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Using BioInteractive.org Resources to Teach:

Gene Expression

(From Gene to Protein)

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From the Author

With the pace of current research, the biological sciences change incredibly fast, particularly in the fields of molecular genetics, specifically gene expression. Therefore, as a veteran biology teacher, I am constantly looking for resources that include up-to-date research, prompt students to process material, help reinforce textbook material, and stimulate discussions and explorations of current biological topics. For these reasons, I routinely use HHMI's BioInteractive website and Holiday Lectures on Science DVDs in my classroom to highlight and strengthen my day-to-day coverage of material.

These resources are accurate, user friendly, free, and easily accessible—all key elements for successful classroom implementation. They have greatly enhanced my teaching methods, my students' ability to understand the material, and our shared knowledge about current findings in biology. The video clips, animations, and lecture chapters enhance formal classroom lecture material, increasing student understanding and assisting student visualization of the subject matter, particularly at the molecular level, where many students struggle. Furthermore, the interactive Click and Learn activities, virtual museum, and classroom activities are used to introduce or complement curricular objectives. Finally, the virtual lab series is an excellent set of computer laboratory simulations.

This curriculum guide assists in filtering and organizing the vast resources available according to topics related to the central dogma of biology, gene expression. Please do not hesitate to contact me with any questions or suggestions.

Most sincerely,

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Introduction

The amount of resources accessible to teachers from various organizations and the Internet can be overwhelming. Furthermore, finding the time to process these resources and develop them into solid, classroom-ready activities and lessons is difficult. This guide provides teacher-ready curriculum ideas using Howard Hughes Medical Institute (HHMI) resources, including the BioInteractive website features and the Holiday Lectures on Science DVDs, to enhance classroom instruction of molecular genetics, specifically instruction related to gene expression.

This curriculum guide organizes HHMI resources into the following categories: gene expression, RNA, transcription, translation, and post-translational events. The resources include animations, video clips, interactive Click and Learn activities, virtual labs, and lectures specific to the topic. The following is a brief overview of the material covered in each section.

"Gene Expression" includes a vast array of information on the central dogma of biology: gene expression. It covers human disease; the use of fruit flies as genetic models; visualizing gene expression in the lab; the role of gene expression in circadian rhythm, AIDS, and the development of the human brain; and the Human Genome Project.

"RNA Structure and Function" reviews the diversity of structure and function of various types of RNA during the gene expression process. Also included is information about RNA serving as a catalyst for cellular processes and its role in interfering with the gene expression process. (More information on RNA interference can be found in the *Gene Regulation* curriculum guide.)

"Transcription" helps students visualize the process of transcription as well as understand the use of RNA expression–level analysis to complete genetic research.

"RNA Processing (Post-transcription)" helps explain how, once transcription is complete, eukaryotic cells undergo a process called RNA splicing in order to prepare the RNA to leave the nucleus.

"Translation" includes animations showing the process of translation. In addition, other resources explain the role of translation in human disease and the circadian rhythm of some organisms.

"Proteasome (Post-translation)" explores what happens to proteins once they are used by the cell. The proteasome is a large molecular machine that plays an important role in recycling and regulating cellular proteins. In this section, students learn about the structure and function of this fascinating cellular machine and its role in neurodegenerative diseases.

BioInteractive.org Gene Expression Resources and Access Instructions

Gene Expression

All of these resources can be accessed via www.BioInteractive.org and/or the Holiday Lectures on Science DVDs.

If you have downloaded this document from BioInteractive.org, simply click on the resource name to open the resource.

Resource Type	Resource Name	Resource Summary	NGSS (April 2013)	AP Biology (2015)	IB Biology (2016)
Click & Learn	Visualizing Gene-Expression Patterns *Resource title on DVD:* Visualizing Gene Expression	Learn about the different ways scientists are able to detect when genes are being expressed in various tissues. (19 slides)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-2 (LS4.B, LS4.C)	3.A.1.e; 3.B.1.a,b,c,d; 3.B.2.a,b; 3.C.1.d	1.5, 2.7, 3.5, 5.2, 7.2, 7.3, B.4
Animation	Wing Morph	This "morph" animation demonstrates how the expression of a particular toolkit gene in a butterfly larva corresponds to the location of the wing eyespots in an adult butterfly. (28 sec.)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-2 (LS4.B, LS4.C)	3.A.1.e; 3.B.1.a,b,c,d; 3.B.2.a,b; 3.C.1.d	1.5, 2.7, 3.5, 5.2, 7.2, 7.3, B.4
Lecture	Lecture 3: Fossils, Genes, and Embryos, Chs. 28–31	Different animals share developmental pathways. (36:06–41:23) *This segment discusses the* Hox *toolkit genes and the expression of these genes in development.*	HS-LS1-4 (LS1.B), HS-LS3-2 (LS3.B), HS-LS4-1 (LS4.A), HS-LS4-2 (LS4.B, LS4.C), HS-LS4-4 (LS4.C), HS-LS4-5 (LS4.C)	1.A.1.c; 1.A.2.b; 1.A.4.b; 1.B.1.a; 2.E.1.a,b; 3.B.1.a,b,c,d; 3.B.2.a,b; 3.C.1.d; 4.A.3.a,b	1.5, 2.7, 3.5, 5.1, 5.2, 7.2, 7.3, B.2
Lecture	Lecture 4: From Butterflies to Humans, Chs. 14–18	Spots evolved via new use of an old toolkit gene. (16:01–21:23) *These chapters include material on toolkit gene expression as related to wing spots.*	HS-LS1-4 (LS1.B), HS-LS3-2 (LS3.B), HS-LS4-1 (LS4.A), HS-LS4-2 (LS4.B, LS4.C), HS-LS4-4 (LS4.C), HS-LS4-5 (LS4.C)	1.A.1.c; 1.A.2.b; 1.A.4.b; 2.E.1.a,b; 3.B.1.a,b,c,d; 3.C.1.d	2.7, 3.1, 3.2, 3.5, 7.2, 7.3, B.2
Lecture	Lecture 2: Unwinding Clock Genetics, Ch. 4	How much of what we are is inherited? Genetics as a tool to search for disease mechanisms. (5:26–7:58)	HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A)	3.A.1.a; 3.A.3.a,c	2.7, 3.1, 10.2
Lecture	Lecture 2: Unwinding Clock Genetics, Chs. 5–6	Pioneering the use of the fruit fly *Drosophila* as a genetic tool. (7:58–10:41) *This section also includes a discussion of mutant fly examples.*	HS-LS1-1 (LS1.A), HS-LS3-2 (LS3.B)	3.A.4.a,b; 3.C.1.a,b,c	1.1, 3.1, 7.2
Video Clip	Rett Syndrome	Dr. Zoghbi introduces the topic of Rett syndrome by showing how development usually progresses in a young girl. She then shows an excerpt from *Silent Angels*, introduced by Julia Roberts, which shows how Rett syndrome affects development. (2 min. 52 sec.)	HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS3-1 (LS3.A)	2.E.1.b; 3.A.1.a,c,d; 3.B.1.c,d; 3.C.1.a; 4.B.1a	2.1, 3.1, 3.5, 5.2, 7.2, A.1
Video Clip	Rett Syndrome Mouse	Dr. Zoghbi shows how a mouse that has been given the gene responsible for Rett syndrome exhibits some of the same neurological symptoms as human Rett patients. (1 min. 14 sec.)	HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS3-1 (LS3.A)	2.E.1.a; 3.B.1.c,d; 3.C.1.a; 4.B.1.a	1.1, 2.1, 3.1, 3.5, 7.2, A.1

Lecture	Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 19	Q&A: How do the nerve cells express specific genes? (31:11–32:18)	HS-LS1-2 (LS1.A), HS-LS3-1 (LS3.A)	2.E.1.a; 3.B.1.c,d	1.1, 7.2
Lecture	Lecture 2: Building Brains: The Molecular Logic of Neural Circuits, Chs. 10–14	How do neurons differentiate during development? (13:06–22:55) *This lecture reviews human development and then discusses specific genes controlling brain development. It includes two animations to help students visualize the process.*	HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A, LS3.B)	2.E.1.a,b; 4.A.3.a,b	1.1, 7.2
Video Clip	Interview with Dr. Eric Lander	An interview with Dr. Eric Lander, a leading genomics researcher. (5 min. 30 sec.) *Dr. Lander is one of the original scientists involved in the Human Genome Project.*	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	1.A.4.b; 3.A.1.e	3.5, 5.1, B.2
Lecture	Lecture 1: Reading Genes and Genomes, Chs. 7–10	Review of genetic advances in the 20th century. (11:46–18:46) *This lecture reviews the history of genetic discovery and relates genetic advances to research on human disease.*	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	3.A.1.e	3.5, B.2
Lecture	Lecture 4: Sexual Evolution: From X to Y, Chs. 7–10	What does the Y chromosome do? (12:14–19:27) *This segment includes a map of the Y chromosome and information about the classes of genes found on the Y chromosome.*	HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A)	3.A.4.b, 3.B.2.a	1.1, 7.2
Animation	Evolution of the Y Chromosome	How did the human Y chromosome become so small relative to its X counterpart? This animation depicts the 300-million-year odyssey of the sex chromosomes that began when the proto X and Y were an identical pair. (5 min. 39 sec.)	HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)	1.A.4.b; 3.A.4.b; 3.B.2.a	1.1, 3.5, 5.1, 7.2
Animation	MIX-1	This animation shows how MIX-1 facilitates both chromosome condensation and dosage compensation. (3 min. 39 sec.)	HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS1-4 (LS1.B), HS-LS3-1 (LS3.A)	2.E.1.a,b,c; 3.A.1.a,d; 3.A.2.a,b; 3.A.3.b; 3.B.1.c,d; 3.B.2.a; 3.D.2.b	1.1, 1.6, 2.6, 2.7, 6.5, 7.1, 7.2, 7.3
Animation	X Inactivation	This animation shows how the random deactivation of one of the X chromosomes in a pair can lead to mosaicism in the expression of genes. (55 sec.)	HS-LS3-1 (LS3.A)	3.A.4.b	3.2, 3.4
Lecture	Lecture 2: Unwinding Clock Genetics, Ch. 38	Q&A: How does X inactivation affect the *per* gene on the fly's X chromosome? (53:16–54:24)	HS-LS3-1 (LS3.A)	3.A.4.b	3.2, 3.4
Lecture	Lecture 2: Unwinding Clock Genetics, Ch. 20	Q&A: What are the characteristics of humans with a biological clock mutation? (29:25–30:23)	HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A)	3.C.1.a	2.7, 3.1, 7.1, 7.2
Lecture	Lecture 2: Unwinding Clock Genetics, Chs. 25–29	Beginning the molecular era: Cloning of the *period* gene. (34:29–42:48) *This segment includes a detailed discussion of the* period *gene and its location, organization, and role.*	HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS1-3 (LS1.A)	2.C.1.a; 2.C.2.a; 2.E.2.b; 2.E.3.b; 3.A.1.c	2.7, 6.6, 7.2, D.5
Lecture	Lecture 2: Unwinding Clock Genetics,	Q&A: What affects biological clocks more: genes or environment? (48:19–	HS-LS4-6 (LS4.C)	4.C.2.a	7.2

	Ch. 34	49:36)			
Lecture	Lecture 3: PERfect TIMing, Chs. 4–6	Summary of the fruit fly's circadian clock. (6:11–11:31) *This segment includes information on genes associated with biological clocks.*	HS-LS1-2 (LS1.A), HS-LS1-3 (LS1.A), HS-LS2-8 (LS2.D), HS-LS4-6 (LS4.C)	2.C.1.a; 2.C.2.a; 2.E.2.b; 2.E.3.b	2.7, 6.6, 7.2
Lecture	Lecture 3: PERfect TIMing, Chs. 8–13	Currently known *Drosophila* clock genes. (12:24–22:06) *These chapters explain the main genes associated with circadian rhythm in fruit flies: the* PER *and* TIM *genes.*	HS-LS1-2 (LS1.A), HS-LS1-3 (LS1.A), HS-LS1-6 (LS1.C), HS-LS2-8 (LS2.D), HS-LS4-6 (LS4.C)	2.C.1.a; 2.C.2.a; 2.E.2.b; 2.E.3.b; 3.A.1.c; 4.A.1.a	2.1, 2.3, 2.4, 2.6, 2.7, 6.6, 7.2
Lecture	Lecture 4: The Mammalian Timekeeper, Ch. 17	Q&A: Have you done overexpression experiments with *Clock*? (26:24–27:06)	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	3.A.1.d,e,f	1.4, 3.5, 5.1, 8.1, B.1, B.2, B.4,
Lecture	Lecture 4: The Mammalian Timekeeper, Ch. 18	Q&A: What experiments do you use to see the difference between mutant and wild-type genes? (27:06–28:09)	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	3.A.1.d,e,f	1.4, 3.5, 5.1, 8.1, B.1, B.2, B.4
Lecture	Lecture 4: The Mammalian Timekeeper, Ch. 19	Q&A: What other kinds of mutations are there in the *Clock* gene? (28:09–29:07)	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	3.A.1.d,e,f	1.4, 3.5, 5.1, 8.1, B.1, B.2, B.4
Animation	HIV Life Cycle	How HIV infects a cell and replicates itself using reverse transcriptase and the host's cellular machinery. (4 min. 52 sec.)	HS-LS1-1 (LS1.A)	2.D.3.a; 2.D.4.a,b; 2.E.1.c; 3.C.3.a,b; 3.D.1.a,d; 3.D.2.a; 3.D.3.a,b; 3.D.4.a; 4.C.1.a	1.4, 6.3, 11.1, A.5, D.5
Lecture	Lecture 1: From Outbreak to Epidemic, Ch. 28	HIV: The retrovirus that causes AIDS. (39:28–40:27)	HS-LS1-1 (LS1.A)	2.D.3.a; 2.D.4.a,b; 2.E.1.c; 3.C.3.a,b; 3.D.1.a,d; 3.D.2.a; 3.D.3.a,b; 3.D.4.a; 4.C.1.a	1.4, 6.3, 11.1, A.5, D.5
Animation	AZT Blocks Reverse Transcriptase	HIV's reverse transcriptase mistakes AZT for thymidine. Once incorporated, AZT stops reverse transcription. (1 min. 46 sec.)	HS-LS1-1 (LS1.A)	2.D.3.a; 2.D.4.a,b; 2.E.1.c; 3.C.3.a,b; 3.D.1.a,d; 3.D.2.a; 3.D.3.a,b; 3.D.4.a; 4.B.1.a; 4.C.1.a	1.4, 6.3, 11.1, A.5, D.5
Animation	Protease Inhibitors	Protease inhibitors prevent maturation of viral proteins inside HIV particles. (1 min. 6 sec.)	HS-LS1-1 (LS1.A)	2.D.3.a; 2.D.4.a,b; 2.E.1.c; 3.C.3.a,b; 3.D.1.a,d; 3.D.2.a; 3.D.3.a,b; 3.D.4.a; 4.B.1.a; 4.C.1.a	1.4, 6.3, 11.1, A.5, D.5

Lecture	Lecture 4: Exploring Obesity: From the Depths of the Brain to the Far Pacific, Chs. 20–27	How does variation in genes lead to obesity? (31:14–47:47) *This material illustrates a genetic variation study using a small, isolated population on a Pacific island. It traces inheritance of single nucleotide polymorphisms and the use of DNA chips to analyze the data.*	HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-4 (LS4.B, LS4.C)	1.A.1.c; 1.A.2.a,b; 1.A.4.b; 1.B.1.a; 1.B.2.c	1.1, 1.6, 2.6, 2.7, 5.1, 5.2, 5.4, 7.1, 7.2, 7.3, 10.3

RNA Structure and Function

Most of these resources can be accessed via www.BioInteractive.org and/or the Holiday Lectures on Science DVDs.

If you have downloaded this document from BioInteractive.org, simply click on the resource name to open the resource.

Resource Type	Resource Name	Resource Summary	NGSS (April 2013)	AP Biology (2015)	IB Biology (2016)
Click & Learn	RNA Diversity	RNA is an information molecule that can also function as an enzyme. Learn about the many different forms that RNA can take and their roles. (11 slides)	HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)	1.B.1.a; 1.D.1.a; 2.C.1.a ; 2.E.1.a; 3.A.1.a,b,c,d; 3.B.1.a,b,c; 3.C.1.a,b,d; 3.C.2.a; 4.A.1.a,b; 4.A.2.a; 4.A.3.a,b,c	1.1, 2.1, 2.3, 2.4, 2.6, 3.1, 3.5, 5.2, 7.1, 7.2, 7.3
Animation	RNA Folding	Since RNA is single stranded, it can fold upon itself and form structures that are protein-like in both appearance and functionality. (33 sec.)	HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b	2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Lecture	Lecture 1: Catalysis: Chemical and Biochemical, Chs. 9–12	RNA as an information carrier and an enzyme. (20:00–28:14) *This segment reviews the roles of DNA, RNA, and proteins in the gene expression pathway.*	HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)	1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b	1.5, 2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Lecture	Lecture 1: Catalysis: Chemical and Biochemical, Ch. 27	Q&A: What allows RNA to form different structures? (55:09–56:47)	HS-LS1-1 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)	1.B.1.a; 1.D.1.a; 3.A.1.a,b,c	1.5, 2.1, 2.6, 2.7, 7.1, 7.2, 7.3
Lecture	Lecture 3: PERfect TIMing, Ch. 16	Q&A: How many different RNAs do we know of? (25:29–26:53)	HS-LS1-1 (LS1.A)	3.A.1.c,e	2.7, 3.5
Video Clip	Enzymes That Are Not Proteins: The Discovery of Ribozymes	Listen to former HHMI President Dr. Thomas Cech discussing his Nobel Prize–winning discovery of RNA's catalytic properties. (19 min.)	HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A)	1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b	1.5, 2.1, 2.6, 2.7, 7.1, 7.2, 7.3
Lecture	Lecture 1: Catalysis: Chemical and Biochemical, Ch. 22	Q&A: What are examples of RNA as a catalyst? (45:49–47:39)	HS-LS1-1 (LS1.A)	3.A.1.c; 4.A.2.a	2.7, 7.3
Lecture	Lecture 2: RNA as an Enzyme: Discovery, Origins of Life, and Medical Possibilities, Chs. 3–5	Review of RNA's dual nature. (2:47–10:20) *This material reviews the roles of RNA in gene expression.*	HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1(LS4.A)	1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b	1.5, 2.1, 2.3, 2.4, 2.6, 2.7, 3.1, 5.2, 6.6, 7.1, 7.2, 7.3

Video Clip	*NOVA scienceNOW*: "RNAi" (RNA interference; available on DVD only)	A story from the PBS science newsmagazine detailing the discovery of RNAi and how it functions. (15 min. 18 sec.)	HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A), HS-LS3-1 (LS3.A), HS-LS4-1 (LS4.A)	1.B.1.a; 1.D.1.a; 2.C.1.a; 3.A.1.a,b,c; 3.C.1.a,b; 4.A.1.a,b	1.5, 2.1, 2.3, 2.4, 2.6, 2.7, 3.1, 5.2, 6.6, 7.1, 7.2, 7.3, D.5

Transcription

All of these resources can be accessed via www.BioInteractive.org and/or the Holiday Lectures on Science DVDs.

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Resource Type	Resource Name	Resource Summary	NGSS (April 2013)	AP Biology (2015)	IB Biology (2009)
Animation	Triplet Code	Once the structure of DNA was discovered, the next challenge was determining how the sequence of letters coded for the 20 amino acids. In theory, one or two letters can only code for 4 or 16 amino acids, respectively. A scheme using three letters, a triplet code, is the minimum necessary to encode all the amino acids. (1 min. 8 sec.)	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b	2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Animation	DNA Transcription (basic detail)	The first phase of the process of reading DNA information to make proteins starts with a molecule unzipping the DNA. The molecule then copies one of the strands of DNA into a strand of RNA, a close cousin of DNA. This process is called transcription. (1 min. 55 sec.)	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b	2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Animation	DNA Transcription (advanced detail)	The process of copying DNA into messenger RNA (mRNA) is called transcription. Transcription factors assemble at the promoter region of a gene, bringing an RNA polymerase enzyme to form the transcription initiation complex. Activator proteins at the enhancer region of DNA then activate the transcription initiation complex. RNA polymerase unzips a small portion of the DNA and copies one strand into an mRNA molecule. (1 min. 55 sec.)	HS-LS1-1 (LS1.A), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b	2.1, 2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Lecture	Lecture 3: Human Genomics: A New Guide for Medicine, Ch. 20	Measuring variations in the levels of all RNA expressions. (32:39–33:57)	HS-LS1-1 (LS1.A)	3.A.1.b	2.6, 2.7, 7.1
Lecture	Lecture 3: PERfect TIMing, Ch. 24	Constant light does not suppress the circadian rhythm of *cryptochrome* mutants. (39:30–41:09)	HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS1-3 (LS1.A)	2.C.2.a; 2.E.2.b	6.6, D.5
Lecture	Lecture 3: PERfect TIMing, Ch. 26	DBT mutant strain showing a long period. (43:17–45:06)		3.B.1.a,c,d	1.1, 3.1, 7.1, 7.2

RNA Processing (Post-transcription)

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Resource Type	Resource Name	Resource Summary	NGSS (April 2013)	AP Biology (2015)	IB Biology (2016)
Animation	mRNA Splicing	Once a gene has been transcribed into messenger RNA (mRNA), it is edited in a process called splicing. Noncoding regions called introns are removed, leaving protein-coding regions called exons. (39 sec.)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b	2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Lecture	Lecture 2: RNA as an Enzyme: Discovery, Origins of Life, and Medical Possibilities, Chs. 7–12	Why study the protozoan *Tetrahymena* and RNA splicing? (12:28–28:33) *This lecture segment explains the details of RNA splicing following DNA transcription.*	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b	2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Lecture	Lecture 3: How to Accelerate a Reaction 100,000,000,000 Times Using Only RNA, Chs. 4–8	Outline of the lecture and the biochemical mechanism of RNA splicing. (7:14–21:05) *This segment discusses the biochemical mechanism of RNA splicing along with the catalytic nature of RNA.*	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b	2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3

Translation

All of these resources can be accessed via www.BioInteractive.org and/or the Holiday Lectures on Science DVDs.

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Resource Type	Resource Name	Resource Summary	NGSS (April 2013)	AP Biology (2015)	IB Biology (2016)
Animation	Translation (basic detail)	The ribosome is a molecular factory that translates the genetic information in RNA into a string of amino acids that becomes a protein. Inside the ribosome, the genetic code of the RNA is read three letters at a time and compared with the corresponding code on a transfer molecule. When a match occurs between the codes, the amino acid carried by the transfer molecule is added to the growing protein chain. (2 min. 6 sec.)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b; 4.A.2.a	2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3
Animation	Translation (advanced detail)	Messenger RNA (mRNA) carries DNA's genetic information to the ribosome, where it is translated into a sequence of amino acids. mRNA is fed into the ribosome, and it is positioned so that it can be read in groups of three letters, known as codons. Each mRNA codon is matched against the transfer RNA molecule's anticodon. If there is a match, the amino acid carried by the transfer RNA is added to the growing protein chain. (3 min. 4 sec.)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b,c; 4.A.1.a,b; 4.A.2.a	2.3, 2.4, 2.6, 2.7, 7.1, 7.2, 7.3

Lecture	Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 14	CAG repeat produces polyglutamine, causing many diseases. (23:56–26:16)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS3-2 (LS3.B), HS-LS4-1 (LS4.A)	3.A.1.c; 3.C.1.a,b,c; 3.C.2.a; 4.B.1.a	1.1, 2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 5.2, 7.1, 7.2, 7.3
Lecture	Lecture 3: A Healthy Nervous System: A Delicate Balance, Chs. 21–22	Is SCA1 caused by a loss-of-function mutation or a gain-of-function mutation? (33:31–36:46)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS3-2 (LS3.B), HS-LS4-1 (LS4.A)	3.A.1.c; 3.C.1.a,b,c; 3.C.2.a; 4.B.1.a	1.1, 2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 5.2, 7.1, 7.2, 7.3
Animation	Sickle Cell Anemia	Sickle cell anemia is a genetic disease that affects hemoglobin. A single nucleotide change in the hemoglobin gene causes an amino acid substitution in the hemoglobin protein from glutamic acid to valine. The resulting proteins stick together to form long fibers and distort the shape of the red blood cells. (1 min.)	HS-LS1-1 (LS1.A), HS-LS1-4 (LS1.B), HS-LS3-2 (LS3.B), HS-LS4-1 (LS4.A)	1.B.1.a; 3.A.1.a,b; 3.C.1.a,b; 3.C.2.a; 4.A.1.a,b; 4.B.1.a	1.1, 2.3, 2.4, 2.6, 2.7, 3.2, 7.1, 7.2, 7.3, 10.1
Lecture	Lecture 1: Reading Genes and Genomes, Ch. 36	Q&A: Is it possible to treat genetic diseases with proteins? (54:52–56:37)	HS-LS3-1 (LS3.A), HS-LS3-2 (LS3.B)	3.A.3.c	3.1, 3.4
Lecture	Lecture 3: PERfect TIMing, Ch. 21	Q&A: Cryptochromes: The light-sensitive protein as a candidate for circadian light sensor. (32:48–35:02)	HS-LS1-1 (LS1.A), HS-LS1-2 (LS1.A), HS-LS1-3 (LS1.A)	1.B.1.a; 2.C.2.a; 2.E.2.b; 2.E.3.b	2.3, 2.4, 2.6, 2.7, 6.6, 7.1, 7.2, 7.3, 9.3, D.5
Lecture	Lecture 4: The Mammalian Timekeeper, Chs. 21–23	Nine different proteins related to circadian clock genes. (30:50–35:10) *This segment discusses the clock genes and related proteins associated with these genes, and it includes an animation.*	HS-LS1-1 (LS1.A), HS-LS1-3 (LS1.A)	2.E.2.b; 2.E.3.b; 3.A.1.c; 4.A.1.a	2.3, .4, 2.6, 2.7, 6.6, 7.1, 9.3

Proteasome (Post-translation)

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Resource Type	Resource Name	Resource Summary	NGSS (April 2013)	AP Biology (2015)	IB Biology (2016)
Click & Learn	The Proteasome and Protein Regulation *Resource title on DVD:* Structure of the Proteasome	The proteasome is a large molecular machine that plays an important role in recycling and regulating cellular proteins. It degrades proteins by chopping them up into small pieces. (4 slides)	HS-LS1-1 (LS1.A)	3.A.1.c; 3.B.1.c; 4.A.1.a	2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 6.6, 7.1, 7.2, 9.3, 10.1
Animation	The Proteasome	A 3-D animation showing how proteins in the cell are tagged for disposal and degraded by the proteasome. (1 min. 44 sec.)	HS-LS1-1 (LS1.A)	3.A.1.c; 3.B.1.c; 4.A.1.a	2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 6.6, 7.1, 7.2, 9.3, 10.1

Lecture	Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 30	Protein accumulation occurs in many neurodegenerative diseases. (44:21–46:31)	HS-LS1-1 (LS1.A)	3.A.1.c; 3.B.1.c; 3.D.4.a; 4.A.1.a	1.6, 2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 6.5, 6.6, 7.1, 7.2, 9.3, 10.1
Lecture	Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 36	Q&A: Does mutant ataxin interfere with proteasome function? (54:24–55:28)	HS-LS1-1 (LS1.A)	3.A.1.c; 3.B.1.c; 3.D.4.a; 4.A.1.a	1.6, 2.3, 2.4, 2.6, 2.7, 3.2, 3.3, 6.5, 6.6, 7.1, 7.2, 9.3, 10.1
Lecture	Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 31	Using chaperones to counteract protein accumulation. (46:31–48:46)	HS-LS1-4 (LS1.B)	3.A.1.d; 3.B.2.a	1.1, 2.1
Lecture	Lecture 3: A Healthy Nervous System: A Delicate Balance, Ch. 35	Q&A: Why do cells degrade proteins? (53:33–54:25)	HS-LS1-4 (LS1.B)	3.A.1.d; 3.B.2.a	1.1, 2.1