BIOLOGY HOW LIFE WORKS

CHAPTER 4

TRANSLATION AND PROTEIN STRUCTURE

ACTIVITIES

Gene Expression: Transcription and Translation

Using clicker questions, students will practice **1)** identifying the template strand in a double-stranded DNA molecule, **2)** determining the sequence of an RNA molecule based on the DNA template, and **3)** deducing the amino acid sequence of a polypeptide based on the nucleotide sequence of an RNA molecule.

CHAPTER 5

ORGANIZING PRINCIPLES

ACTIVITIES

Surface Area-to-Volume

This activity was developed to reinforce the importance of the plasma membrane as a selective barrier to movement of substances into and out of the cell. Students will calculate the cell surface area occupied by glucose transporters. Their calculations will demonstrate that as they model larger and larger cells, at some point the cytoplasmic requirement for glucose would exceed the transporter capacity even if the plasma membrane was 100% covered by transporters, demonstrating that surface area-to-volume ratios can directly limit cell size.

Protein Sorting Activity: ABO Blood Groups

In this activity, students will build a protein sorting model relating to the ABO blood group antigens. They will be tasked with building models for **1)** the glycoproteins that carry the ABO antigens, and **2)** the enzymes responsible for adding the ABO antigens. Since these gene products are differently targeted in or on the cell, it should help students solidify their understanding of protein targeting signals, the endomembrane system and organelle functions, and how information flow intersects with structure/function relationships.

Membrane Structure and Function

This in-class activity is designed to facilitate the exploration of membrane structure and function. Using clicker questions and completing a group handout, students will practice **1)** predicting the ability of a substance to move across the membrane, **2)** discriminating between different modes of transport across the membrane, and **3)** relating how changes in the environment and constituents of the plasma membrane affect fluidity.

Membrane Fluidity: Interpretation and Application

The fluidity of biological membranes is affected by temperature, fatty acid side chain saturation, and fatty acid side chain length. This activity presents several graphs and asks students to interpret the graphs to correctly answer questions about the relationships among the factors listed above and membrane fluidity. It also reinforces the relationship between the presence or absence of double bonds and the saturation state of fatty acids.

CHAPTER 6

MAKING LIFE WORK: CAPTURING AND USING ENERGY

ACTIVITIES

Allosteric modulation of enzyme activity — using ACE inhibitors to control hypertension

This exercise is intended to expand on the idea of allosteric regulation of enzymes. Students will interpret graphs of enzyme rate vs substrate concentration to determine how allosteric regulators alter enzyme function, specifically an enzyme's affinity for substrate and its catalytic efficiency. The activity includes a few slides presenting very brief background on hypertension and Angiotensin Converting Enzyme (ACE).

CHAPTER 7

CELLULAR RESPIRATION: HARVESTING ENERGY FROM CARBOHYDRATES AND OTHER FUEL MOLECULES

ACTIVITIES

Respiration Box-and-Arrow Activity

This activity provides a systems view of cellular respiration and its stages (glycolysis, pyruvate oxidation, the citric acid cycle, and oxidative phosphorylation). Students build or manipulate simple models that encourage them to think about the inputs and outputs of each stage and to account for the transfers of energy and substrates between stages.

Connecting Processes in Cellular Respiration

The biochemical processes of cellular respiration are connected through the use of common currency—ATP, acetyl CoA, and NADH—to exchange energy, carbon, and reducing power, respectively. Students work through a series of questions, making clear how the function of each process in cellular respiration can influence the others by altering the currencies of metabolism. At the end of this activity, students should be able to answer this question: In conditions with abundant glucose, but low oxygen, what would happen to the rate of pyruvate transport?

CHAPTER 8

PHOTOSYNTHESIS: USING SUNLIGHT TO BUILD CARBOHYDRATES

ACTIVITIES

Diagramming Photosynthesis Systems

This activity provides a systems view of photosynthesis and its sub-processes (light-harvesting reactions and the Calvin cycle). Students build or manipulate simple models that encourage them to think about the inputs and outputs of each sub-process and to account for the transfers of energy and substrates between them.

CHAPTER 9

CELL SIGNALING

ACTIVITIES

Cell Signaling: Cancer, Activity Description

In this activity, students will interpret a diagram that presents many components of a receptor tyrosine kinase signaling pathway (as illustrated by the PDGF response) as it impacts regulation of cell division. The primary activity is group interpretation of the diagram followed by clicker assessments with interspersed mini-lectures as needed. A final (and optional) take-home assignment is to suggest a mutation for each pathway step that could lead to unregulated proliferation of cells (cancer).

Cell Signaling: Fight-or-Flight Response Version 1: Interpret a diagram

In this activity students will reinforce their understanding of cell signaling by working with a schematic model of how the adrenaline signaling pathway functions to mobilize glucose for the fight-or-flight response. The model will be based on an understanding of the detailed information provided in the chapter and in the VS Animation on Cell Signaling. They will consider glycogen mobilization as the signaling response. The final student product, which is optional, is a simplified box-and-arrow diagram of the system. Cell Signaling: Fight-or-Flight Response

Version 2: Build a simplified model

In this activity students will develop a simplified diagrammatic model to reinforce their understanding of the fight-or-flight adrenaline signaling response. Their models will be based on an understanding of the detailed information provided in the chapter and in the VS Animation on Cell Signaling. Rather than model the identical response depicted in the animation (heart rate), however, they will consider glycogen mobilization as the signaling response.

CHAPTER 11

CELL DIVISION: VARIATIONS, REGULATION, AND CANCER

ACTIVITIES

Ploidy vs. Number of Copies

This activity is designed to help students better distinguish two of the "doublings" involved in DNA and chromosomes: homologous pairs vs. replicated chromatids. Students are asked to fill in a table of cell cycle stages with both the ploidy (n) and the copy number (c). In this way they will see that in the normal diploid cell cycle, n does not change while c cycles from 1c (G1) to 2c (following S) then back to 1c as an outcome of mitosis. The changes in meiosis, however, are more revealing as both n and c change, but change in specific parts of the process.

Double-Double-Double Activity

This activity is a very brief set of guided questions that will challenge students to correctly distinguish between often-confused "doubles" of DNA and chromosome structure: **1)** DNA is a double helix. **2)** Most familiar eukaryotic cells are diploid (2n). **3)** DNA is replicated prior to cell division. Students often demonstrate confusion when moving among various representations of chromosomes and DNA, and this is in part a result of the multiple pairs or "doubles" involved. This activity, composed of a short sequence of questions (especially suitable for clickers), can quickly bring 90%+ of students to a correct understanding of the relationships between the 3 doubles

CHAPTER 12

DNA REPLICATION AND MANIPULATION

ACTIVITIES

Replication Bubble Activity

This activity challenges students to actually put to use many of the key concepts relating to DNA replication. They are given a handout depicting a replication origin and are assigned tasks to start building primers on the leading and lagging strands, which requires that they account for the limitations of DNA polymerase and for the anti-parallel orientation of complementary strands. It reinforces DNA structure, strand orientation, and the difference between the continuous synthesis of the leading strand and the discontinuous synthesis of the lagging strand.

DNA Pairs

In this short sequence of guided questions, students will work at distinguishing between 3 potentially confusing pairings of molecular biology: paired DNA strands, paired sister chromatids, and paired homologous chromosomes. Questions include ones that specifically call for comparison of sequence similarity between members of each pair (for example, while paired DNA strands are complementary, their base sequence is entirely different, whereas sister chromatid pairs, which arise via replication, have essentially identical sequence). The questions also tie these concepts back to the cell cycle, mitosis, and meiosis, for example asking which pair is separated during Meiosis I.

CHAPTER 14

MUTATION AND DNA REPAIR

ACTIVITIES

Mutation effects on central dogma

This activity spans material covered in multiple chapters and summarizes the effects of mutations on the central dogma. Instructors use a set of diagrams of gene structure and gel electrophoresis provided in the activity to guide students through a series of questions that ask them to understand the effects of mutations that could alter the mRNA and protein produced from a gene. The mutations types include changes in the coding sequence including missense, nonsense, and frameshift mutations as well as insertions, duplications, or deletions that could affect transcription, RNA processing, or translation.

CHAPTER 17

INHERITANCE OF SEX CHROMOSOMES, LINKED GENES, AND ORGANELLES

ACTIVITIES

Pedigree analysis through genetic hypothesis testing

This activity guides students through a series of simple pedigree problems in order to practice the skills required to solve a complex pedigree problem, an example of which is given at the end of the exercise. Students are first exposed to a complex pedigree with a real-world look and feel. They then are provided with a method of genetic hypothesis testing that they practice by solving a series of very simple pedigree problems. Finally, they apply their skills to the original complex pedigree.

CHAPTER 18

THE GENETIC AND ENVIRONMENTAL BASIS OF COMLEX TRAITS

ACTIVITIES

Genetics of a Complex Trait

This activity allows students to discover how much variation in phenotype is possible from combinations of a few genes and some environmental effect. In it, students explore the quantitative results of various permutations of multiple genes, first in the absence of an environmental effect, and then with an environmental effect added to the genetics. The logic that must be applied derives from the principles of transmission genetics covered in Chapter 16, but explores those principles as the genes interact in determining the ultimate phenotype of the complex trait. The complexity of the model is built sequentially with the intention that smaller bites will be easier to digest.

Genetics of Complex Traits, Exploring a Regression Model

This activity provides an extended chance to work with graphs as a way to interpret data and model concepts. Students will explore and manipulate the plot of parental vs. offspring height (HLW Fig. 18.8) by creating alternative plots based on either hypothetical examples, or examples with specific alternative conditions. Execution of these modifications should strengthen students' fundamental understanding of regression to a population mean, especially within the context of complex genetic traits. The specific steps in the activity can be flexibly assigned before, during, and after class, as appropriate to the particular course. The activity includes a suggested scenario, in which students gather their family's height data pre-class to verify the classical data, followed by problems intended to generate classroom discussion, and finishing with exploration of Fig. 18.8 and similar plots.

CHAPTER 19

GENETIC AND EPIGENETIC REGULATION

ACTIVITIES

Iron-Response Element: Translation and Post-transcriptional control of gene expression.

This activity uses the process of iron sensing and response to illustrate post-transcriptional control of gene expression. Students will build graphic representations of cellular iron homeostasis mechanisms based on ferritin and transferrin expression. Control of gene expression, often emphasizes transcriptional control mechanisms, leaving important post-transcriptional controls largely unexplored and potentially challenging for many students. This activity was designed to help students visualize important aspects of post-transcriptional control: regulation of protein levels both by regulating translation from mRNA and by regulating mRNA half-life, but in the same pathway – iron uptake. The exercise also illustrates how a molecular interaction (in this case the iron response element and its binding protein) can elicit distinct but coordinated responses (cellular iron uptake and subsequent sequestering).

Genetic and Epigenetic Regulation

This activity has students explore a model of regulation of a set of genes involved in the control of cell division. Transcription of these genes is regulated by the binding of particular combinations of transcription factors, the activation of which is regulated by cell signaling pathways. The activity requires students to determine which combinations of transcription factors will activate particular genes and ultimately how cell signaling will allow cell division. To explore gene regulation more broadly, students are required to interpret the role of alternative splicing of RNA, chromatin remodeling and microRNAs.

CHAPTER 21

EVOLUTION: HOW GENOTYPES AND PHENOTYPES CHANGE OVER TIME

ACTIVITIES

Population Genetics and Mechanisms of Evolution

This activity is an exploration of the mechanisms of evolution and their potential effects on allele frequencies. After a quick review of parallels between Mendelian and population genetics, students will work through a series of clicker questions about a hypothetical population and how different evolutionary mechanisms may alter allele frequencies. The activity incorporates class discussion, think-pair-share, and practice calculations using Hardy-Weinberg equation.

Evolution – How Genotypes and Phenotypes Change over Time

This activity is designed to help students understand how many different factors can affect whether or not the frequencies of specific genes or alleles will remain or increase in a population over time. To fully understand this, students must have a good understanding of what makes a gene or allele advantageous, how selection can change the frequencies of alleles and how we can determine mathematically (Hardy-Weinberg relation) whether or not such change may be occurring. The activity is set up as a series of clicker assessments. A final (and optional) take-home assignment asks student to compare mutation rates for and incidence of both Huntington's chorea and Tay Sachs disorder to examine how and the there is a difference in the frequency of these lethal disorders in the population.

CHAPTER 22

SPECIES AND SPECIATION

ACTIVITIES

Are they species yet?

Chapter 22 introduces the concept of speciation and the factors affecting it. This Chapter 22 activity – "Are they species yet?" examines whether differences in species data on two islands in the Galapagos indicate that speciation is occurring. It also introduces students to how to conduct basic descriptive statistics and develop graphs using data for two species of finch, Geospiza fortis and Geospiza fulginosa, from two different islands, Pinta and Marchena.

Population Genetics and Mechanisms of Evolution

This activity asks students to explore allopatric speciation through vicariance. A hypothetical population is split and students are asked a series of clicker questions that requires them to integrate information from chapter 21 in order to master concepts related to speciation, selection, drift, and reinforcement.

CHAPTER 23

EVOLUTIONARY PATTERNS: PHYLOGENY AND FOSSILS

ACTIVITIES

Phylogeny Construction

This activity provides students with practice using phylogenetic trees to test hypotheses. Students begin by formulating their hypothesis using an in-class worksheet and making predictions on the branching pattern for the phylogeny based on morphologic data from flightless birds. They then evaluate their hypotheses, compare them to a molecular data set, and reevaluate their original trees and the support for their earlier hypothesis.