Decoding Genetics

Introduction

Knowledge of the structure and function of DNA and RNA is key to an understanding of molecular biology and cellular genetics. The processes of transcribing DNA to create mRNA and translating RNA to produce a sequence of amino acids are fundamental functions of cells.

Concepts

- Nucleotide (base) pairing rules
- Transcription vs. translation
- DNA vs. RNA

Background

The DNA that makes up a genome can be subdivided into genes. Each gene encodes for an entire protein or part of a protein that performs a specific function within a cell. The two-step process of transcription and translation is responsible for transforming the DNA instructions into a functional protein. First, the genetic instructions encoded in the DNA double helix are read in the nucleus by an enzyme called RNA polymerase II. RNA polymerase II and other cellular enzymes cause the DNA double helix to unwind or unzip at very specific areas on the DNA strand. These "start" areas have a specific base sequence that is recognized by the enzymes. The nucleotide pairing rules for transcribing DNA to RNA are slightly different than the base pairing rules for replicating a strand of DNA. In DNA, the purine adenine (A) always pairs with the pyrimidine thymine (T), and the pyrimidine cytosine (C) always pairs with the purine guanine (G). In RNA, the pyrimidine cytosine (C) still pairs with the purine guanine (G), but the purine adenine (A) pairs with the pyrimidine uracil (U).

RNA polymerase II "reads" the DNA strand and creates a strand of messenger RNA (mRNA), which then travels out through the nuclear membrane to a ribosome in the cytoplasm of the cell. The ribosome binds to the mRNA strand at the start codon. The *start codon* is a three base-pair nucleotide sequence—adenine-uracil-guanine (AUG). The ribosome reads triplets of mRNA called *codons*. Each codon is matched to an anticodon on a transfer RNA (tRNA) molecule. The tRNA molecule has two key areas that are important for translation. The first area is the anticodon. The *anticodon* is a three base-pair nucleotide sequence which mirrors one of the 64 codon sequences found in mRNA. The second area has a specific amino acid bonded to it. Sixty-one of the 64 codons correspond to one of the twenty amino acids. The remaining three codons are stop codons which trigger the ribosome to detach from the mRNA strand. The codons are a universal code, meaning that the mRNA codon GCC codes for alanine in all living things from bacteria to humans. It is the specific pattern of amino acids that varies to create different proteins. Changes in the amino acid sequence cause the amino acid "string" to bend and fold in unique ways, creating different proteins for different organisms.

Materials

Decoding the Genetic Code Worksheet
Index cards, six colors, 64 cards of each color
Paper, six colors, three sheets of each color

Safety Precautions

This is a paper-and-pencil laboratory activity and is considered safe. Follow all normal classroom safety guidelines.

Procedure

1. Copy each amino acid code "word" on one side of an index card and the corresponding mRNA codon on the opposite side. Make six sets, one of each color. See chart on page 4. These sets of cards will be used by the students.
2. On a sheet of paper, create sentences using the amino acid code words in the table. Give one example for each step. Create one or two protein sentences per student. Assign each sentence a number. Do not forget to start the sentence with "start" and end with "stop." *Example: Start/Mrs. Smith is the best science teacher at the school/stop.*
3. "Reverse" translate each protein "sentence" into the corresponding mRNA codons. Ensure the sentence number assigned in step 2 appears next to the mRNA codons. *Example: AUGGAGGCAAUCACUGAAGGGCGAAUCCAAUAA*
4. "Reverse" transcribe the mRNA codons from step 3 into the correct DNA base pair codes creating a DNA code "sentence." Ensure the sentence number assigned in step 2 appears next to the DNA code. *Example: TACCTCCGTTAGTGACTTCCCGCTTAGGTTATT*
5. Using a word processing program, type the DNA code sentence onto one line of text. Ensure the sentence number appears next to the DNA code sentence.

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6. Use a copy machine to copy the DNA code sentences onto the colored paper.
7. Cut the DNA code sentences into strips.
8. Arrange a circle of desks around one desk in the center of the room. Place six other desks randomly outside the circle of desks. See Figure 1.
9. The center desk represents the nucleus. Place the DNA code sentence strips on the nucleus.
10. The circle of desks represents the nuclear membrane. Spaces between the desks are the nuclear pores through which mRNA travels to reach the cytoplasm.
11. The six desks arranged outside the circle of desks represent ribosomes. Place one color (complete set) of amino acid cards with the mRNA codons facing up on each ribosome. Students will transport the mRNA code to a ribosome for translation, creating a protein sentence.
12. Give each student a colored DNA code sentence strip to transcribe and translate. Remind the students to be careful not to mutate the genetic code during the activity.
13. Check all decoded messages individually as each student completes one. Assign additional DNA code sentence strips as appropriate.

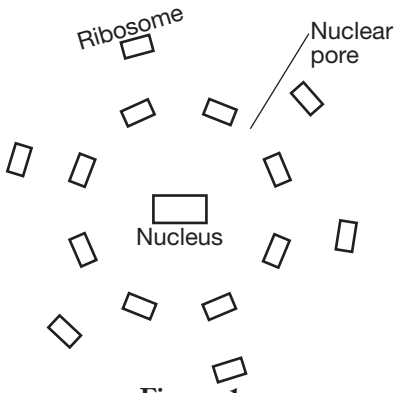

Figure 1.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-LS3 Heredity: Inheritance and Variation of Traits
LS3.A: Inheritance of Traits
LS3.B: Variation of Traits
Disciplinary Core Ideas: High School
HS-LS3 Heredity: Inheritance and Variation of Traits
LS3.A: Inheritance of Traits
LS3.B: Variation of Traits

Science and Engineering Practices
Developing and using models
Constructing explanations and designing solutions

Crosscutting Concepts
Cause and effect
Systems and system models
Structure and function

Tips

- Craft a large paper chromosome to place on the center desk, as well as large paper ribosomes to place on the random desks outside the nuclear membrane. Create RNA polymerase name tags for each student to wear as they transcribe the DNA genetic code.
- Noncoding regions of DNA called introns may be added to the DNA genetic code. The introns can be coded using italics so the student knows to cut this section of RNA out of the genetic code before continuing out of the nucleus to the ribosome.

A *Genetic Code Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
FB1441	Genetic Code Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Amino Acid Code Words

Amino Acid Name	mRNA Codon	Amino Acid Word
Alanine	GCA	Is/Are
Alanine	GCU	Was/Were
Alanine	GCC	Create(s) (d)
Alanine	GCG	Make(s)
Arginine	CGA	At
Arginine	CGU	By
Arginine	CGC	Which
Arginine	CGG	Like
Arginine	AGA	On
Arginine	AGG	In
Asparagine	AAC	School Color i.e., Maroon
Asparagine	AAU	School Color i.e., White
Aspartic Acid	GAU	State i.e., IL
Aspartic Acid	GAC	Students
Cysteine	UGU	Biology
Cysteine	UGC	Team
Glutamic acid	GAA	Science
Glutamic acid	GAG	Science Teacher name i.e., Mrs. Smith
Glycine	GGA	School Name i.e., MCHS
Glycine	GGU	Science Club
Glycine	GGC	Laboratory(s)
Glycine	GGG	Teacher
Glutamine	CAA	School
Glutamine	CAG	Sport
Histidine	CAU	Group
Histidine	CAC	Work
Isoleucine	AUA	A/An
Isoleucine	AUU	His/Her/Us
Isoleucine	AUC	The
Leucine	UUA	Win/Won
Leucine	UUG	Smart
Leucine	CUA	Succeed(s)
Leucine	CUU	Triumph(s)
Leucine	CUC	Pride
Leucine	CUG	Achieve(s)
Lysine	AAA	Amazing
Lysine	AAG	Incredible
Methionine (start)	AUG	Start
Phenylalanine	UUU	Which
Phenylalanine	UUC	Why
Proline	CCA	All
Proline	CCU	Each
Proline	CCC	With
Proline	CCG	To
Serine	AGU	And
Serine	AGC	Or
Serine	UCA	So
Serine	UCU	Because
Serine	UCC	For
Serine	UCG	Of
Threonine	ACA	Good
Threonine	ACU	Best
Threonine	ACC	Great
Threonine	ACG	Talented
Tryptophan	UGG	School Mascot i.e., Atoms
Tyrosine	UAU	Book(s)
Tyrosine	UAC	He/She/It
Valine	GUA	Learn(s)
Valine	GUU	Review(s)
Valine	GUC	Understand(s)
Valine	GUG	Read(s)
Stop	UAA	Stop
Stop	UAG	Stop
Stop	UGA	Stop

Decoding the Genetic Code Worksheet

1. Carefully copy (no mutations!) the assigned DNA genetic code onto the worksheet.
2. Transcribe the DNA code "sentence" to the mRNA code while inside the nucleus.
3. Next, transport the mRNA code through a nuclear pore to a ribosome outside the nucleus. Each ribosome contains a complete set of mRNA codons with an amino acid code word on the reverse side.
4. On the worksheet, translate the mRNA code into the correct amino acid code word, creating a protein sentence.
5. Allow your teacher to check the protein sentence to make sure there have been no mutations.
6. Decode other DNA codes as directed by your teacher.

Example

DNA (# ___) _____

mRNA _____

Protein Sentence _____

DNA (# ___) _____

mRNA _____

Protein Sentence _____

DNA (# ___) _____

mRNA _____

Protein Sentence _____

DNA (# ___) _____

mRNA _____

Protein Sentence _____

DNA (# ___) _____

mRNA _____

Protein Sentence _____