From Gene to Protein -- Transcription and Translation
Teacher Preparation Notes

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Introduction

This lab is intended for students who have already learned about biological polymers (including the basic structure of proteins and DNA) and have been introduced to the concepts of chromosomes and genes. The questions on page 1 provide an opportunity to review some of the relevant concepts. We also assume that students have learned about the importance of the base-pairing rule in DNA structure and DNA replication (e.g. using the "DNA" activity on this website).

If you have already introduced transcription and translation, your students probably can complete this activity in two 50-minute periods. However, if you would like to use this activity to introduce the topic, another possible sequence for 3.5-4 50-minute periods is:

Period 1: Introduce the basic functions and processes of transcription and translation (including the material on page 1) and show and discuss an animation of transcription and translation. We suggest the following real-time animation of the transcription and translation of the hemoglobin gene produced by the Howard Hughes Medical Institute:
http://www.hhmi.org/biointeractive/dna/animations.html#dna-transcription_vo1
http://www.hhmi.org/biointeractive/dna/animations.html#dna-translation_vo1

Period 2: Further explain transcription (page 2 to the top of page 3) and have students model transcription and answer the questions (pages 3-4).

Period 3: Further explain translation (page 4 through the top of page 6) and have students model translation and answer the questions (pages 6-9).

Period 4: discuss how different alleles affect phenotype, including sickle cell anemia and have students answer the questions (pages 9-11). We also recommend showing and discussing the sickle cell anemia video available at http://www.hhmi.org/biointeractive/dna/animations.html

In order for students to understand the process of transcription, it is important for them to add each nucleotide one at a time, mimicking the actual activity of RNA polymerase. Some students will want to lay out all the mRNA nucleotides and tape them together all at once, which is more efficient in getting the task done, but less effective in modeling and understanding the real biological process. Similarly, during translation, the students should insert one tRNA with amino acid at a time, similar to the actual activity of the ribosome. You may want to make a transparency of the RNA polymerase, ribosome, and relevant molecules and use these on an overhead projector to demonstrate the proper procedures.

Supplies needed

Use the templates shown, beginning on page 3, to make <u>for each pair of students</u> a page labeled **Nucleus**, a page labeled **Ribosome**, and a packet containing the following:

- 2 **DNA molecules** on colored paper (cut in strips; tape together each piece labeled "Beginning of..." with the corresponding line of additional nucleotides from the next page)
- 18 **RNA nucleotides** on a different color paper (5 of each nucleotide per packet; 2 of the A nucleotides will be extra)
- 6 **tRNA molecules** on same color paper as RNA nucleotides (cut each tRNA rectangle to include the three nucleotides and the words "amino acid" directly above these nucleotides; one of each type of tRNA per packet)
- 6 **amino acids** on a different color paper (cut rectangles that include the name of a specific amino acid and will fit over the words "amino acid" in the tRNA; one of each amino acid per packet)

Each pair of students will also need transparent tape.

[1]These Teacher Preparation Notes and the related Student Protocol are available at http://serendip.brynmawr.edu/sci_edu/waldron/.

Suggestions for Discussion

The modeling procedures for transcription and translation demonstrate the basic biological processes, but we have omitted many points and you may want to include some of these if your students already have a good grasp of the basic processes. For example, multiple different nucleotides enter and leave the RNA polymerase, but, for each DNA nucleotide only the complementary RNA nucleotide that can form hydrogen bonds with that specific DNA nucleotide will remain in place to be covalently bonded to the preceding RNA nucleotide. Although the modeled process may seem rather long and tedious to some students, it occurs very rapidly in real cells; RNA polymerase adds about 50 nucleotides per second to the growing mRNA molecule.

Some students have difficulty understanding the function of the tRNA molecule. An analogy that may help them understand is as follows. Suppose a group of American tourists goes into a restaurant in China and each one wants to order his or her favorite Chinese dish. Suppose the tourists only speak English, and the cook only speaks Chinese. It will be very helpful to have a waiter who understands English and can speak Chinese, so he can serve as a translator. The tourists are equivalent to the mRNA which specifies which amino acids should be incorporated in the growing protein molecule, and the cook is equivalent to the cytoplasm which provides lots of different types of amino acids. The waiter is equivalent to the tRNA molecules which bring the right amino acids to the right locations.

You may want to relate the tendency of sickle cell hemoglobin to clump together in long rods to the lower solubility of nonpolar valine in the watery cytosol of the red blood cell, compared to the high solubility of ionic glutamic acid. This difference in amino acid solubility is crucial because amino acid 6 is on the outside of hemoglobin molecule.

Key Concepts for Students to Learn:

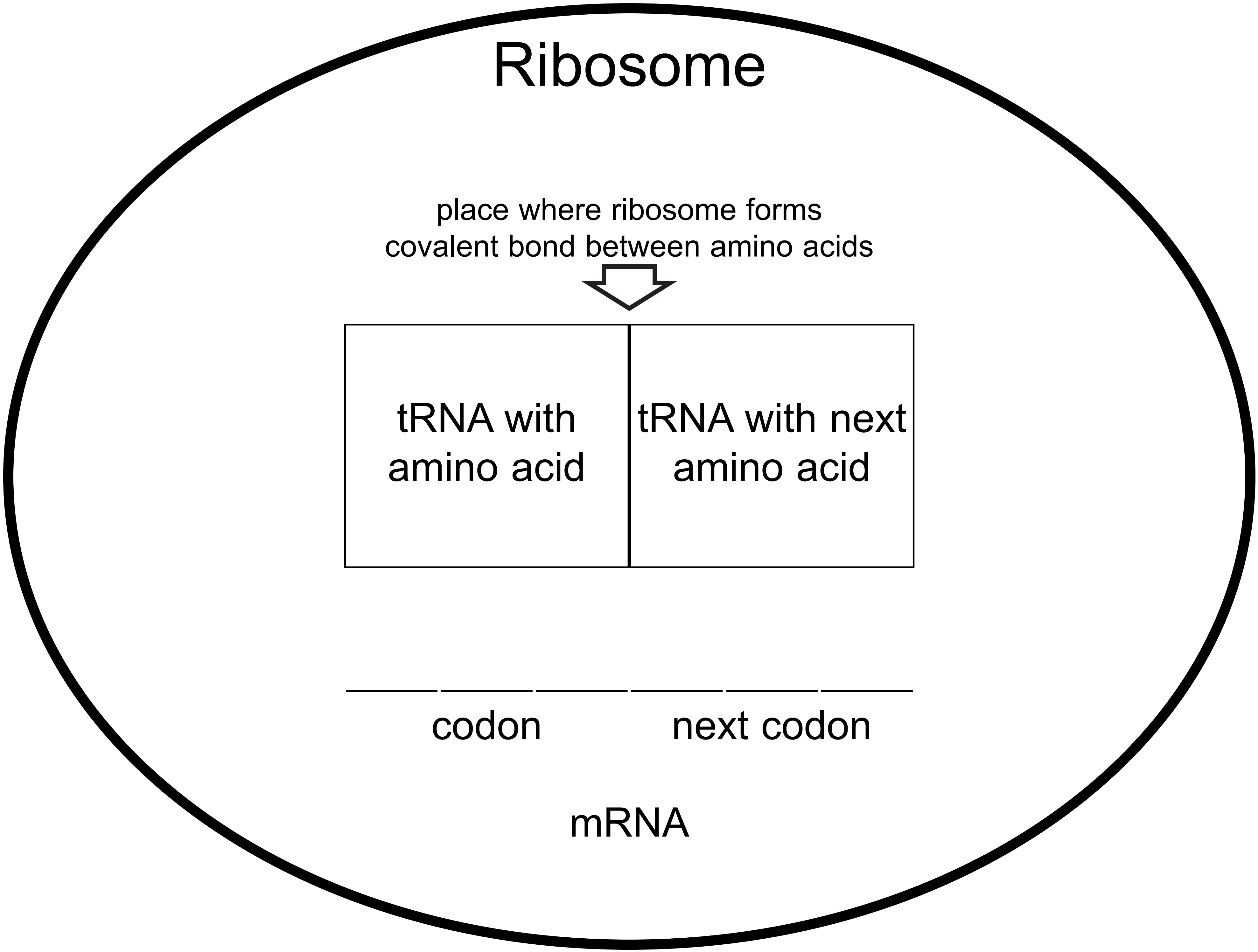
-- describe similarities and differences between DNA and mRNA

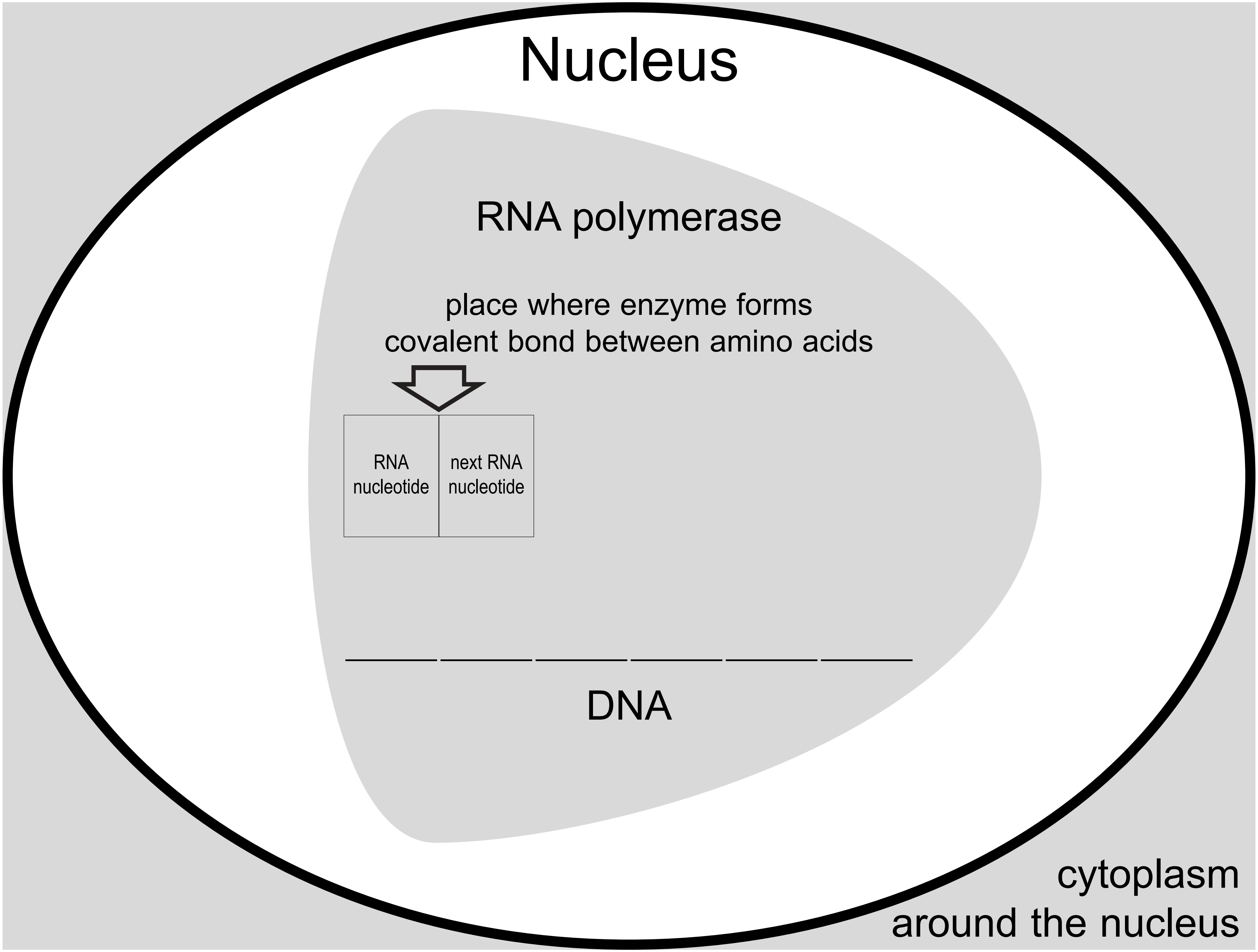
-- understand process of transcription
    and comparison of transcription vs. replication
        -- similarities: base-pairing rule crucial for both; monomers added one at a time and joined by covalent bonds; carried out by a polymerase enzyme
        -- differences (see table on page 4 of student protocol)

-- understand process of translation, including roles of mRNA, tRNA and ribosomes
-- understand structure and function of mRNA and tRNA
    -- mRNA carries genetic message from nucleus to ribosomes
    -- tRNA needed for translation; tRNA anti-codon has three nucleotides which are complementary to the three nucleotides in an mRNA codon; the other end of the tRNA molecule binds to the amino acid specified by that mRNA codon

-- explain how proteins are synthesized using genetic information from DNA
    -- incorporate understanding of transcription and translation

-- understand how genes influence phenotype by determining amino acid sequence in proteins
    -- examples: albinism and sickle cell anemia


Ribosome
place where ribosome forms
covalent bond between amino acids
tRNA with amino acid
tRNA with next amino acid
codon
next codon
mRNA


Nucleus
RNA polymerase
place where enzyme forms
covalent bond between amino acids
RNA nucleotide
next RNA nucleotide
DNA
cytoplasm
around the nucleus

Beginning of Normal Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Sickle Cell Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Normal Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Sickle Cell Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Normal Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Sickle Cell Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Normal Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Sickle Cell Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Normal Hemoglobin Gene	C	A	C	G	T	A	G	A	C
Beginning of Sickle Cell Hemoglobin Gene	C	A	C	G	T	A	G	A	C

Beginning of hemoglobin gene (page 1 of 2)
5 sets

T	G	A	G	G	A	C	T	C
T	G	A	G	G	A	C	A	C
T	G	A	G	G	A	C	T	C
T	G	A	G	G	A	C	A	C
T	G	A	G	G	A	C	T	C
T	G	A	G	G	A	C	A	C
T	G	A	G	G	A	C	T	C
T	G	A	G	G	A	C	A	C
T	G	A	G	G	A	C	T	C
T	G	A	G	G	A	C	A	C

Beginning of hemoglobin gene (page 2 of 2)
5 sets

A	A	A	A	A	A	A	A	A	A
C	C	C	C	C	C	C	C	C	C
G	G	G	G	G	G	G	G	G	G
U	U	U	U	U	U	U	U	U	U
A	A	A	A	A	A	A	A	A	A
C	C	C	C	C	C	C	C	C	C
G	G	G	G	G	G	G	G	G	G
U	U	U	U	U	U	U	U	U	U

RNA neuclotides
4 sets

Amino Acid
C A C

Amino Acid
C A C

Amino Acid
C U C

Amino Acid
G U A

Amino Acid
G U A

Amino Acid
C U C

Amino Acid
G A C

Amino Acid
G A C

Amino Acid
U G A

Amino Acid
U G A

Amino Acid
G G A

Amino Acid
G G A

12 tRNA molecules
2 sets

Leucine	**Histidine**	**Valine**
Leucine	**Histidine**	**Valine**
Leucine	**Histidine**	**Valine**
Leucine	**Histidine**	**Valine**
Leucine	**Histidine**	**Valine**
Threonine	**Proline**	**Glutamic Acid**
Threonine	**Proline**	**Glutamic Acid**
Threonine	**Proline**	**Glutamic Acid**
Threonine	**Proline**	**Glutamic Acid**
Threonine	**Proline**	**Glutamic Acid**

amino acids
5 sets