AP® EDITION

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# BIOLOGY

## Fourteenth Edition

**Sample Chapter**
**Teacher Manual**

McGraw Hill

CHAPTER 13

# Regulation of Gene Expression

| Section | Pacing (class periods) | AP Topics |
|---|---|---|
| 13.1 Prokaryotic Regulation | 1 | 4.2 Introduction to Signal Transduction<br>4.3 Signal Transduction<br>4.4 Changes in Signal Transduction Pathways<br>6.5 Regulation of Gene Expression<br>6.6 Gene Expression and Cell Specialization |
| 13.2 Eukaryotic Regulation | 2 | 4.4 Changes in Signal Transduction Pathways<br>6.5 Regulation of Gene Expression<br>6.6 Gene Expression and Cell Specialization |
| 13.3 Gene Mutations | 1 | 4.4 Changes in Signal Transduction Pathways<br>6.7 Mutation |
| **Chapter Resources** | | |
| *Practice Questions and Exams*<br>Chapter 13 Test Bank<br>Additional AP Practice Questions<br>Unit Review: AP Unit 4<br>Unit Review: AP Unit 6<br><br>*Online Activities*<br>Operons<br>Gene Switches<br>Identical Twins, Identical Fates? An Introduction to Epigenetics<br>Lost in Translation | | |

## Teaching Strategy and Approach

Regulation of gene expression is an abstract concept and hard for many students to visualize. Videos and models are a great way to help students connect with the material.

The reasons for gene regulation are multiple but should be pointed out to students. I always like to remind them that the liver cell is oozing bile but that the skin cells on their face are not oozing bile because of gene regulation. Cell specialization is one of the most important reasons for gene regulation. Only certain parts of DNA are active in any cell so that the cell has what it needs to function.

Class time: four 45-minute class periods

**Day 1:** Lecture—20 minutes on operons

Activity 1: Operons—25 minutes

**Day 2:** Lecture—20 minutes on eukaryotic gene regulation

Activity 2: Gene Switches—25 minutes

**Day 3:** Lecture—10 minutes on epigenetics

Activity 3: Identical Twins, Identical Fates?—35 minutes

**Day 4:** Lecture—10 minutes on mutations in DNA

Activity 4: Lost in Translation—35 minutes

**Teaching Tips:** Case studies are a good way to get students involved and thinking deeply about content. The National Center For Case Study Teaching In Science has a case study on epigenetics that can be found on their website. You can print these materials and have students work in groups to read and analyze the data and provide answers to the critical thinking questions.

## Student Misconceptions and Pitfalls

Students tend to forget that all cells in a multicellular organism contain the same DNA. Somehow they think that the DNA is divided according to function. This information should make them realize the intricate regulation that must occur in a multicellular organism.

## Suggested Activities

These activities can be found in the teacher resources section of your online course.

1. Operons: Students will construct a model of an operon (*trp* or *lac*). Full directions and student worksheets available in your online course.
2. Gene Switches: Students watch an HHMI animation and navigate an interactive website to better understand how gene regulation works. Additional directions and a link to the activity are available in your online course.
3. Identical Twins, Identical Fates? An Introduction to Epigenetics: Students read a case study which features epigenetics prepared by the National Center for Case Study Teaching in Science. Links and further directions are available in your online course.

   **Differentiated Instruction:** For students who are stronger visual learners, provide a link to the Nova Science Now video on Epigenetics (available in your online course). This video provides an excellent animation of DNA methylation.

   You can also review the discussion questions found in Supported Materials after viewing.

4. Lost in Translation: Students build a series of pipe cleaner bumblebees following amino acid coding instructions to learn the effects of mutation.

## EL Strategies

These activities are designed for those students in need of language support.

### Listening – Beginning

Have students log in to their ebook to hear pronunciations of chapter vocabulary terms. They can also listen to a complete audio read of the text.

### Oral Language Development – Intermediate

Have partners make and use flashcards to check each other's pronunciation and understanding of vocabulary.

# Answers to Questions in the Student Edition

## Section 13.1, Check Your Progress

1. Explain the difference between the roles of the promoter and operator of an operon.

   The promoter signals the start of the operon and the location where transcription begins, while the operator controls transcription of structural genes.

2. Summarize how gene expression differs in an inducible operon versus a repressible operon.

   In an inducible operon, the enzymes only need to be active when the specific nutrient is present, and are then turned on. In a repressible operon, the enzymes instead can be turned off by a change in shape of the repressor.

3. Describe the difference between positive control and negative control of gene expression.

   Positive control of gene expression is when a molecule that is active (inducer) promotes the activity of the operon. Negative control is when an active molecule (repressor) shuts down an operon.

4. Explain which operon discussed in this section is catabolic and which operon is anabolic.

   Inducible operons are usually catabolic and repressible operons are usually anabolic.

## Section 13.2, Check Your Progress

1. List the five levels of genetic control in eukaryotes.

   chromatin structure, transcriptional control, posttranscriptional control, translational control, posttranslational control

2. Explain how chromatin structure influences gene expression.

   Chromatin structure influences gene expression through chromatin packing: it is used as a way to keep genes turned off. If genes are not accessible to RNA polymerase, they cannot be transcribed.

3. Discuss how small RNA molecules and proteasomes regulate gene expression.

   Small RNA molecules regulate gene expression through altering DNA compaction, disabling the translation of mRNA in the cytoplasm, and joining with an enzyme to form an active silencing complex. Proteasomes regulate gene expression because they help control the amount of protein product in the cytoplasm.

## Section 13.3, Check Your Progress

1. List some common causes of spontaneous and induced mutations.

   Spontaneous mutations are caused by any number of normal biological processes, such as a transposon jumping or a chemical change in a DNA base. Induced mutations are caused by environmental factors, such as exposure to toxic chemicals or radiation.

2. Explain how a frameshift mutation may disrupt a gene's function.

   Frameshift mutations can disrupt a gene's function because all the codons downstream of the mutation get shifted through the addition or deletion of one or more nucleotides. This results in a completely new sequence of codons, yielding a nonfunctional protein.

3. Discuss how a mutation in a tumor suppressor gene and in proto-oncogenes disrupts the cell cycle.

   A mutation in a tumor suppressor gene and in proto-oncogenes disrupts the cell cycle because it can allow the cell to continue dividing unchecked. Tumor suppressor genes ordinarily act as brakes on cell division, and proto-oncogenes are usually turned off but when turned on stimulate cell division.

## AP Assessment

1. Regulatory proteins control the expression of genes in both prokaryotes and eukaryotes through transcriptional control. At what stage in the gene expression process would regulatory proteins have their effect?

   A) They modulate the binding of RNA polymerase to the DNA promoter.
   B) They control RNA editing and processing.
   C) They moderate the rate at which tRNAs assemble at the ribosome.
   D) They interfere with the joining of amino acids to tRNAs.

   Answer: A; Regulatory proteins interact with the binding of RNA polymerase. When they bind on, they either block transcription by literally blocking RNA polymerase, or they facilitate transcription by making it easier for RNA polymerase to bind to the promoter.

2. Your classmate is lactose intolerant, and therefore consumes no lactose-containing foods. Consider the population of *E. coli* living in your classmate's gut. Which statement best describes these bacteria?

   A) Their *lac* operon must operate at high speed to manufacture enough lactose.
   B) Their *lac* operon will be deactivated and removed from the bacterial chromosome, due to the permanent lack of lactose.
   C) Their *lac* operon is always turned on, utilizing other disaccharides to interact with their lac repressor.
   D) Their *lac* operon is always turned off, without lactose to interact with their lac repressor.

   Answer: C; The presence of lactose is necessary to interact with the repressor. Without lactose, the repressor will always be bound to the operator on the operon. Transcription by RNA polymerase will always be blocked, and the operon's genes cannot be read: the operon is always turned off.

**3.** Posttranscriptional control provides another avenue for gene regulation in eukaryotic cells. One such control mechanisms involves small RNA's. What is the most common effect of microRNAs (miRNAs)?

A) amplification of gene expression by copying genes

B) increasing rate of RNA processing in the nucleus

C) silencing genes by inhibiting the translation of their mRNA

D) inhibiting gene expression by blocking transcription

Answer: C; These small pieces of RNA can bind to mRNA and disable its translation. Thus, the gene is read (transcribed), but not expressed (translated).

**4.** The term mutation refers to any change in the nucleotide sequence of a gene. Of the types of mutations listed below, predict which would likely cause the least change in the gene.

A) point mutation

B) frameshift mutation

C) transposon

D) nondisjunction

Answer: A; A point mutation is a change in single point, in this case a single nucleotide. In some cases, there is no change in the final product, as the same amino acid is coded for. In other cases, the amino acid product is changed and causes drastic results (as in sickle cell anemia).

**5.** A mutagen is chemical that can cause DNA to mutate. It is very important, then, for scientists to determine if compounds are mutagens or not. The Ames test is used to identify mutagens. The test uses a strain of bacteria that cannot make the amino acid histidine. The bacteria are exposed to a suspected mutagen and grow on a medium without histidine. The bacteria that grow have a mutation called a reversion because they reverted to the natural condition of making histidine. The compounds in the graph were Ames tested.

A) Describe the relationship between the amount of the compound and the mutation.

The greater the amount of compound in the culture, the greater the reversion rate.

B) Analyze which compound is the strongest mutagenic compound.

A is the strongest mutagen, producing the most colonies with reversion mutations.

**6.** Eukaryotes have evolved a variety of regulatory mechanisms that allow them to fine-tune gene expression and produce a large number of proteins from a relatively small number of genes. Explain how three regulatory mechanisms of gene expression support efficient cell function.

Explanation for how the regulatory mechanism in supports efficient cell function (1 point each):

- Promoters, terminators and enhancers are regulatory sequences (stretches of DNA) that interact with regulatory proteins to control transcription allowing for cell specialization in that only what is needed is coded for, and only when it is needed.
- The expression of specific genes can be turned on by the presence of an inducer or activator (a small molecule that interacts with regulatory proteins and/or regulatory sequences) when gene expression is needed.
- Regulatory proteins stimulate gene expression by binding to DNA and stimulating transcription (positive control) or binding to repressor to inactivate repressor function when the specific outcome of gene expression is needed, and therefore not using energy and resources when they are not necessary at other times.
- The expression of specific genes can be inhibited by the presence of a repressor (a small molecule that interacts with regulatory proteins and/or regulatory sequences) when gene expression is not needed, thus saving materials and energy for the cell.
- Regulatory proteins inhibit gene expression by binding to DNA and blocking transcription (negative control) when the results of gene expression are not needed by the cell so energy and materials are not wasted.
- Certain necessary genes are continuously expressed; that is, they are always turned "on," e.g., the ribosomal genes.
- Transcription factors bind to specific DNA sequences and/or other regulatory proteins. The combination of transcription factors binding to the regulatory regions at any one time determines how much, if any, of the gene product will be produced.