SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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Student Materials

Learning Sequence Item:

1050

The Watson-Crick Model of DNA Structure

May 1997
Adapted by: Diane Schranck

Contents

This micro-unit was adapted by **Diane Schranck** (Yates High School, Houston)

Science as Inquiry

Where Do Genes Begin?

What is going on inside your cells?

Overview:

Within the nucleus of each living cell in your body is a complete set of chromosomes. On each chromosome are genes, which are bits of protein and nucleic acids (DNA) that control the heredity and protein synthesis of your cells. DNA is a large molecule that resembles a twisted ladder. In this activity, you will make a model of deoxyribonucleic acid (DNA) and investigate its structure.

Procedure:

With your partner, select *one* amino acid from the list below to make a triplet code.

alanine - CGC, CGA, CGT
arginine - TCC
asparagine - TTA
aspartic acid - CTA
cysteine - ACG
glycine - CCC
isoleucine - TAG, TAT
leucine - GAG, AAC
lysine - TTT
methionine - TAC
phenylalanine - AAA
proline - GGG, GGT, GGA
serine - AGC, AGG
threonine - TGA
tryptophan - ACC
tyrosine - ATA
valine - CAG, CAC

Fill in the Side 1 and Side 2 sections of the chart below. Use the following color code to select the proper "colors" for your amino acid code and write the colors next to the letters.

red = guanine (G)
orange = cytosine (C)
blue = adenine (A)
green = thymine (T)

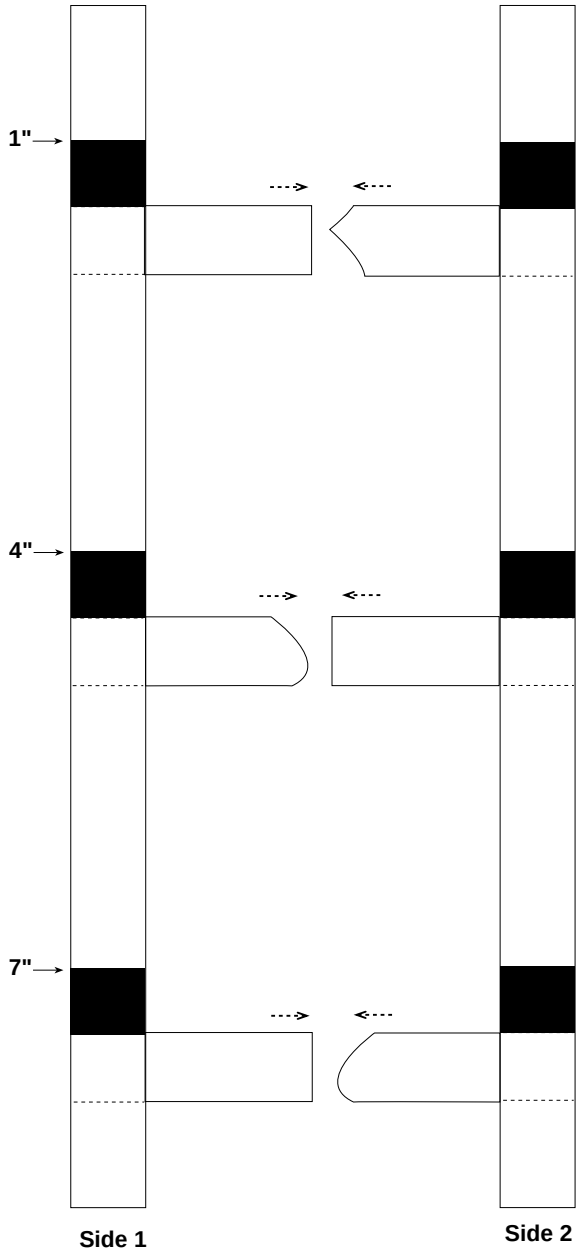
Color	Side 1	Side 2	Color

Pick one base strip to correspond with each color you wrote down (six strips). Now obtain two long yellow strips of paper to represent sugar molecules. Placing a ruler next to the yellow strips, mark them at 1", 4", and 7" and draw lines across the strips (see illustration). Glue the white phosphate squares onto the strips right below the lines. Cut one end of each *orange* base strip (cytosine) into a rounded end. Cut one end of each *blue* base strip (adenine) into a pointed end. Leave the ends of *red* and *green* strips squared. Cut each base strip to an overall length of 1 3/4".

Glue each base strip to the sugar strip by placing the base strip behind and directly below the white phosphate squares as shown in the illustration. Dotted lines indicate the base strip is behind the sugar strip. Make sure that the order of the base strips is exactly like you have them written. Build the segments so that the base strips will meet in the middle like a ladder. *Do not glue these two halves together.*

Place the two strips together to form a ladder. Place the shaped base on top of its partner so that the pattern can be seen from the front. Turn the ladder over carefully so that the ladder is back side up. Reposition the base pairs if they get messed up. Move the yellow strips so that the distance between the outside edges of the strips is *exactly* 3". (If you are not exact in your measurement, your model will not fit in the overall DNA molecule.)

Carefully tape the backs of the base pairs together using small pieces of tape to represent hydrogen bonds. Draw a line on the front side, midway between each phosphate. Label each of the six phosphates with a P, each of the six sugars with an S, and each of the base strips with the appropriate base letter. Save this model for your next activity.



Questions:

1. Which amino acid have you chosen?

2. What is the code that you will use?

3. What is the complementary DNA code for Side 2?

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.

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?

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?

Student Sheet

Science as Inquiry

It's Not Hamburger Anymore

How do food molecules get turned into useful cell molecules?

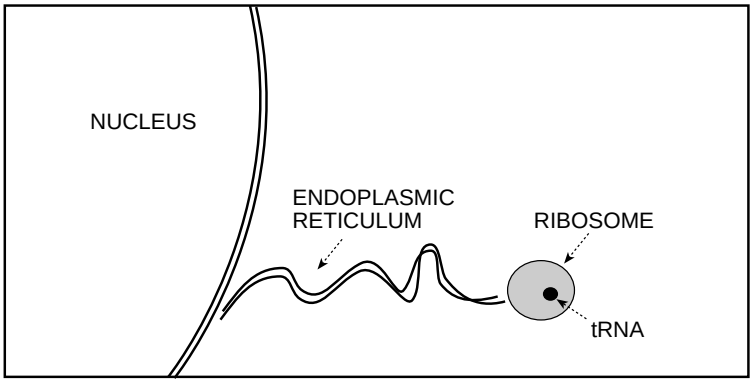
Overview:

The process of protein synthesis involves several steps. First of all, you ingest protein in the food that you eat. However, your cells cannot make use of that hamburger without first digesting it into smaller units. As you will recall, those smaller units of protein are amino acids. Amino acids are absorbed into your blood from your small intestine and then transported, along with other essential elements and molecules, to each of your billions of living cells. The molecules are then dropped at the cell and absorbed into it by the process of diffusion.

Once inside the cell, most of the molecules hang around in the cytoplasm until the cell needs them. Inside the nucleus, a particular need for a particular protein molecule is noticed and instructions go the DNA molecules to initiate the making (synthesis) of that protein. In this simulation you will go through the steps necessary for one of your cells to make one *very* short chain protein so that you can see how it is done.

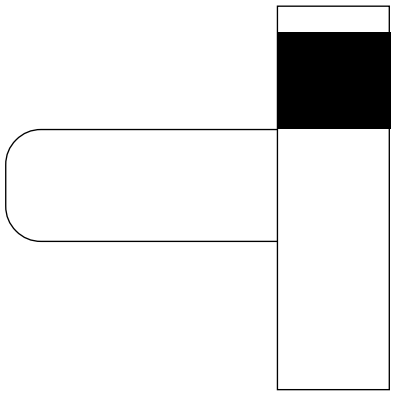
Procedure:

First, using the construction paper provided by your teacher, prepare a basic model of a cell and some of its organelles. Draw a nuclear membrane similar to that in the drawing below and glue down two strands of yarn to form the membrane. Draw in a rough endoplasmic reticulum (E.R.) similar to that in the drawing and glue down two strands of yarn of a different color. Cut out the ribosome and glue it to the E.R. as illustrated, using a single strand of yarn to hide the cut edge. Now cut out the ribosomal RNA and glue it inside the ribosome close to the edge. Since rRNA is a molecule, not a structure, do not outline it in yarn.



Put your name, your partner's name, class period, and date on the front of the envelope. Glue the back of the envelope to the upper right corner of the back of your model. Make sure that you can open the flap. You will place your model pieces in this envelope if necessary.

Identify *all* of the bases you used previously when you made a DNA segment. This DNA molecule should be placed in the nucleus of the model you have prepared. You will be making an RNA nucleotide for only the left side (side one) of the DNA. Determine what DNA code you will be using.



As messenger RNA nucleotides move into the nucleus, the DNA unzips. The complementary mRNA bases pair with the DNA bases. Glue a phosphoric acid at one end of the dark purple strips and then a base strip that is complementary to part of your DNA molecule (as illustrated here). You should make three of the mRNA nucleotides. Make sure that they are facing in the correct direction (to pair with the left side of the DNA molecule).

Pair the mRNA nucleotides to the DNA molecule in order to determine the proper mRNA sequence. Gently tape the three nucleotides together and remove them from the nucleus. The mRNA carries the DNA code to the rRNA, which is located in the ribosome. The rRNA is in charge of keeping the correct sequence.

On the long light-purple strips, make a triplet similar to the DNA triplet that will be complementary to the mRNA code. Use the tRNA code to select the correct amino acid from the amino acid sheet. Cut out the amino acid and attach it to the tRNA triplet. It is the job of tRNA to bring the amino acid to the ribosome. The code is deciphered in the ribosome by reading the bases of the tRNA. Remember that most proteins are very long chains of amino acids and your model is a simplification of what actually happens in your cells.

After the tRNA deposits the amino acid, it returns to the cytoplasm to retrieve another amino acid. The amino acid that was deposited at the ribosome will join the chain of amino acids to eventually form a protein molecule. The mRNA nucleotides split apart and return, when needed, to the DNA.

Glue your pieces to your model at the stage the cell would appear at the end of this final step.

Questions:

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

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

3. Briefly describe the steps of protein synthesis.

Student Sheet

Science as Inquiry

It's in the Genes

What determines what we look like?

Overview:

In this activity, you will determine the traits of a fictitious animal. You will do this by flipping a coin to determine which of the two possible sequences for each trait your organism has. Then you will go through the transcription and translation procedures, coding both the mRNA and the tRNA, and determine the sequence of the amino acids present.

Procedure:

Your teacher will review the roles of DNA, mRNA, tRNA, nucleotide sequencing, and amino acids before you start working on this activity. Look at the observation tables on the following page (Table A). For each gene, flip your penny to determine which of each pair of traits your organism will have. This will give you the DNA code for the gene. Repeat for each gene.

Record the complementary mRNA and tRNA codes in the proper spaces in the observation tables in Table A. Using your tRNA codes in the tables, consult Table B to determine each amino acid number and record your amino acid sequences in the observation tables. Look up each of these exact same sequences in Table C to determine the traits of your organism and record each trait in the space provided. Finally, draw the critter.

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.

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

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?

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

TABLE A

GENE A
DNA
__ H TAC-AGC-CGA
__ T TAC-AGC-CGA
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 C
DNA
__ H ACC-ATA-TCC
__ T TAT-ATA-TCC
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 E
DNA
__ H TTT-AAA
__ T TTT-AAC
mRNA : _____
tRNA: _____
Amino Acid sequence number:
_____
trait: _____

GENE F
DNA
__ H TGA-ACG
__ T TGA-ATA
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 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 J

DNA

__ H GGA-CGC-CGA

__ T GGA-CGC-CGC

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 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

Science as Inquiry

It's on the Chromosome

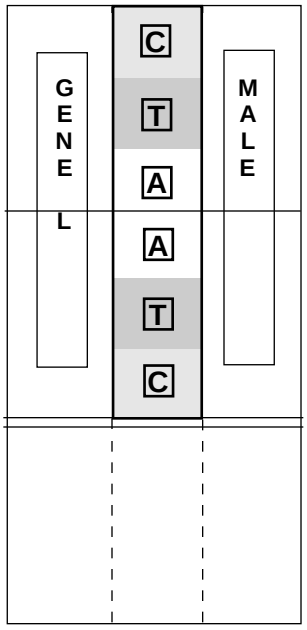
How are amino acids translated into traits?

Overview:

In the previous activity, you flipped a penny to determine which traits your critter would have. You translated and transcribed the DNA code into messenger RNA and transfer RNA codes. From those codes you determined the amino acid sequence and finally which trait that sequence determined. Now you are going to create the chromosome of your critter (aren't you glad that it only has one?). You will do this with construction paper and glue.

Procedure:

Analyze your copy of "It's in the Genes" to determine if your critter is male or female and to select the correct color of base paper (used to represent the chromosome). You will have to glue two or more strips together (approximately four will be needed) to form a paper chain long enough to hold all of the nucleotide sequences.



Start by gluing two strips together. You will need several of each color of base. Using the DNA code for each of the genes that were selected in the previous activity, glue down the nucleotide bases as follows. For Gene 1, glue down the first DNA triplet (amino acid), the second triplet, and then the third triplet. Remember that the bases must remain in the exact order that they appear in your observation tables. Draw a single line across the base strip to separate the individual amino acids. Draw a double line across the base strip to separate Gene 1 from Gene 2 (see illustration).

Continue with the second gene and proceed until all the genes have been coded. Try to place the squares close to midway between the sides of the base strips so that you may write on the strips later. If you are using the given template, then you will place your squares between the dotted lines.

Identify the gene number on the left side of the chromosome strip. Identify the gene trait on the right side. Identify the bases, by letter, on the squares. After you have finished, hang your chromosomes in a place designated by your teacher. Since these chromosomes will be needed for the next activity, it may be helpful to separate them by sex.

Questions:

1. Is gene order important? Justify your answer.

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

3. Is nucleotide order important? Justify your answer.

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

Student Sheet

Science as Inquiry

Let's Make a New Critter

Creating a new critter from chromosomes

Overview:

In the previous four activities you explored the roles of DNA, RNA, amino acids, proteins, genes, and chromosomes, and the relationships among them. You created a critter, analyzed its genes, and made a chromosome. Now you are going to create an offspring for this imaginary critter. Your critter has an unusual inheritance pattern. It has only one chromosome, and its offspring inherits only one gene for each trait. There are alternatives to almost all of the traits, however, and the gene inherited must be the dominant gene if that gene is carried by either of its parents. If neither parent is dominant for the trait, then of course the recessive trait is inherited by the offspring.

The sex of the offspring is determined by the parent that contributes most of the dominant traits (the offspring inherits the sex of that parent). If the number of dominant traits is equal from both parents, then the offspring becomes female, since it is an adaptive advantage for the species to have more females than males.

Procedure:

Pair off into teams by using the male/female chromosomes from your strips as guides. Each team must have one male chromosome and one female chromosome. Place the two chromosomes side by side and analyze each pair of genes to determine which gene the offspring will inherit. The only genes that can be inherited automatically by the offspring are the dominant genes. As you work on this activity, record the inherited genes for your offspring by checking D (dominant) or R (recessive) for each trait. Refer to the observation tables (Table A) in this activity to help you to figure out which of the two genes is dominant. Place a check mark in the space for the DNA sequence inherited from the genes.

After you have determined which genes are to be inherited, translate and transcribe the DNA code into the mRNA and tRNA triplets as you did in the previous activity to determine which traits your offspring will have. Use Table B to determine the amino acid sequence for that trait. Record the sequence in the proper space. Use Table C to determine which trait was inherited by the offspring.

Questions:

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

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

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

TABLE A

GENE A
DNA
__ H TAC-AGC-CGA
__ T TAC-AGC-CGA
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 C
DNA
__ H ACC-ATA-TCC
__ T TAT-ATA-TCC
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 E
DNA
__ H TTT-AAA
__ T TTT-AAC
mRNA : _____
tRNA: _____
Amino Acid sequence number:
_____
trait: _____

GENE F
DNA
__ H TGA-ACG
__ T TGA-ATA
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 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 J

DNA

__ H GGA-CGC-CGA

__ T GGA-CGC-CGC

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 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