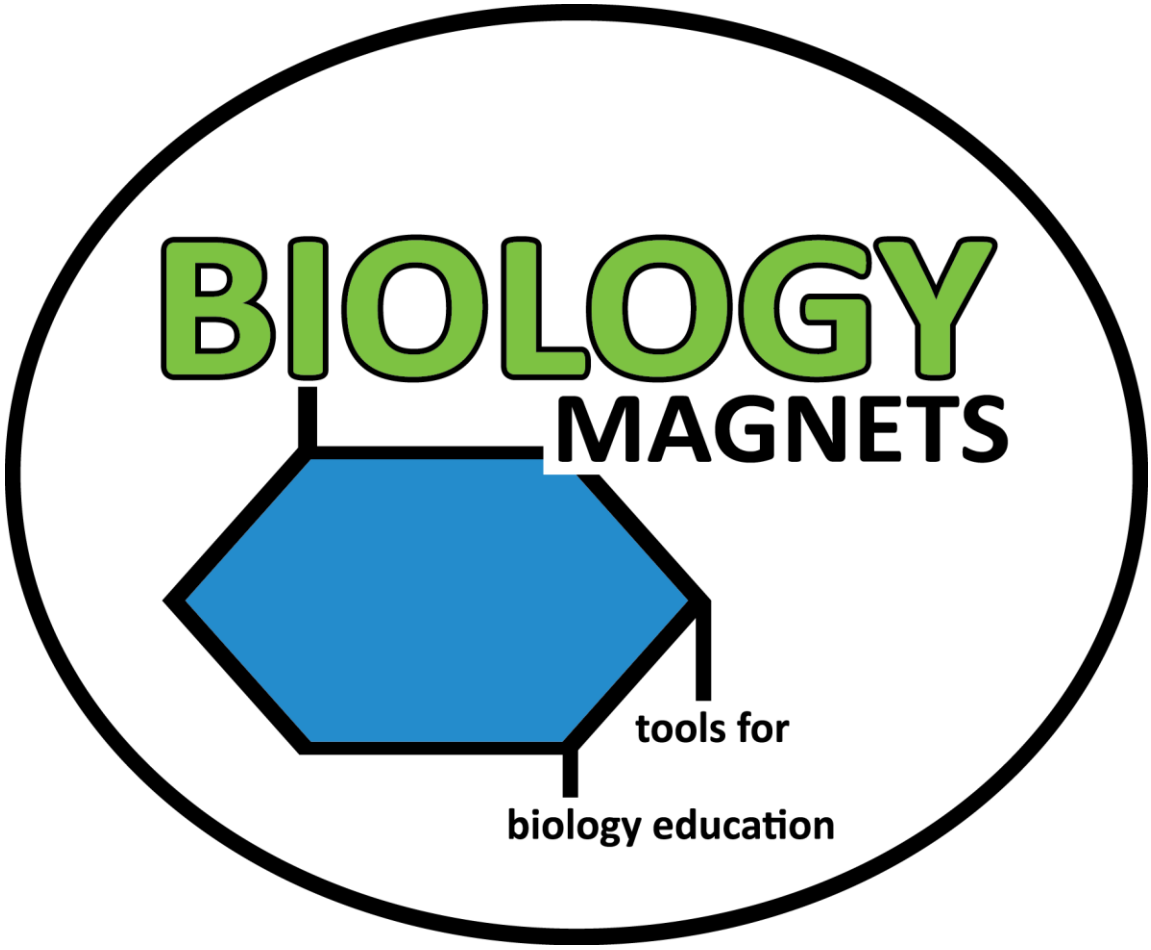
Biology Magnets Module 6: Transcription and Translation - Teacher and Student Guides



Teacher Information

This module uses magnets designed for teacher and student interaction to guide learning the processes of transcription and translation. Contained in this guide are lesson ideas that can last from 10 minutes each to an entire class period, depending upon teacher preference. Each lesson has both teacher-centered and student-centered activities. The student-centered activities are most effective if students are in small groups. It may be necessary to have multiple magnet sets for large classes. A student handout is provided which can be printed out and given to each student group to help guide their progress as they work with the Biology Magnets. If budget or white board space is limited, groups can alternate between using a set of Biology Magnets and doing other activities. Teachers can refer to the videos posted at the Biology Magnet web site at BiologyMagnets.com for guided teaching instructions. The guides presented here are written to supplement, not replace, textbooks and lessons and thus do not fully elaborate on all processes and terms.

Magnet Care and Maintenance

Biology magnets are made to last for years. Periodically magnets will fall off or are knocked off the plastic. A piece of magnetic tape is included with each module, which should be able to replace around 10-12 magnets if necessary. Simply cut a new magnet and peel off the back to replace. Magnetic tape can be purchased from a hobby store to replace magnets lost over time. Laminate may peel off, especially on small pieces. Transparent tape can be used as a replacement or to re-attach laminate that comes loose by curling the tape over the back of the magnet. The machines used to cut Biology Magnets are not always perfectly accurate. Sometimes a bit of white or black outline on the edges occurs or a cut might be slightly off center. Use scissors to remove extra outline that is unnecessary if desired. Store magnets in the clasp envelopes in which they arrived for easy organization.

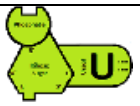
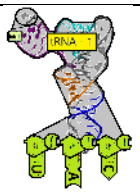
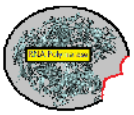
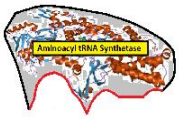
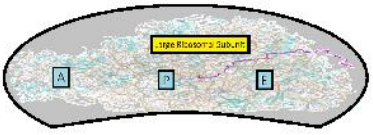
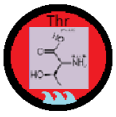
Copyright Information – Module 6 – Transcription and Translation

Spliceosome: By Jawahar Swaminathan and MSD staff at the European Bioinformatics Institute - http://www.ebi.ac.uk/pdbe-srv/view/images/entry/1xtk600.png, displayed on http://www.ebi.ac.uk/pdbe-srv/view/entry/1xtk/summary, Public Domain, https://commons.wikimedia.org/w/index.php?curid=6190214. This image has been released into the public domain by its creator and original copyright holder. This applies worldwide. As such you are entirely free to reproduce it, create derivative works, or make commercial use of it as you see fit, without any requirement to give the creator credit. However, as a courtesy, a link back to http://www.ebi.ac.uk/ would be appreciated. Modified to add border, label, and background. Released under the same license as above.

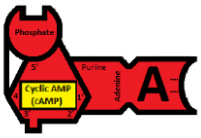
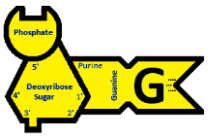
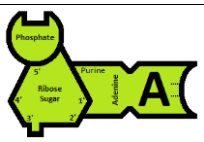
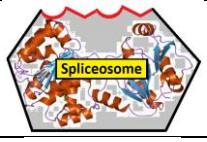
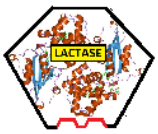
Repressor Protein: By Jawahar Swaminathan and MSD staff at the European Bioinformatics Institute - http://www.ebi.ac.uk/pdbe-srv/view/images/entry/1cop600.png, displayed on http://www.ebi.ac.uk/pdbe-srv/view/entry/1cop/summary, Public Domain, https://commons.wikimedia.org/w/index.php?curid=5912238. This image has been released into the public domain by its creator and original copyright holder. This applies worldwide. As such you are entirely free to reproduce it, create derivative works, or make commercial use of it as you see fit, without any requirement to give the creator credit. However, as a courtesy, a link back to http://www.ebi.ac.uk/ would be appreciated. Modified to add border, label, and background. Released under the same license as above.

Lactase enzyme: By Jawahar Swaminathan and MSD staff at the European Bioinformatics Institute - http://www.ebi.ac.uk/pdbe-srv/view/images/entry/1m98600.png, displayed on http://www.ebi.ac.uk/pdbe-srv/view/entry/1m98/summary, Public Domain, https://commons.wikimedia.org/w/index.php?curid=5938051. This image has been released into the public domain by its creator and original copyright holder. This applies worldwide. As such you are entirely free to reproduce it, create derivative works, or make commercial use of it as you see fit, without any requirement to give the creator credit. However, as a courtesy, a link back to http://www.ebi.ac.uk/ would be appreciated. Modified to add border, label, and background. Released under the same license as above.

Biology Magnets Module 6 Materials List

Magnet Name	Quantity	Picture
DNA Nucleotide	34 – 30 on two strings, 4 free	
RNA Nucleotide	31 – 15 on a string, 16 free	
tRNA	4	
Release Factor	1	
RNA Polymerase	2	
Aminoacyl tRNA Synthetase	1	
Small Ribosomal Subunit	1	
Large Ribosomal Subunit	1	
Amino Acids	13	
3” Magnetic Tape Strip	1	
Total Quantity	**89**	

Biology Magnets Module 6 RNA Processing/Operon Supplement Materials List

Magnet Name	Quantity	Picture
Cyclic AMP	2	
CAP Protein	1	
Modified Guanine Cap	3	
Adenine Nucleotide	4	
Spliceosome	1	
Repressor Protein – Lac Operon	1	
Lactase Enzyme	1	
Repressor Protein – Trp Operon	1	
Lactose	8	
Tryptophan	8	
Total Quantity	**30**	

Lesson 6A – Transcription (10-50 minutes)

Teacher Centered Activity (10-20 minutes): This lesson utilizes the Biology Magnets to model transcription of DNA to RNA.

Step 1 - **Initiation:** Start by placing the two strands of DNA attached to strings on the board so they link together in the center. For ease of using the Biology Magnets, start with the sequence ATG on the top left running 5'->3'. The left strand is called the sense strand and the right is the antisense strand. Use a marker to extend the DNA ladder above and below the magnets to make promoter and terminator sites. Attach the RNA polymerase to the promotor site (**Figure 6.A.1**).

Step 2 – Elongation: Using RNA polymerase, unzip the DNA strand and add free RNA nucleotides one by one to the DNA chain according to the pairing rules, G-C and A-U. Build the RNA strand from 5' to 3', so the template (antisense) DNA strand will be the one starting TAC on the right side. Extend the marker to show that the DNA chain is never broken but just becomes unwound in the area of the RNA polymerase (**Figure 6.A.2**).

Step 3 – Termination: Continue adding RNA nucleotides until the terminator portion of the DNA is reached and the RNA polymerase detaches. Move the newly transcribed mRNA away and allow the template DNA strand to reattach to the nontemplate strand (**Figure 6.A.3**).

Figure 6.A.1 – Initiation

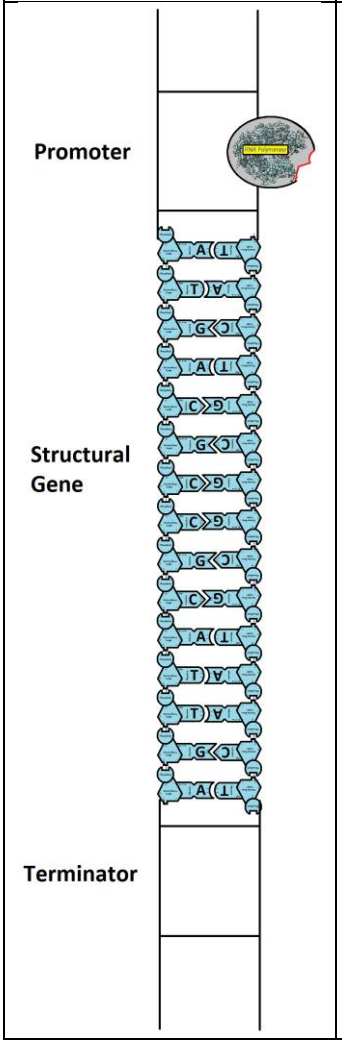


Figure 6.A.2 – Elongation

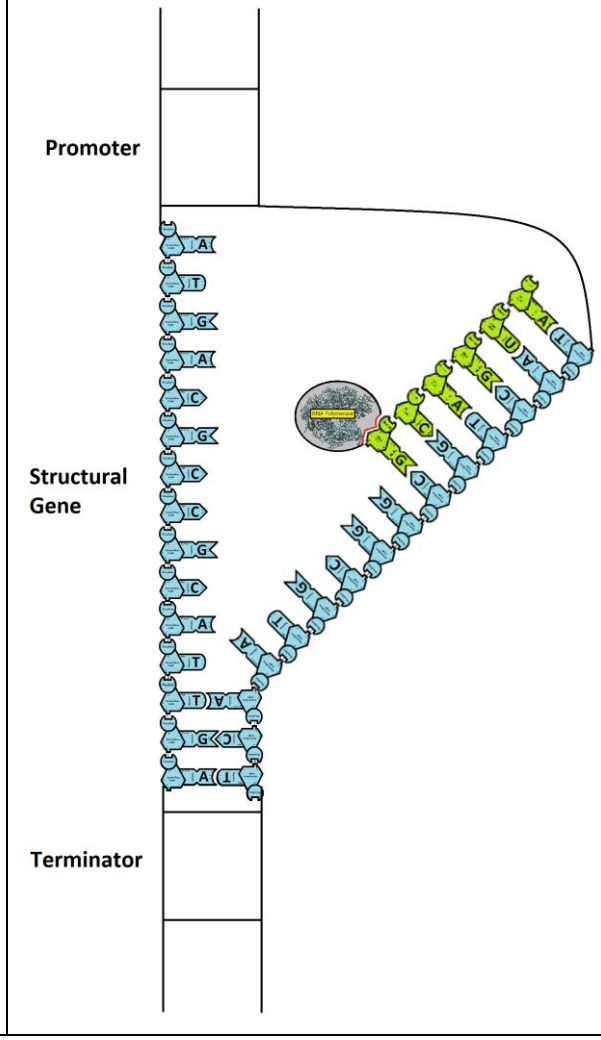
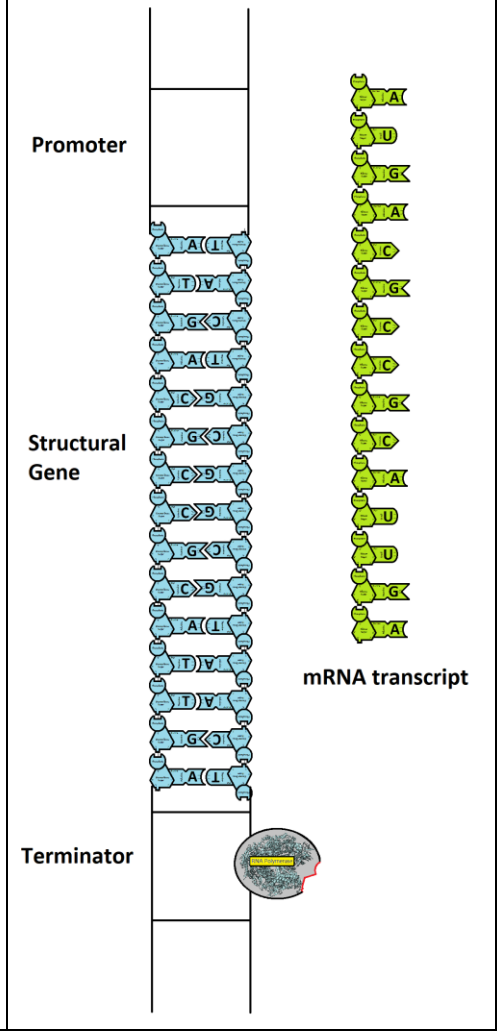


Figure 6.A.3 – Termination



Student centered activity (10-30 minutes): After teaching transcription, put students into small groups. A copy of the student guide for the lesson may be given to each group if necessary. Have the students take turns moving the Biology Magnets to accurately model the process of transcription. Allow the students to correct and help one another. Continue to practice until each student can model transcription without looking at the guide.

Extra Exercise:

Step 4 – mRNA processing: To model the mRNA processing which occurs in eukaryotic cells with Biology Magnets will require the Module 6 mRNA processing/Operon supplement package. Start with the mRNA strand that was transcribed from the DNA. This is called pre-mRNA. First, use the spliceosome enzyme to remove introns and splice together exons (**Figure 6.A.4**). Second, add a modified guanine cap to the 5' end of the mRNA and a poly-adenine tail to the 3' end of the mRNA (**Figure 6.A.5**). Now the mRNA is known as mature mRNA and is ready for the next step, transcription.

Figure 6.A.4 – Splicing out introns

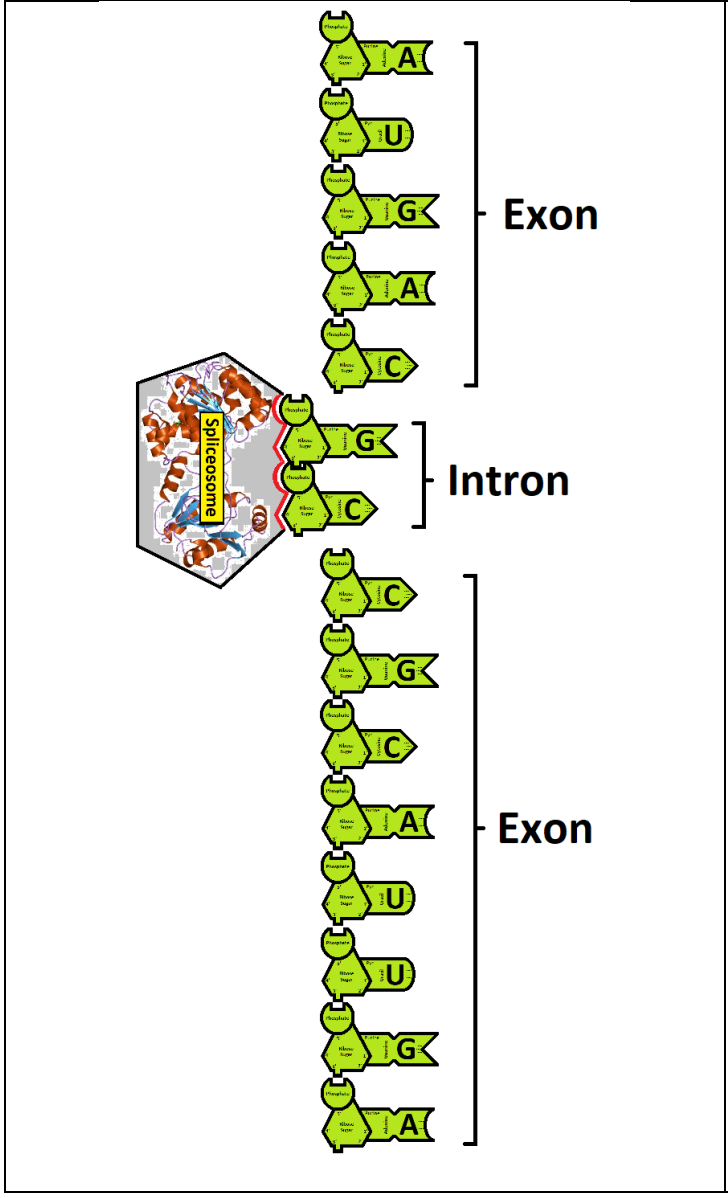
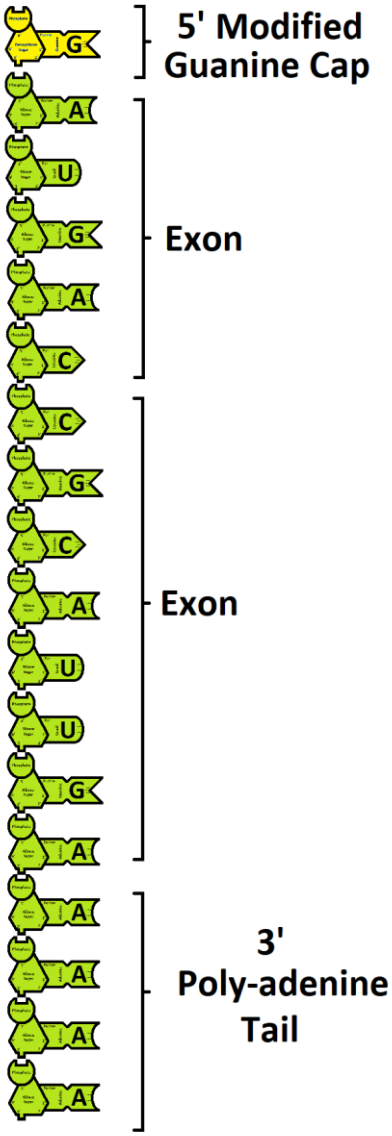


Figure 6.A.5 – Guanine cap and poly-adenine tail

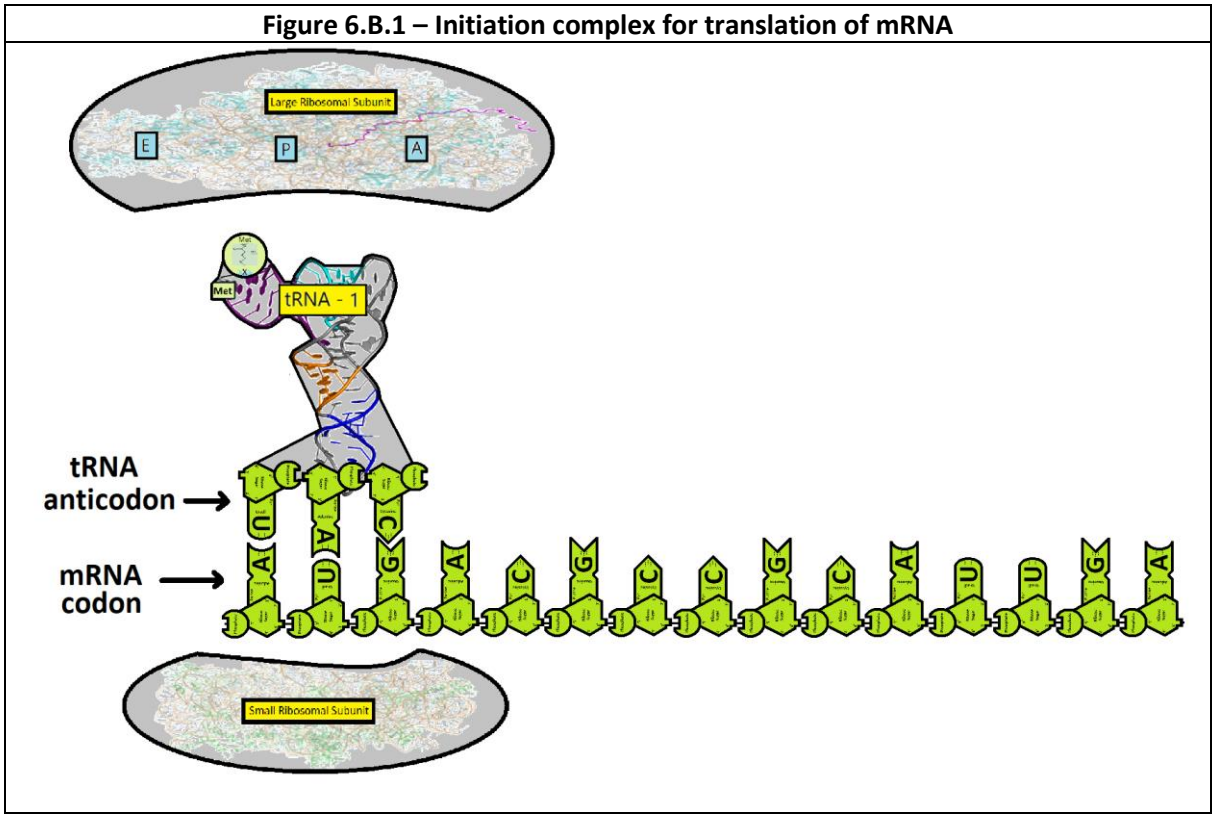


Lesson 6B – Translation (20-80 minutes)

Teacher Centered Activity (20-30 minutes): This lesson uses the Biology Magnets to model translation of mRNA to protein.

Step 1 - **Initiation:** Start with the tRNA-1 molecule with the methionine (Met) amino acid attached to the top magnet. Attach it to the top of the small ribosomal subunit Bring the two of them together with the mRNA strand that is on a string. The mRNA should lay flat with nitrogen bases pointing upward. Bind the anticodon of tRNA-1 (UAC) with the codon of the mRNA (UAG). Finally, bring the large ribosomal subunit in above so the tRNA sits at the P site. This structure is called the initiation complex (**Figure 6.B.1**).

Figure 6.B.1 – Initiation complex for translation of mRNA



Step 2 – Elongation: Move tRNA-2 in with its threonine (Thr) amino acid to attach to the next codon which is exposed at the A site of the ribosome. When the tRNA binds, form a peptide bond between two amino acids in the ribosome by drawing a line with a marker (**Figure 6.B.2**). Move the ribosome forward one codon on the mRNA from 5'->3'. The tRNA-1 molecule will be in the E site of the ribosome. Move the tRNA-1 molecule out of the ribosome, leaving its amino acid in place, forming a peptide bond with the previous amino acid. A new codon is now exposed in the A site of the ribosome. Move tRNA-3 with its amino acid into the ribosome and bind it to the codon (**Figure 6.B.3**). Continue the process, bringing in tRNA-4 to the next codon and exiting tRNA-2 from the ribosome.

Step 3 – Termination: To finish the process of translation, move the release factor into place over the stop codon (UGA) (**Figure 6.B.4**). When the release factor binds, the ribosome comes apart and the tRNA-4 releases its amino acid which remains bonded to the chain. Move the tRNA-4 away. Finally, the release factor breaks away from the mRNA. The primary structure of the protein is intact and will fold into its final three-dimensional shape. The mRNA is free to go through another ribosome **(Figure 6.B.5)**.

Figure 6.B.2 – Elongation part 1

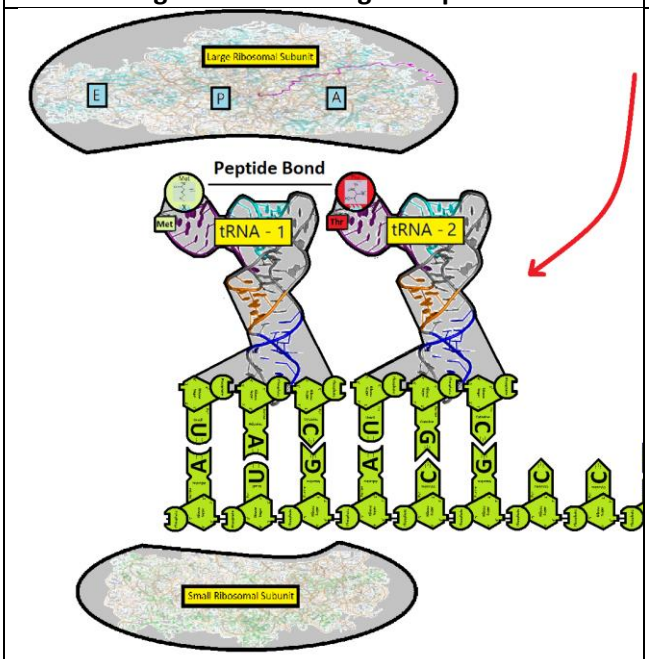


Figure 6.B.3 – Elongation part 2

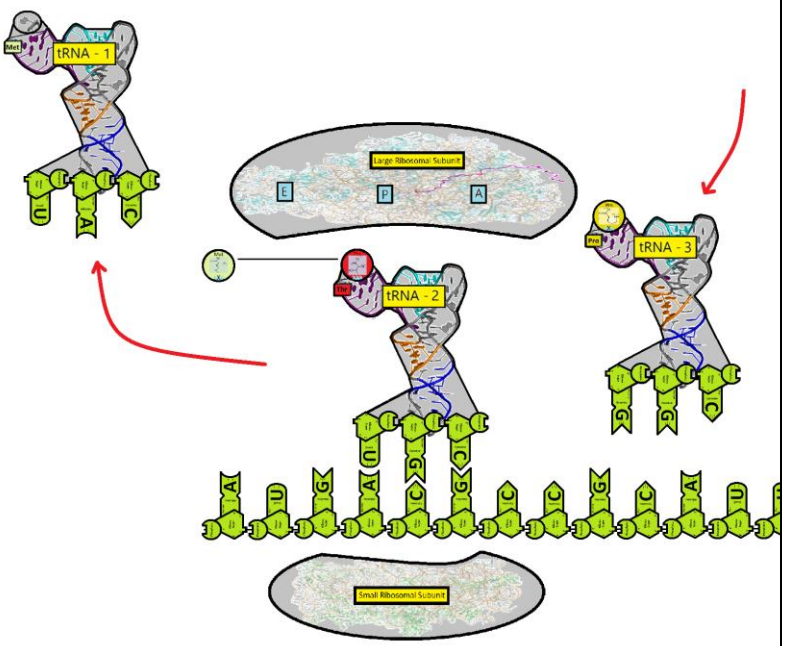


Figure 6.B.4 – Termination part 1

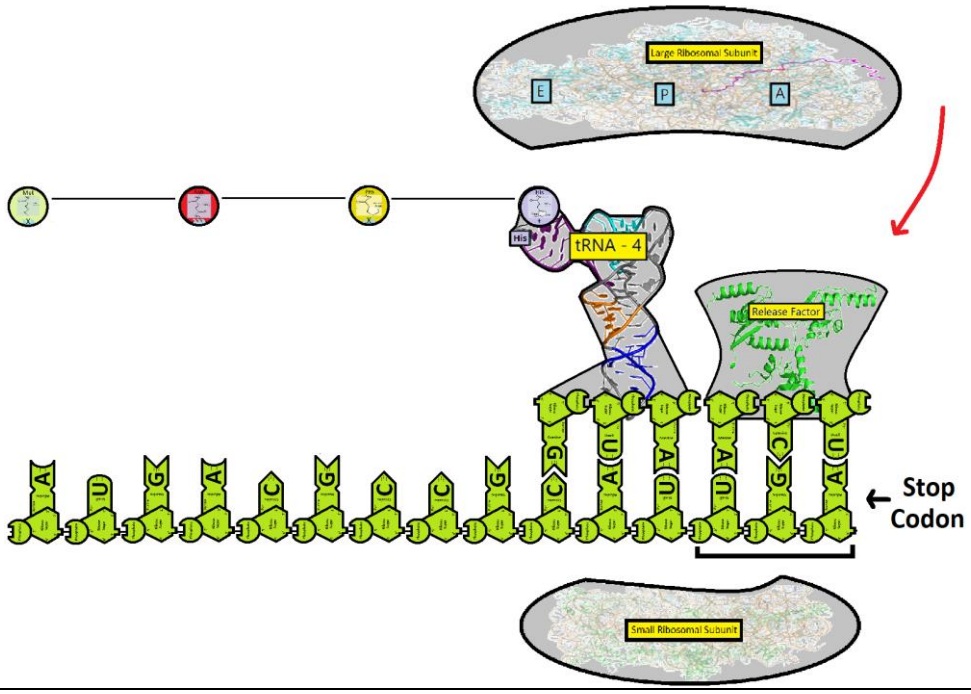
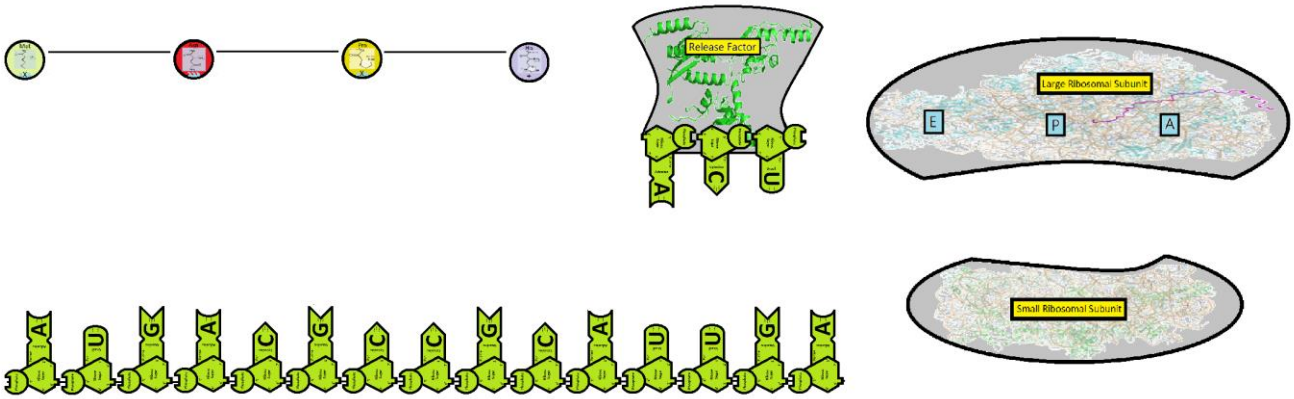


Figure 6.B.5 – Termination Part 2

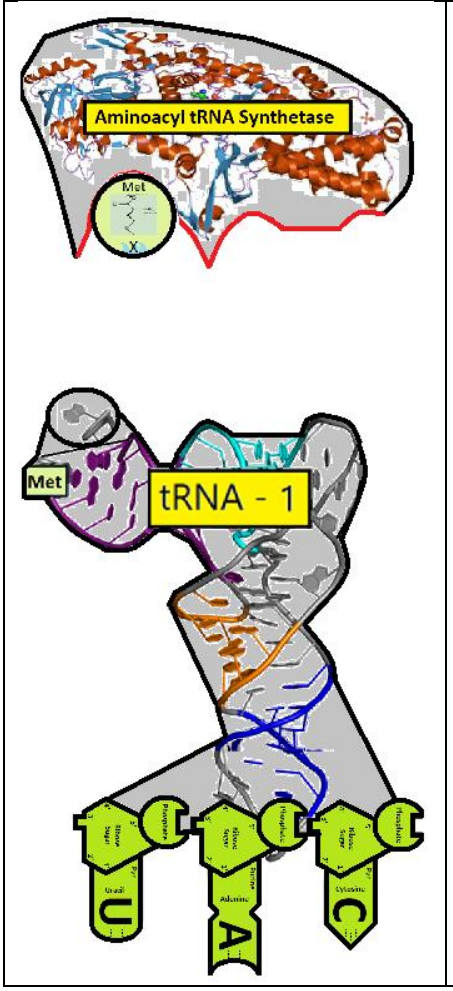
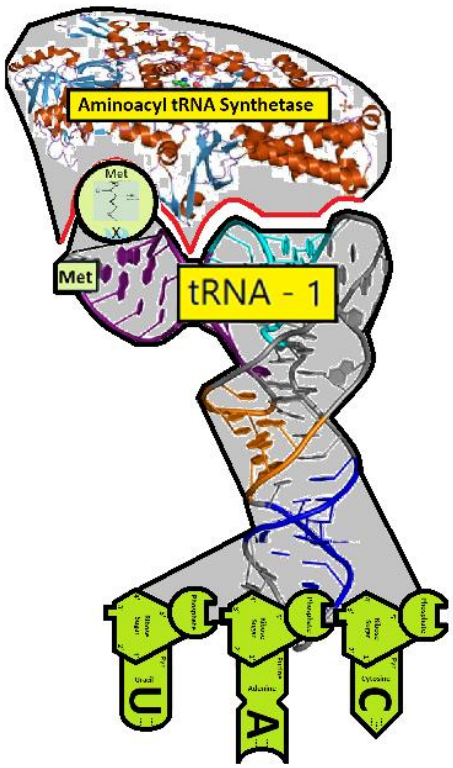
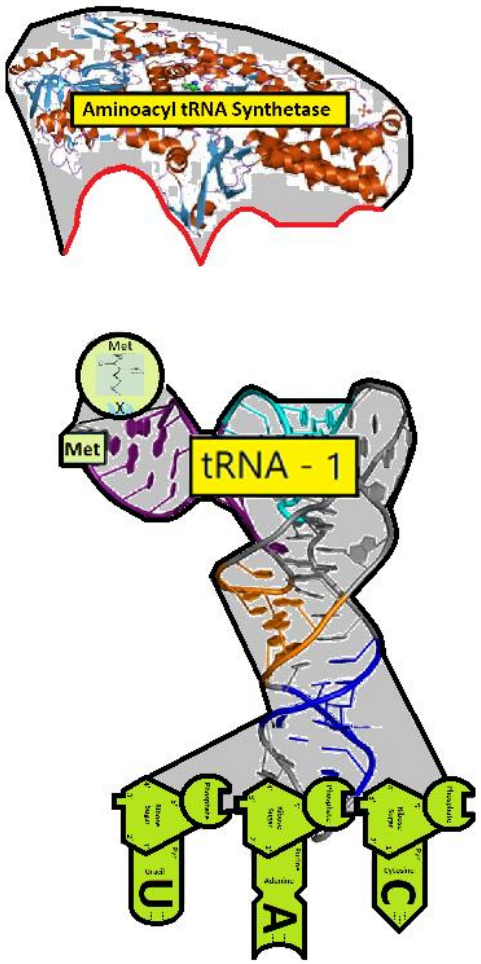


Student centered activity (20-50 minutes): After teaching translation, put students into small groups. A copy of the student guide for the lesson may be given to each group if necessary. Have the students take turns moving the Biology Magnets to accurately model the process of translation. Allow the students to correct and help one another. Continue to practice until each student can model translation without looking at the guide.

Extra Exercises:

Aminoacyl tRNA synthetase: Use the aminoacyl tRNA synthetase enzyme to affix a new amino acid to the tRNA after it leaves the ribosome. Put the amino acid into the enzyme that is specific for the tRNA leaving the ribosome. For example, tRNA-1 can only carry the amino acid methionine (Met), so place a Met into the enzyme (**Figure 6.B.6**). Have the tRNA attach to the enzyme (**Figure 6.B.7**) and pick up the amino acid (**Figure 6.B.8**). In reality, there is a different aminoacyl tRNA synthetase enzyme for each amino acid.

Protein Folding Review: If Biology Magnets Module 1 is available, have students do the protein folding exercise found in lesson 1C. Use the beads found in that kit to model secondary structures, and the amino acids to investigate tertiary folding. This can be a good review exercise even if the students have previously completed the module.

Figure 6.B.6 – Aminoacyl tRNA synthetase part 1	Figure 6.B.7 – Aminoacyl tRNA synthetase part 2	Figure 6.B.8 – Aminoacyl tRNA synthetase part 3
		

Lesson 6C – Operon System (10-50 minutes)

Teacher Centered Activity (10-20 minutes): This activity requires the Module 6 mRNA processing/Operon supplement package to model the operon system. Start with the DNA on strings and use a marker to extend the DNA ladder and draw and label the different sections of the DNA to include the operator, promoter, and terminator as shown. Use the Lac repressor protein as a stencil to draw binding sites at the operator of the DNA (**Figure 6.C.1**). For the Lac operon, which is an inducible operon, attach the repressor protein to the operator. This turns the genes to the "off" position because the RNA polymerase cannot get past the operator to transcribe the gene (**Figure 6.C.2**). Place lactose magnets on the board to simulate lactose being present in the environment. When the lactose binds to the repressor protein, it changes shape so it no longer binds to the DNA. Attach one of the lactose molecules to the repressor protein and move the protein away from the operator. Now the gene is in the "on" position because the RNA polymerase can move past the operator and transcribe the genes (**Figure 6.C.3**). The genes cause the construction of the lactase protein. Use the lactase enzyme magnet to break down the lactose present (**Figure 6.C.4**). The lactase enzyme even breaks down the lactose attached to the repressor, which causes it to change shape and be able to attach back to the operator, turning the gene off (**Figure 6.C.5**).

Figure 6.C.1 – Operon setup

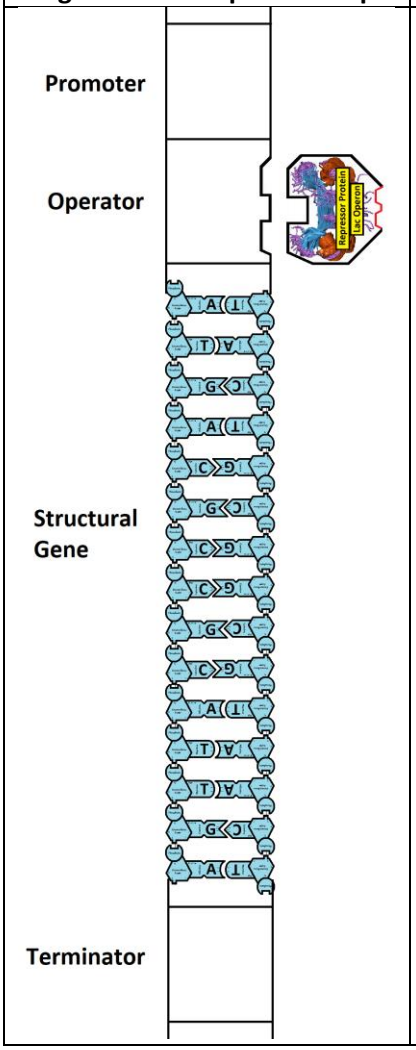


Figure 6.C.2 – Gene off

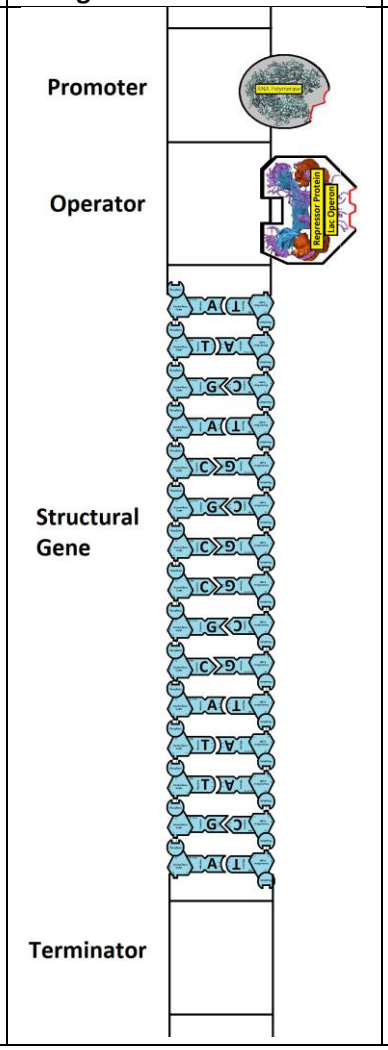


Figure 6.C.3 – Gene on

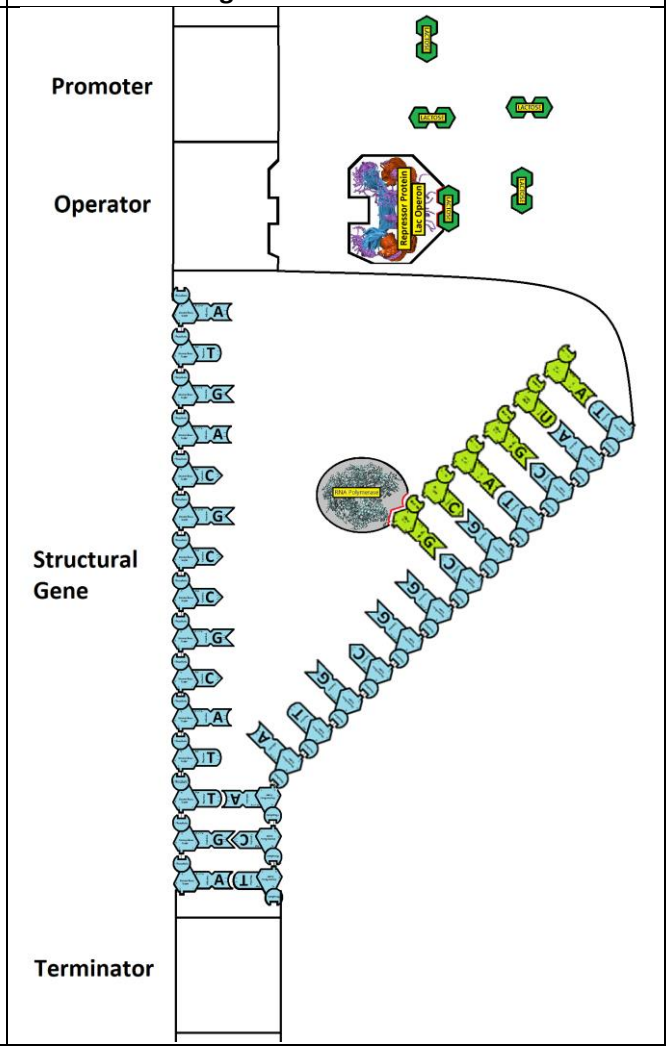
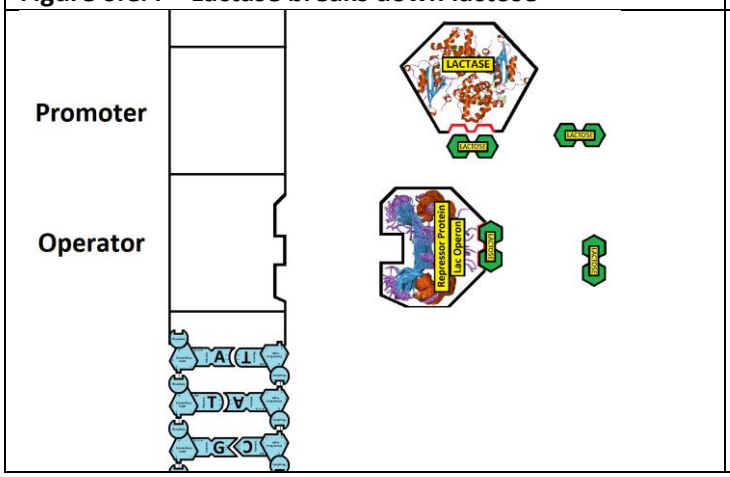
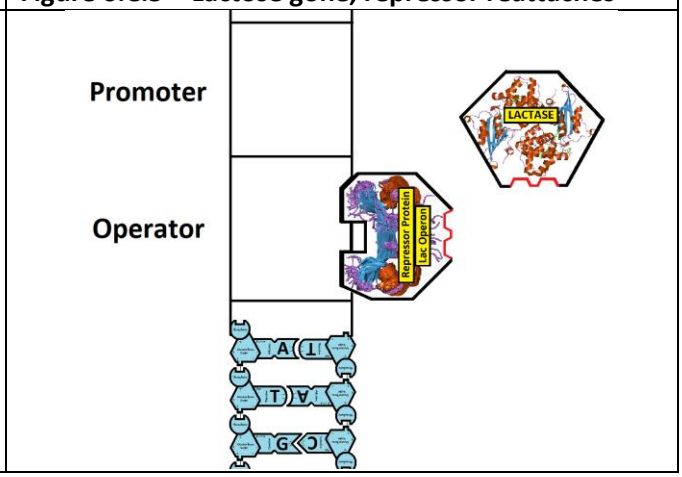
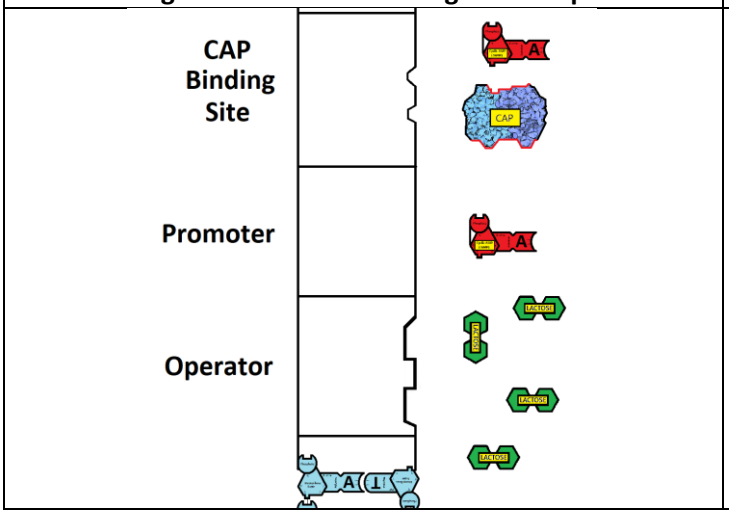
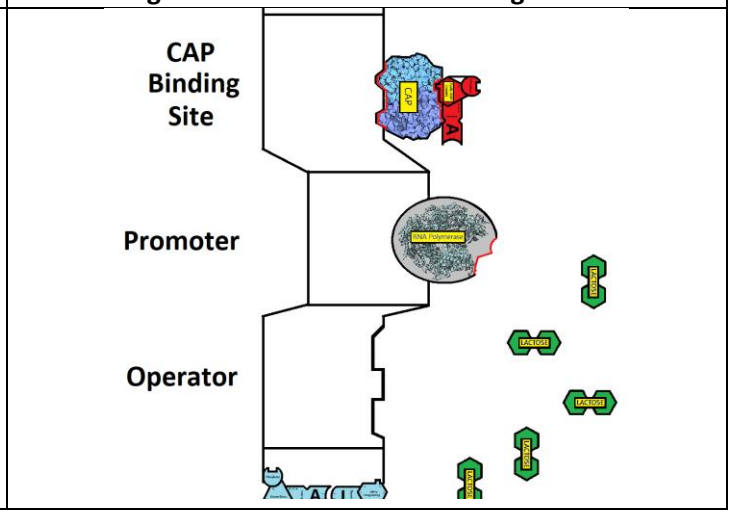


Figure 6.C.4 – Lactase breaks down lactose	Figure 6.C.5 – Lactose gone, repressor reattaches
	

Student centered activity (10-30 minutes): After teaching translation, put students into small groups. A copy of the student guide for the lesson may be given to each group if necessary. Have the students take turns moving the Biology Magnets to accurately model the operon. Allow the students to correct and help one another. Continue to practice until each student can model the operon without looking at the guide.

Extra exercises:

CAP Binding Site: This activity requires the Module 6 mRNA processing/Operon supplement package. When glucose levels are low, cyclic AMP goes up and CAP binding acts as a positive control to speed up transcription of the gene. Draw an extension of the DNA beyond the promotor and use the CAP protein as a stencil to draw a binding site for CAP with a marker (**Figure 6.C.6**). Attach cAMP to the CAP protein, then attach the CAP-cAMP complex to the CAP Binding site. This causes the DNA to bend so the promotor is more accessible to the RNA polymerase. Draw the bent promotor with a marker to illustrate (**Figure 6.C.7**). Transcription will speed up and the lactose will be broken down more quickly.

Figure 6.C.6 – CAP Binding Site setup	Figure 6.C.7 – CAP-cAMP binding action
	

Trp Operon: This activity requires the Module 6 mRNA processing/Operon supplement package. Use the Trp repressor protein to represent the Trp operon, a repressible operon. Normally, the gene is in the "on" position and when expressed, enzymes are produced that make the amino acid tryptophan. When tryptophan builds up, one of them will attach to the repressor protein, which will change shape and attach to the operator. This turns the gene to the "off" position. Demonstrate this with the Biology Magnets, and have the students model it as well.

Lesson 6A – Transcription – Student Guide

Student Centered Activity: After learning about transcription, use the Biology Magnets to demonstrate the process.

Step 1 - **Initiation:** Start by placing the two strands of DNA attached to strings on the board so they link together in the center. For ease of using the Biology Magnets, start with the sequence ATG on the top left running 5'->3'. The left strand is called the sense strand and the right is the antisense strand. Use a marker to extend the DNA ladder above and below the magnets to make promoter and terminator sites. Attach the RNA polymerase to the promotor site (**Figure 6.A.1**).

Step 2 – Elongation: Using RNA polymerase, unzip the DNA strand and add free RNA nucleotides one by one to the DNA chain according to the pairing rules, G-C and A-U. Build the RNA strand from 5' to 3', so the template (antisense) DNA strand will be the one starting TAC on the right side. Extend the marker to show that the DNA chain is never broken but just becomes unwound in the area of the RNA polymerase (**Figure 6.A.2**).

Step 3 – Termination: Continue adding RNA nucleotides until the terminator portion of the DNA is reached and the RNA polymerase detaches. Move the newly transcribed mRNA away and allow the template DNA strand to reattach to the nontemplate strand (**Figure 6.A.3**).

Figure 6.A.1 – Initiation

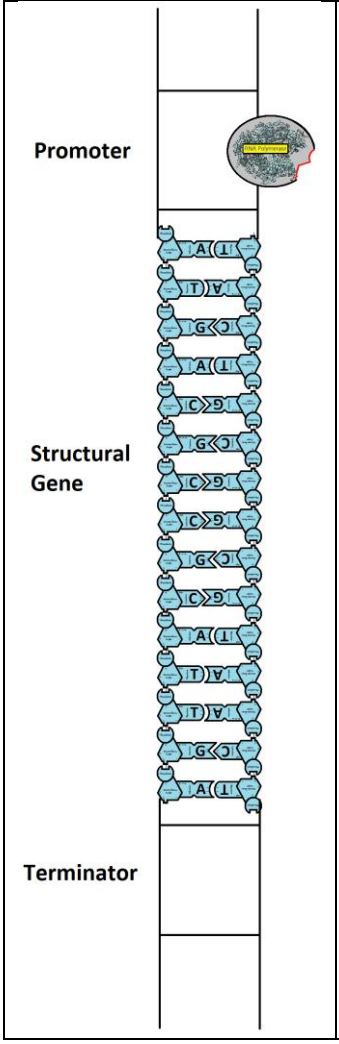


Figure 6.A.2 – Elongation

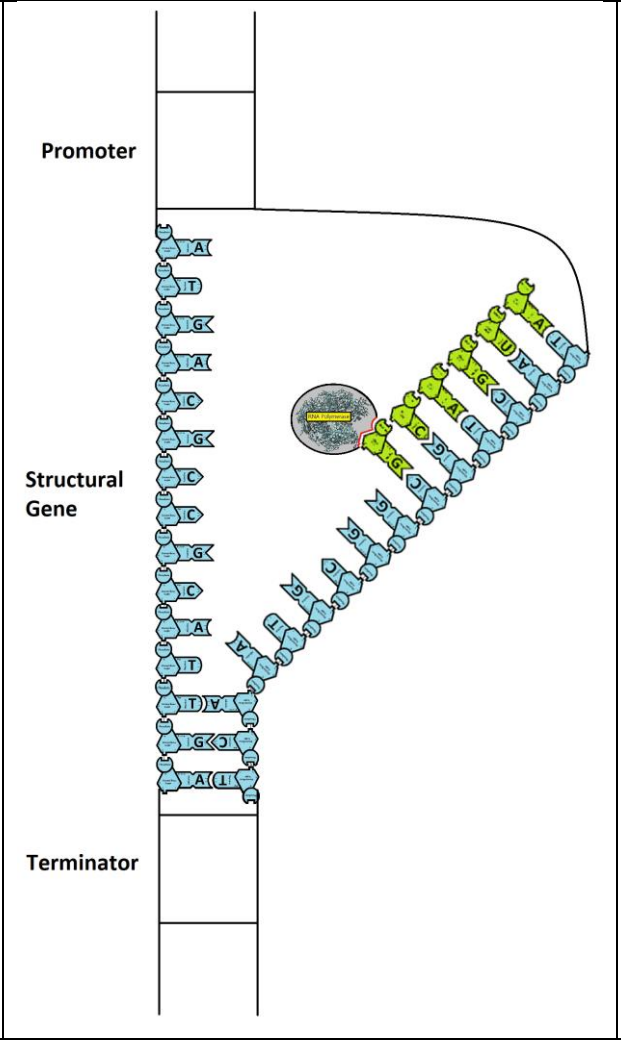
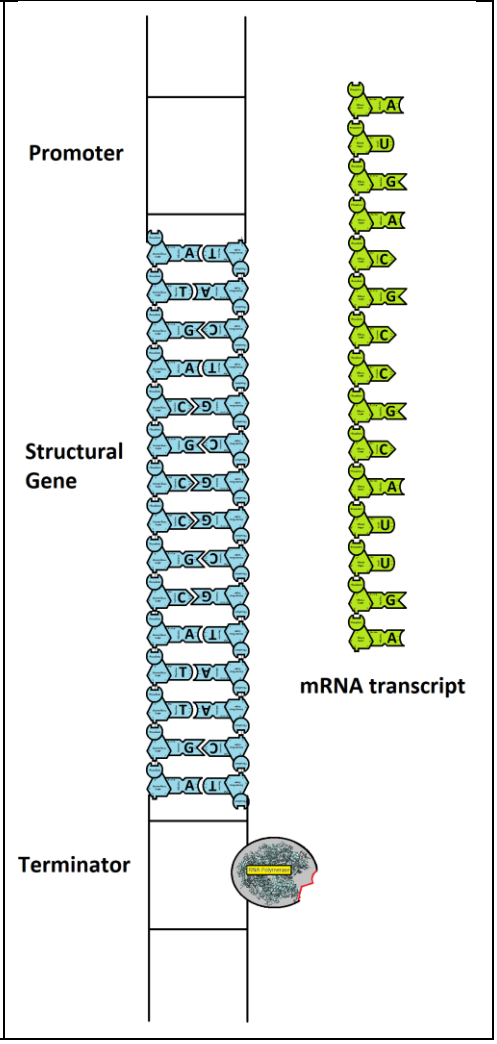


Figure 6.A.3 – Termination



Each student should practice modeling until the process can be done without looking at the student guide.

Extra Exercise:

Step 4 – mRNA processing: To model the mRNA processing which occurs in eukaryotic cells with Biology Magnets will require the Module 6 mRNA processing/Operon supplement package. Start with the mRNA strand that was transcribed from the DNA. This is called pre-mRNA. First, use the spliceosome enzyme to remove introns and splice together exons (**Figure 6.A.4**). Second, add a modified guanine cap to the 5' end of the mRNA and a poly-adenine tail to the 3' end of the mRNA (**Figure 6.A.5**). Now the mRNA is known as mature mRNA and is ready for the next step, transcription. Each student should practice modeling until the process can be done without looking at the student guide.

Figure 6.A.4 – Splicing out introns

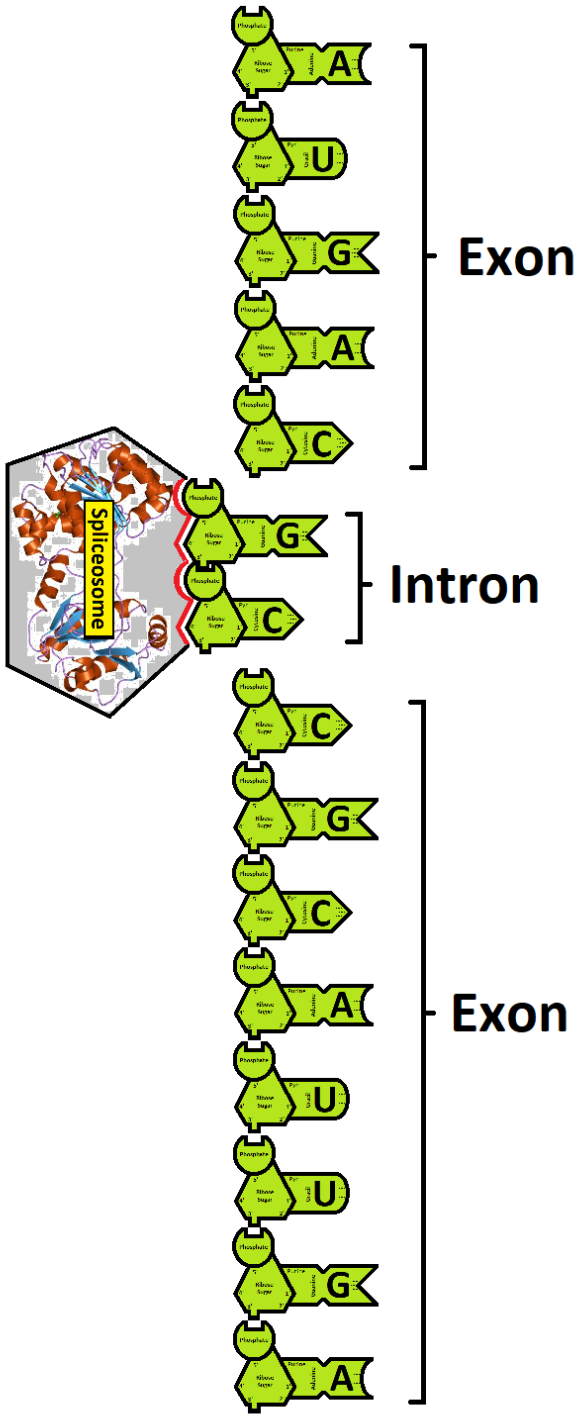
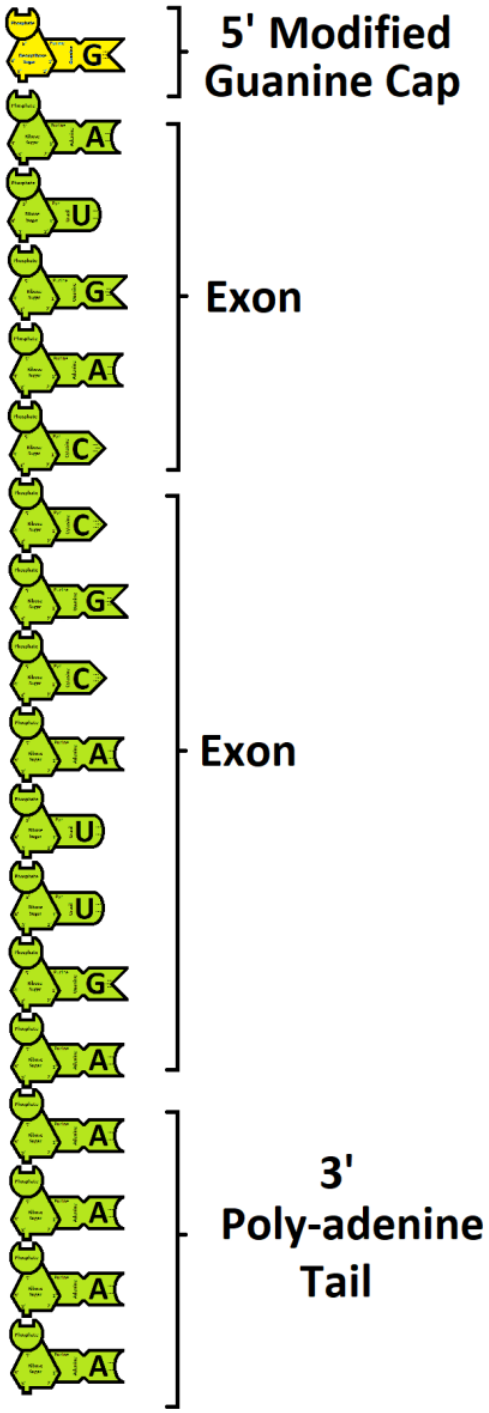


Figure 6.A.5 – Guanine cap and poly-adenine tail

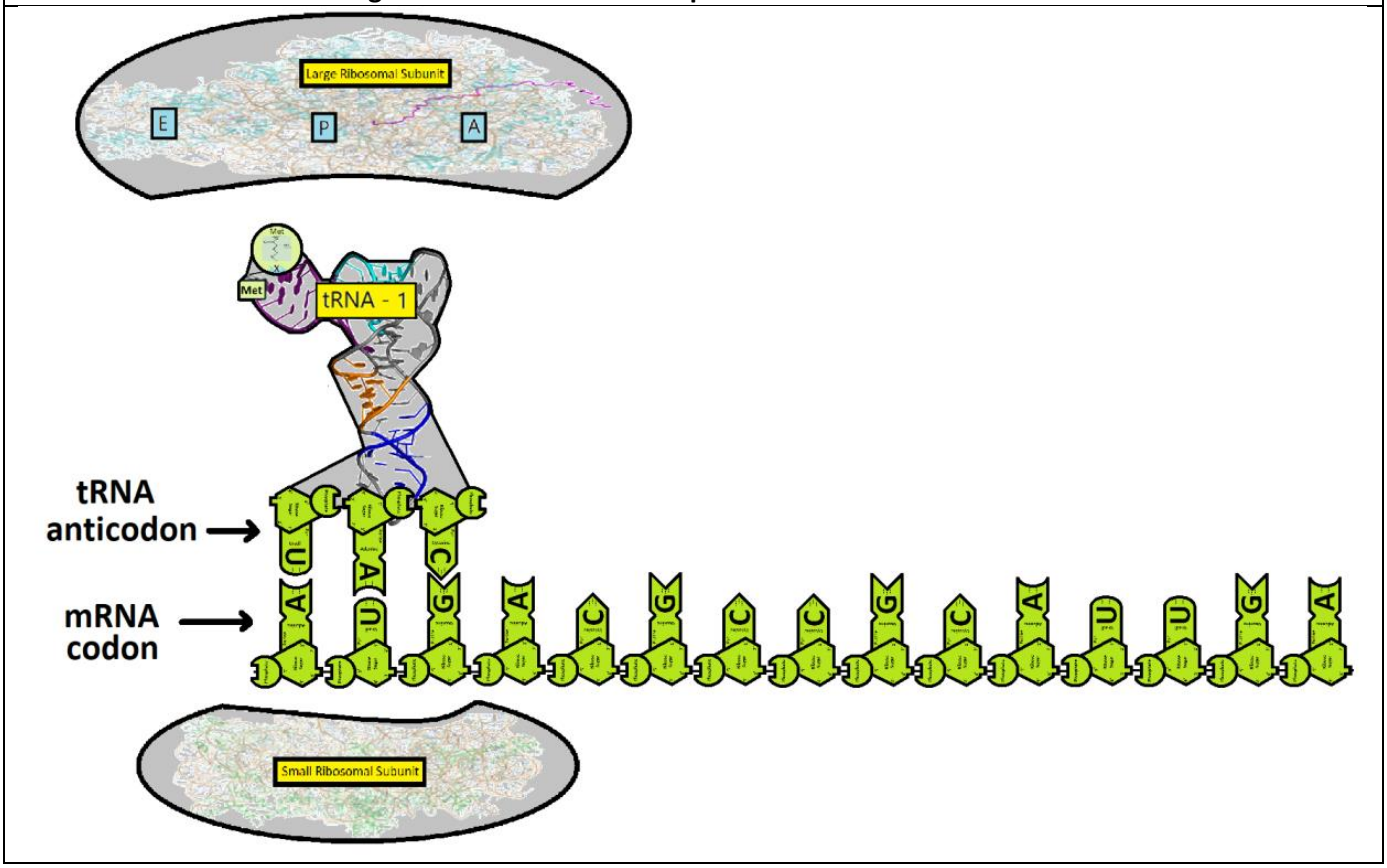


Lesson 6B – Translation – Student Guide

Student Centered Activity: After learning about translation, use the Biology Magnets to demonstrate the process.

Step 1 - **Initiation:** Start with the tRNA-1 molecule with the methionine (Met) amino acid attached to the top magnet. Attach it to the top of the small ribosomal subunit Bring the two of them together with the mRNA strand that is on a string. The mRNA should lay flat with nitrogen bases pointing upward. Bind the anticodon of tRNA-1 (UAC) with the codon of the mRNA (UAG). Finally, bring the large ribosomal subunit in above so the tRNA sits at the P site. This structure is called the initiation complex (**Figure 6.B.1**).

Figure 6.B.1 – Initiation complex for translation of mRNA



Step 2 – Elongation: Move tRNA-2 in with its threonine (Thr) amino acid to attach to the next codon which is exposed at the A site of the ribosome. When the tRNA binds, form a peptide bond between two amino acids in the ribosome by drawing a line with a marker (**Figure 6.B.2**). Move the ribosome forward one codon on the mRNA from 5'->3'. The tRNA-1 molecule will be in the E site of the ribosome. Move the tRNA-1 molecule out of the ribosome, leaving its amino acid in place, forming a peptide bond with the previous amino acid. A new codon is now exposed in the A site of the ribosome. Move tRNA-3 with its amino acid into the ribosome and bind it to the codon (**Figure 6.B.3**). Continue the process, bringing in tRNA-4 to the next codon and exiting tRNA-2 from the ribosome.

Step 3 – Termination: To finish the process of translation, move the release factor into place over the stop codon (UGA) (**Figure 6.B.4**). When the release factor binds, the ribosome comes apart and the tRNA-4 releases its amino acid which remains bonded to the chain. Move the tRNA-4 away. Finally, the release factor breaks away from the mRNA. The primary structure of the protein is intact and will fold into its final three-dimensional shape. The mRNA is free to go through another ribosome **(Figure 6.B.5)**. Each student should practice modeling until the process can be done without looking at the student guide.

Figure 6.B.2 – Elongation part 1

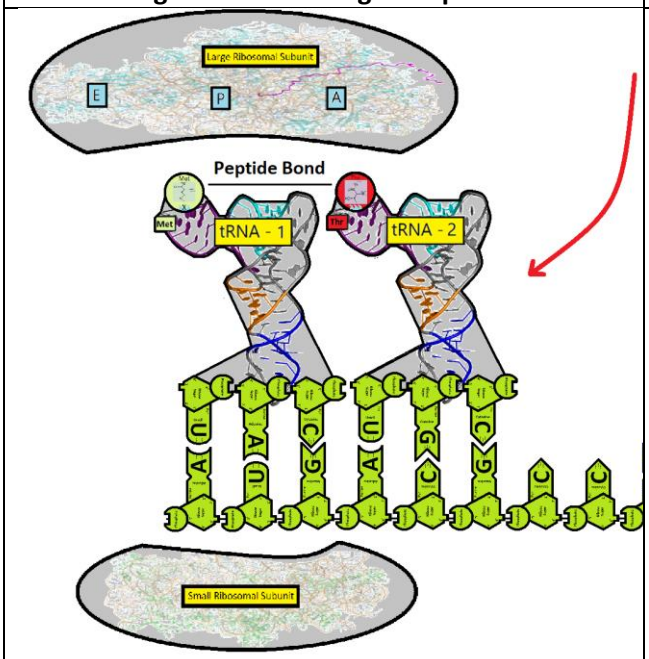


Figure 6.B.3 – Elongation part 2

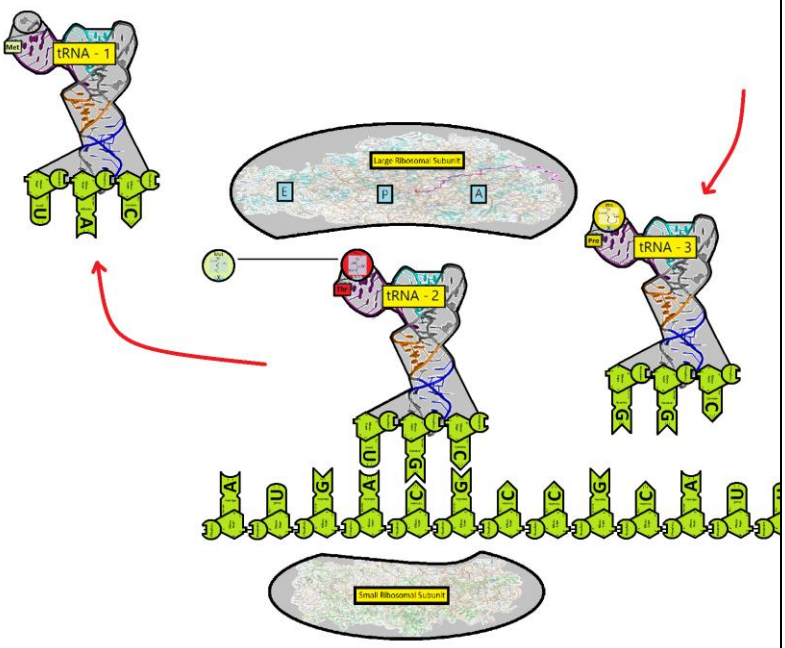


Figure 6.B.4 – Termination part 1

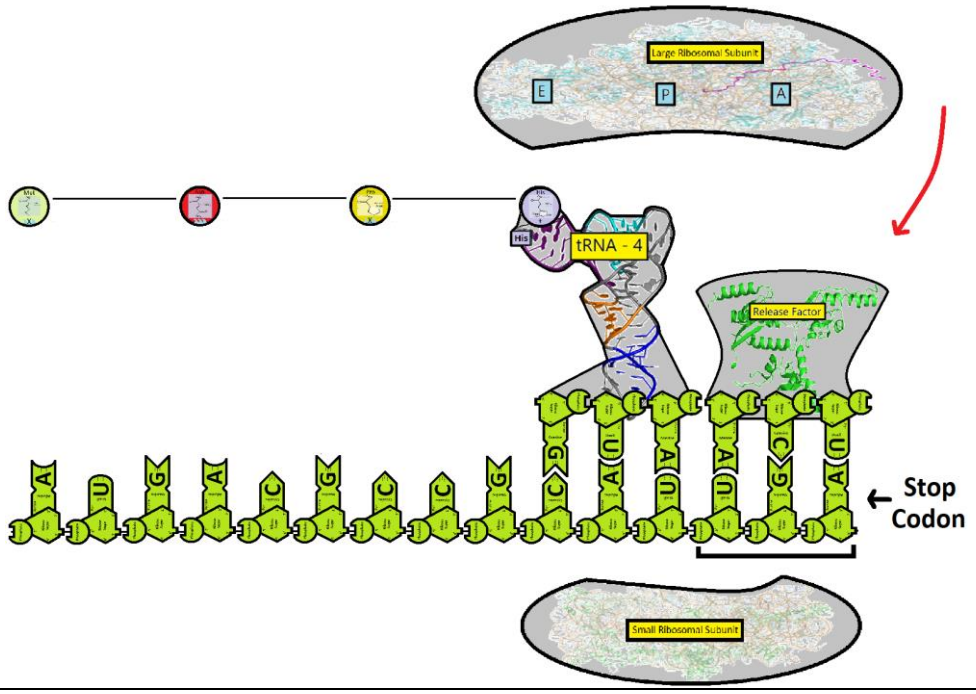
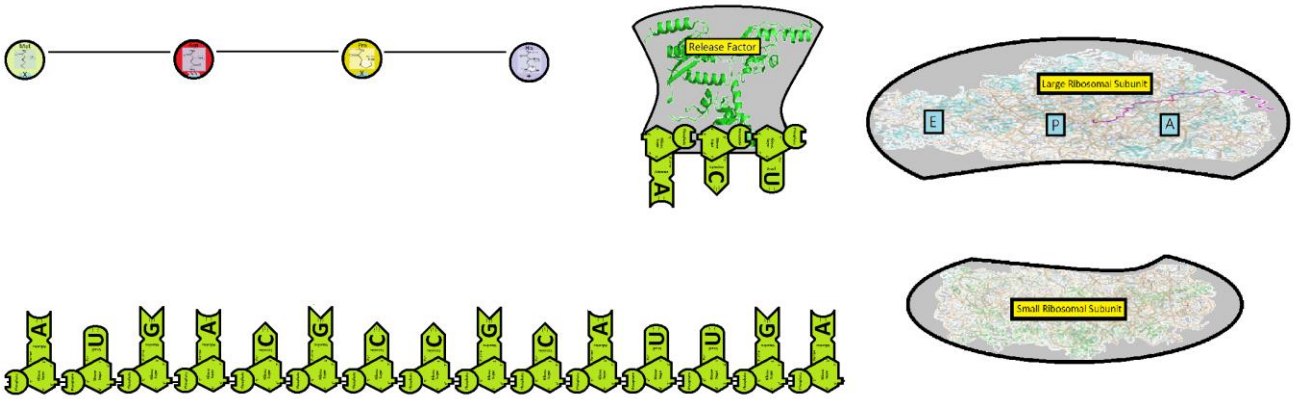


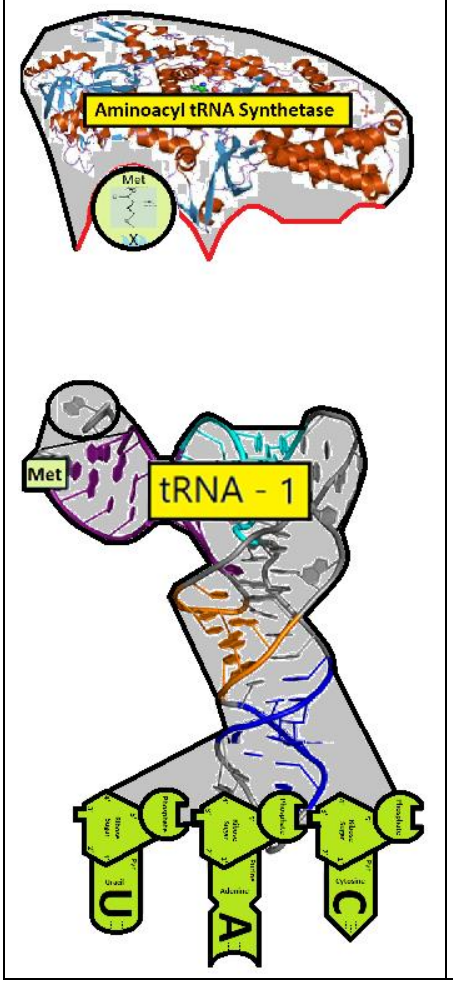
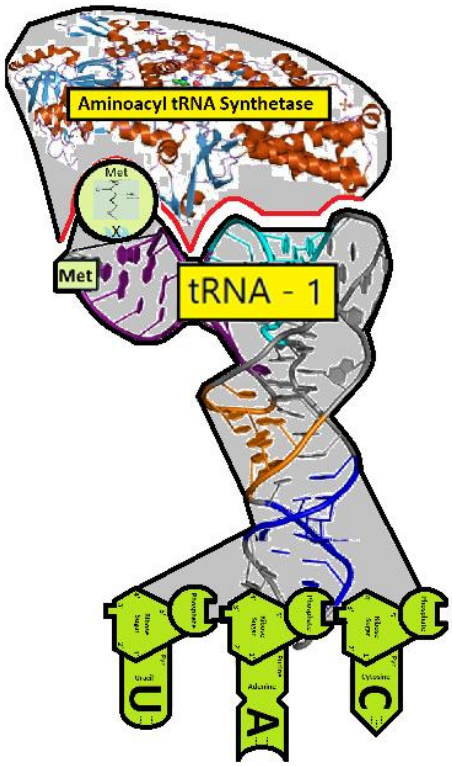
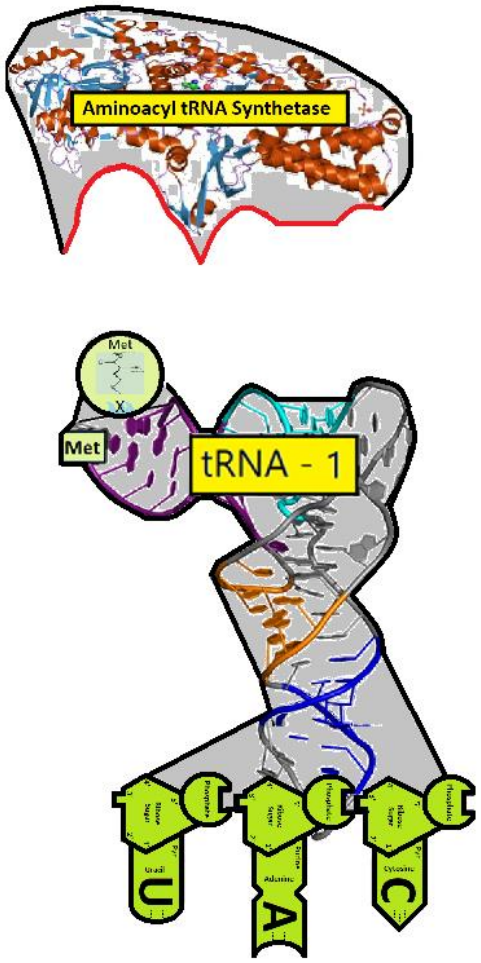
Figure 6.B.5 – Termination Part 2



Extra Exercises:

Aminoacyl tRNA synthetase: Use the aminoacyl tRNA synthetase enzyme to affix a new amino acid to the tRNA after it leaves the ribosome. Put the amino acid into the enzyme that is specific for the tRNA leaving the ribosome. For example, tRNA-1 can only carry the amino acid methionine (Met), so place a Met into the enzyme (**Figure 6.B.6**). Have the tRNA attach to the enzyme (**Figure 6.B.7**) and pick up the amino acid (**Figure 6.B.8**). In reality, there is a different aminoacyl tRNA synthetase enzyme for each amino acid.

Protein Folding Review: If Biology Magnets Module 1 is available, have students do the protein folding exercise found in lesson 1C. Use the beads found in that kit to model secondary structures, and the amino acids to investigate tertiary folding.

Figure 6.B.6 – Aminoacyl tRNA synthetase part 1	Figure 6.B.7 – Aminoacyl tRNA synthetase part 2	Figure 6.B.8 – Aminoacyl tRNA synthetase part 3
		

Lesson 6C – Operon System – Student Guide

Student Centered Activity (10-20 minutes): After learning about the operon, use the Biology Magnets to model the process. Start with the DNA on strings and use a marker to extend the DNA ladder and draw and label the different sections of the DNA to include the operator, promoter, and terminator as shown. Use the Lac repressor protein as a stencil to draw binding sites at the operator of the DNA (**Figure 6.C.1**). For the Lac operon, which is an inducible operon, attach the repressor protein to the operator. This turns the genes to the "off" position because the RNA polymerase cannot get past the operator to transcribe the gene (**Figure 6.C.2**). Place lactose magnets on the board to simulate lactose being present in the environment. When the lactose binds to the repressor protein, it changes shape so it no longer binds to the DNA. Attach one of the lactose molecules to the repressor protein and move the protein away from the operator. Now the gene is in the "on" position because the RNA polymerase can move past the operator and transcribe the genes (**Figure 6.C.3**). The genes cause the construction of the lactase protein. Use the lactase enzyme magnet to break down the lactose present (**Figure 6.C.4**). The lactase enzyme even breaks down the lactose attached to the repressor, which causes it to change shape and be able to attach back to the operator, turning the gene off (**Figure 6.C.5**). Each student should practice modeling until the process can be done without looking at the student guide.

Figure 6.C.1 – Operon setup

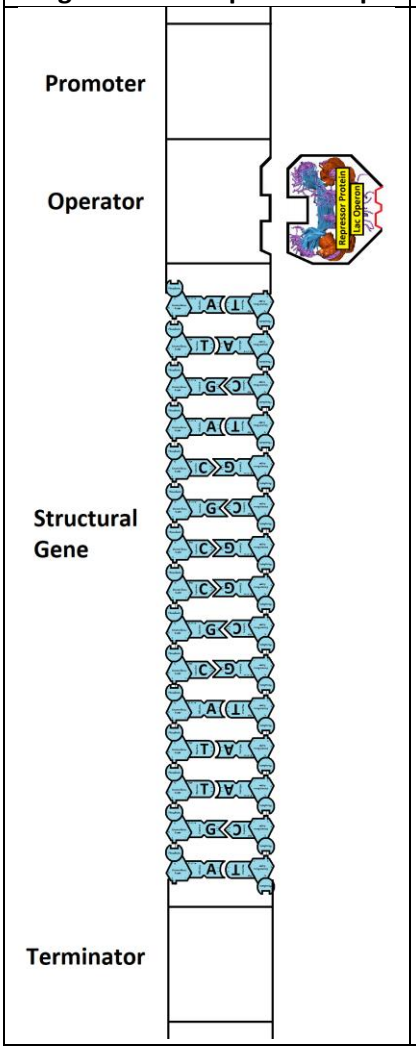


Figure 6.C.2 – Gene off

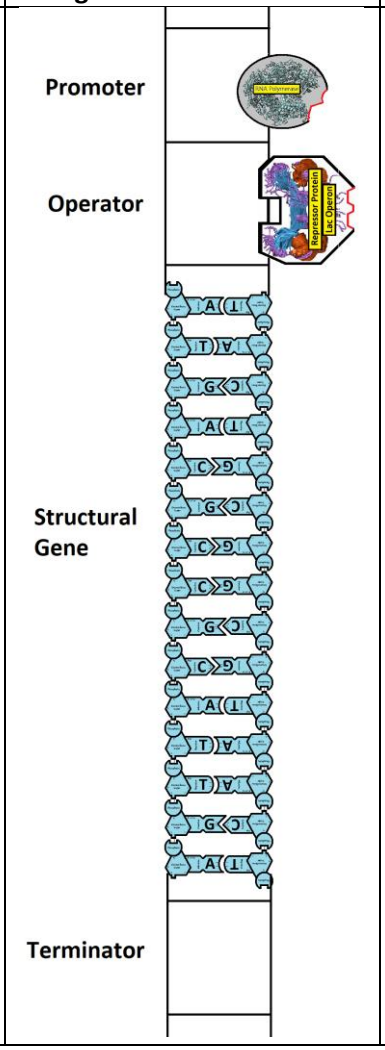


Figure 6.C.3 – Gene on

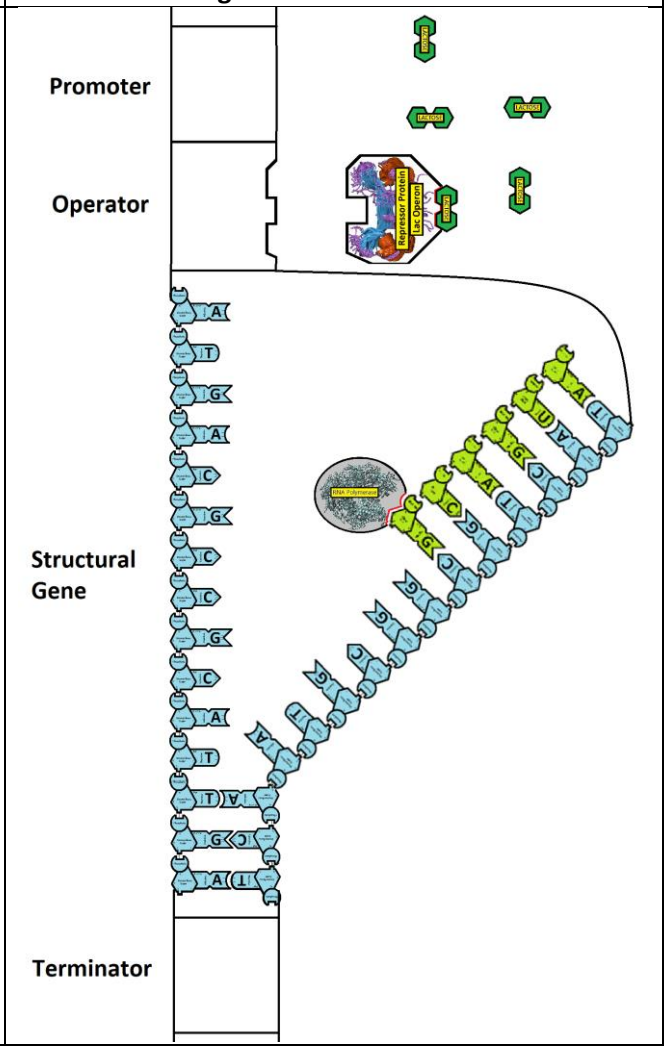
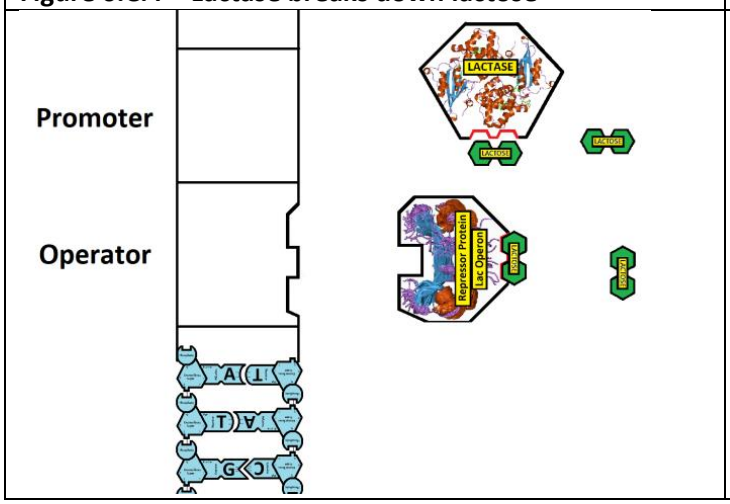
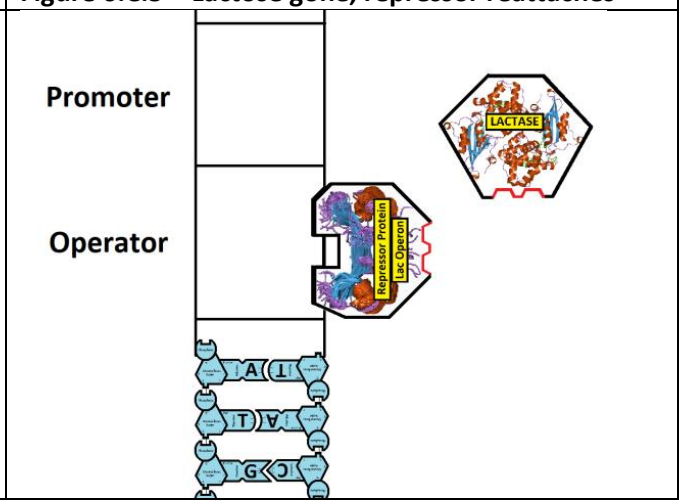
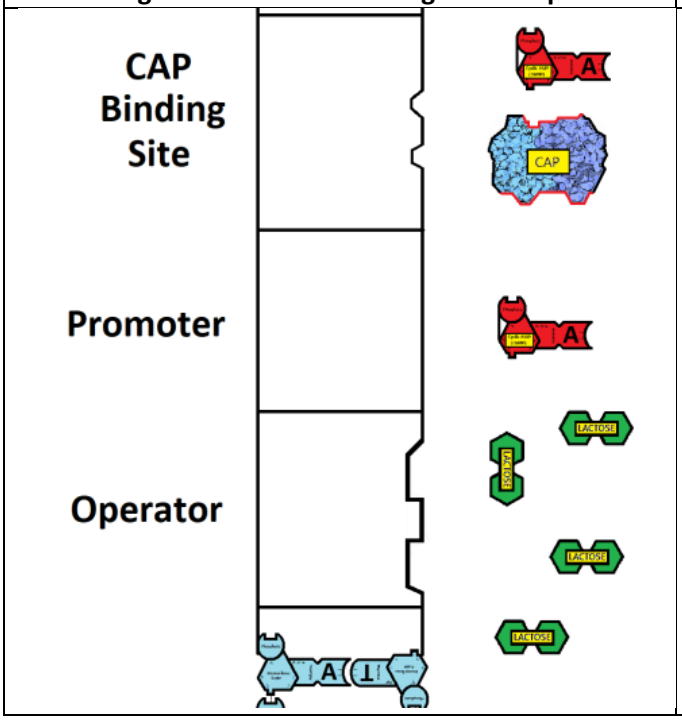
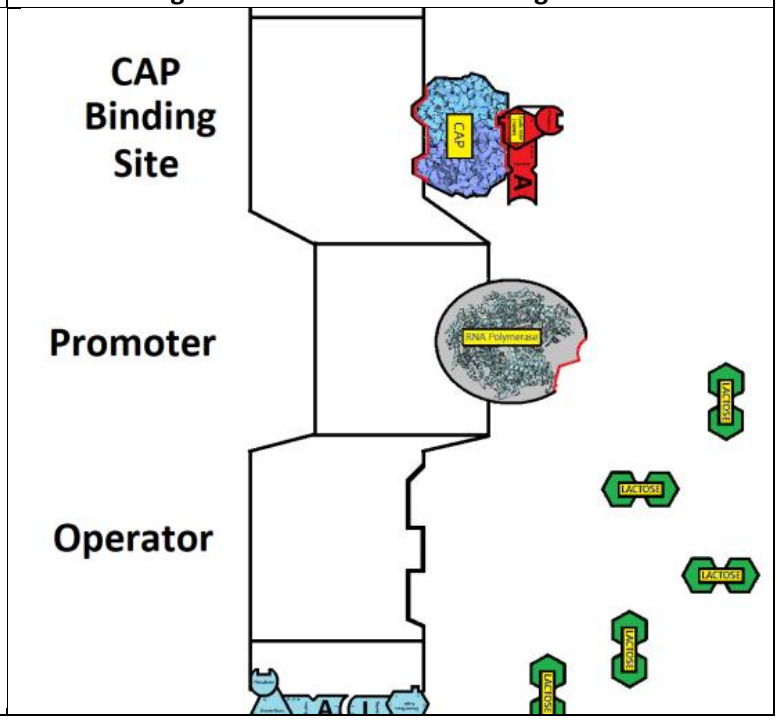


Figure 6.C.4 – Lactase breaks down lactose	Figure 6.C.5 – Lactose gone, repressor reattaches
	

Extra exercises:

CAP Binding Site: This activity requires the Module 6 mRNA processing/Operon supplement package. When glucose levels are low, cyclic AMP goes up and CAP binding acts as a positive control to speed up transcription of the gene. Draw an extension of the DNA beyond the promotor and use the CAP protein as a stencil to draw a binding site for CAP with a marker (**Figure 6.C.6**). Attach cAMP to the CAP protein, then attach the CAP-cAMP complex to the CAP Binding site. This causes the DNA to bend so the promotor is more accessible to the RNA polymerase. Draw the bent promotor with a marker to illustrate (**Figure 6.C.7**). Transcription will speed up and the lactose will be broken down more quickly.

Figure 6.C.6 – CAP Binding Site setup	Figure 6.C.7 – CAP-cAMP binding action
	

Trp Operon: Use the Trp repressor protein to represent the Trp operon, a repressible operon. Normally, the gene is in the "on" position and when expressed, enzymes are produced that make the amino acid tryptophan. When tryptophan builds up, one of them will attach to the repressor protein, which will change shape and attach to the operator. This turns the gene to the "off" position. Each student should demonstrate this with the Biology Magnets.