to any trait is undesirable, only different.

Students may work with their own chromosome or with another, but the distribution of sexes must be equal throughout the room. You may have to fill in if you have an uneven number of students. Explain to students that even though there is a male and a female parent, the offspring only inherits one gene. Students must choose the dominant gene whether from the male or female parent. Of course, if the dominant gene is present in neither parent, then the recessive trait is chosen.

Answers to Student Questions:

1. How is the mixing of genes related to variation within the species?

Answer: In this case a critter may have yellow hair and be plump with a big nose or it could be just the opposite. And differences between members of the same species are variations. When genes are united from two parents as in sexual reproduction, a mixing of the genes occurs. When an organism reproduces asexually the genetic structure remains the same from parent to offspring.

2. How could a similar pattern of gene expression account for the variation that exists among humans?

Answer: As genes are mixed during reproduction, the baby will inherit genes from both parents—some will be dominant, some codominant, and some recessive. It is the mixing of the inherited genes that gives us variation in skin, eye, and hair color, plus all of the variations in body stature.

3. Make a general statement concerning the relationships between DNA, RNA, amino acids, proteins, genes, chromosomes, and gene expression.

Answer: The nuclear DNA unwinds, unzips, and exposes its bases in the section that will code for the protein that the cell needs. The messenger RNA nucleotides pair with the DNA, then leave the nucleus and take the code to the ribosome. At the ribosome, ribosomal RNA reads the code and maintains the mRNA nucleotides in proper sequence. The transfer RNA picks up specific amino acids with matching codes and moves them to the ribosome. If that particular amino acid is needed, the tRNA drops it off and returns to the cytoplasm for another amino acid. If that amino acid isn't needed, it stays attached to the tRNA until it is. After the amino acids are joined, the new protein chain leaves the ribosome to perform the job for which it was made. The DNA rezeips and recoils. The process is repeated as needed.

As genes on chromosomes are mixed in the new individual, the baby will inherit a combination of dominant and recessive traits from its parents. If a dominant trait is present, then that is the trait that will show in the physical being (phenotype).

Adapted from: none

Science as Inquiry

How Do We Express Ourselves?**Item:**

Describe how the molecule DNA controls gene expression.

Answer:

The section of DNA for which a protein is made becomes active and pairs with messenger RNA, which then takes the code to a ribosome. Transfer RNA brings amino acids to the ribosome, where they are correctly sequenced. The chain of amino acids forms a protein molecule. It is thought that proteins activate gene expression.

Science as Inquiry

The Same, but Not the Same**Item:**

Explain how all life on Earth is genetically related but appears so different.

Answer:

All known life forms on this planet share a common molecule that controls the organism's heredity. This molecule is DNA. From the smallest organism to the largest, the DNA molecule is found in each living cell. Since DNA controls a cell's heredity and protein synthesis and since all cells have DNA, all cells are related. It is the expression of DNA and the genes that makes organisms different.

Science in Personal
and Social Perspectives

Can We Pollute Too Much?

Item:

We all know that our environment is not what it should be due to air, water, and soil pollution. Some of these pollutants are known to cause genetic changes. What do you think might happen to genes if these pollutants increase?

Answer:

Environmental pollution causes genetic change in the heredity patterns of individuals. Mutations within individual organisms have been noted in polluted areas. Continued mutations might result in new species or lead to extinction of some species.

Science in Personal
and Social Perspectives

Why Do We Have to Be Good to Ourselves?

Item:

We all know that humans do things to themselves that sometimes aren't in their best interest. Such things include smoking cigarettes, taking illegal drugs, and drinking alcohol. Each of these things have been proven to cause genetic changes within the individual and also in that individual's future offspring. Relate what you feel are some of the problems that genetic change can cause, on both personal and societal levels.

Answer:

If an individual's cells begin to mutate due to the activities listed above, the individual may experience death or dysfunction of cells—especially brain and liver cells. Other cells may not be able to divide correctly, and the individual could develop cancer. If certain inabilities to carry on normal life functions are passed on to an individual's offspring, birth defects may result. The cost in lost wages is extensive, largely unnecessary, and in most cases preventable. The cost to society for health care is staggering.

Consumables		
Item	Quantity per lab group	Activity
bond paper (pink or blue), strips 17 cm × 5 cm	4 per student	4
bond paper (any color), 1/2" squares	105 per student	
construction paper (yellow), strips 1/2" × 9"	2	1
construction paper (white), 1/2" squares	6	1
construction paper (green, blue, orange, and red), strips 1/2" × 3"	6 strips	1
construction paper (white), 18" × 12"	1 sheet	2
construction paper (dark purple), strips 1/2" × 3"	3	2
construction paper (light purple), 1/2" × 9"	1	2
large envelope	1	2
glue	—	1, 2, 4
glue applicator	1	1, 2
pencils, blue or yellow	1 per student	3, 5
ribosome cutout (see Teacher Materials)	1	2
ribosomal RNA cutout (see Teacher Materials)	1	2
template of amino acids (see Teacher Materials)	1	2
waxed paper squares (to hold glue)	—	4
wood splints, toothpicks, etc., to spread glue	—	4
yarn (three colors)	1 skein of each color per class	2

Nonconsumables		
Item	Quantity per lab group	Activity
penny	1 per student	3
ruler (12")	1	1
scissors	1	1, 2

Key to activities:

1. Where Do Genes Begin?
2. It's Not Hamburger Anymore
3. It's in the Genes
4. It's on the Chromosome
5. Let's Make a New Critter

Activity Sources

Miller and Levine, *Biology Laboratory Manual*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1991.
 Knowlton, D.A., *Cliff Quicktm Review—Biology*. Lincoln, Neb.: Cliff Notes, Inc. 1993.