Key: Yellow highlight = required component

Modeling Protein Synthesis

Subject Area(s) (Select from TE subject areas)

Biology

Associated Unit

N/A

Associated Lesson

Building Proteins

Activity Title

How to Build a Protein

Header

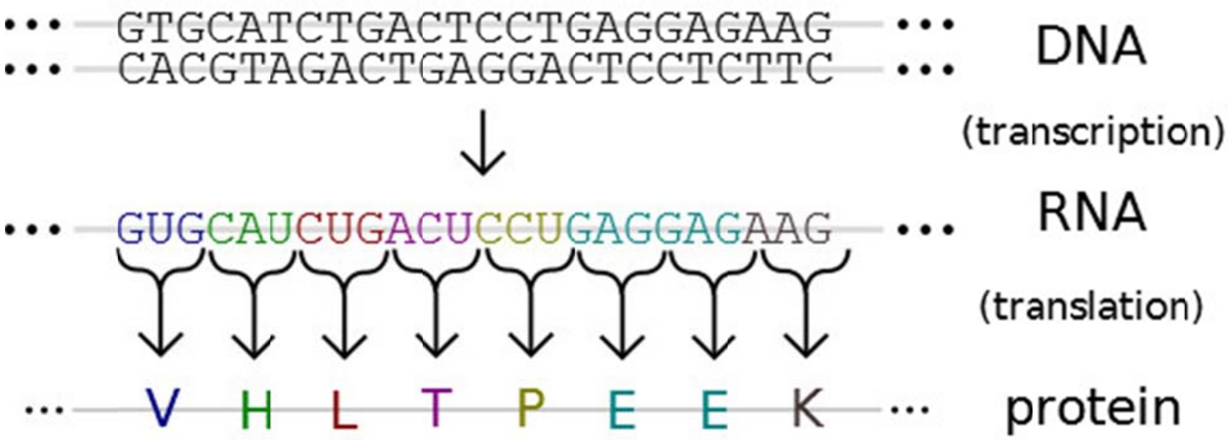

Image 1

Image file: Genetic_code.jpg

ADA Description: A DNA sequence is shown, followed by the corresponding mRNA sequence, and then the amino acid sequence derived from the codons.

Source/Rights: Copyright © 2006 Madprime, Wikimedia Commons http://commons.wikimedia.org/wiki/File:Genetic_code.svg

Caption: Protein synthesis process.

Grade Level 9 (7-10)

Activity Dependency

Time Required 45 minutes

Group Size

3

Expendable Cost per Group

US $0.00

Summary

Students play the role of different RNA molecules and follow the same instructions as those molecules to complete the process of protein synthesis. Students learn about the different types of RNA and how each are necessary to construct a functional protein.

Engineering Connection

Genetic engineers are able to change certain traits of an organism by modifying the organism's DNA. While the DNA is the only thing the engineers modify, the goal is to cause the organism to produce different proteins. These proteins are responsible for the traits of the organism (not the DNA directly), therefore it is important for genetic engineers to understand the process of protein synthesis to comprehend why changing the DNA of any organism works to change its traits.

Engineering Category = 1

Choose the category that best describes this activity's amount/depth of engineering content:

1. Relating science and/or math concept(s) to engineering
2. Engineering analysis or partial design
3. Engineering design process

Keywords

Amino Acid, DNA, Gene, mRNA, Protein, Ribosome, RNA, Synthesis, Transcription, Translation, tRNA

Educational Standards (List 2-4)

National and State

Texas, science, 2010, Biology 6 (A): Identify components of DNA, and describe how information for specifying the traits of an organism is carried in the DNA.

Texas, science, 2010, Biology 6 (C): Explain the purpose and process of transcription and translation using models of DNA and RNA.

ITEEA Educational Standard(s)

ITEEA, Standard 14, Grades 9-12, M. The sciences of biochemistry and molecular biology have made it possible to manipulate the genetic information found in living creatures.

NGSS Standard

NGSS, Life Sciences, High School (9-12), HS-LS1-1, Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

Pre-Requisite Knowledge

Students should have knowledge of the structure of nucleic acids and proteins. This activity is to reinforce the concepts involved in protein synthesis, so a basic understanding of the process is necessary.

Learning Objectives

After this activity, students should be able to:

- List the steps of protein synthesis and tell where they occur

- Describe the different types of nucleic acids and what roles they perform in protein synthesis
- Explain the end result of a change made to the DNA of an organism.

Materials List

Each group needs:

- 1 handout per student
- 1 ribosome cutout for the table (these may be reused for multiple classes)

To share with the entire class:

- 1 set of nucleus cut outs
- 3 – 4 sets of amino acid cutouts

Introduction / Motivation

In Captain America, scientists are able to create a soldier with superhuman abilities. Hollywood does this by injecting a weak Steve Rogers with a sort of magic potion that they had developed. But is there any way we could realistically cause a change so drastic? (Let students provide some answers) Well with the knowledge we have today, it would be impossible to cause such a drastic change, but we can make small changes in the traits of an organism by using genetic engineering. Genetic engineers alter the DNA of certain organisms to cause them to express new or different proteins that will be beneficial. These proteins can be thought of as the traits of the organism. For example we could give make Steve stronger or faster by changing his DNA to produce larger or more plentiful muscle proteins. In order to do this though, genetic engineers must understand how changes in DNA effect protein synthesis.

Today we are going to model the process of protein synthesis, and each one of you will play the role of a different RNA molecule. What types of RNA are involved in protein synthesis? (Messenger RNA, mRNA, and transfer RNA, tRNA) There is also a third type of RNA we will mention in today's activity: ribosomal RNA, or rRNA. This rRNA is responsible for forming the peptide bonds between the amino acids that the tRNA brings to the ribosome, it essentially puts the protein together.

Before we get started on the activity, let's review the entire process of protein synthesis. First imagine that our entire classroom is one giant cell. Can anyone tell me what the first step of protein synthesis is? (Transcription) And where does transcription occur? (The Nucleus) Right, the entire transcription process occurs in the nucleus, so at the front of the room we have the nuclei of a few different cells from the same organism, this will represent the nucleus of our cell. What is the result of transcription? (Information from the DNA is copied onto mRNA). When the mRNA is completely formed, what happens to it? (Exits the nucleus through the nuclear pore into the cytoplasm.) At this point transcription is complete.

What is the second step of protein synthesis? (Translation) And what organelle found in the cell helps with translation? (The ribosome) Do you see a ribosome anywhere in the room? (The students should have a ribosome cutout at their desk) Right, your desk or table will represent the ribosome. Now, what type or RNA is used in translation? (Transfer RNA, tRNA) Right, the tRNA with the anti-codon that matches the codon on the mRNA comes to the ribosome and brings an amino acid with it. The tRNA molecules are found in the cytoplasm, and since the entire cell contains cytoplasm the tRNA molecules can be found in the back of the classroom. The rRNA then takes the amino acids from the tRNA and forms bonds between them to create the protein. The empty tRNA then returns to the cytoplasm to be recycled.

Now answer the four pre-activity questions. Once those are done, assign each group member to be a certain type of RNA: mRNA, tRNA, or rRNA, and begin the activity.

Vocabulary / Definitions

Word	Definition
Amino Acid	Basic building blocks of proteins, there are 21 amino acids that are used in the synthesis of all proteins in eukaryotes
Anti-Codon	Set of three nitrogenous bases found on the tRNA which form matching base pairs with the mRNA codon
Codon	Set of three nitrogenous bases located on the mRNA
DNA	Deoxyribonucleic acid, molecule which contains an organisms complete genetic information
Gene	A subset of DNA, contains the instructions to construct one protein
mRNA	Messenger Ribonucleic acid, nucleic acid molecule whose nitrogenous bases form matching base pairs with the template strand of a DNA molecule
Nucleic Acid	Large polymeric biomolecules used to encode genetic information, constructed from sub-units of nucleotides.
Nucleotide	Monomer unit of nucleic acids, composed of a phosphate group, sugar, and nitrogenous base. The nitrogenous bases vary, and the sequence allows the storage of complex information.
Ribosome	Organelle responsible for the construction of proteins, takes information from the mRNA and links the appropriate amino acids to form a protein
rRNA	Ribosomal Ribonucleic acid, responsible for forming the peptide bonds between amino acids when forming the protein
Transcription	The copying of information from the template strand of DNA onto mRNA by forming matching base pairs between the two nucleic acids. Occurs in the nucleus of a cell.
Translation	The reading of the mRNA by the ribosome to convert the information into a protein using tRNA. Takes place in the ribosomes located in the cytoplasm of a cell.
tRNA	Transfer Ribonucleic acid, nucleic acid molecule which brings the needed amino acid to the ribosome when its anti-codon matches the mRNA codon being read.

Procedure

Before the Activity

- Print out all necessary materials:
    - 1 handout per student
    - 1 classroom set of ribosome cutouts (1 per group, may be reused for many classes)
    - 3-4 sets of tRNA cutouts (you can use one set of AA cutouts, but students may get stuck looking for one anti-codon if another group is using it, see troubleshooting tips)

- 1 classroom set of nuclei (1 nuclei for each type of cell, these will put in one location and not allowed to move)

- Cut the tRNA cutouts apart, fold the top down to cover the amino acid so only the anti-codon is visible, and sort them by the first base of the anti-codon (this makes it easier for the students to find them).
- Tape a ribosome to the desk/table of each group
- Tape the nuclei of the cells on the table/desk which will represent the nucleus of the classroom cell
- Place the sorted tRNA molecules somewhere easy to access.

With the Students

1. For the student playing the role of mRNA:
    a. Go to the lab table in the front of the room. This is where the nucleus of a cell is located.
    b. Write down the type of cell and gene number that cell uses.
    c. Then write down the DNA sequence AND the mRNA codons *AT THE NUCLEUS*.
    d. Bring your lab handout back to the ribosome (table).

2. Back at the lab table everyone must record the mRNA message. Then everyone writes down the corresponding tRNA anti-codon.

3. The student representing the tRNA will need to go to the cytoplasm (the entire room) where the tRNA cutouts are located, and bring the CORRECT tRNA based on its anti-codon to the ribosome.

4. The student representing rRNA will then unfold the tRNA cutout to reveal the amino acid and copy down the amino acid found on the tRNA.

5. The tRNA will return the tRNA to the cytoplasm IN THE SAME SPOT IT WAS FOUND. The tRNA will then find the next tRNA needed based on the anti-codon and bring it to the ribosome.

6. Again, the rRNA will copy down the amino acid found on the tRNA and hand it back to the tRNA who will replace and get the last tRNA.

7. rRNA writes down the last amino acid and tRNA returns the tRNA.

8. Everyone writes down the amino acid sequence the rRNA connected.

9. Now repeat steps 1-8, for three different cells and genes.

10. After all your data is on the data sheet, answer the analysis questions.

Image Insert Image # or Figure # here (use Figure # if referenced in text)

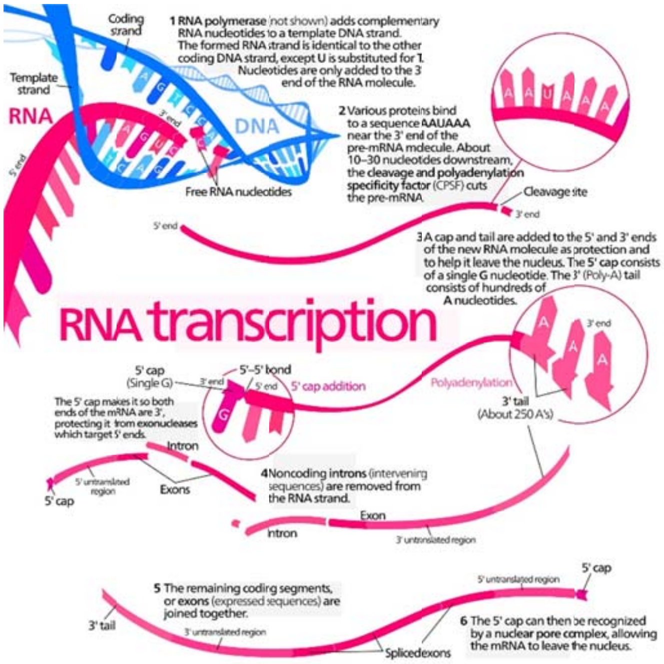

Figure 1

Image file: MRNA.jpg

ADA Description: A large infographic depicting transcription, from DNA to mRNA

Source/Rights: Copyright © 2012 Kelvinsong, Wikimedia Commons
http://commons.wikimedia.org/wiki/File:MRNA.svg

Caption: Figure 1. Transcription

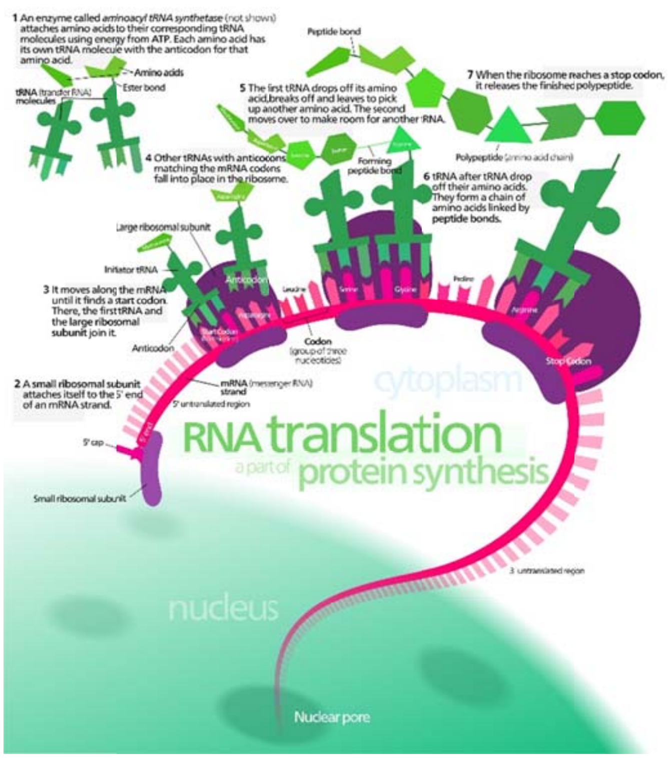

Figure 2

Image file: Protein_synthesis.jpg

ADA Description: A large infographic depicting translation, from mRNA to assembled protein

Source/Rights: Copyright © 2012 Kelvinsong, Wikimedia Commons
http://commons.wikimedia.org/wiki/File:Protein_synthesis.svg

Caption: Figure 2. Translation

Attachments
Handout

Handout (key)

tRNA cutouts

Ribosome cutouts

Nucleus cutouts

Safety Issues
- none

Troubleshooting Tips
- Make sure that the nuclei are not moved, and that the students perform the transcription step at the desk/table where these are located since transcription occurs in the nucleus.
- If using one set of tRNA cutouts, several groups may end up looking for the same anti-codon. We recommend using multiple sets of cutouts. Since some are not used at all (unless you add to the activity), you may look at the key and only print extra copies of the tRNA molecules that are needed.

Assessment

Pre-Activity Assessment
Pre-Activity Questions: 4 questions included on top of page 2 of the handout.

Activity Embedded Assessment
Collecting Data: The students right down information from each step of the protein synthesis process in the charts on page 2 of the handout

Post-Activity Assessment
Follow up Questions: Students answer questions on page 3 of the handout to think more in depth about the activity they just performed.

Activity Extensions
For more advanced classes, you make extend the length of the genes or add additional cell nuclei. You may also reduce the group size to 2, and have the same student perform the roles of tRNA and rRNA since the contribution from the rRNA role is small in this activity.

References

Other

Redirect URL

Contributors
Kimberly Anderson, Matthew Zelisko

Supporting Program

University of Houston, National Science Foundation GK-12 Program

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant Number 0840889.

Classroom Testing Information

This activity was performed Fall 2014 at Clear Creek High School, League City, TX for 9th grade regular biology classes. The activity was done after a few lessons on protein synthesis. The students needed a little help with the first round, but after that the activity went very smoothly. This was done to reinforce the steps of protein synthesis since the students were having trouble learning it by just taking notes.

NAME ____ DATE _________ PER ____

Activity: Modeling Protein Synthesis

PROCEDURES

Today our classroom are different eukaryotic cells that are synthesizing various proteins. You will be working in a group to simulate the process that builds proteins for your cell. This process is called protein synthesis.

In your group (3 students) assign the following roles: mRNA, tRNA, and rRNA (found in ribosome and help catalyze the assembly of amino acids). Below is the role of each RNA:

ROLES OF EACH RNA

1. mRNA – transcribe the DNA message
2. tRNA – bring the correct tRNA to the ribosome based on the mRNA sequence
3. rRNA – assemble the amino acids brought in by the tRNA

Steps to perform the simulation:

1. For the student playing the role of mRNA:
   a. Go to the lab table in the front of the room. This is where the nucleus of a cell is located.
   b. Write down the type of cell and gene number that cell uses.
   c. Then write down the DNA sequence AND the mRNA codons *AT THE NUCLEUS*.
   d. Bring your lab handout back to the ribosome (table).

2. Back at the lab table everyone must record the mRNA message. Then everyone writes down the corresponding tRNA anti-codon.

3. The student representing the tRNA will need to go to the cytoplasm (the entire room) where the tRNA cutouts are located, and bring the CORRECT tRNA based on its anti-codon to the ribosome.

4. The student representing rRNA will then unfold the tRNA cutout to reveal the amino acid and copy down the amino acid found on the tRNA.

5. The tRNA will return the tRNA to the cytoplasm IN THE SAME SPOT IT WAS FOUND. The tRNA will then find the next tRNA needed based on the anti-codon and bring it to the ribosome.

6. Again, the rRNA will copy down the amino acid found on the tRNA and hand it back to the tRNA who will replace and get the last tRNA.

7. rRNA writes down the last amino acid and tRNA returns the tRNA.

8. Everyone writes down the amino acid sequence the rRNA connected.

9. Now repeat steps 1-8, for three different cells and genes.

10. After all your data is on the data sheet, answer the analysis questions.

Activity: Modeling Protein Synthesis

Pre-Activity Question: Use your notes to answer.

1. What is the purpose of protein synthesis? ____
2. What is the first step in protein synthesis?_____________________ Second step? ____________________
3. What is a codon? ____
4. What is an anti-codon? ____

DATA

Cell Type ____________________________ Gene # _________									
DNA									
mRNA codon									
tRNA anti-codon									
Amino Acid									

Cell Type ___________________________ Gene # _________									
DNA									
mRNA codon									
tRNA anti-codon									
Amino Acid									

Cell Type ___________________________ Gene # ___________									
DNA									
mRNA codon									
tRNA anti-codon									
Amino Acid									

Protein Synthesis Activity Analysis Questions

Part I. Look at the protein sequences you made to answer the following questions.

1. How are all of the proteins that were assembled similar?

2. How are all of the proteins that were assembled different?

3. Look at the DNA in ALL the cell's nucleus at the black lab table in the front of the room. Do different somatic cells (liver, nerve, bone, etc.) have the same DNA? Explain your answer.

4. Why do these different cells synthesize different proteins, if their genetic code is identical?

5. If you were to look at the DNA inside one of your skin cells and compare it to the DNA inside one of your blood cells, would the DNA be the same even though blood cells and skin cells look different and do different functions? _______

Part II. Identify what each of the following represented in the simulation you just completed.

6. Lab table with DNA:___________________________________

7. Table where you brought the tRNA:_________________________________

8. The person in your group who copied the genes from the front of the room onto their paper: ____________________

Part III. Lab Analysis

9. One DNA strand has the base sequence "AACTGA" How many amino acids are coded for this DNA fragment?

10. Would a protein still be successfully produced if your mRNA code were passed to another group?
Why or why not?

11.What would happen if your "ribosome" made a mistake in carrying out the instructions?

Part IV. Critical Thinking

12. If we wanted to purposely have a gene encode for a different protein, what would we change in the cell?

13. If we know the amino acids in the desired protein, will there be a <u>single</u> DNA sequence we can find that will encode for these proteins? Why or why not?

NAME ____ DATE _________ PER ____

Activity: Modeling Protein Synthesis

PROCEDURES

Today our classroom are different eukaryotic cells that are synthesizing various proteins. You will be working in a group to simulate the process that builds proteins for your cell. This process is called protein synthesis.

In your group (3 students) assign the following roles: mRNA, tRNA, and rRNA (found in ribosome and help catalyze the assembly of amino acids). Below is the role of each RNA:

ROLES OF EACH RNA

1. mRNA – transcribe the DNA message
2. tRNA – bring the correct tRNA to the ribosome based on the mRNA sequence
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Steps to perform the simulation:

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2. Back at the lab table everyone must record the mRNA message. Then everyone writes down the corresponding tRNA anti-codon.

3. The student representing the tRNA will need to go to the cytoplasm (the entire room) where the tRNA cutouts are located, and bring the CORRECT tRNA based on its anti-codon to the ribosome.

4. The student representing rRNA will then unfold the tRNA cutout to reveal the amino acid and copy down the amino acid found on the tRNA.

5. The tRNA will return the tRNA to the cytoplasm IN THE SAME SPOT IT WAS FOUND. The tRNA will then find the next tRNA needed based on the anti-codon and bring it to the ribosome.

6. Again, the rRNA will copy down the amino acid found on the tRNA and hand it back to the tRNA who will replace and get the last tRNA.

7. rRNA writes down the last amino acid and tRNA returns the tRNA.

8. Everyone writes down the amino acid sequence the rRNA connected.

9. Now repeat steps 1-8, for three different cells and genes.

10. After all your data is on the data sheet, answer the analysis questions.

Activity: Modeling Protein Synthesis

Pre-Activity Question: Use your notes to answer.

1. What is the purpose of protein synthesis? __To build proteins____

2. What is the first step in protein synthesis?__transcription_______ Second step? ____translation______

3. What is a codon? ____a set of three nucleotide bases on mRNA_____________________________________

4. What is an anti-codon? __the set of three nucleotide bases on tRNA which form base pairs with the codon_____

DATA

Cell Type __Liver___________________________
Gene # _____1_______

DNA	A	A	T	G	A	T	A	C	C
mRNA codon	U	U	A	C	U	A	U	G	G
tRNA anti-codon	A	A	U	G	A	U	A	C	C
Amino Acid	Leu			Leu			Trp		

Cell Type __Skin___________________________
Gene # _____2_______

DNA	A	C	G	G	C	G	A	A	T
mRNA codon	U	G	C	C	G	C	U	U	A
tRNA anti-codon	A	C	G	G	C	G	A	A	U
Amino Acid	Cys			Arg			Leu		

Cell Type ___Blood__________________________
Gene # ______3______

DNA	G	T	T	G	A	T	A	A	T
mRNA codon	C	A	A	C	U	A	U	U	A
tRNA anti-codon	G	U	U	G	A	U	A	A	U
Amino Acid	Glu			Leu			Leu		

Protein Synthesis Activity Analysis Questions

Part I. Look at the protein sequences you made to answer the following questions.

1. How are all of the proteins that were assembled similar?

All built from amino acids

2. How are all of the proteins that were assembled different?

Have different sequences of amino acids

3. Look at the DNA in ALL the cell's nucleus at the black lab table in the front of the room. Do different somatic cells (liver, nerve, bone, etc.) have the same DNA? Explain your answer.

Yes, the cells all come from the same organism so they all contain the same DNA

4. Why do these different cells synthesize different proteins, if their genetic code is identical?

Different cells use different genes from the DNA

5. If you were to look at the DNA inside one of your skin cells and compare it to the DNA inside one of your blood cells, would the DNA be the same even though blood cells and skin cells look different and do different functions? _______

Yes

Part II. Identify what each of the following represented in the simulation you just completed.

6. Lab table with DNA:_______Nucleus______________________________

7. Table where you brought the tRNA:_____Ribosome____________________________

8. The person in your group who copied the genes from the front of the room onto their paper: _____mRNA___________

Part III. Lab Analysis

9. One DNA strand has the base sequence "AACTGA" How many amino acids are coded for this DNA fragment?

Two

10. Would a protein still be successfully produced if your mRNA code were passed to another group? Why or why not?

Yes, the mRNA can be used by any ribosome in the cytoplasm to build a protein.

11.What would happen if your "ribosome" made a mistake in carrying out the instructions?

The resulting protein would be different

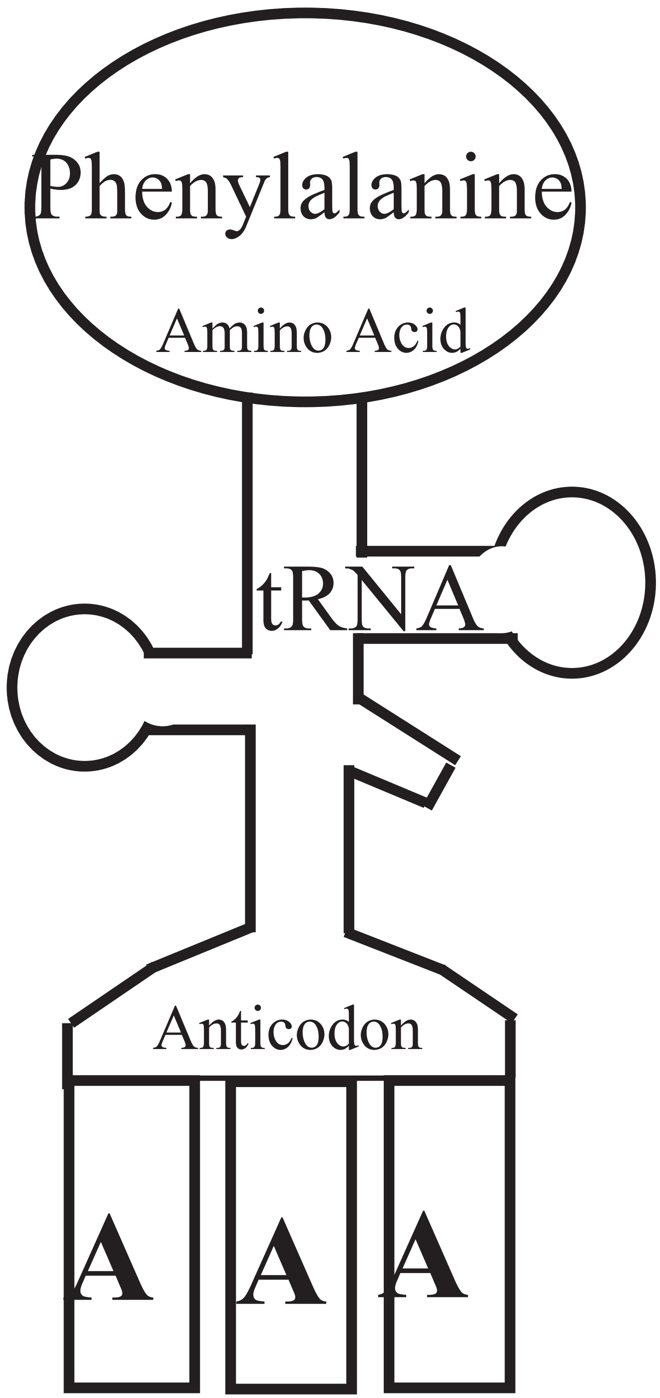
Part IV. Critical Thinking

12. If we wanted to purposely have a gene encode for a different protein, what would we change in the cell?

The DNA

13. If we know the amino acids in the desired protein, will there be a single DNA sequence we can find that will encode for these proteins? Why or why not?

No, several codons may encode for the same amino acid, therefore there will be many DNA sequences which can make the same protein.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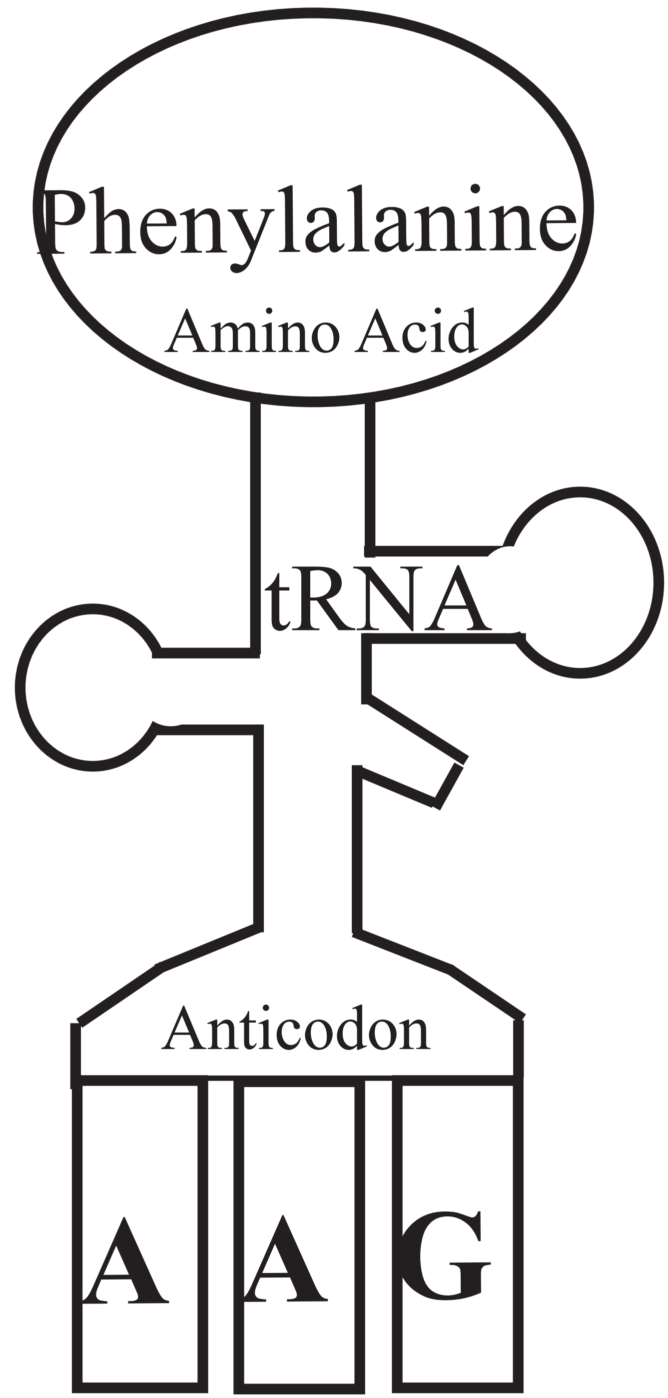
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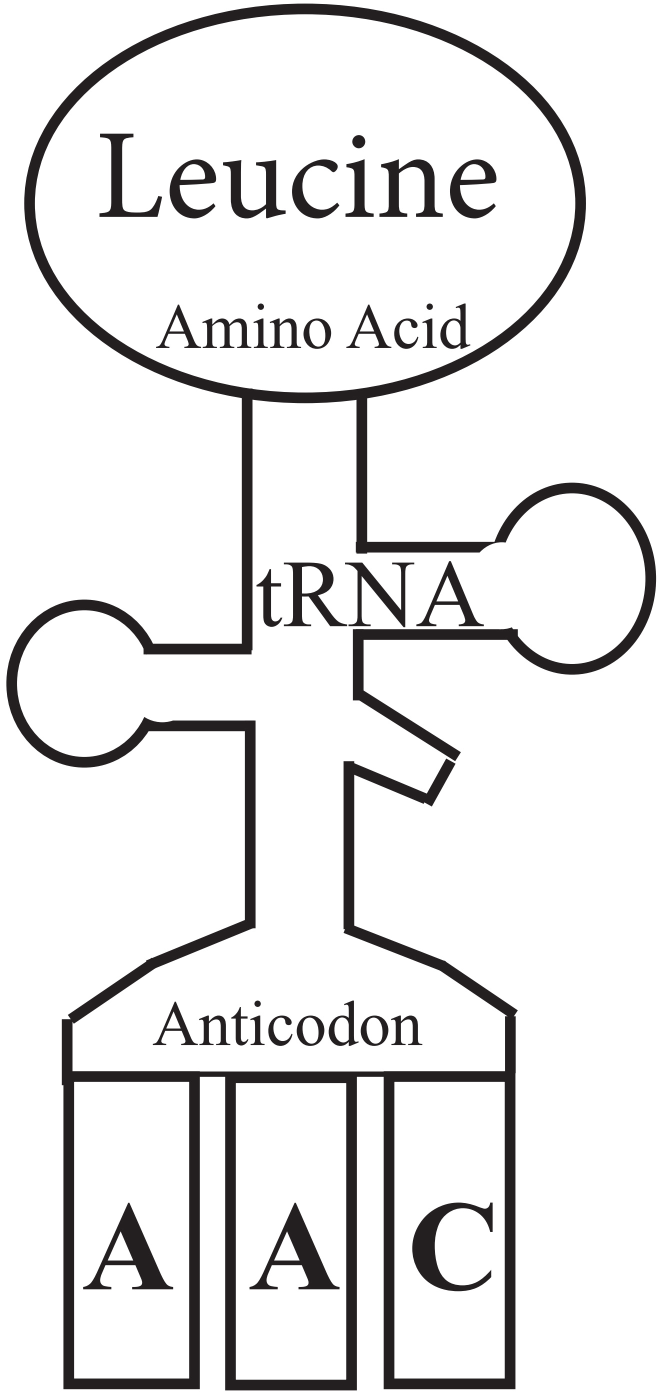
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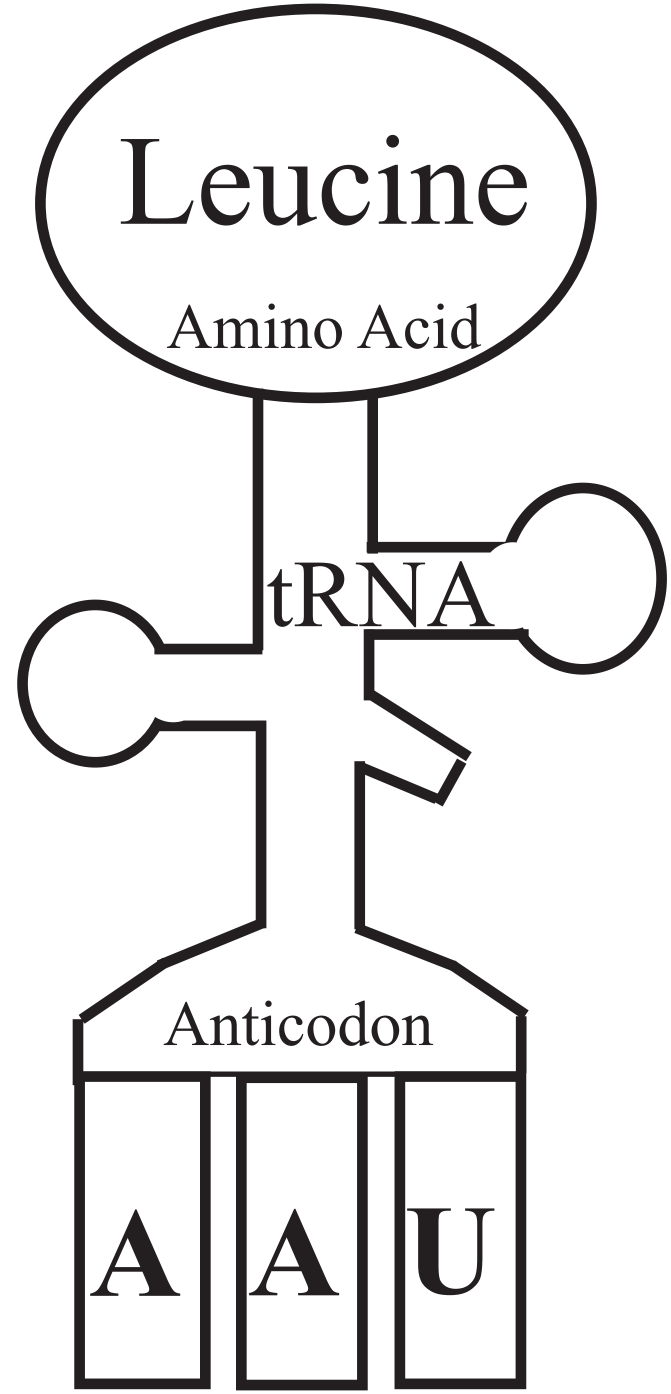
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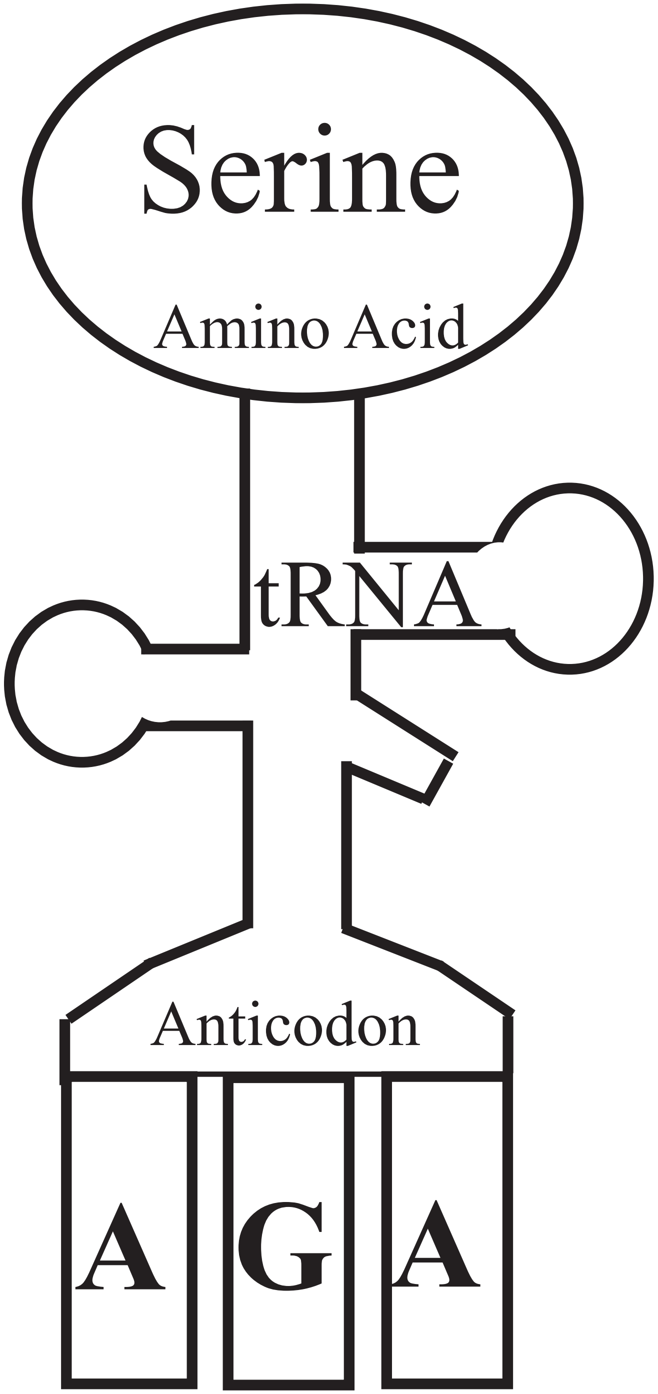
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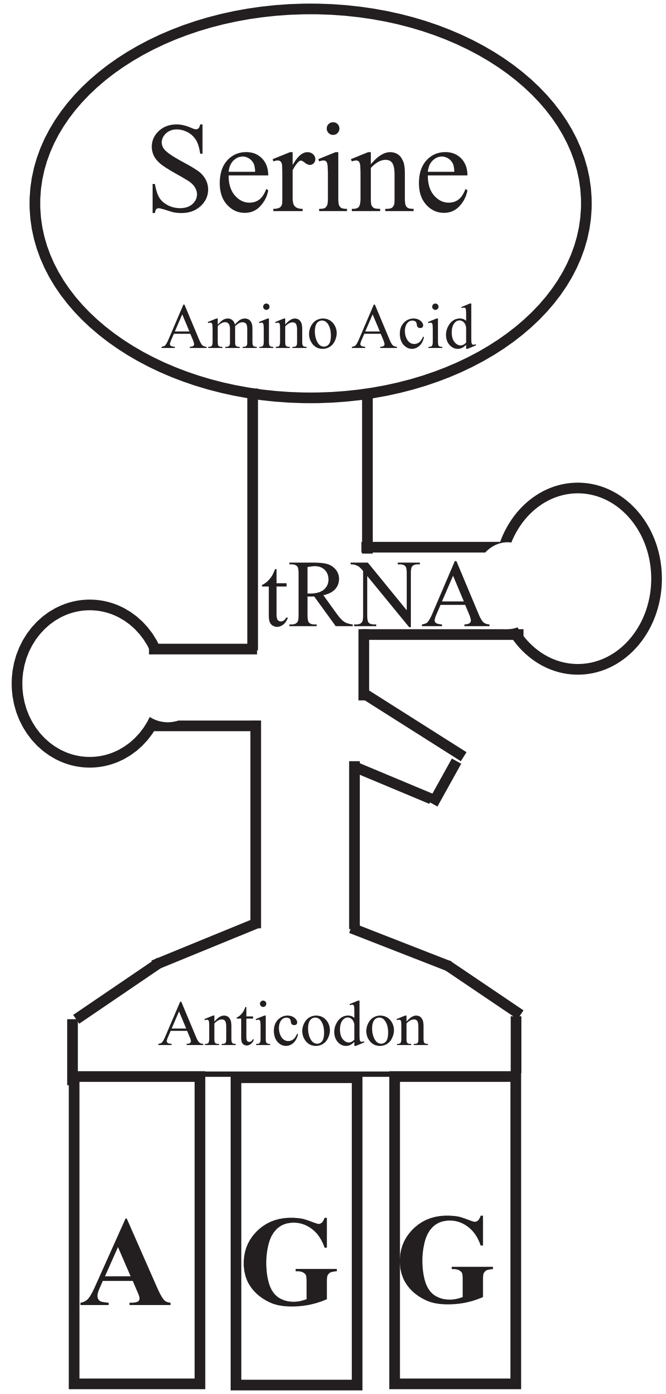
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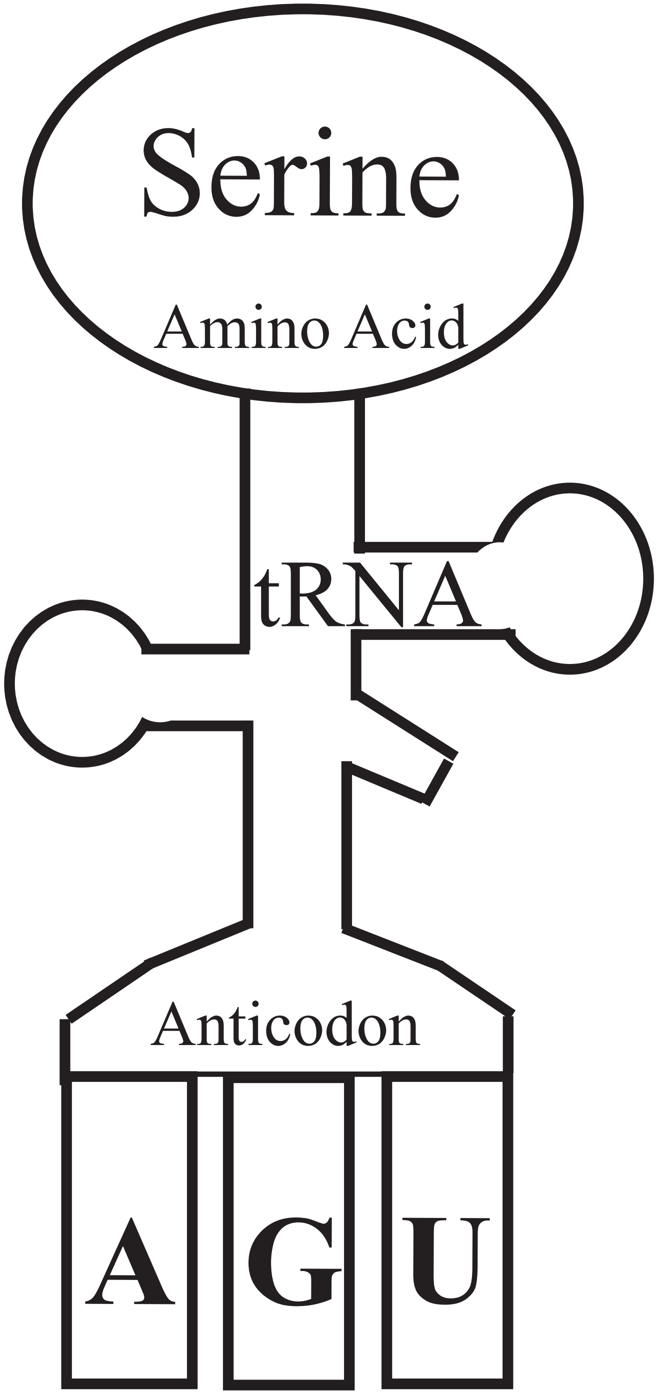
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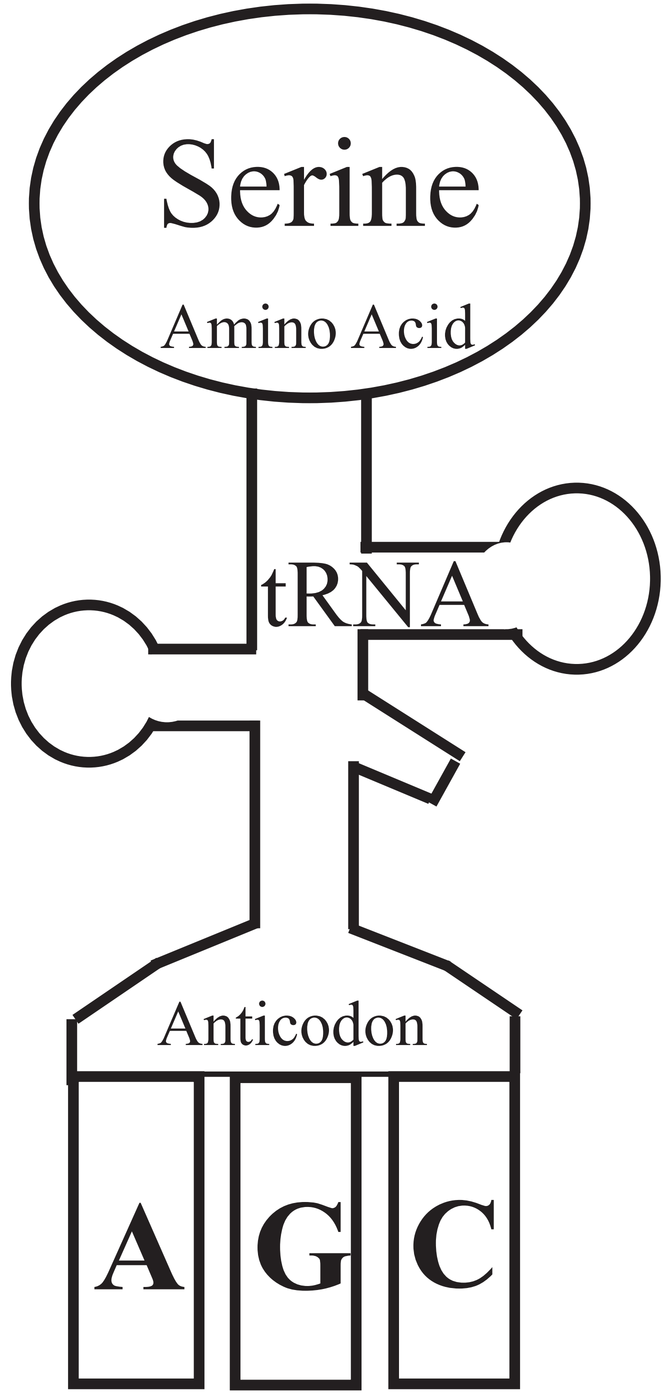
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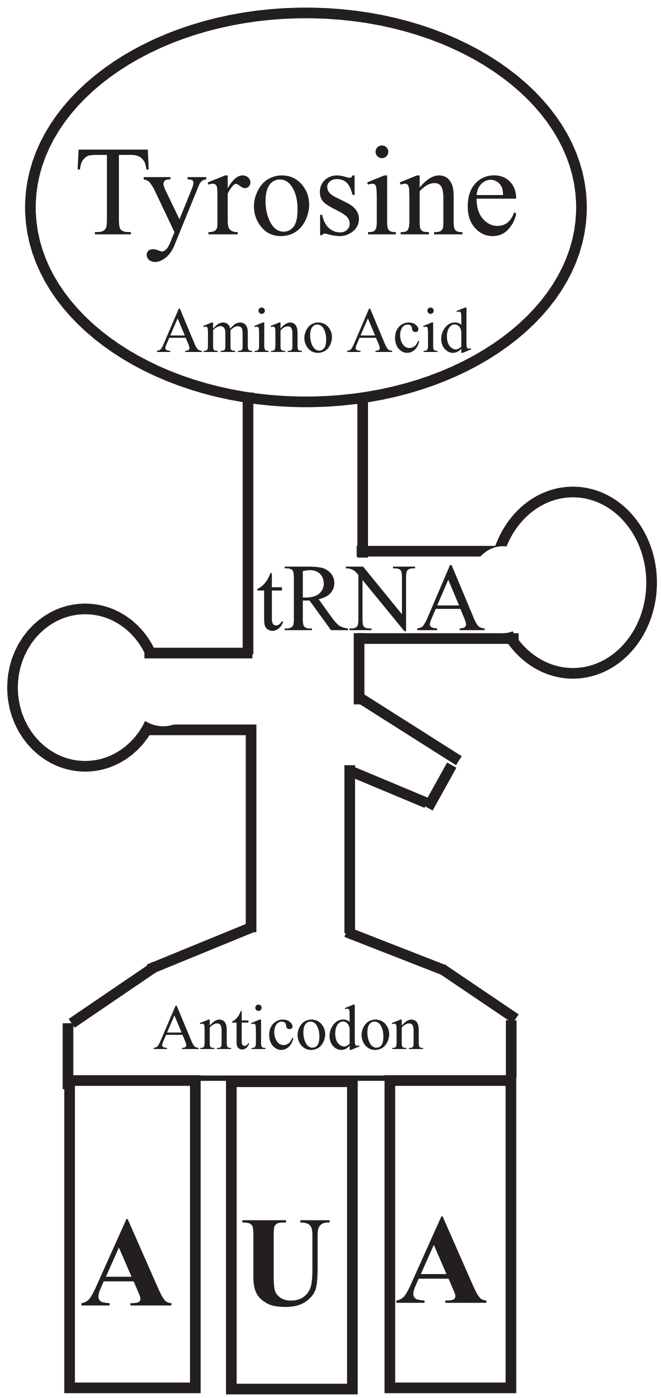
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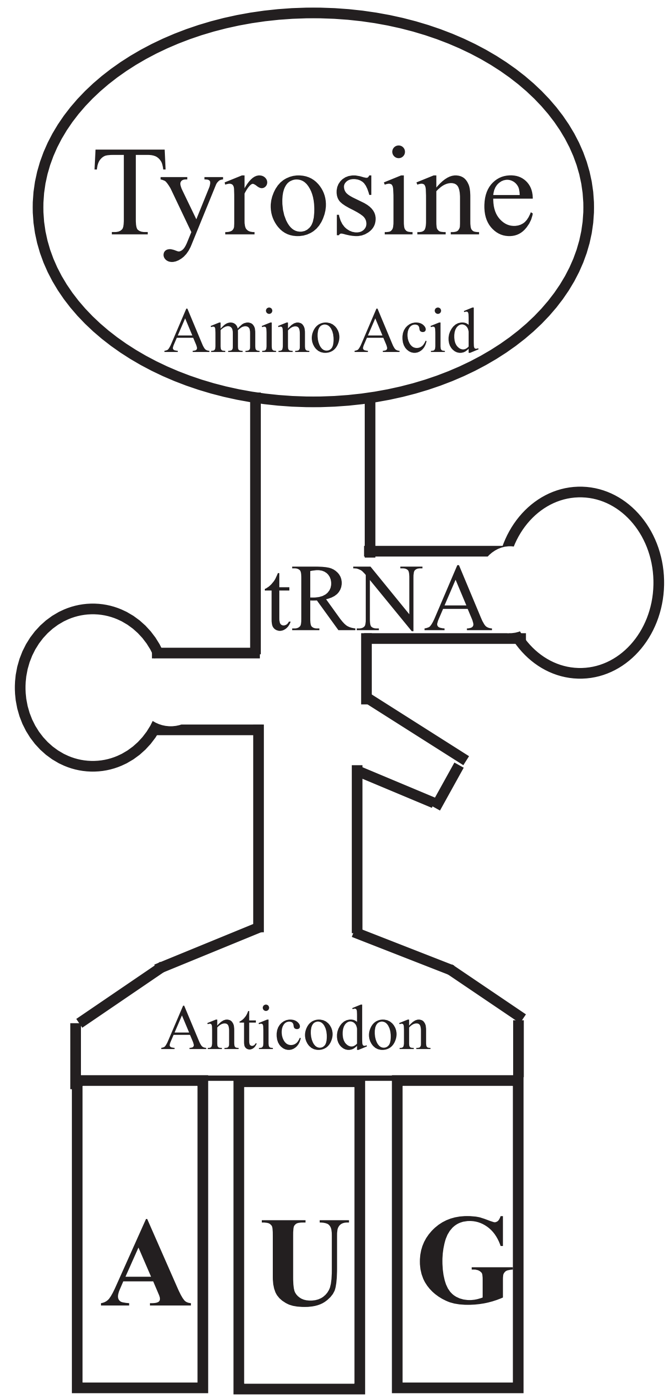
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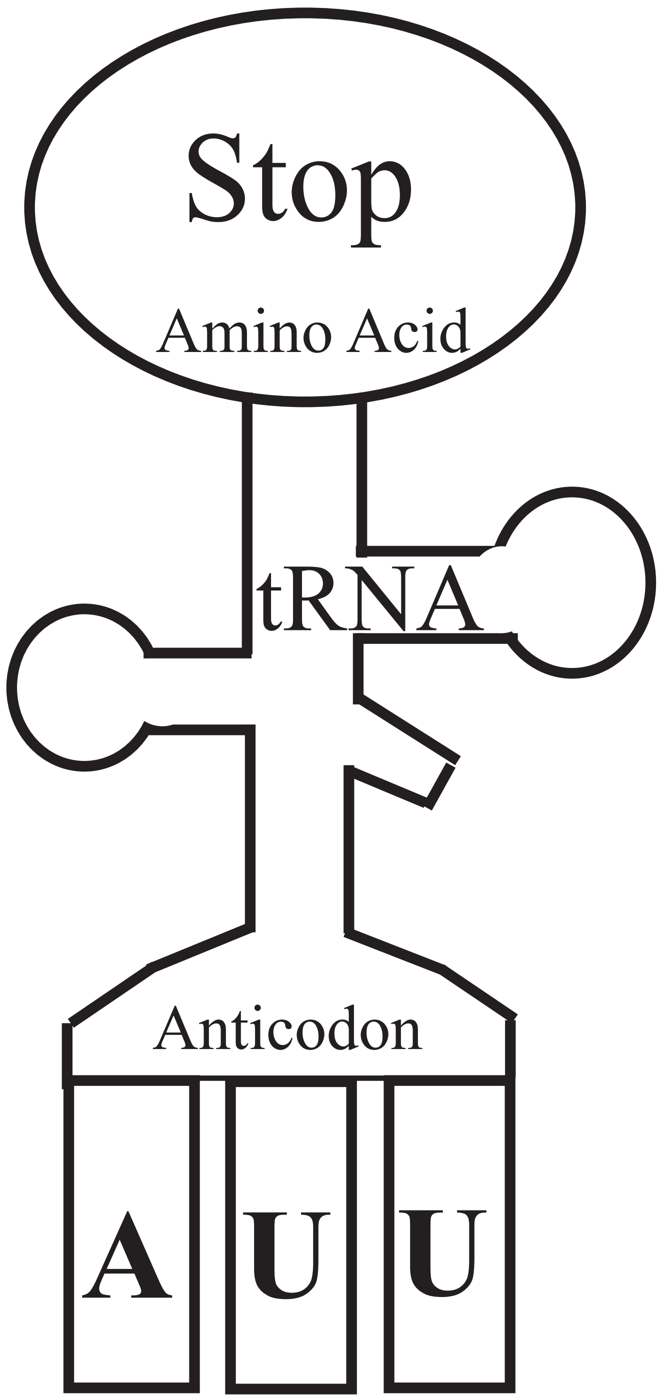
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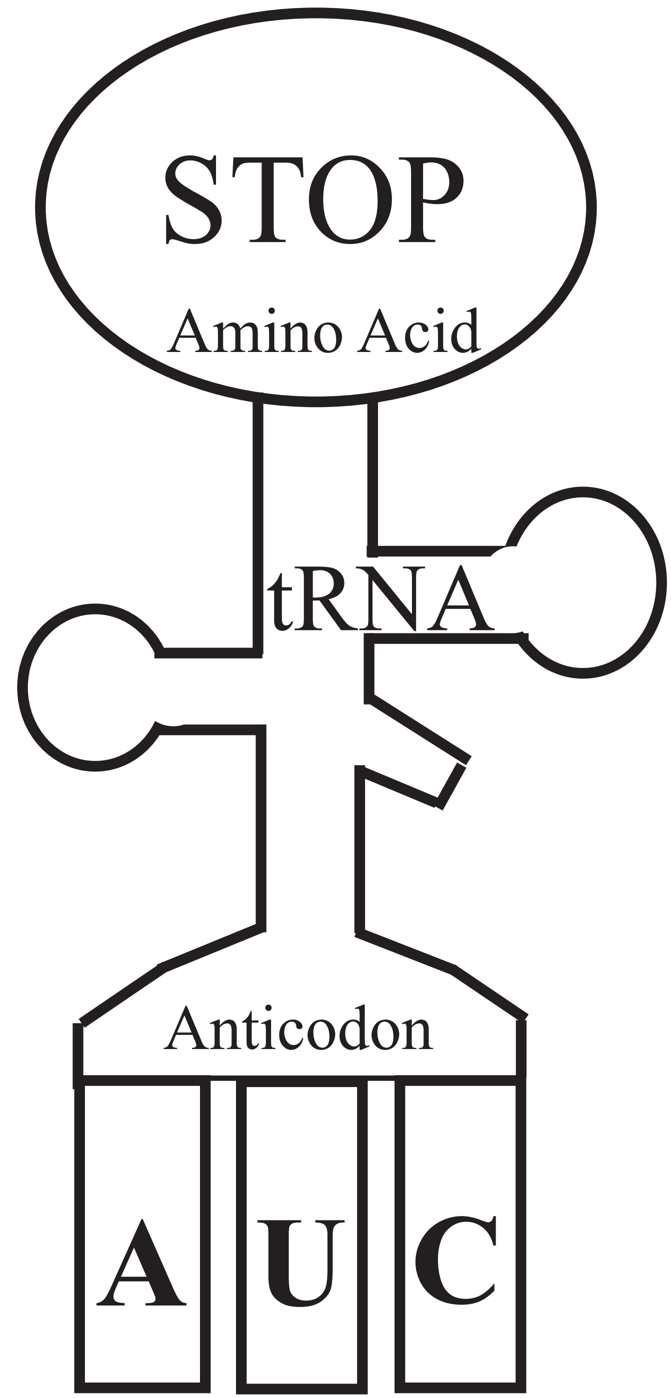
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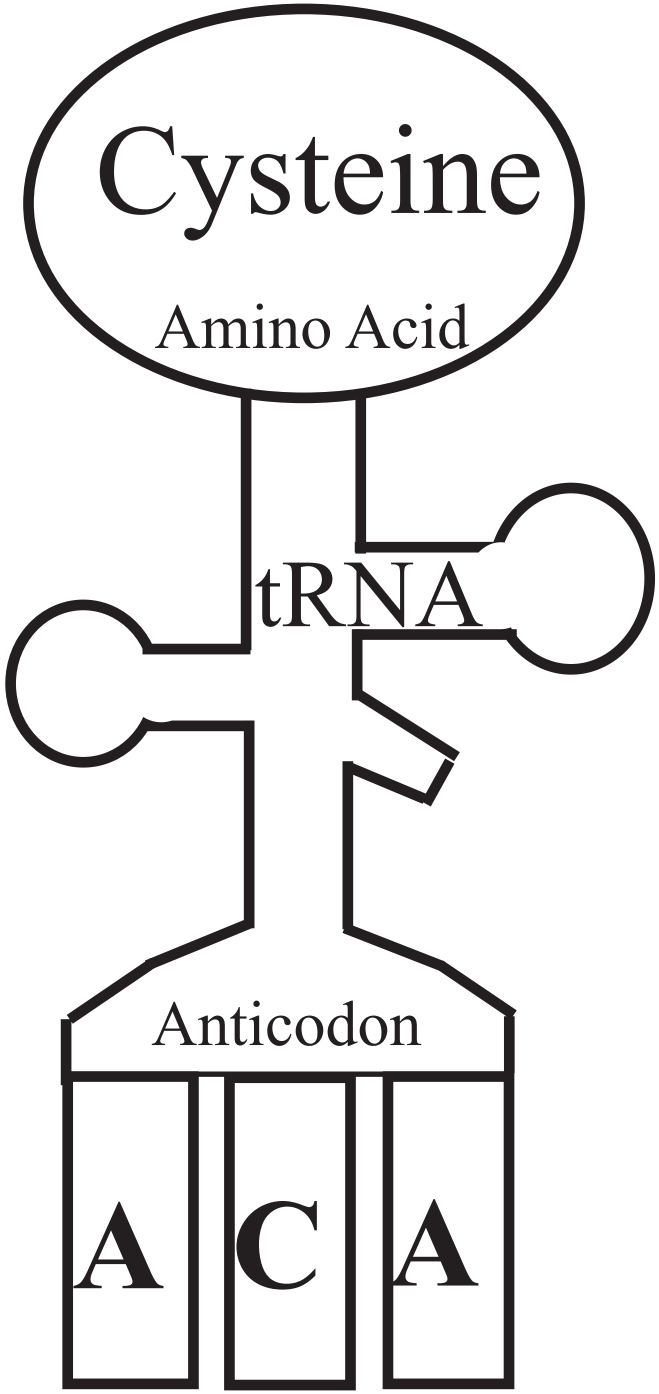
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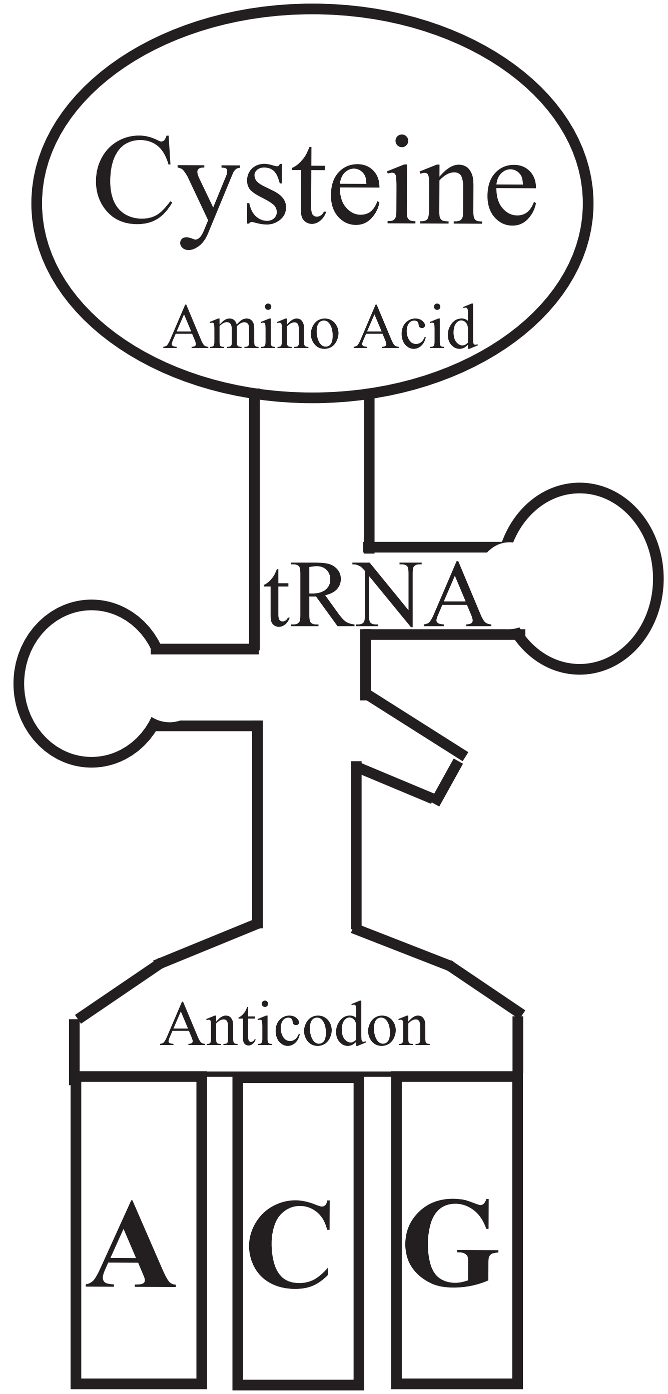
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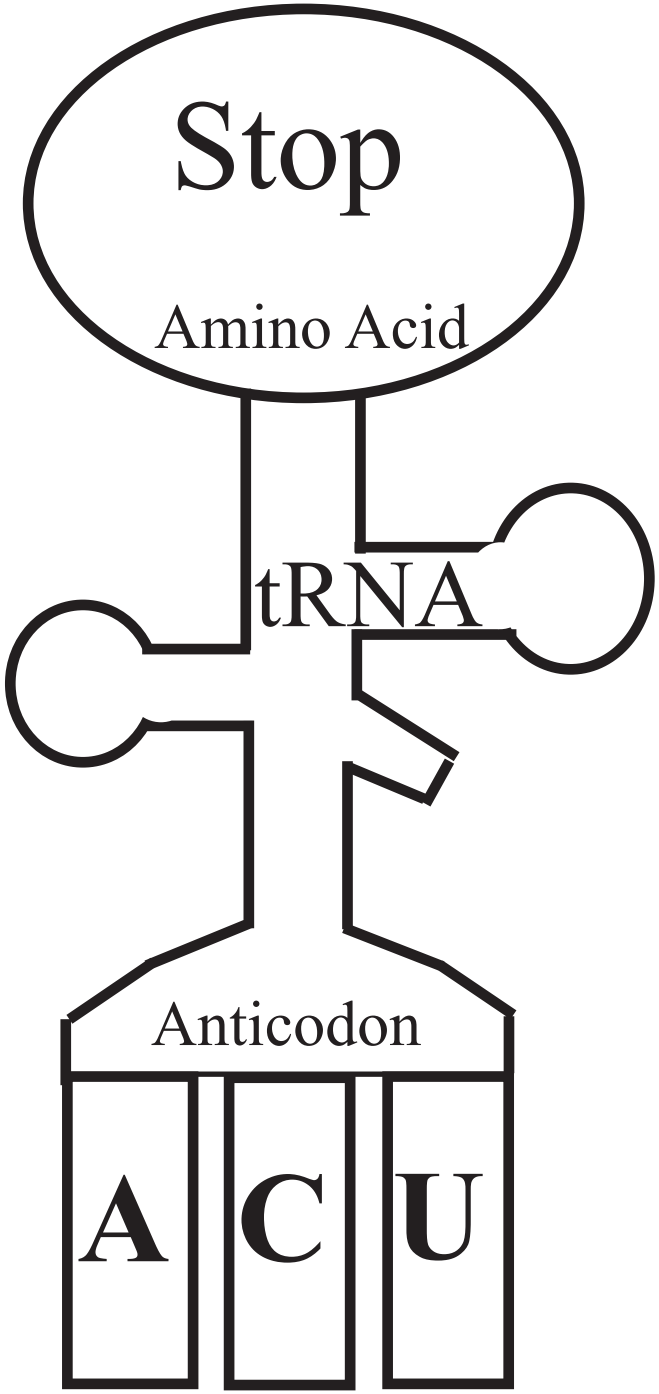
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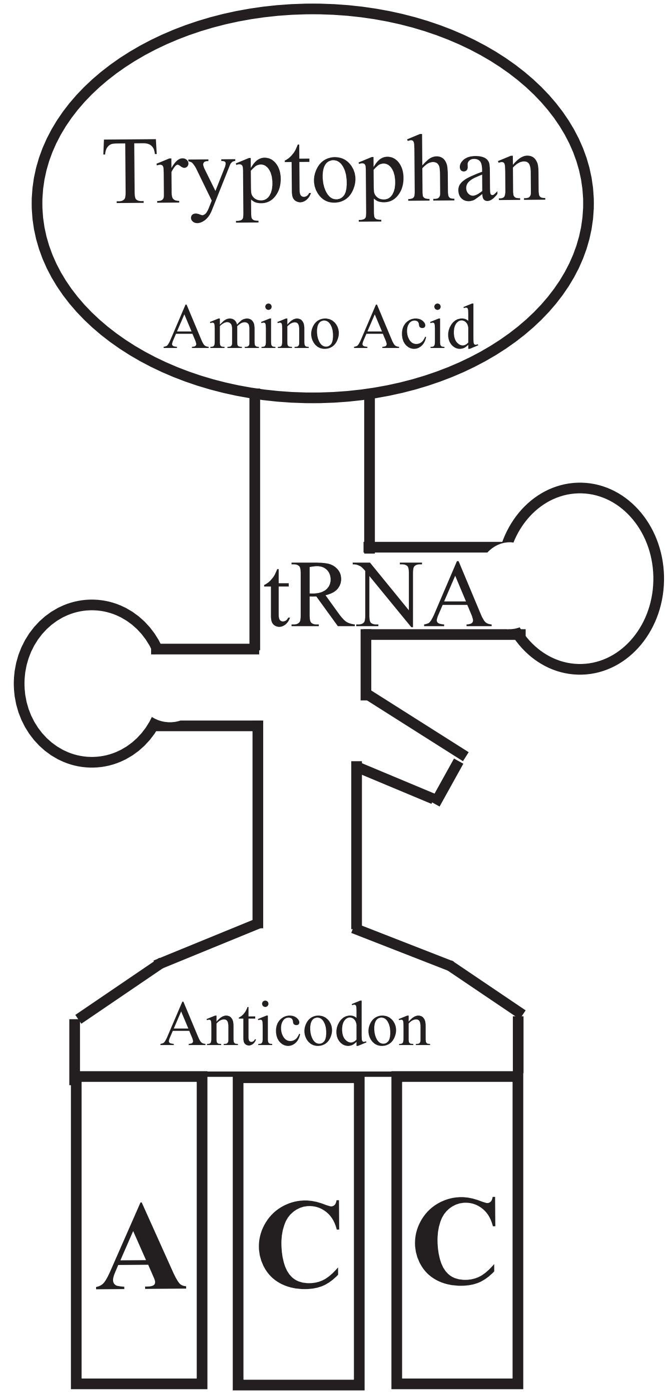
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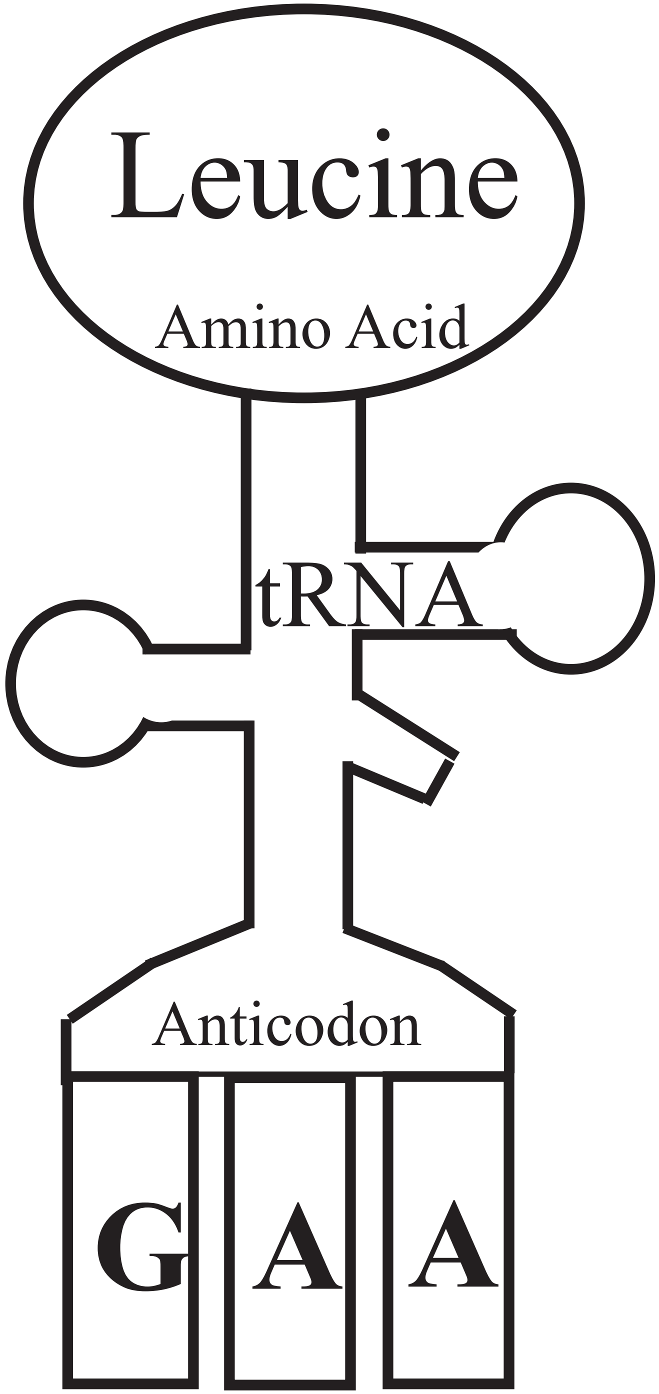
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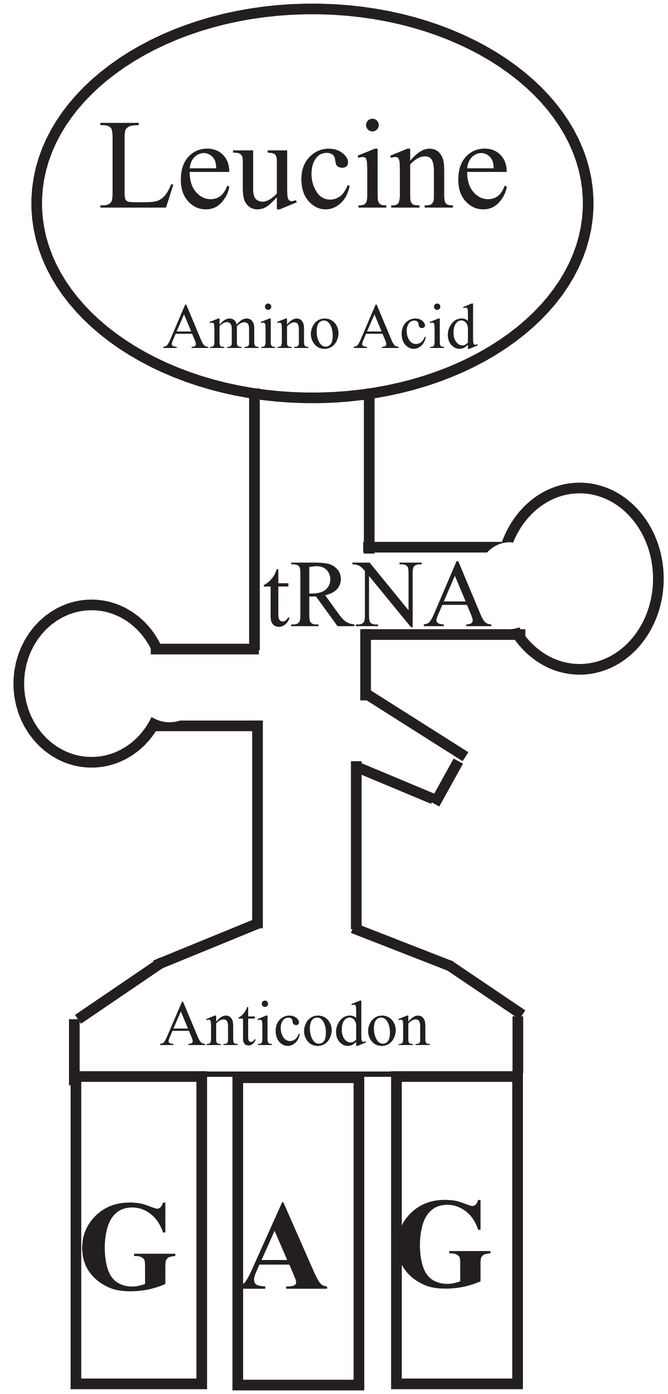
tRNA
Anticodon
G A A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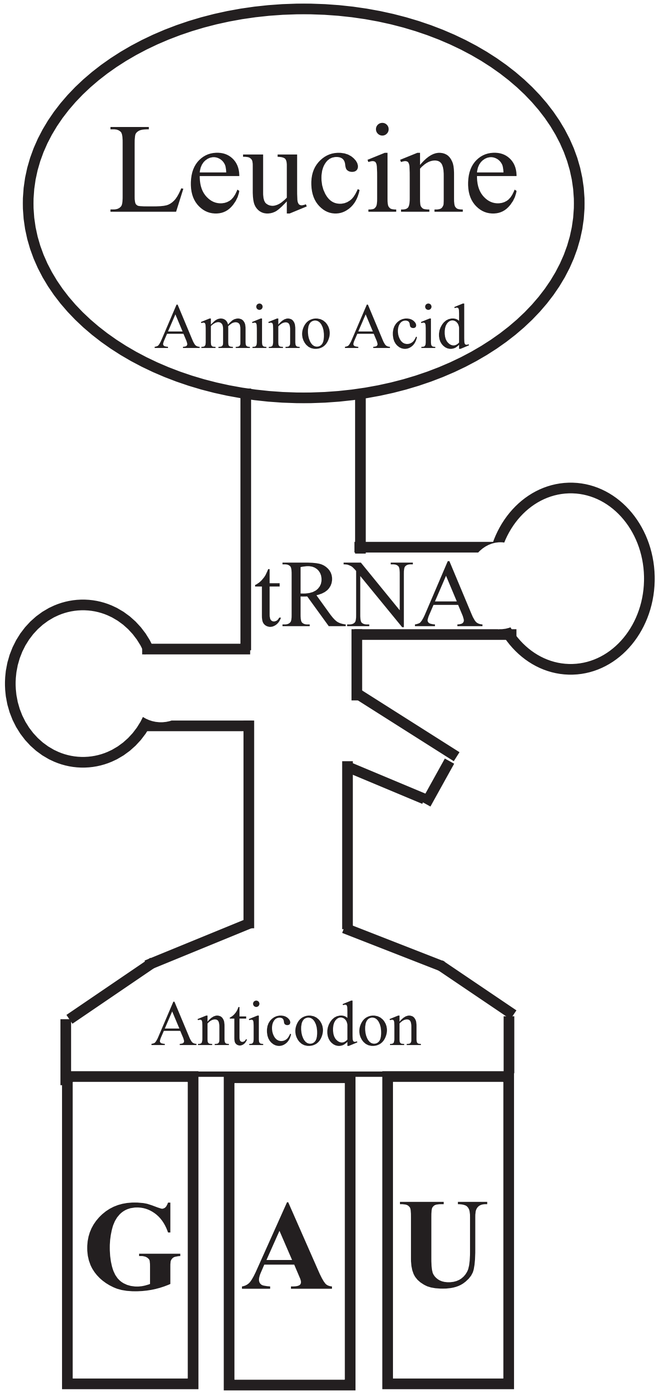
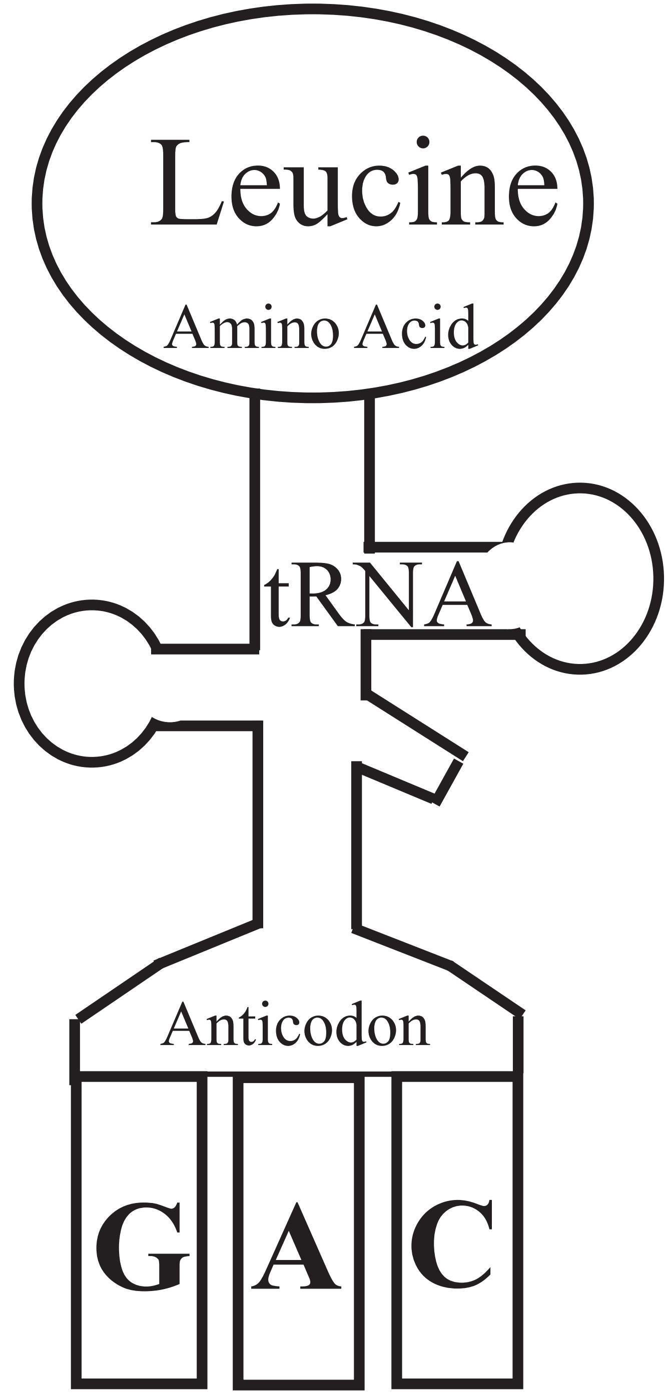


Leucine
Amino Acid
tRNA
Anticodon
G A U



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Amino Acid
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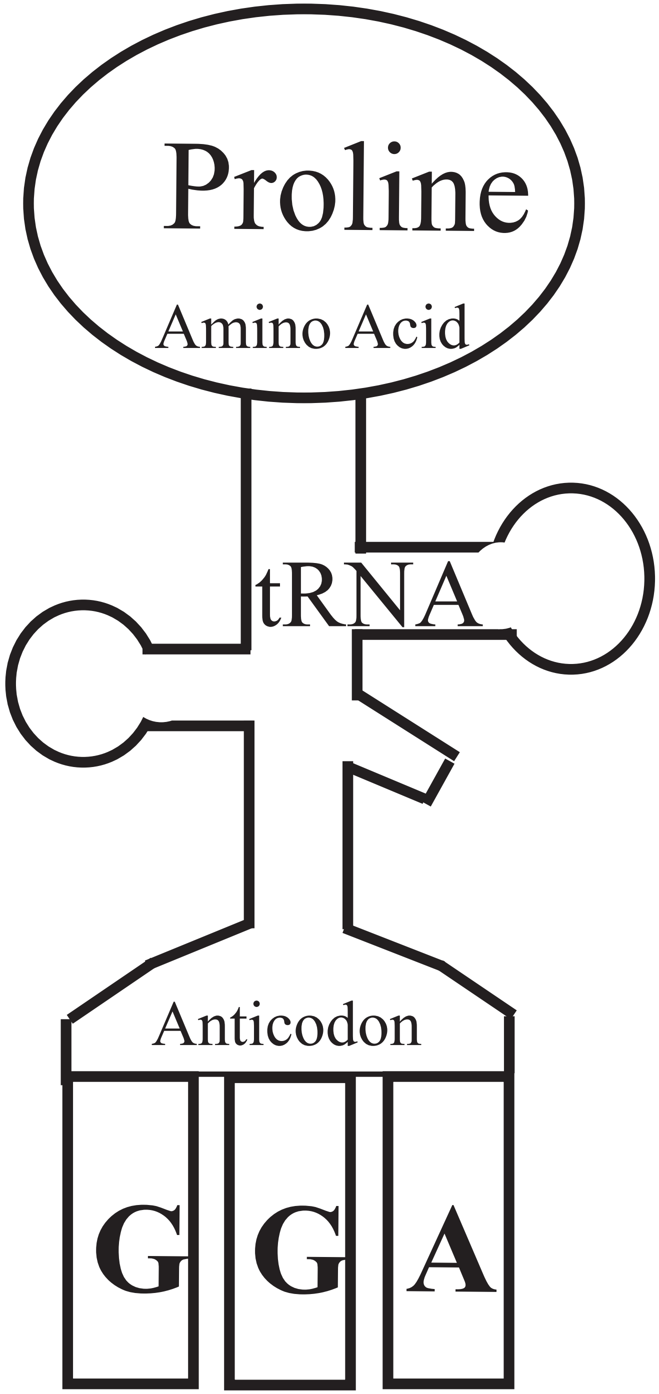
G A C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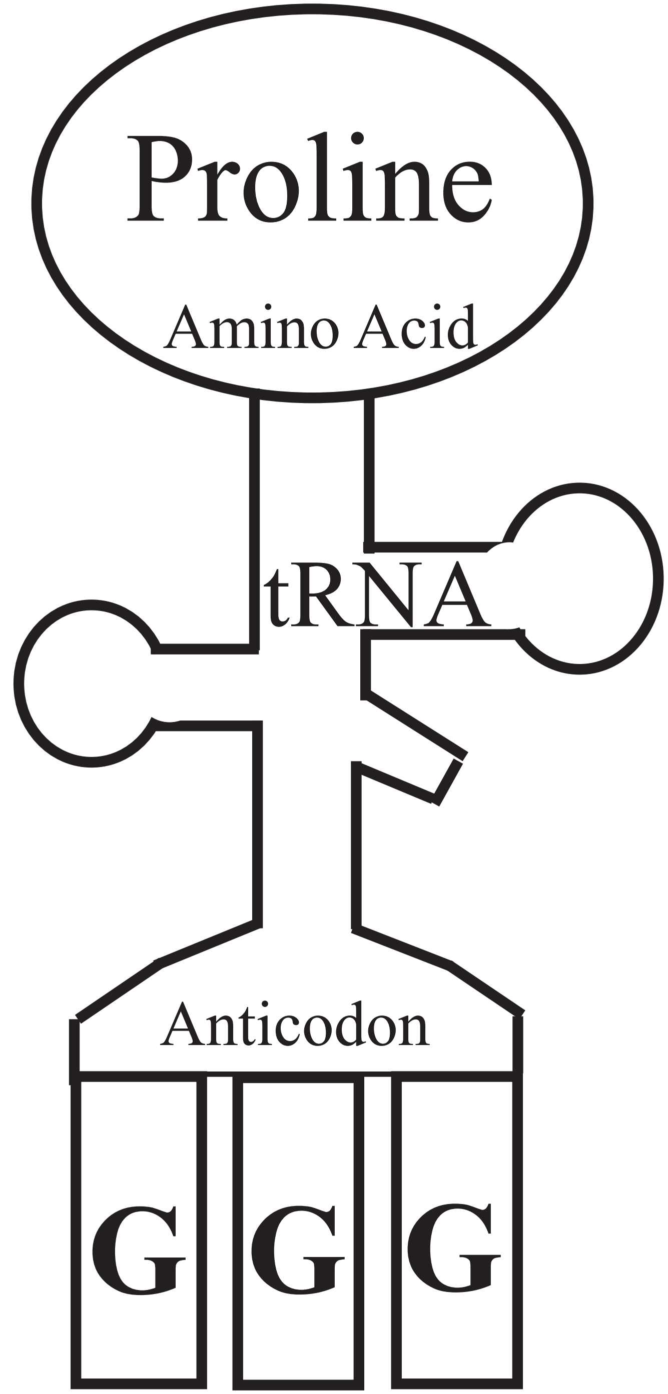
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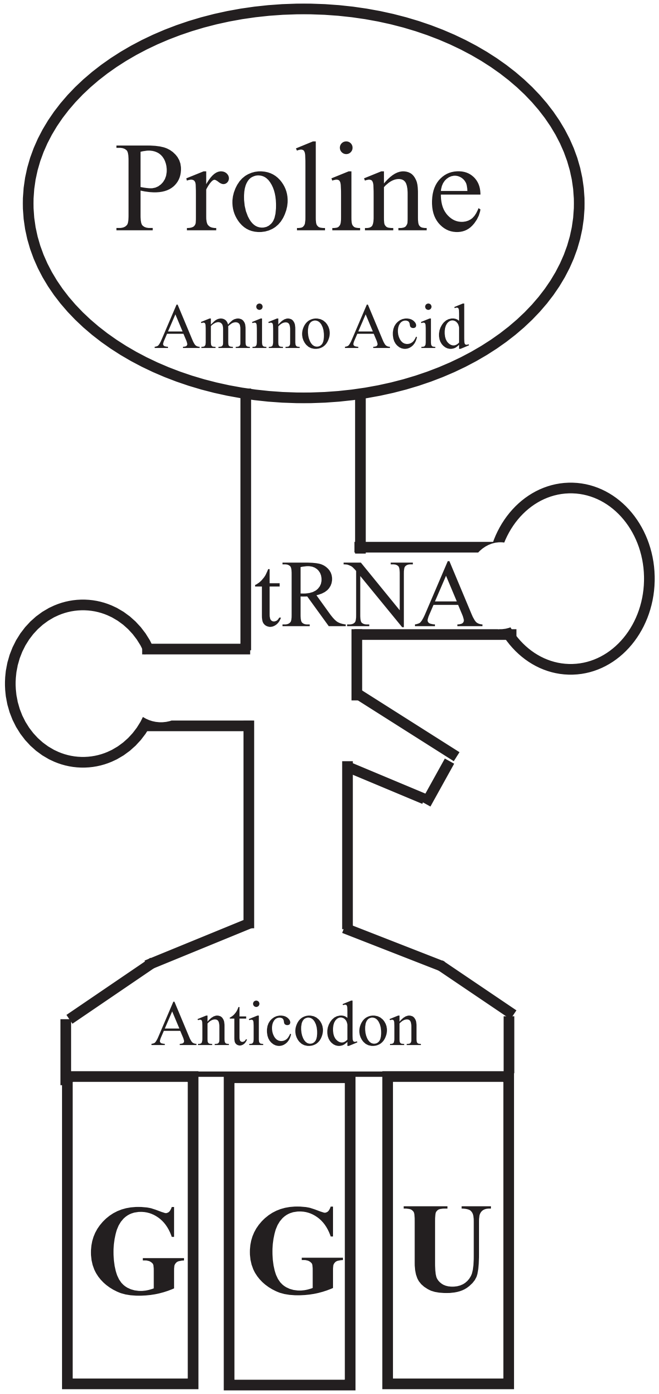
G G G



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Amino Acid
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G
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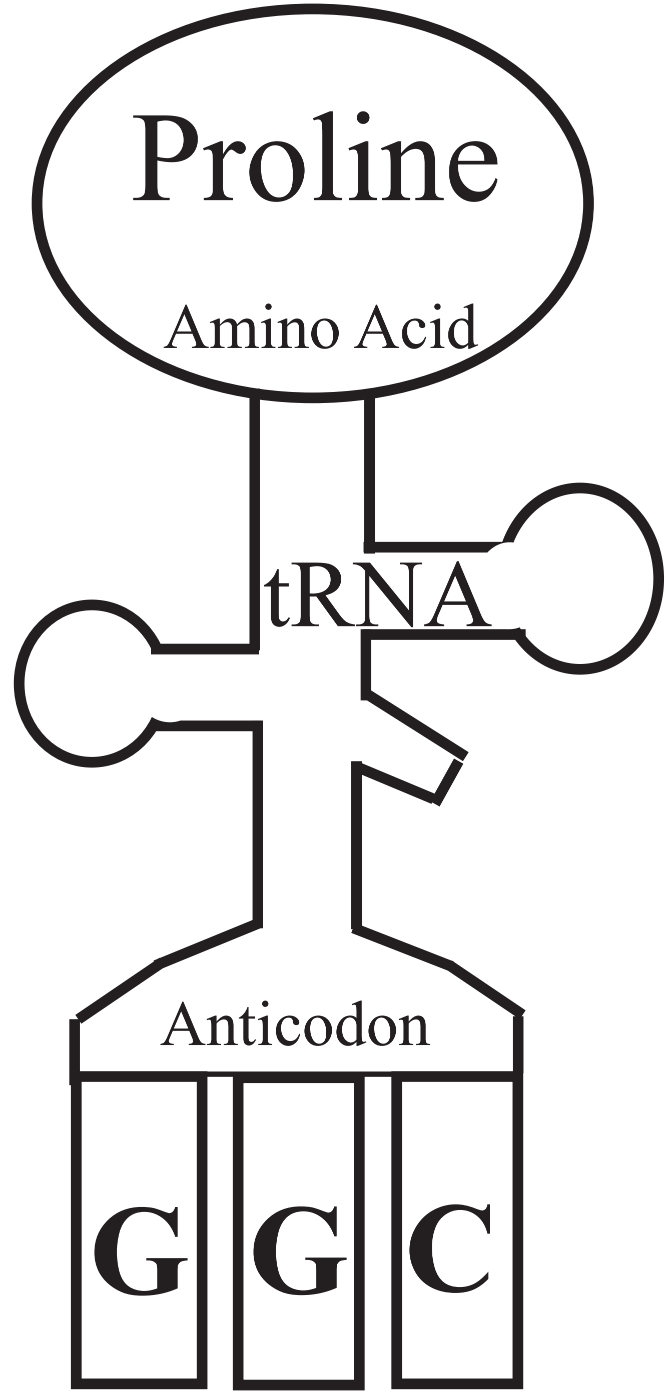

Proline
Amino Acid
tRNA
Anticodon
G
G
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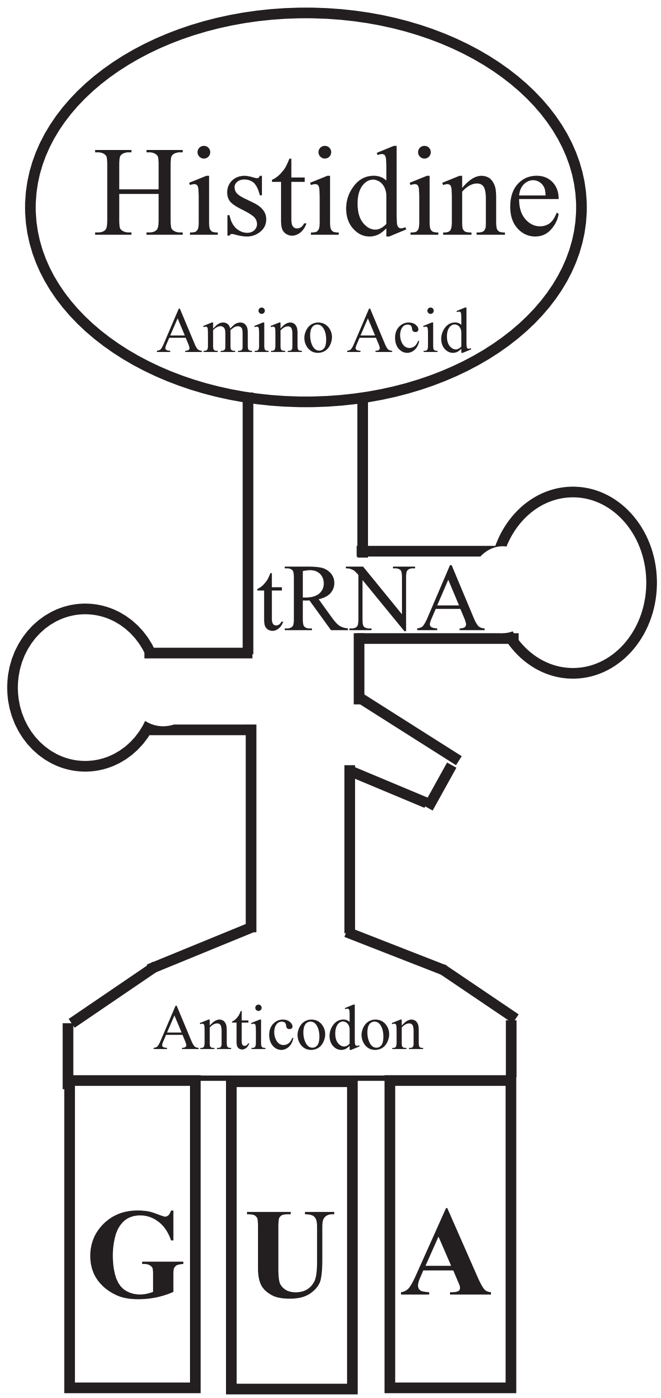
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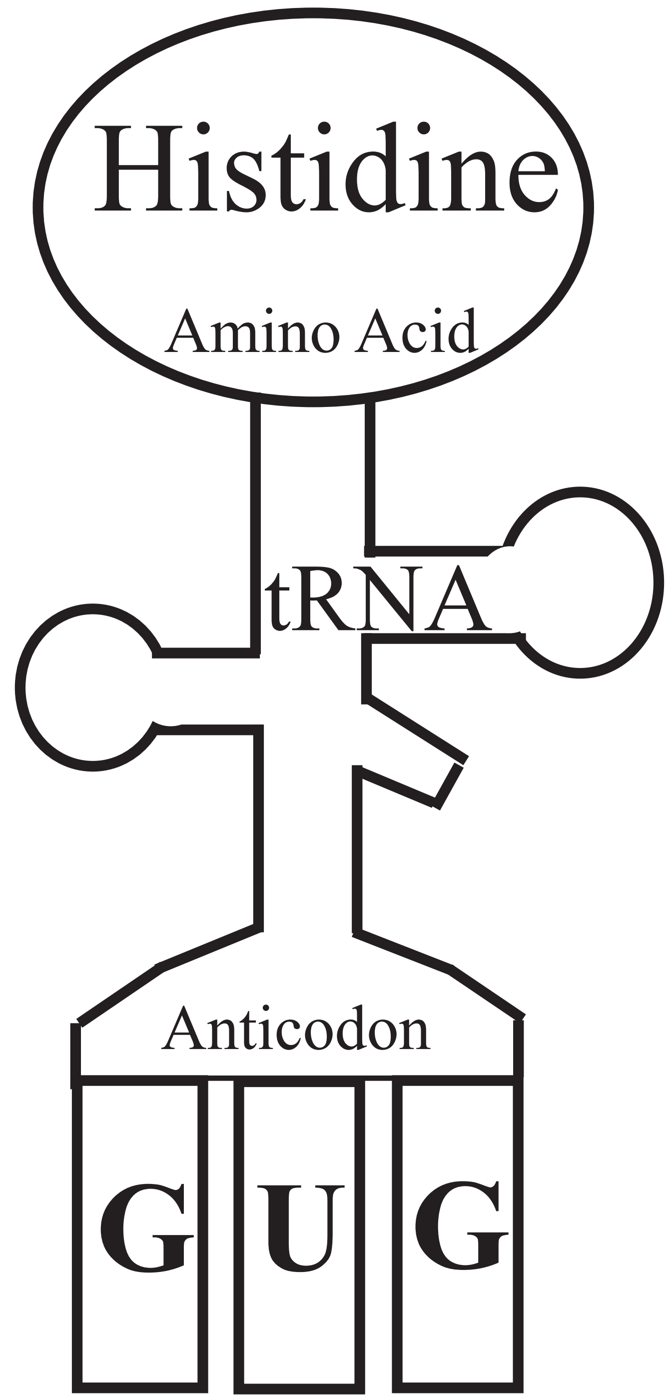
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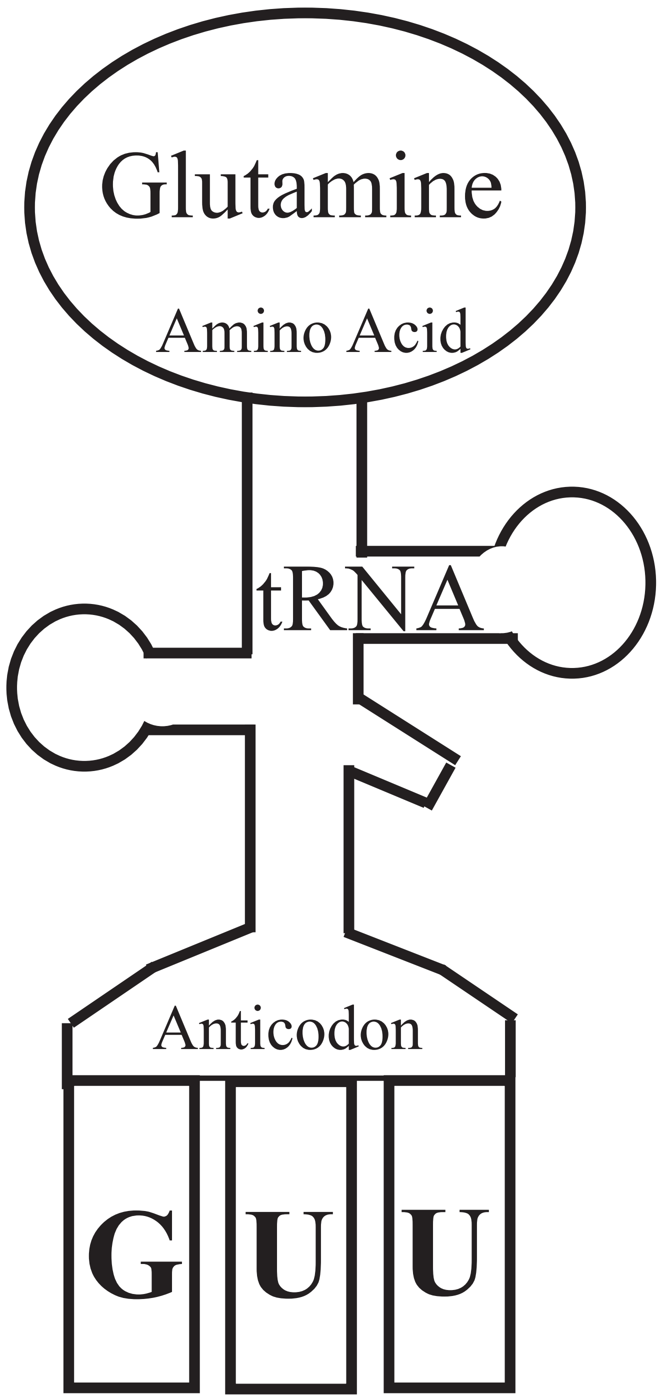
Anticodon
G
U
G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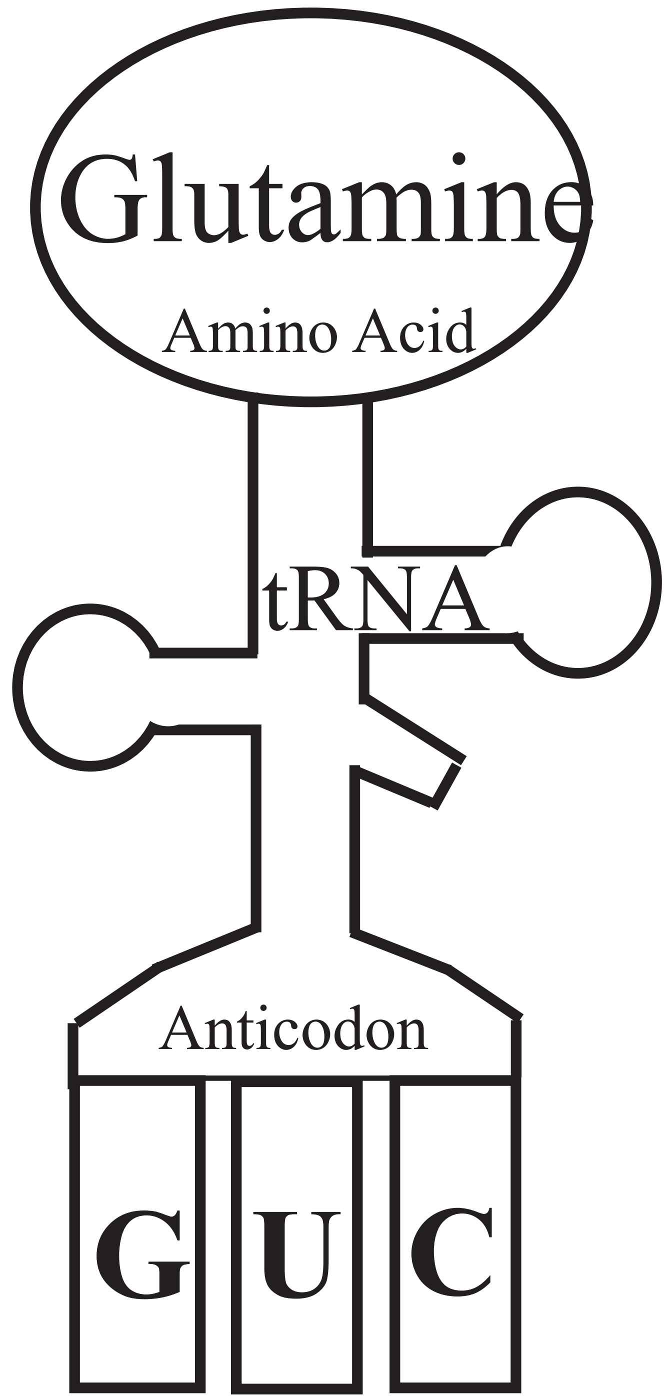
Anticodon
G U U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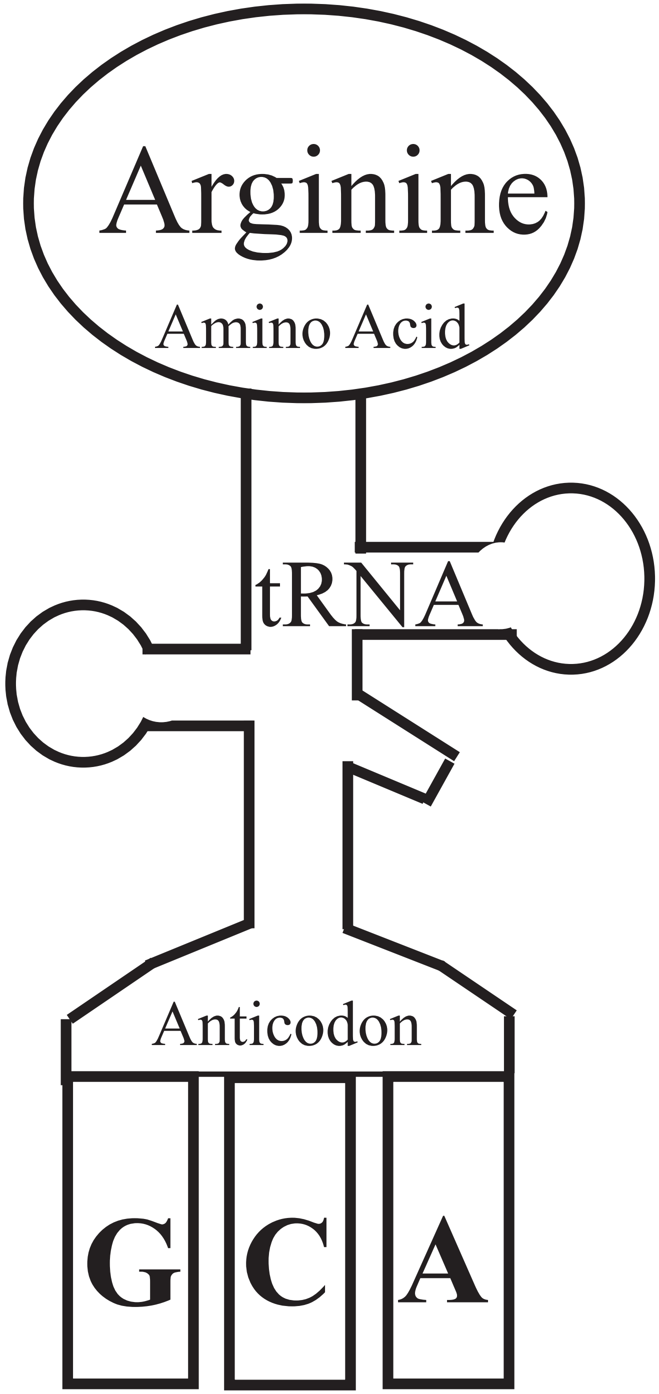
G U C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C
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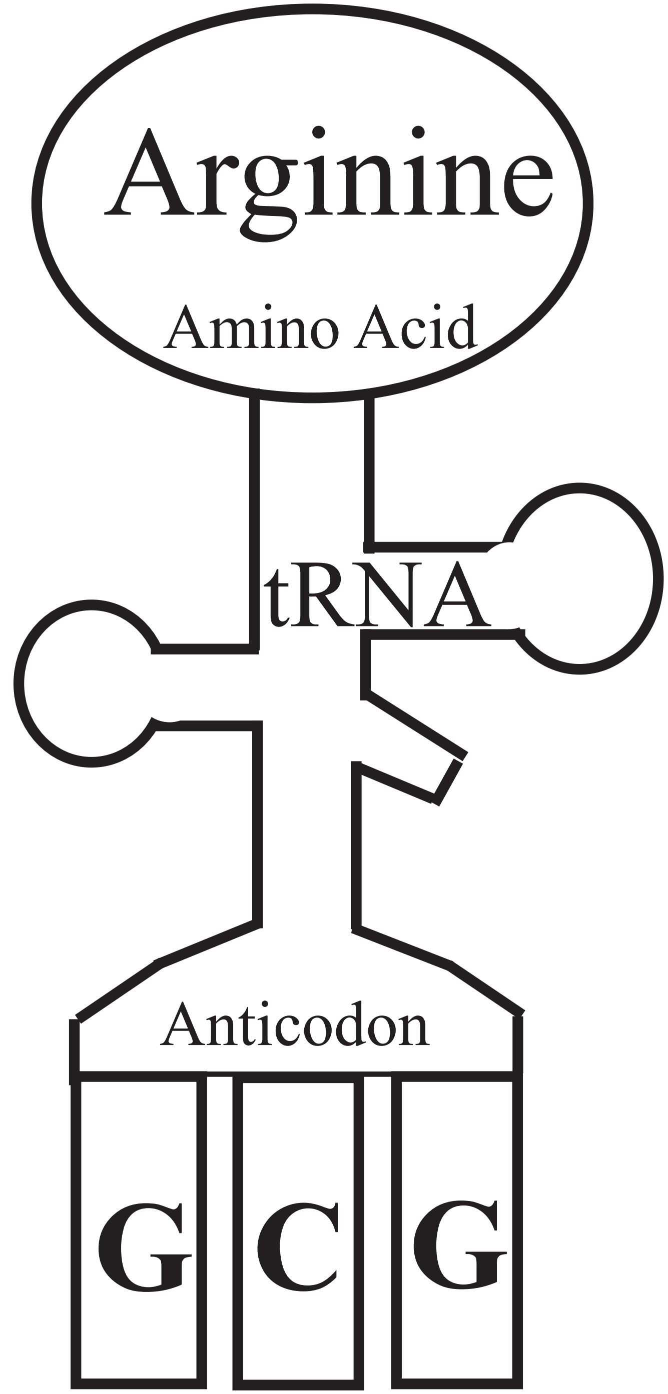
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C
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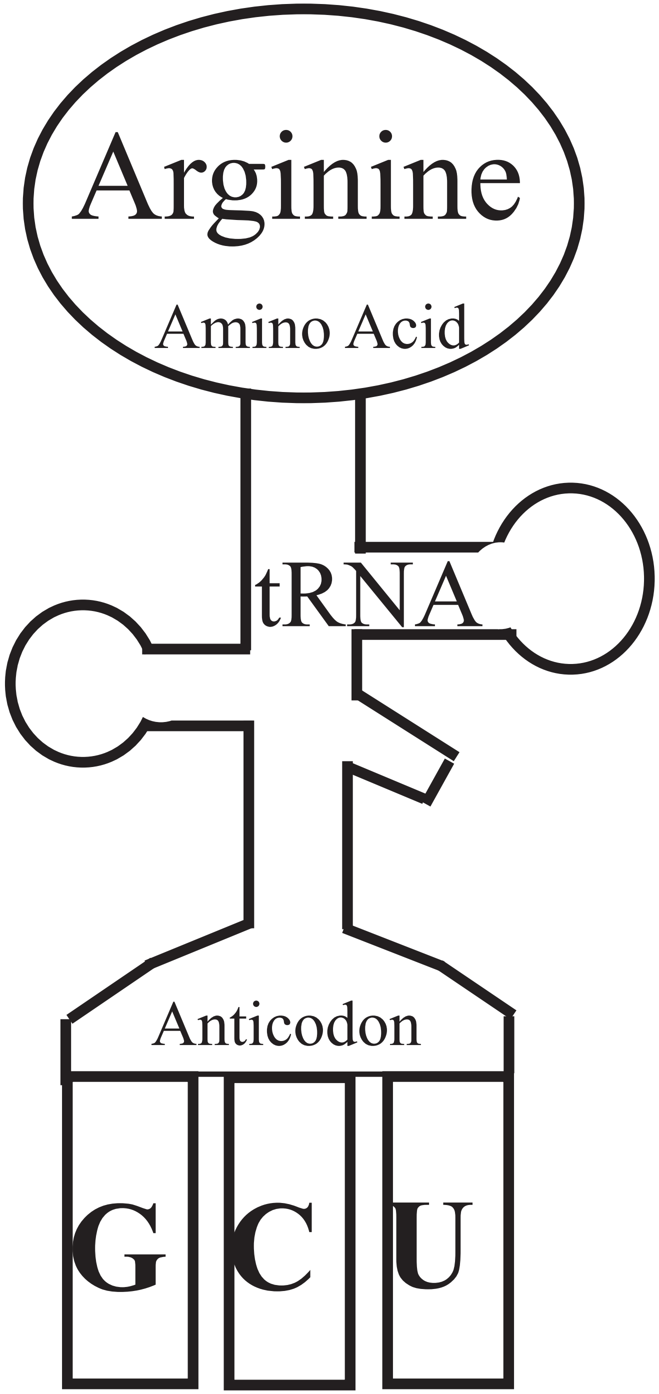
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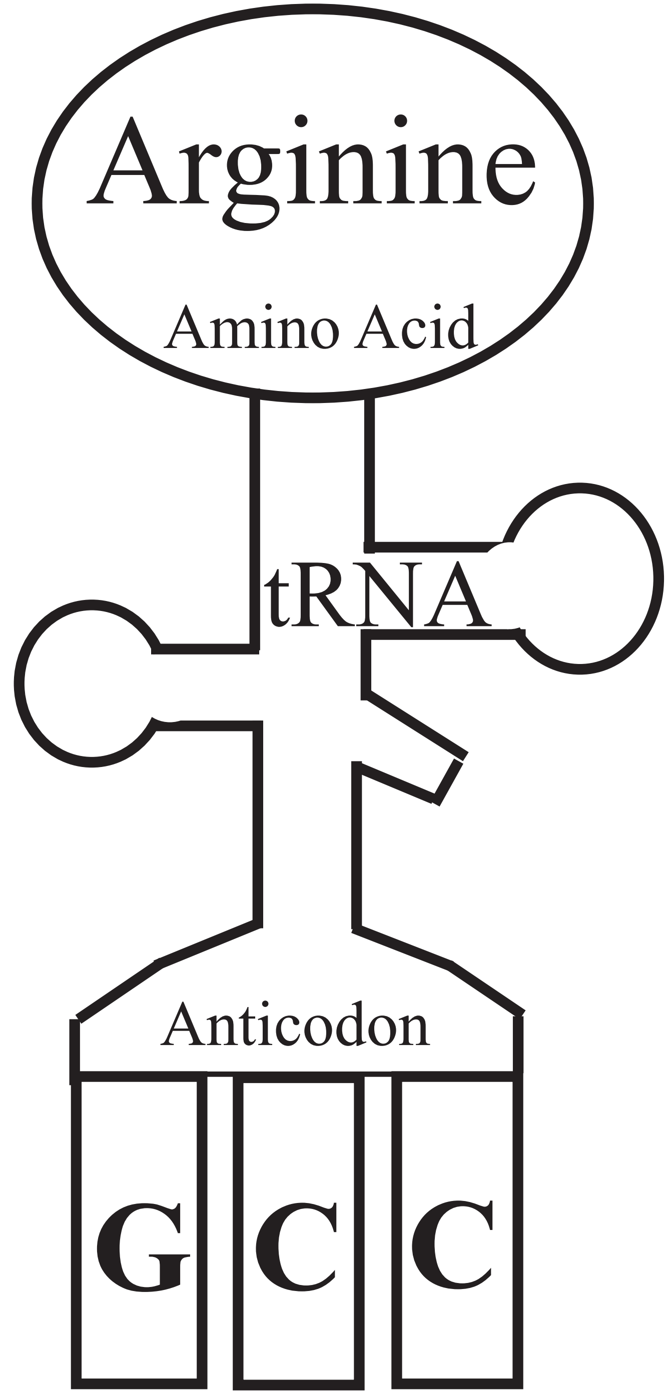
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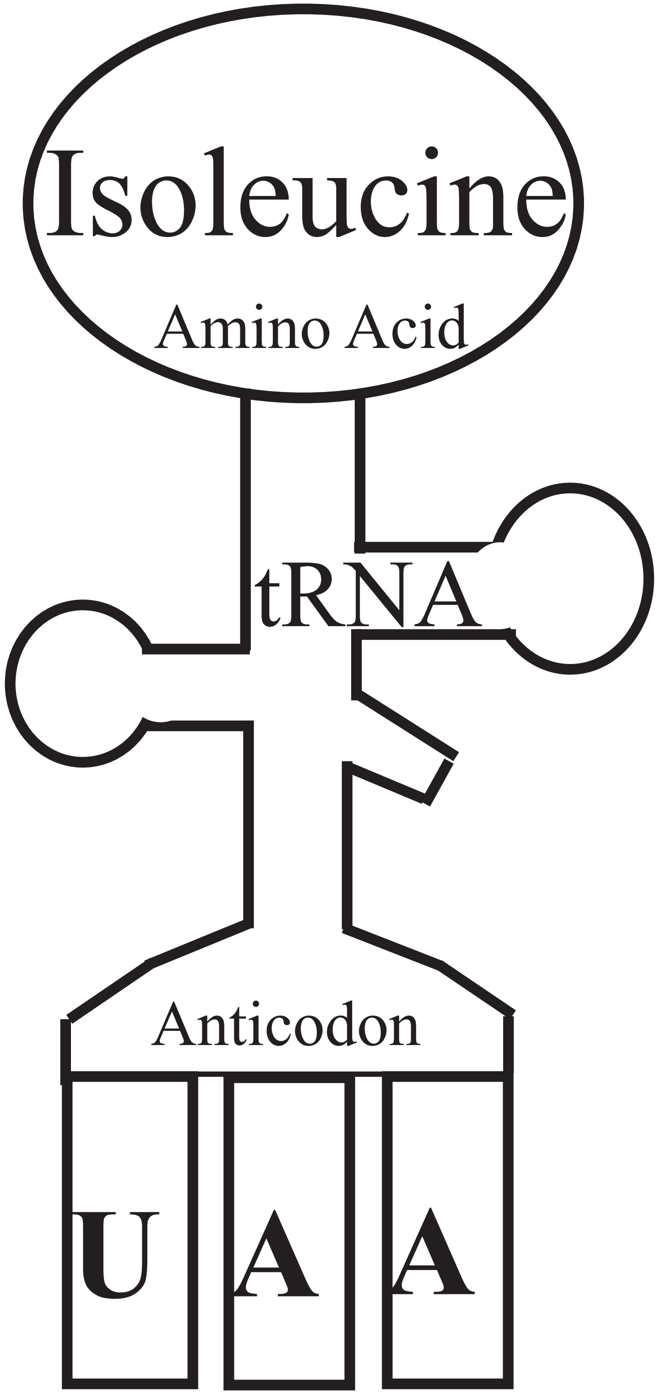
Anticodon
G C C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Amino Acid
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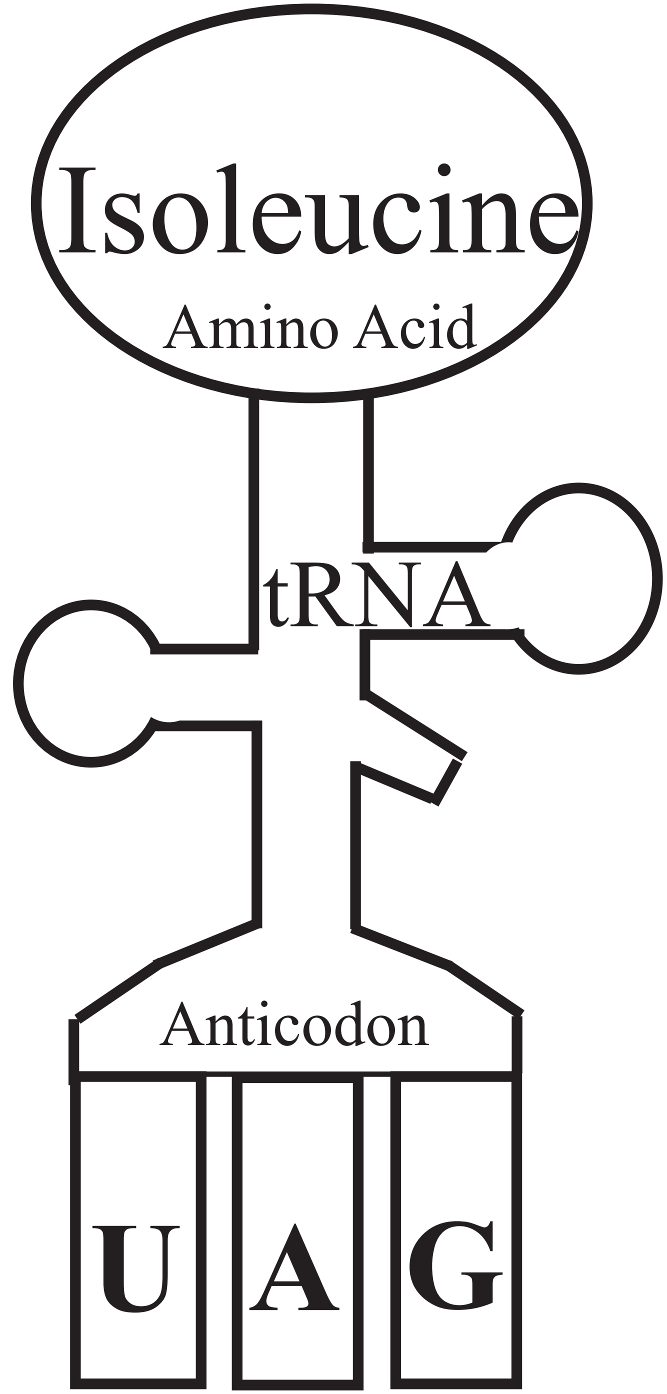
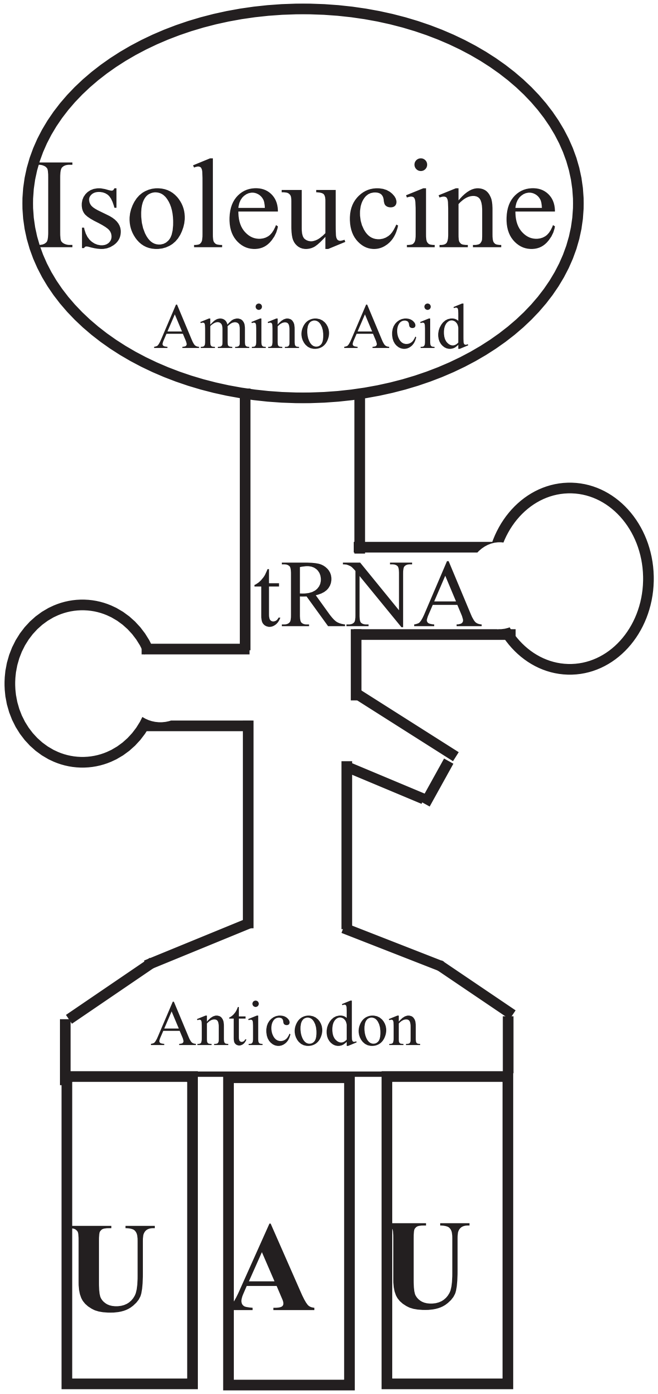
Anticodon
U A A


Isoleucine
Amino Acid
tRNA
Anticodon
U A G


Isoleucine
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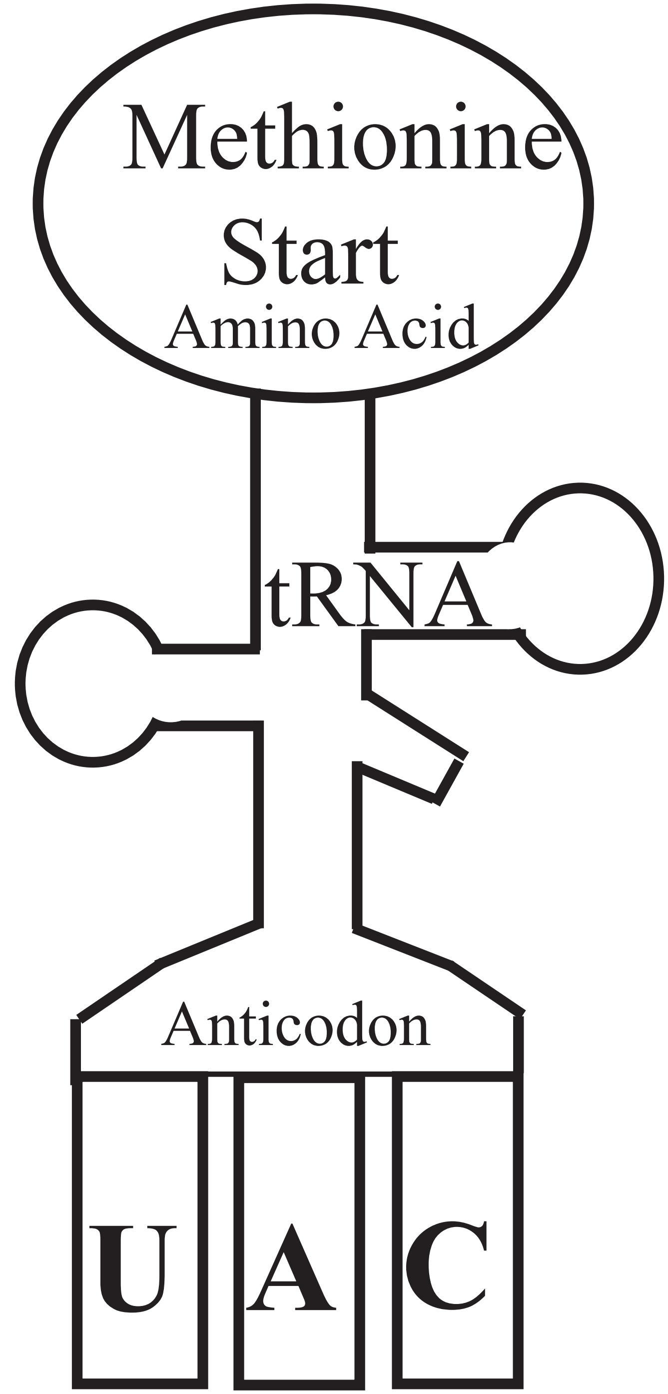
Anticodon
U
A
U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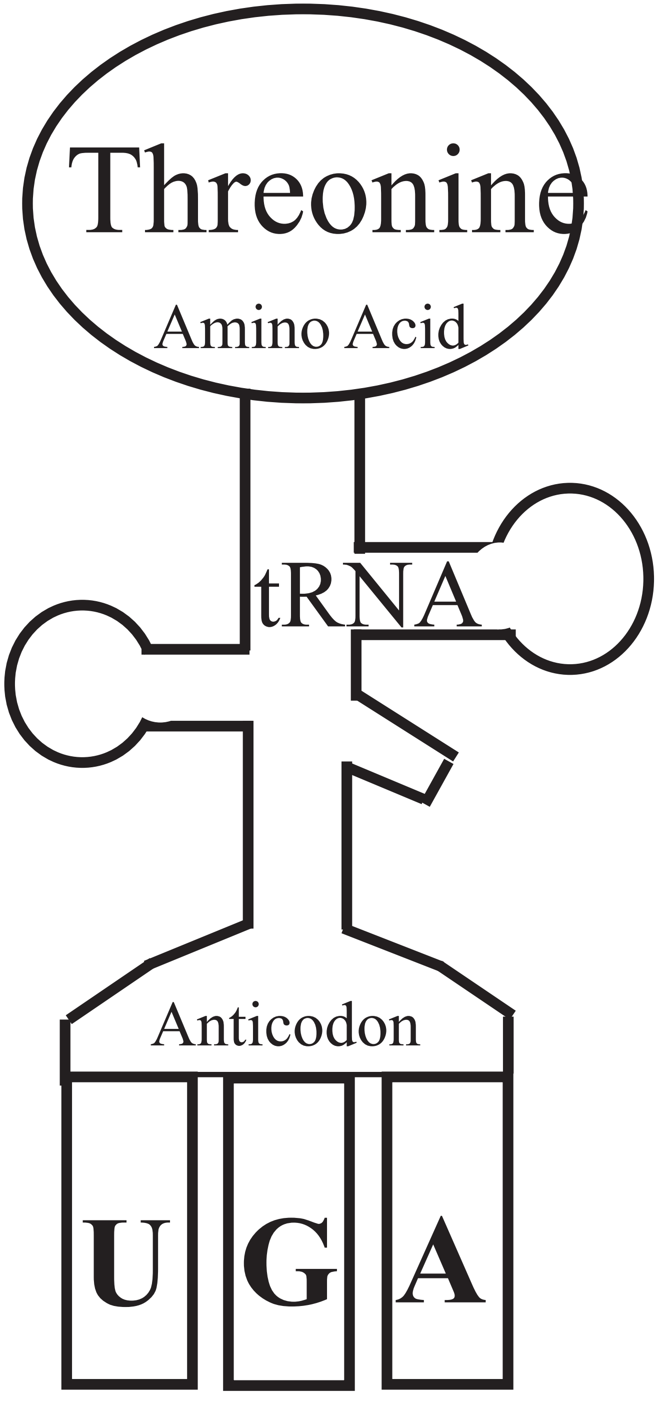
Start
Amino Acid
tRNA
Anticodon
U
A
C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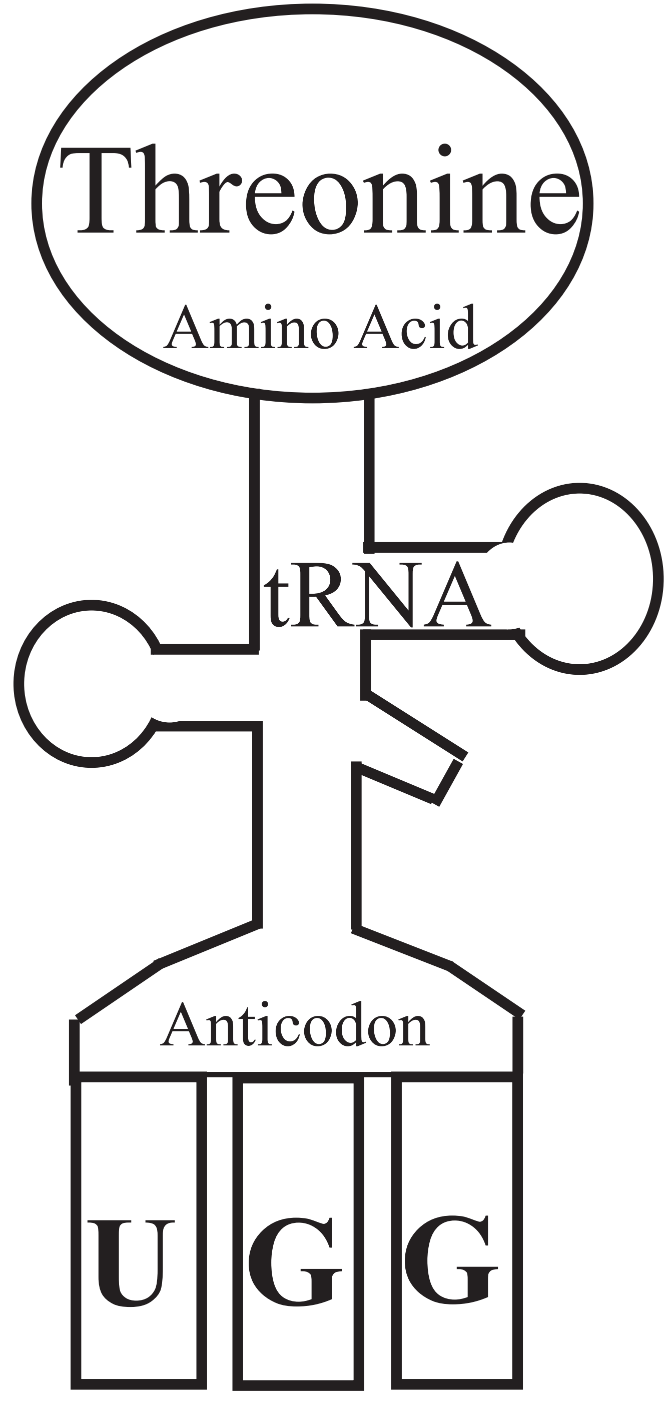
Anticodon
U G A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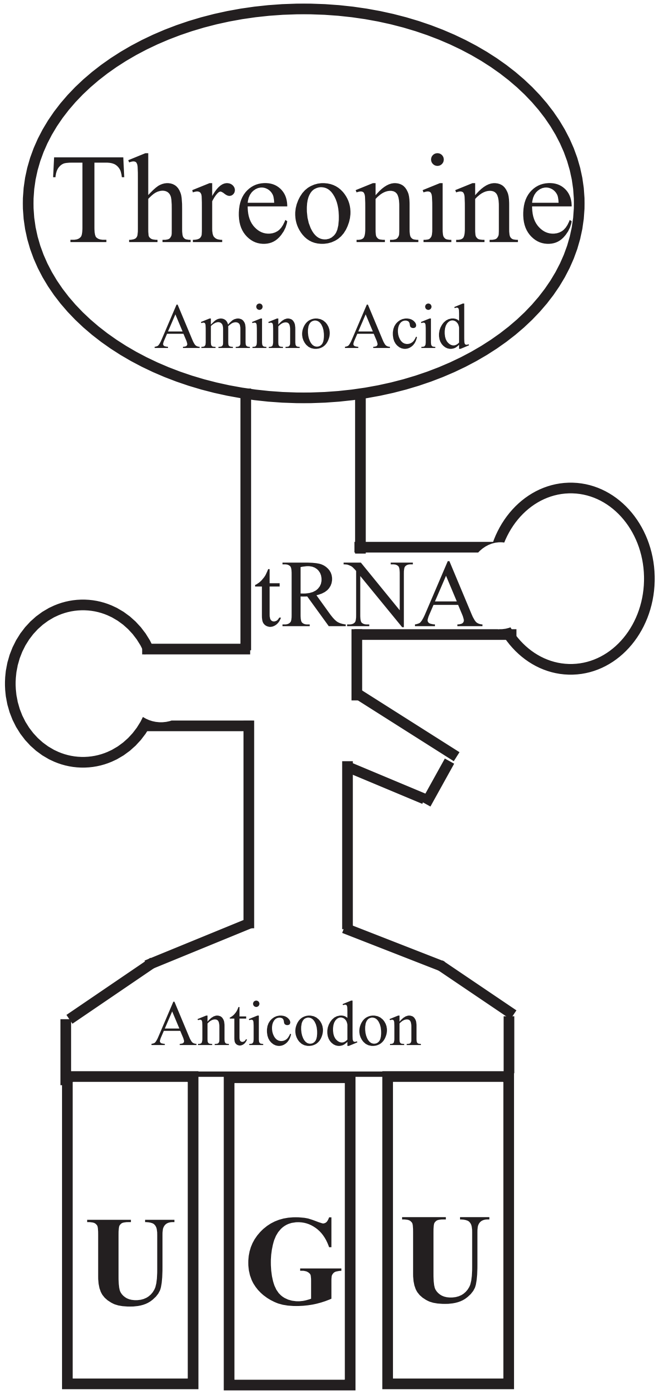
U G G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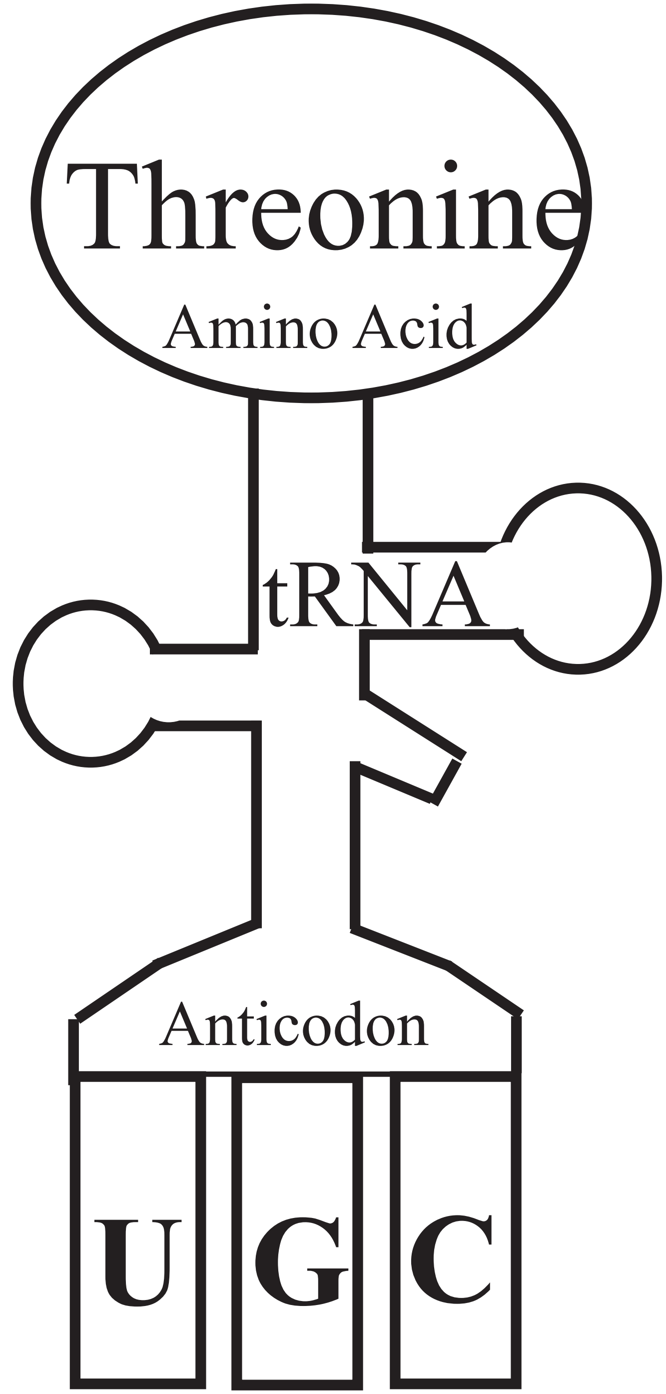
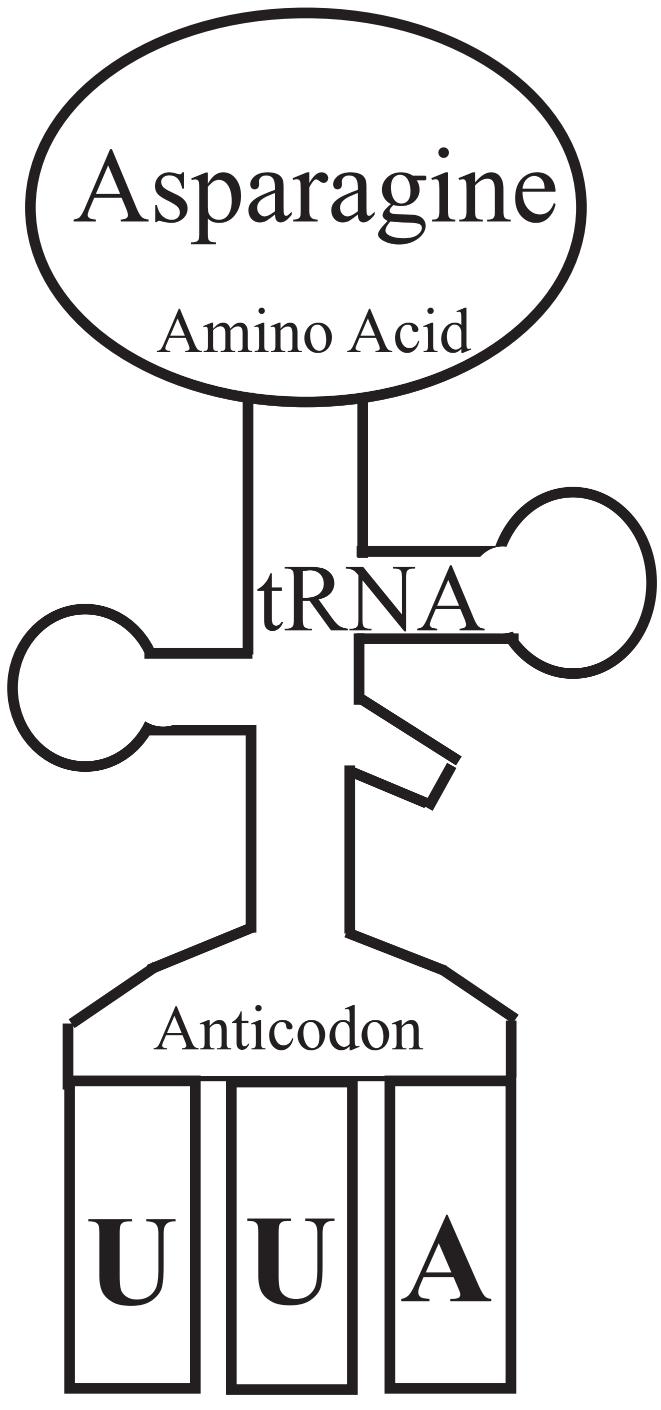

Threonine
Amino Acid
tRNA
Anticodon
U G C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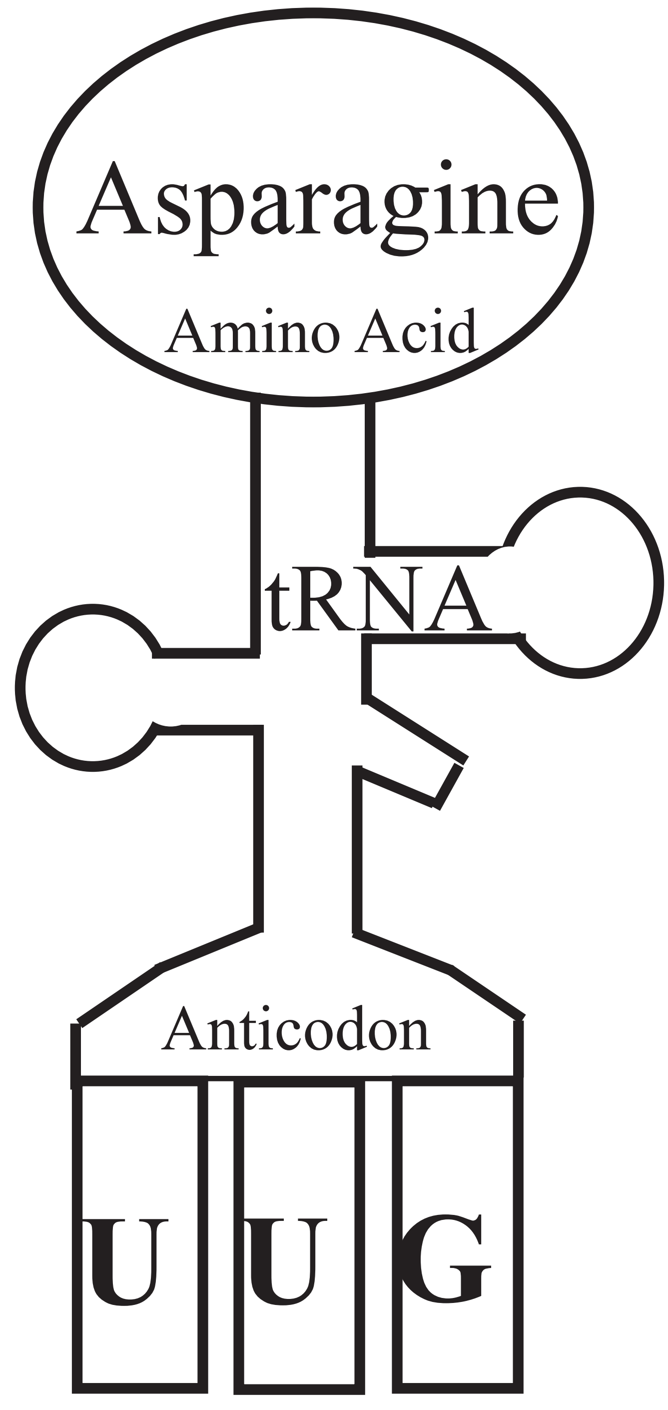
Amino Acid
tRNA
Anticodon
U U A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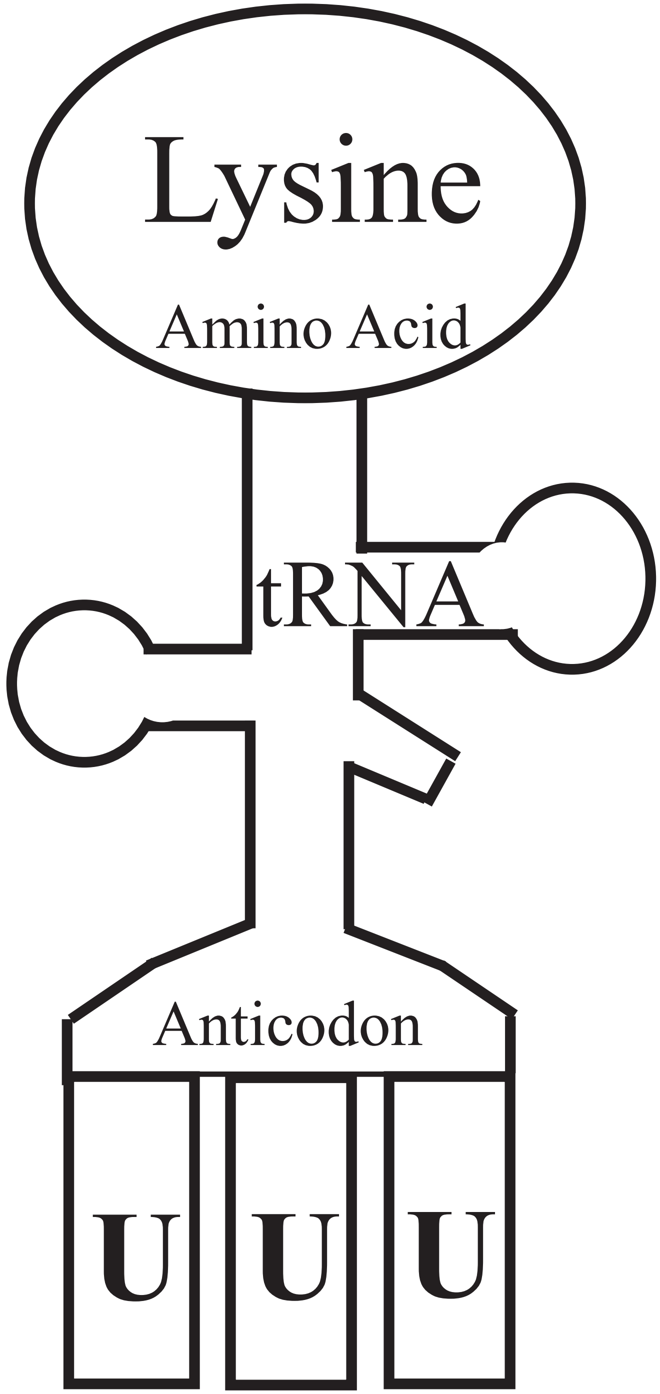
Amino Acid
tRNA
Anticodon
U U G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Amino Acid
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Anticodon
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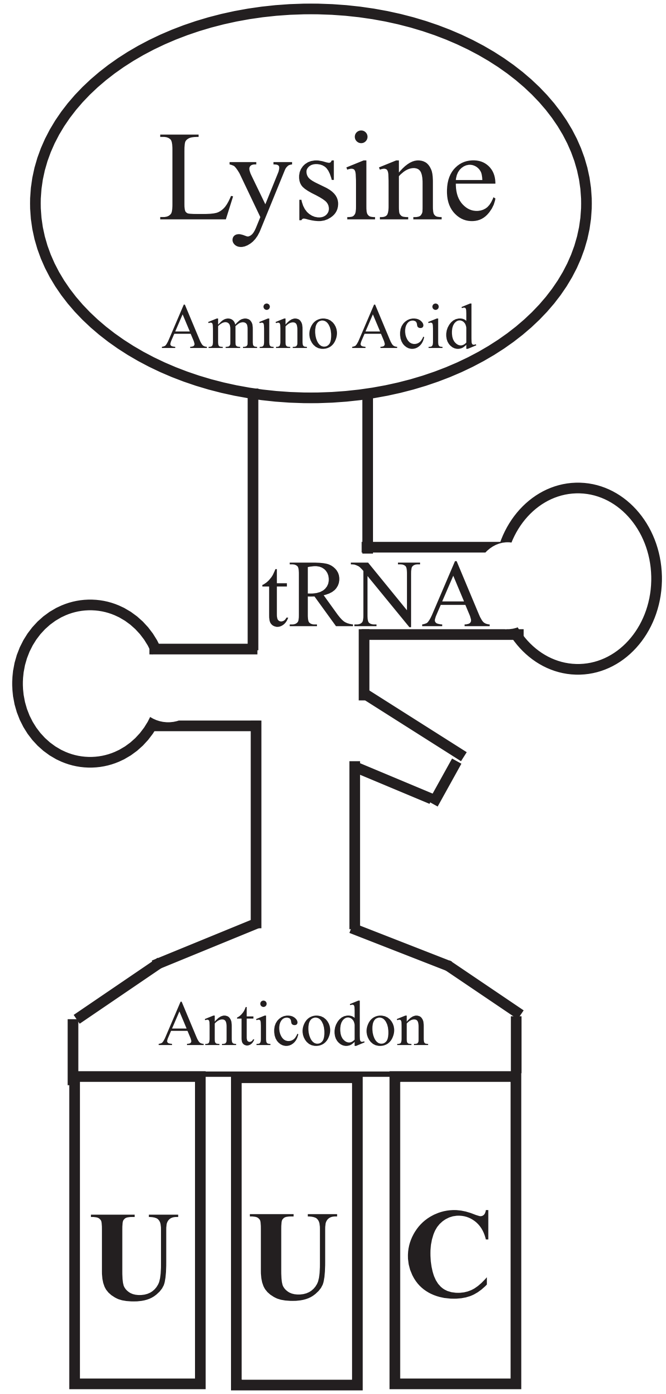
U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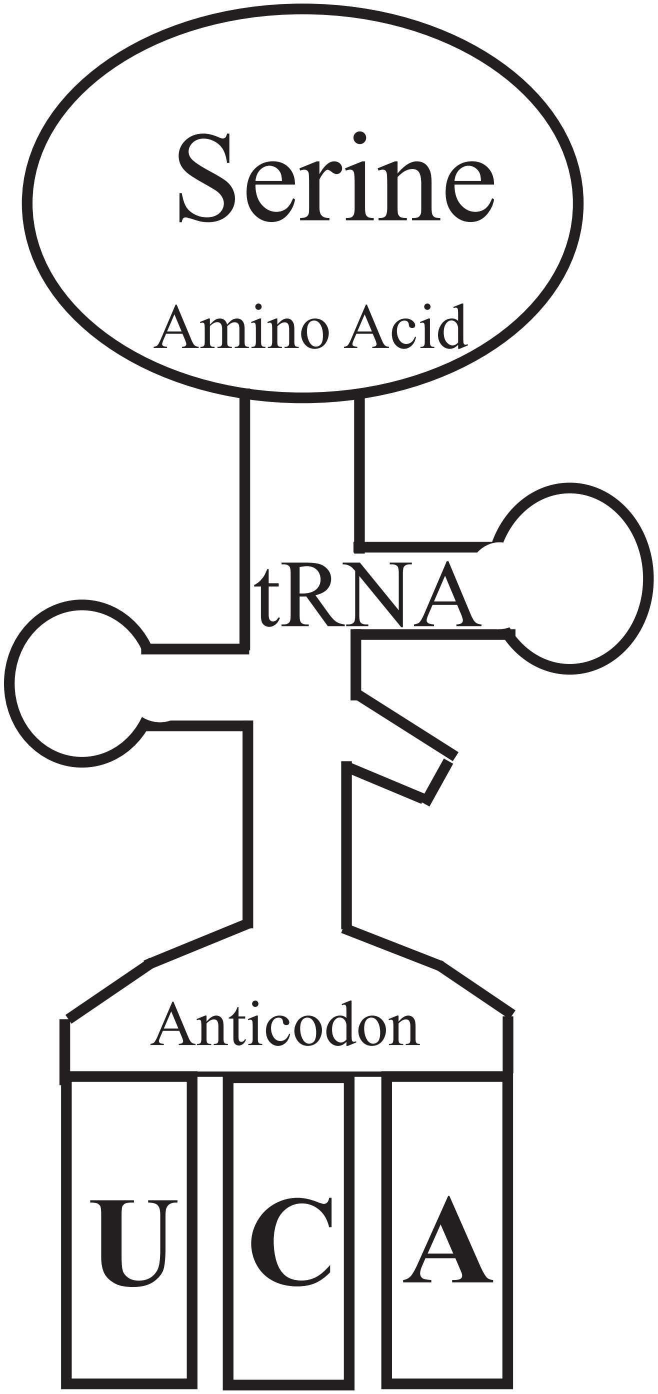
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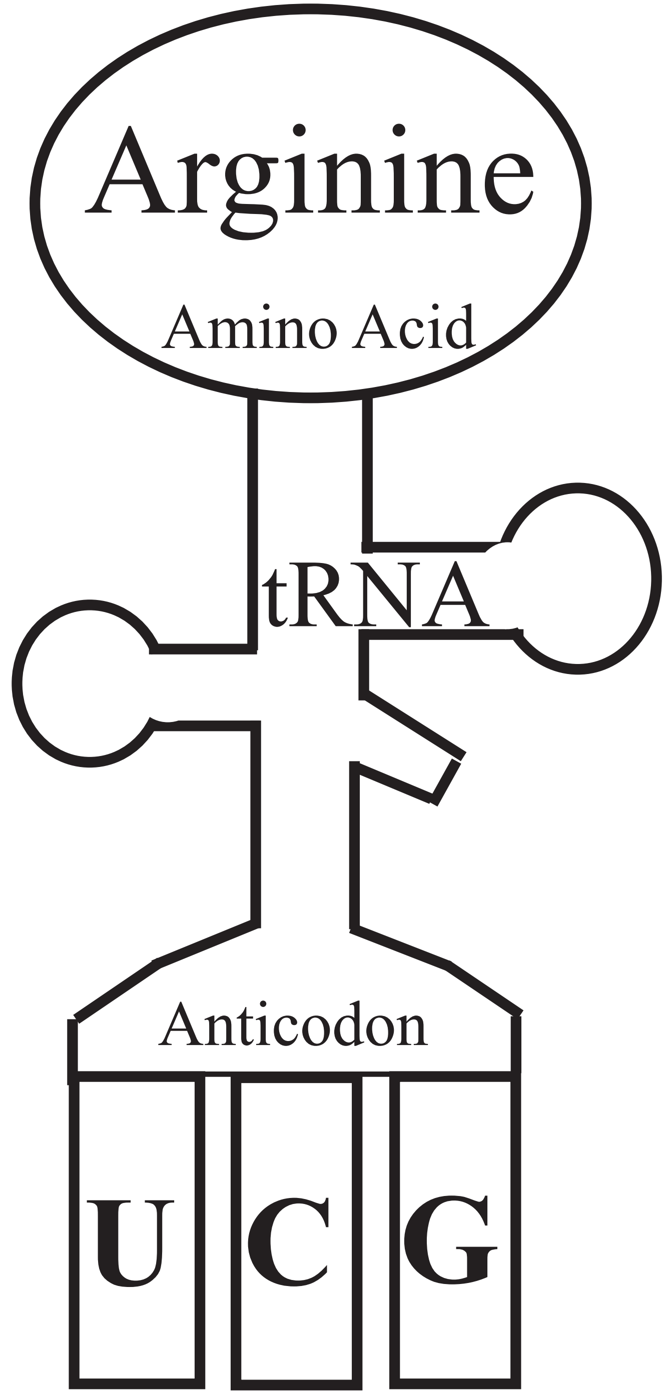
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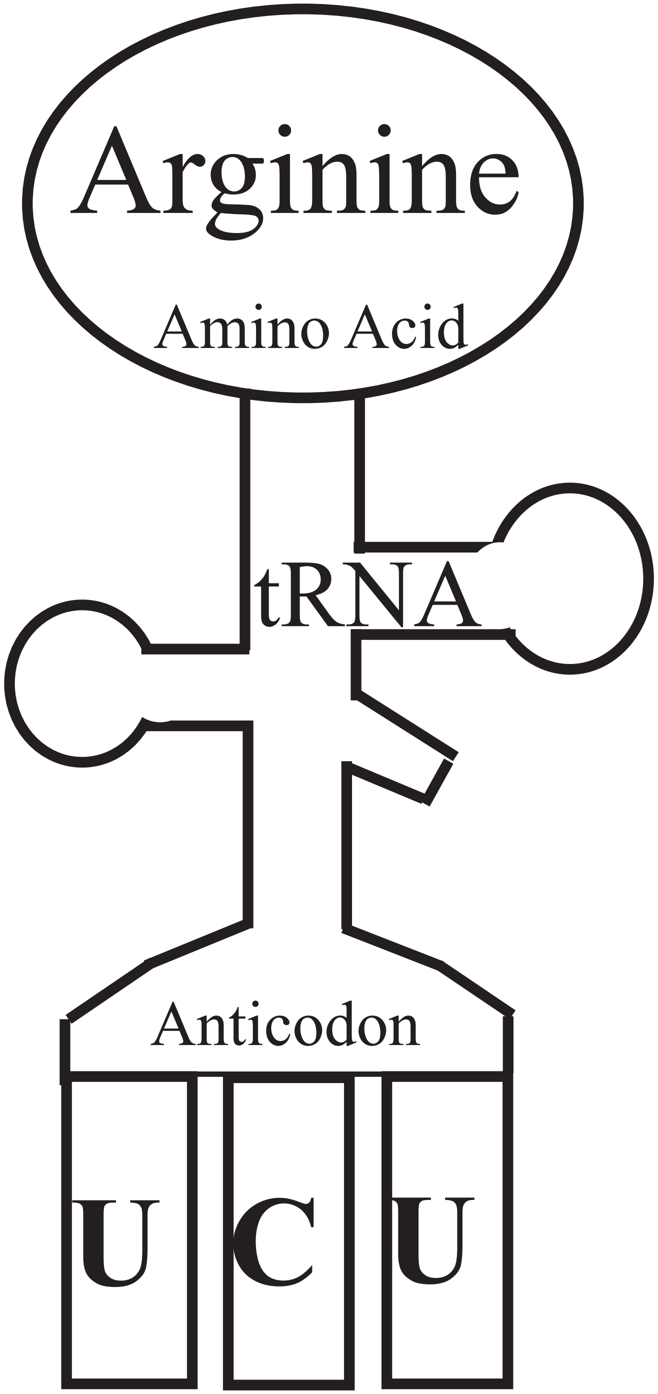
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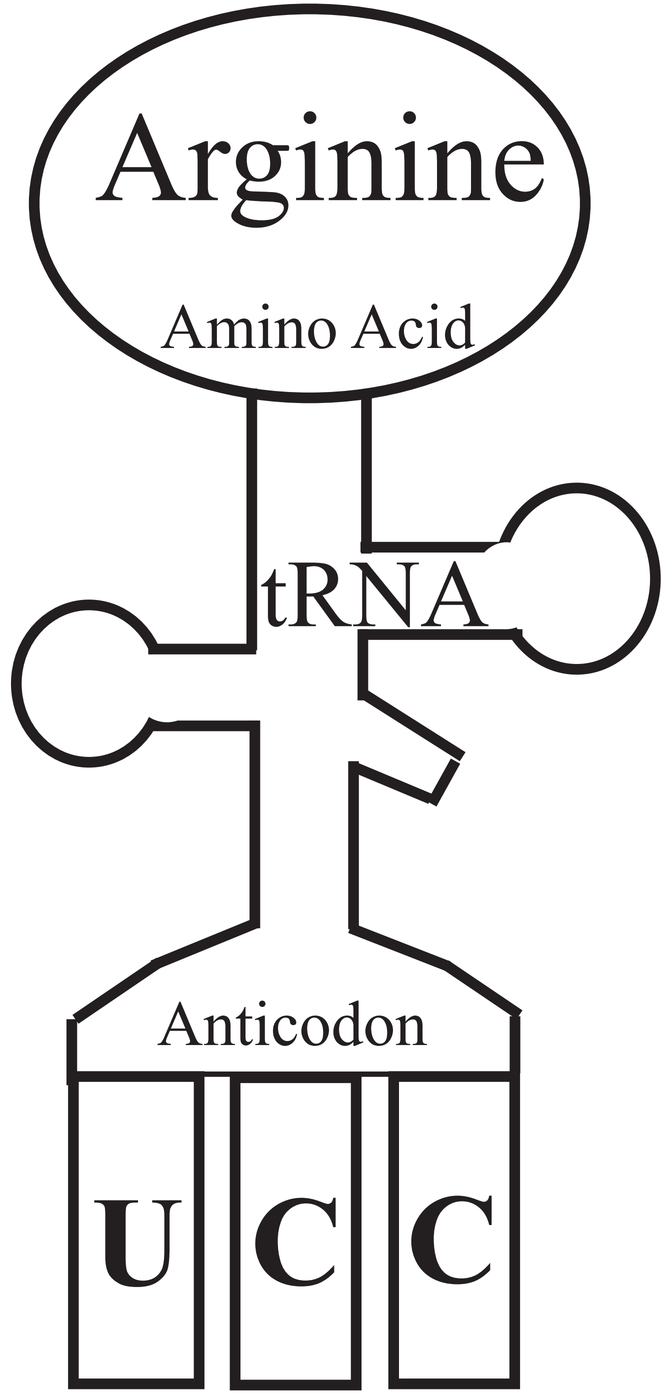
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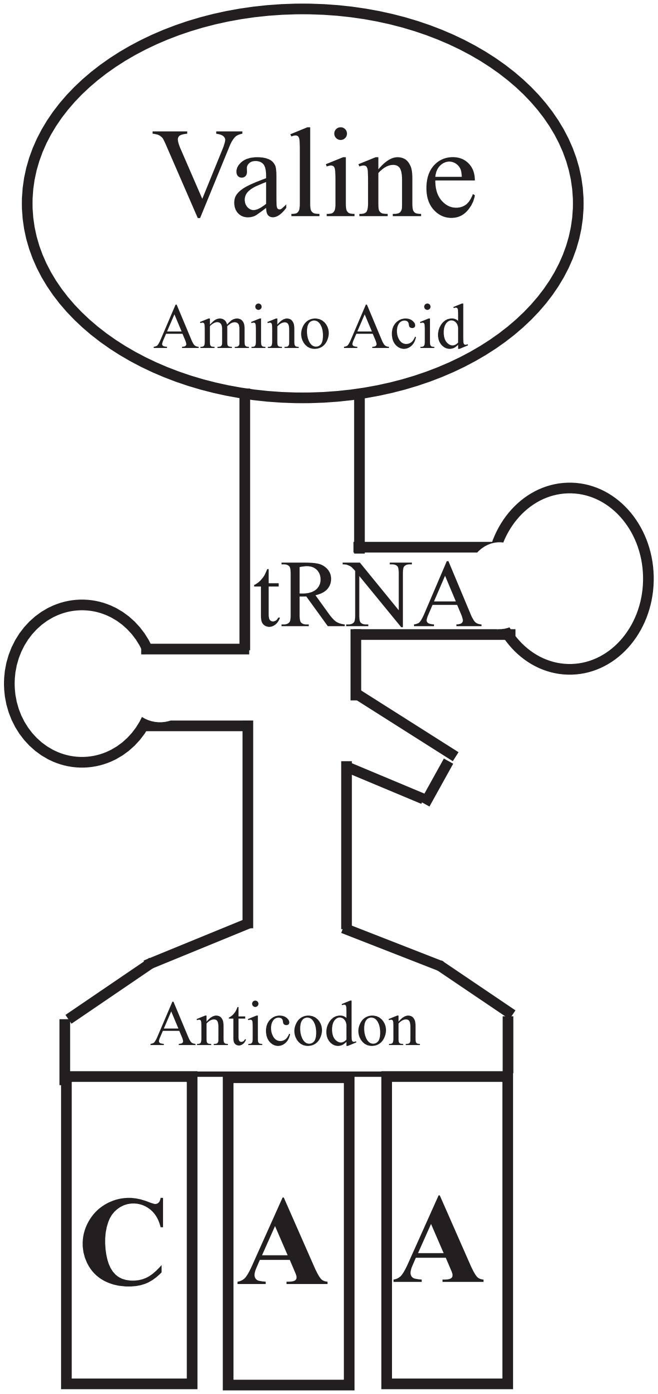
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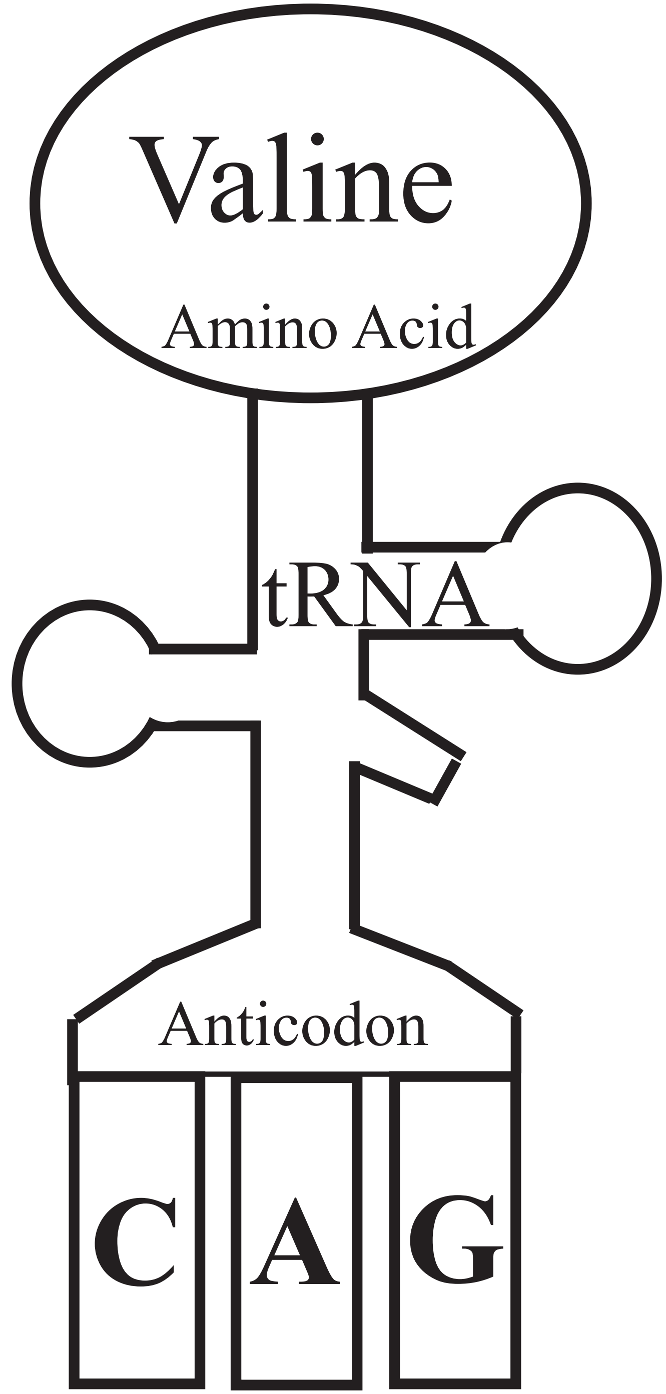
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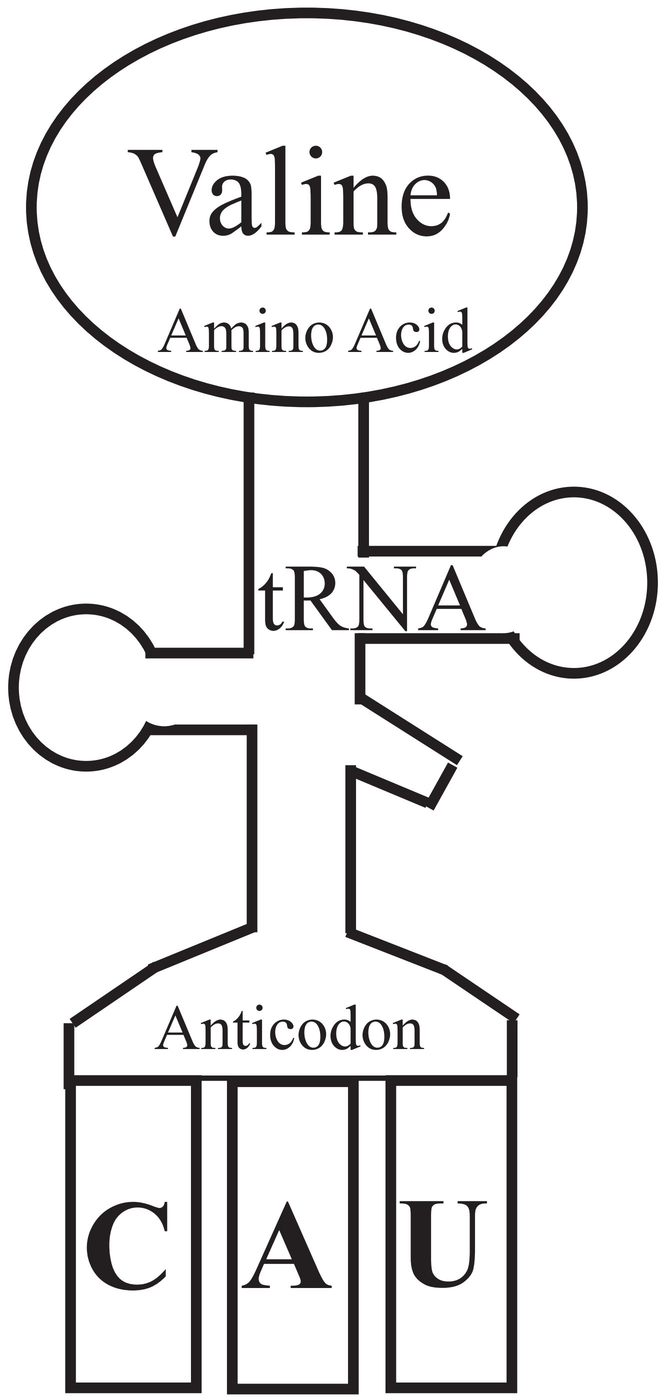
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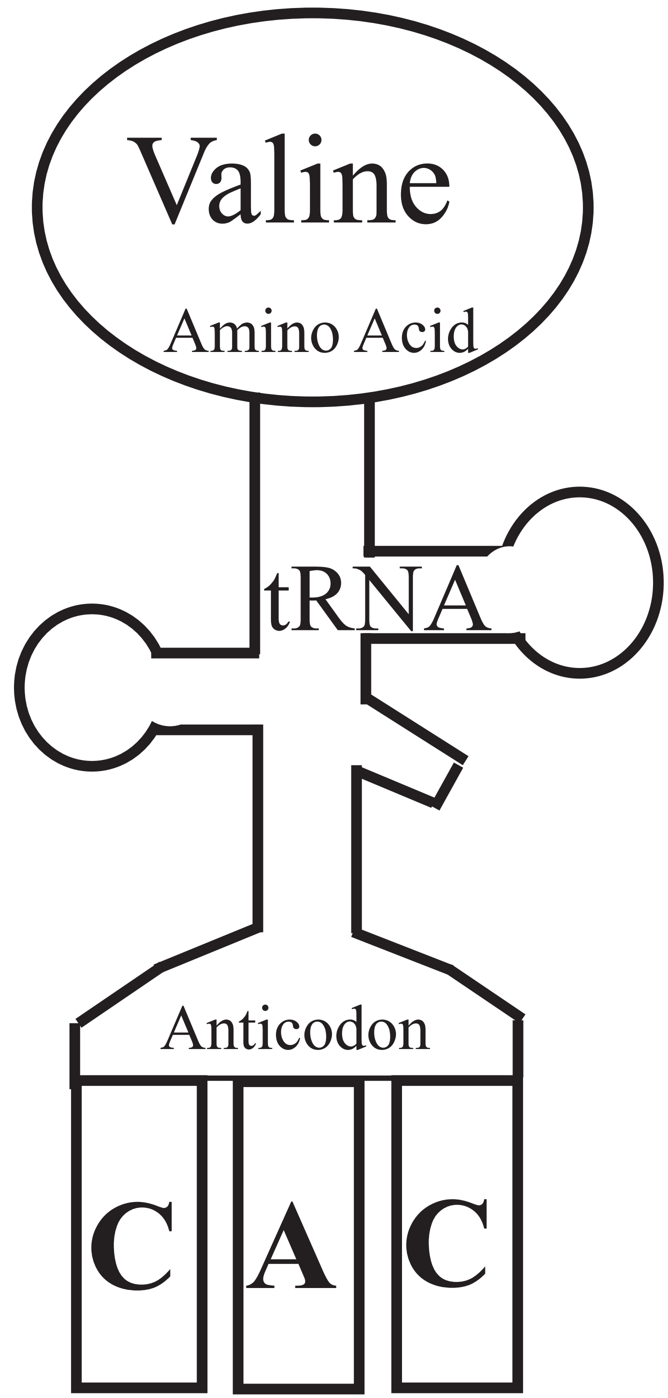
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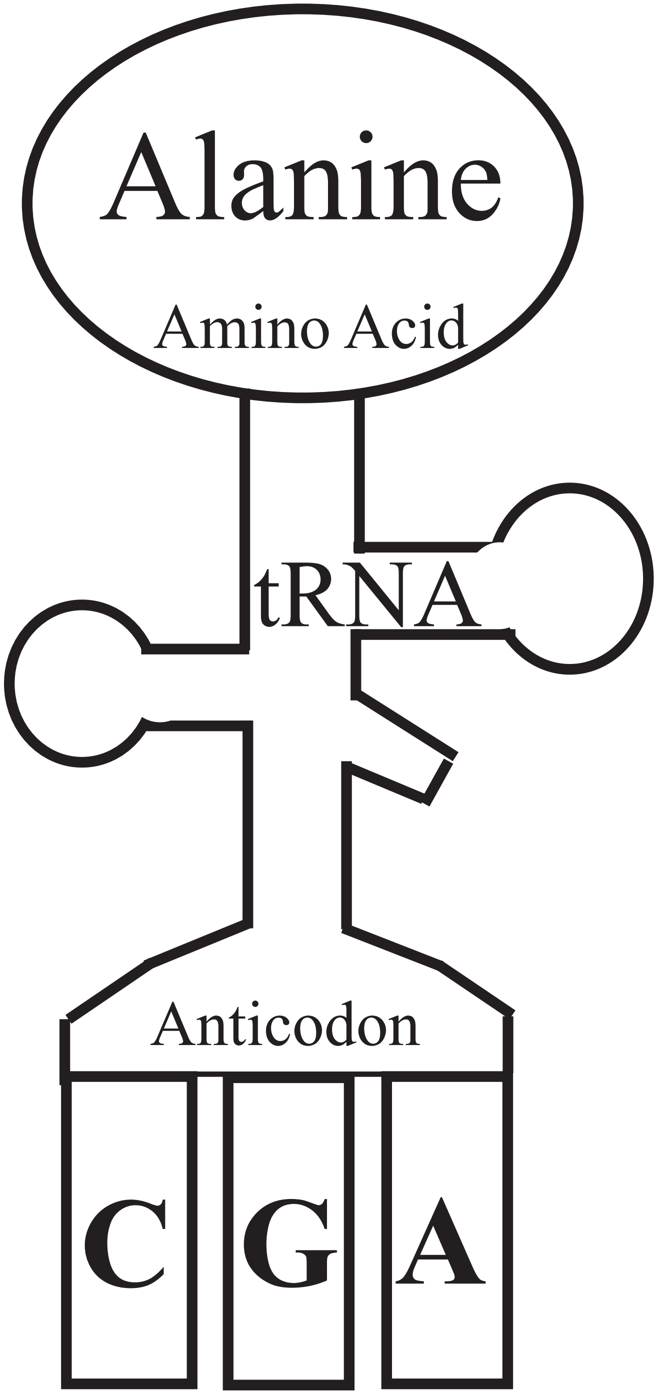
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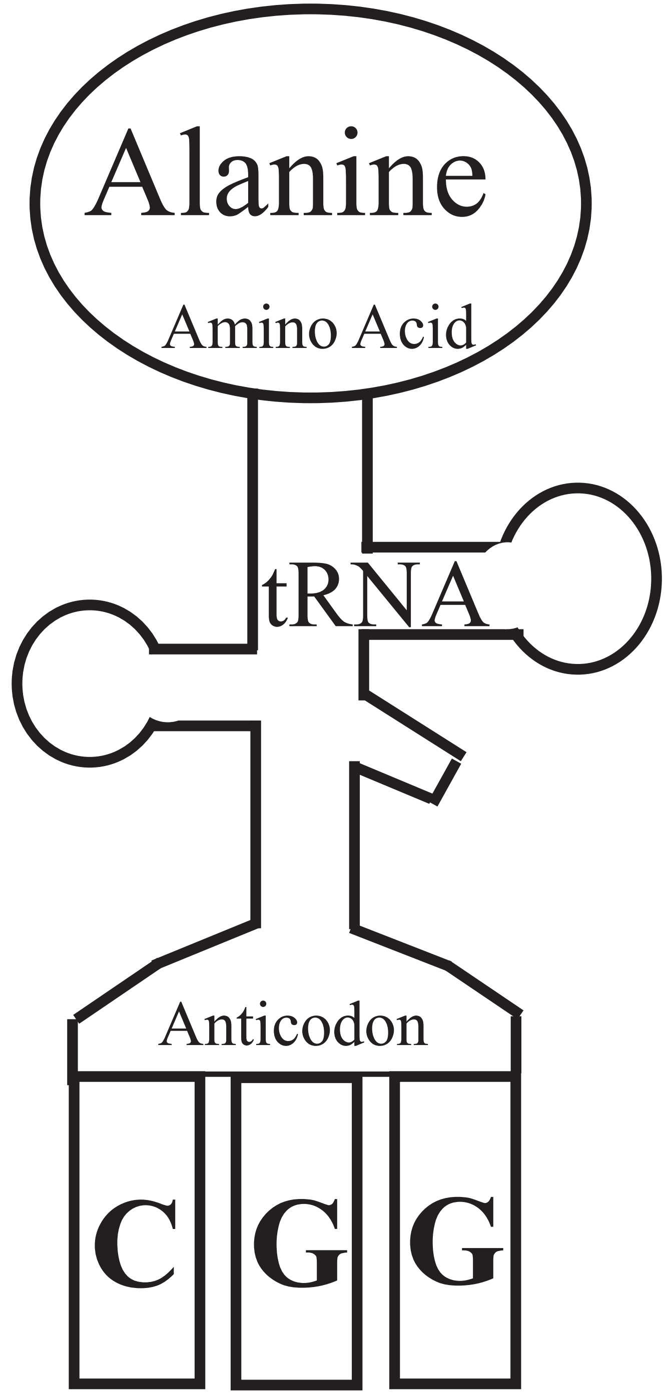
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Amino Acid
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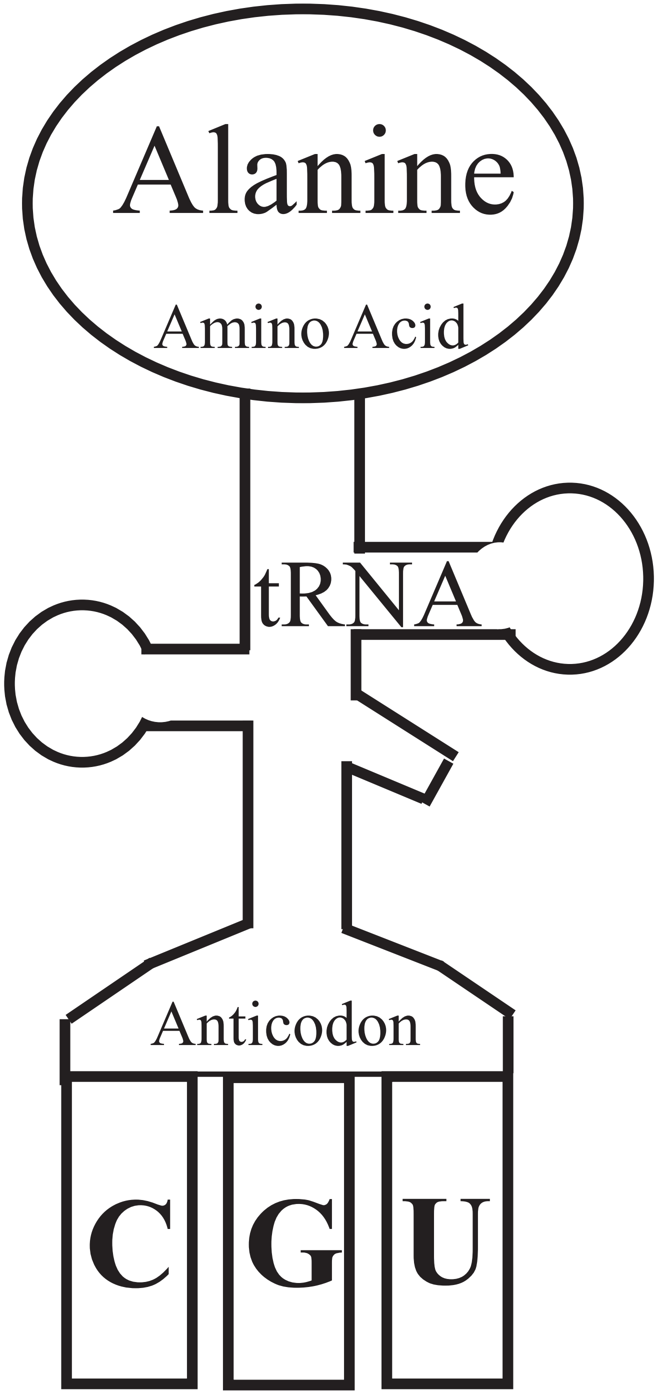
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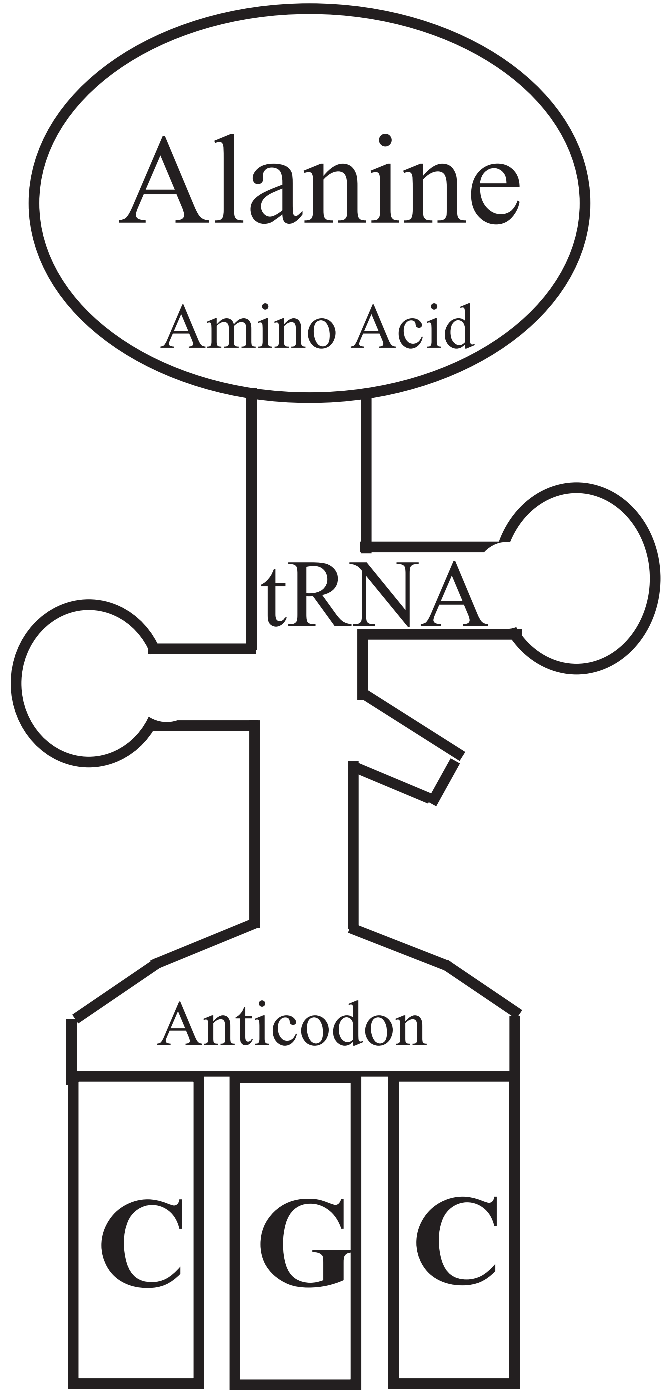
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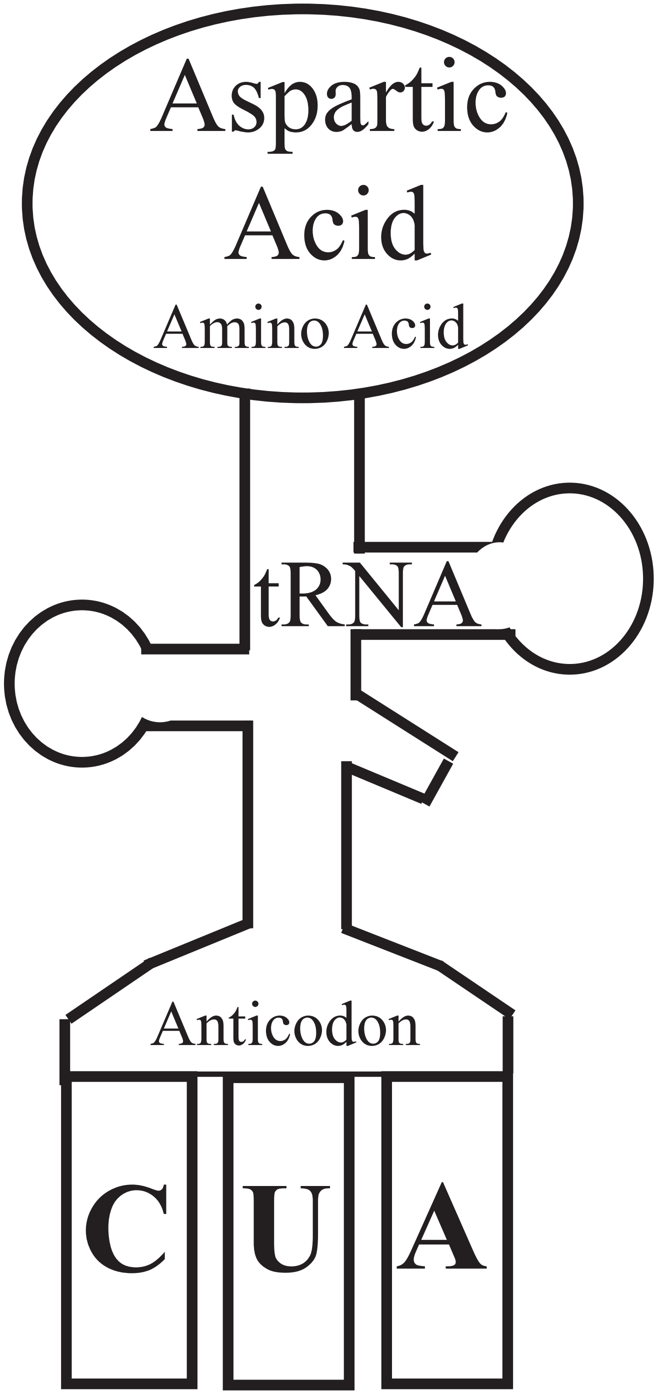
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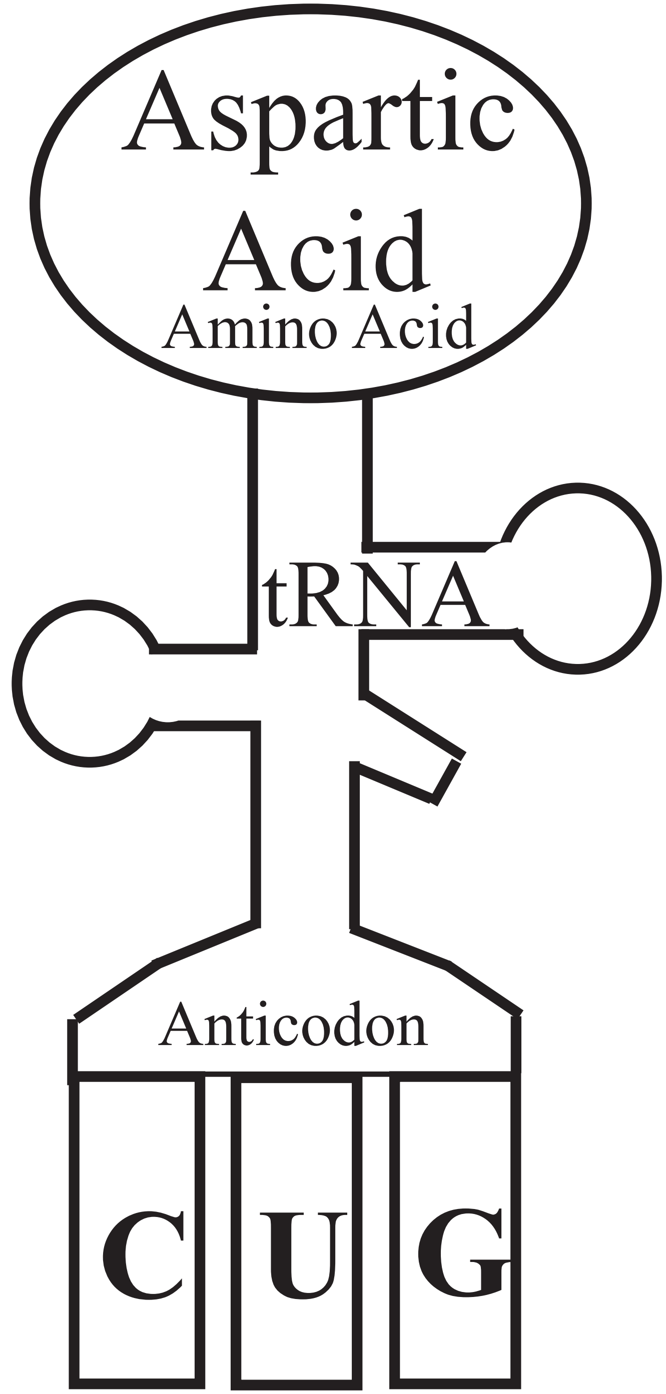
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Amino Acid
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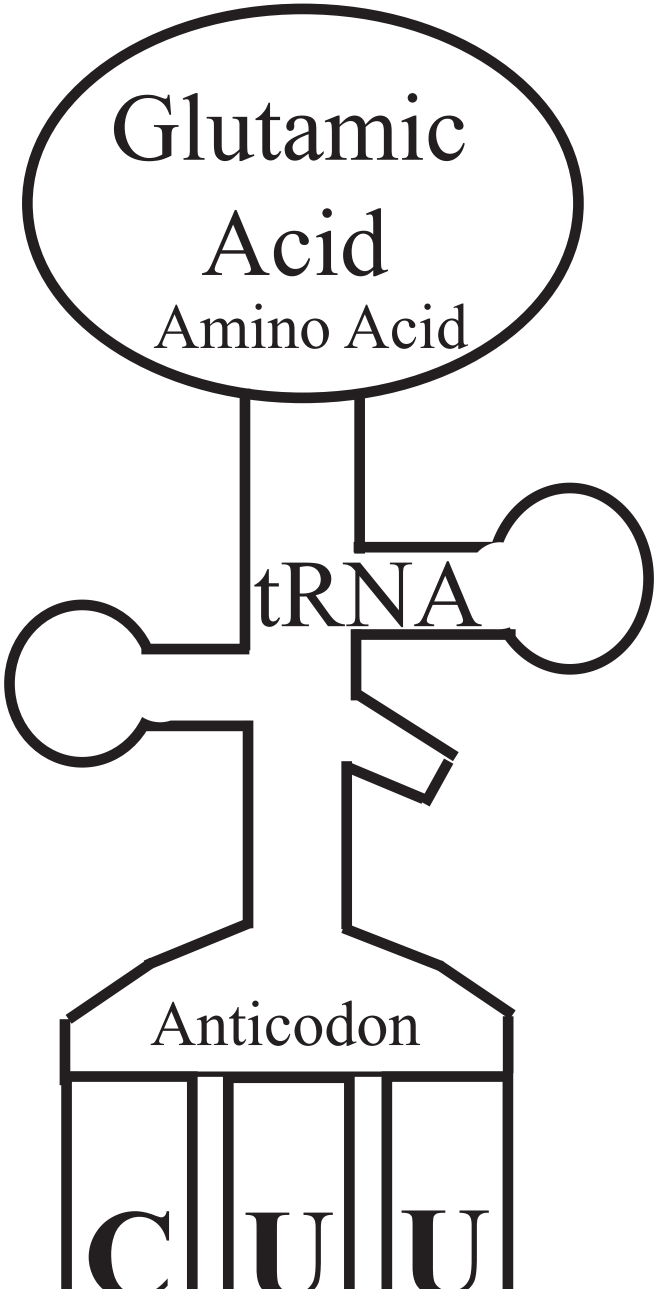
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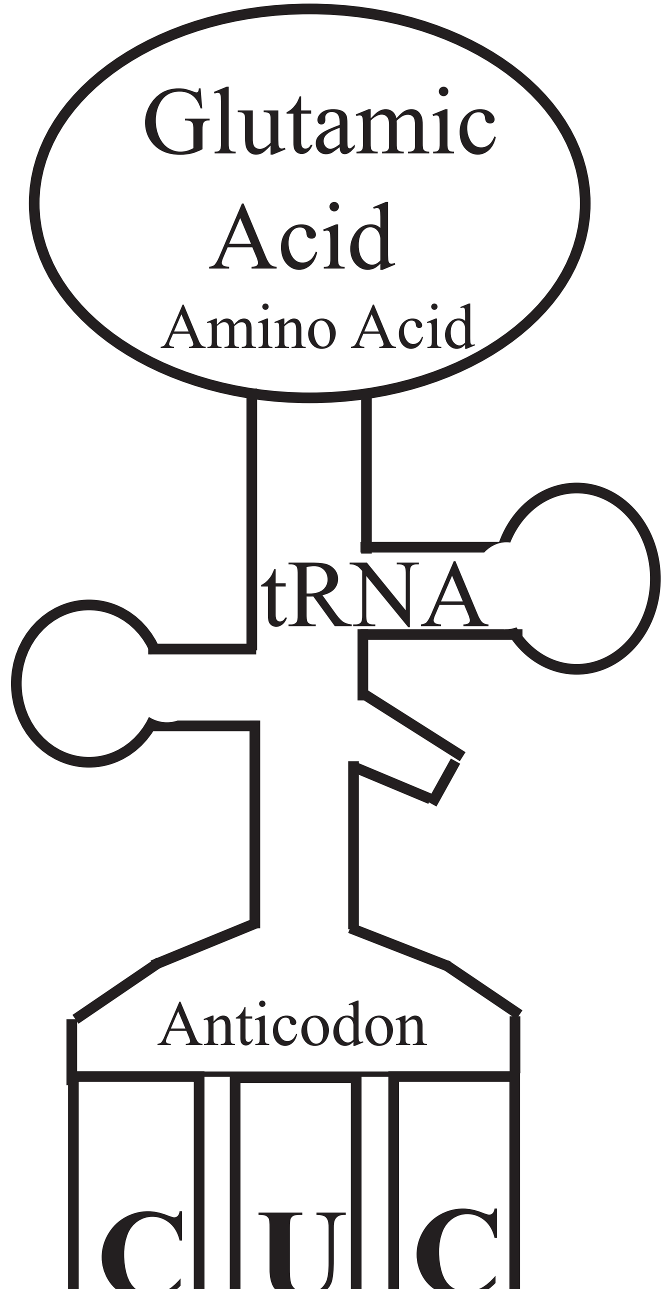
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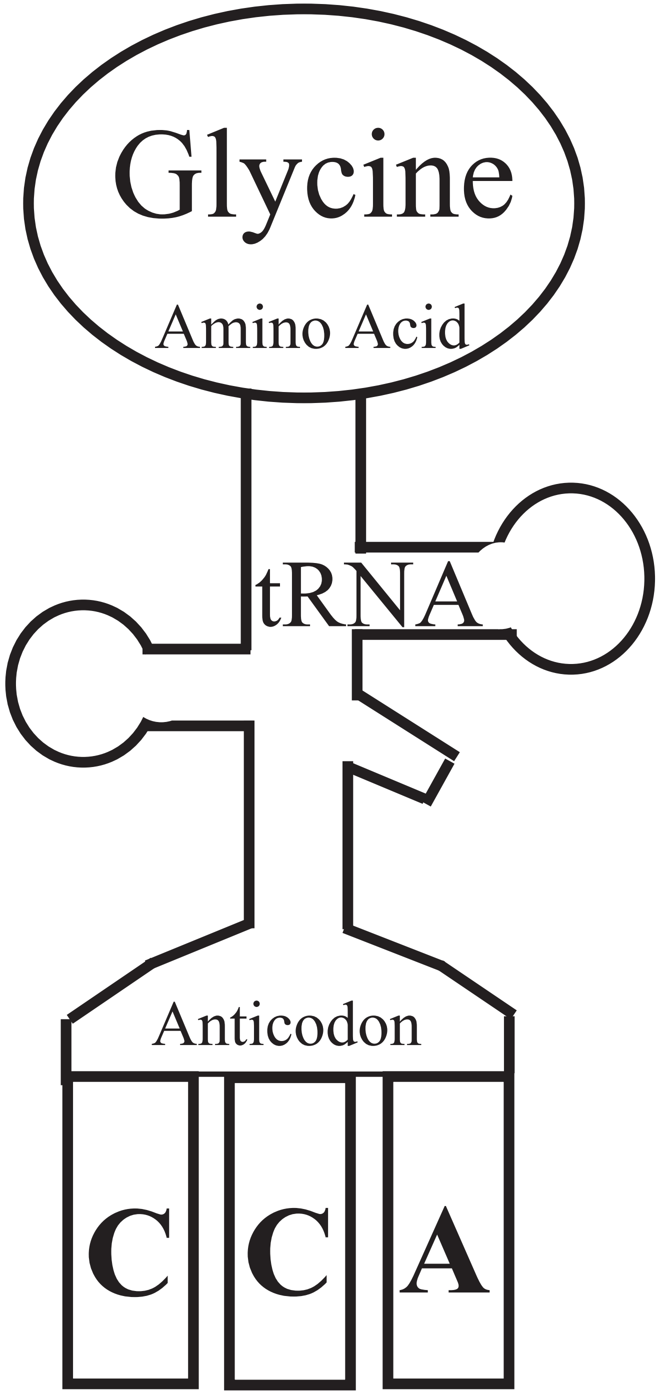

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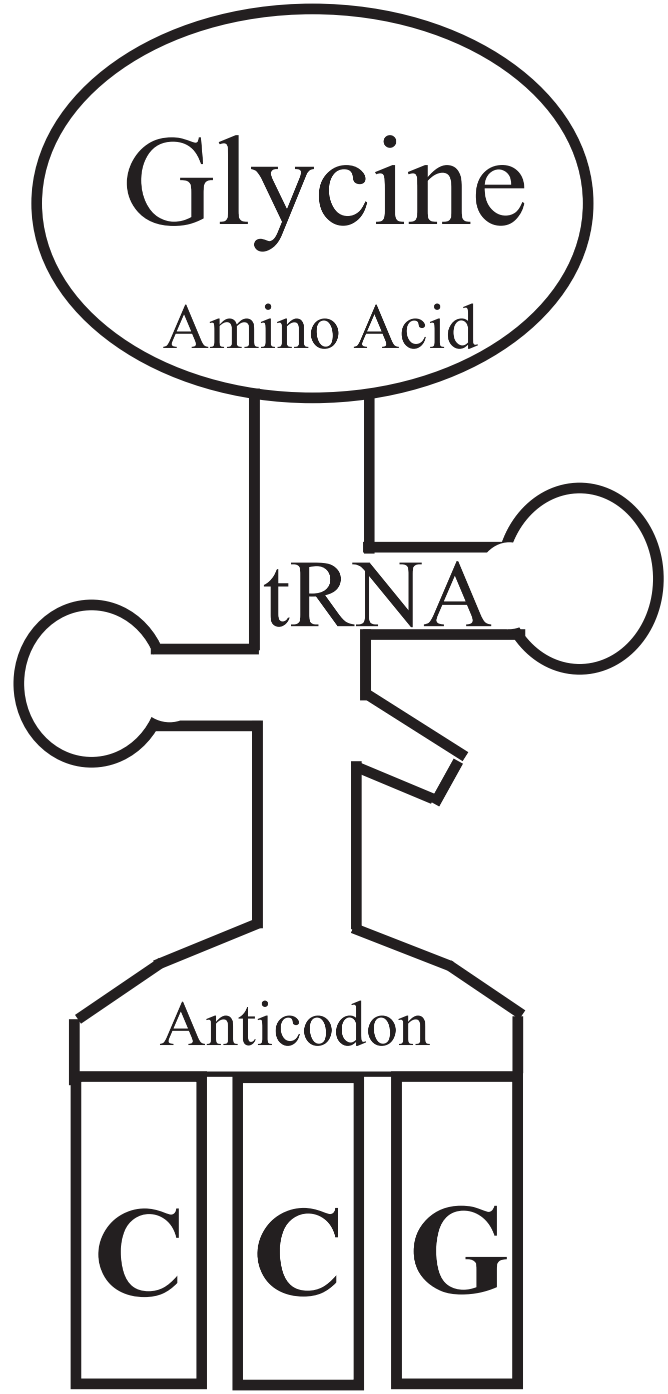

Glycine
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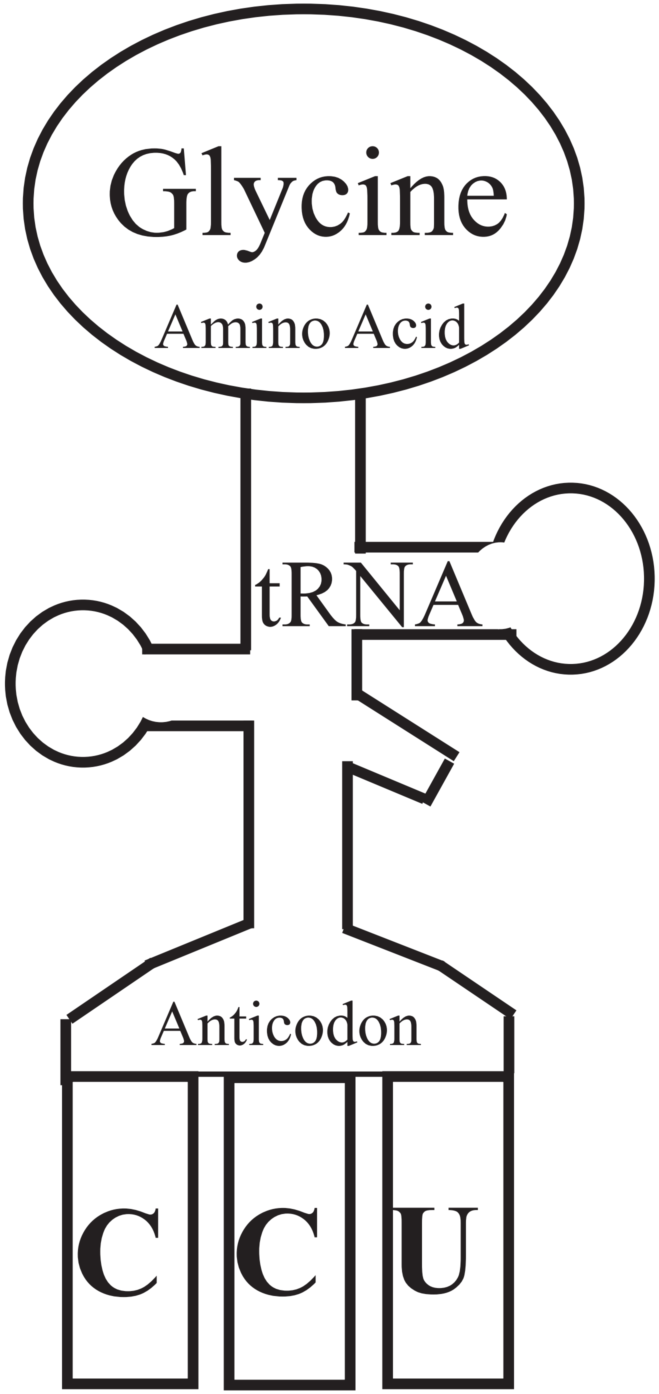
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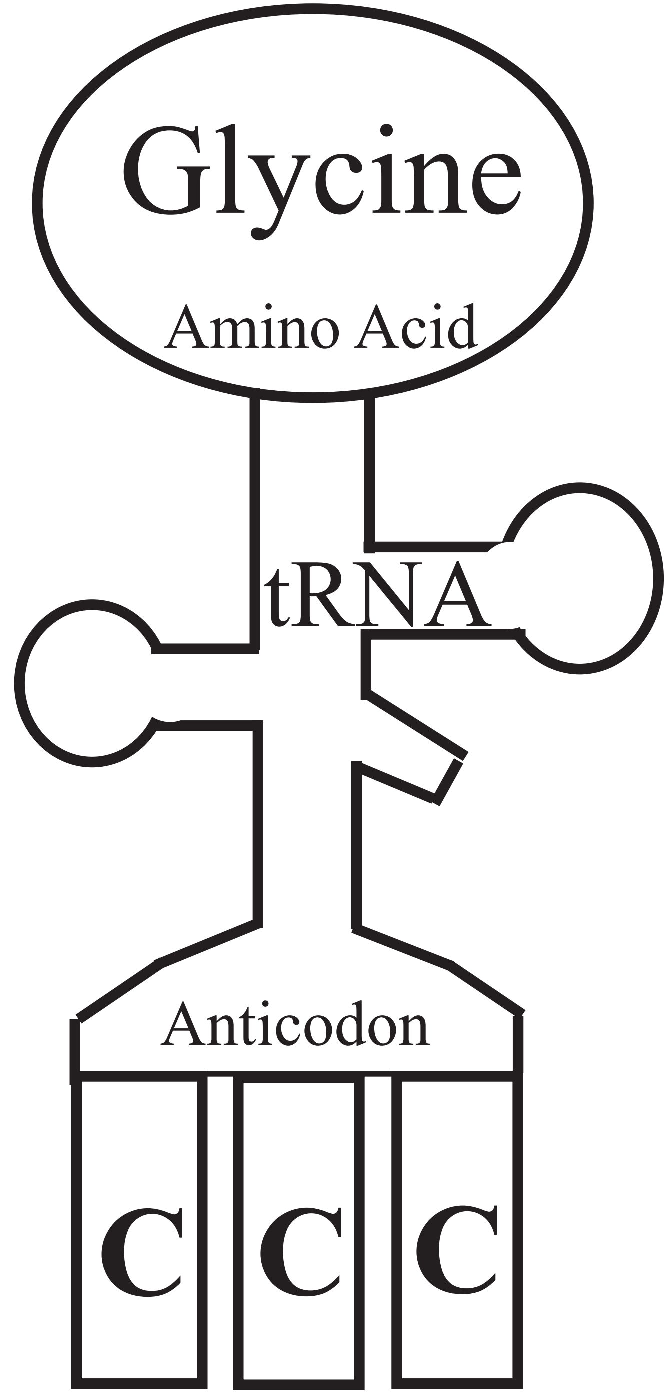
C C U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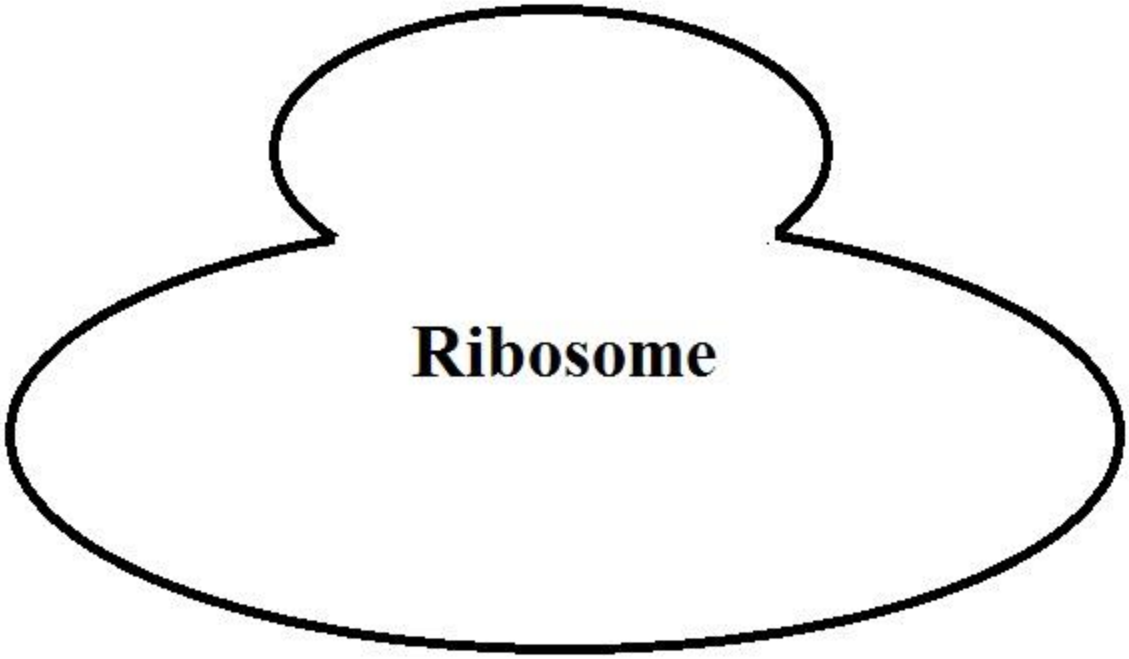
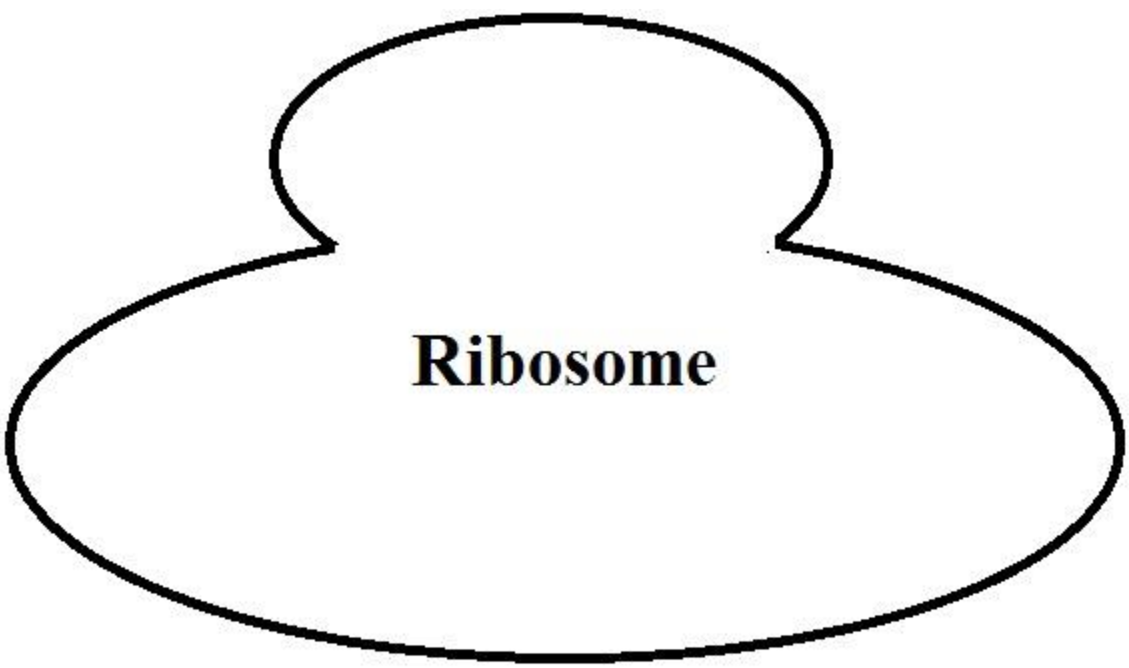
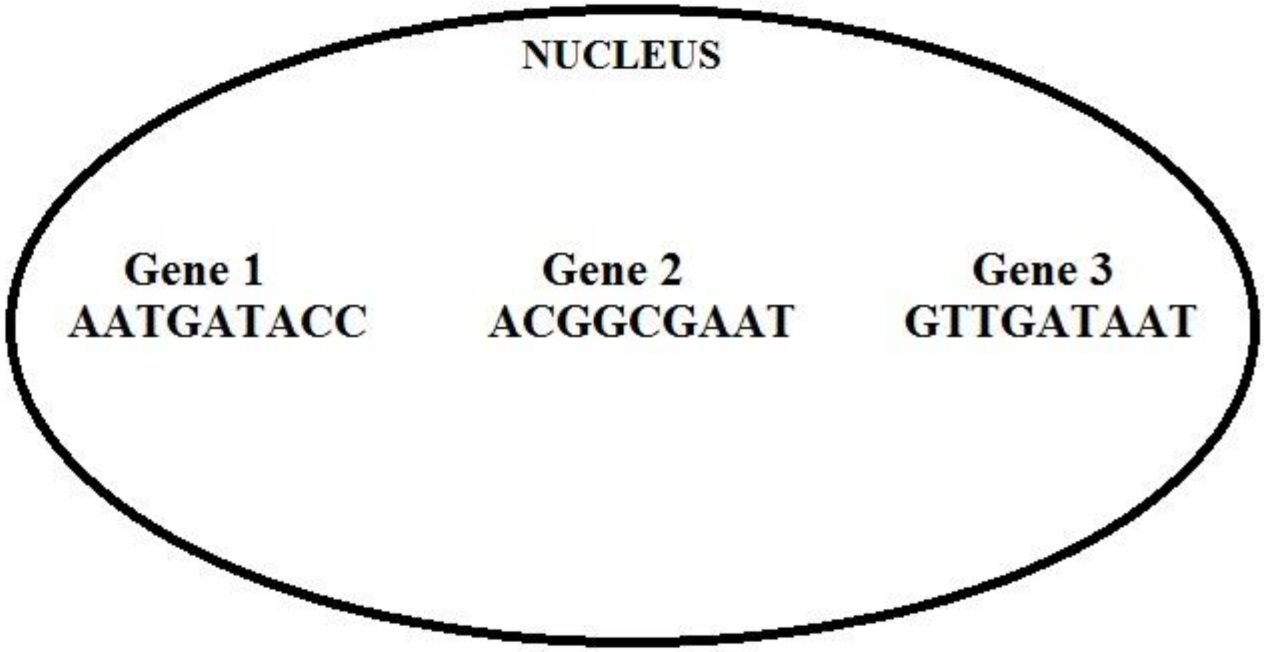
C C C

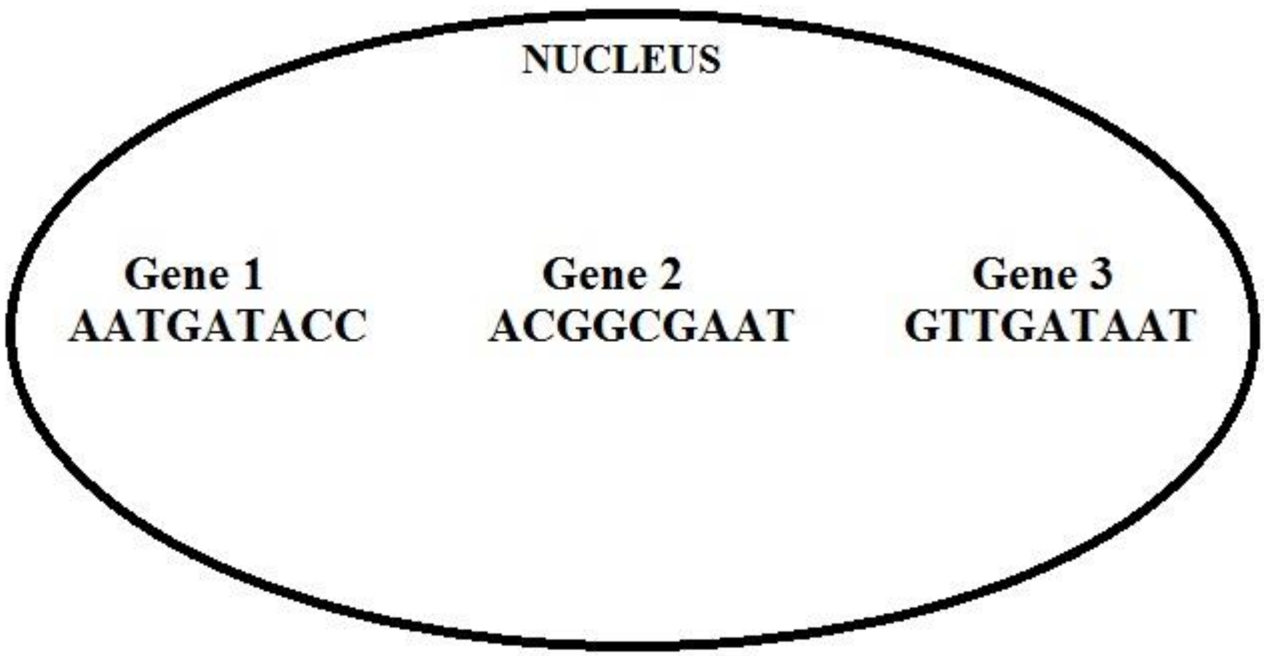

Ribosome


Ribosome

Liver Cell
Gene 1



Skin Cell
Gene 2



Blood Cell
Gene 3