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Use Howard Hughes Medical Institute Resources to Teach:

Chromosomes, DNA Structure, and DNA Replication

Prepared by:

Ann Brokaw

AP Biology/Biology Teacher
Rocky River High School
Rocky River, Ohio

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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 biology and genetics. 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 of charge, and easily accessible; all key elements for successful classroom implementation. They have greatly enhanced my teaching methods in the classroom, 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-learns, 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 through the vast available resources and organizes the material according to various topics related to DNA, including DNA structure, replication, and repair. Please do not hesitate to contact me with any questions or suggestions.

Most sincerely,

Ann Brokaw
Rocky River High School
Rocky River, Ohio
abrokaw44@gmail.com

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 utilizing 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 related to DNA.

This curriculum guide organizes HHMI resources in the following categories: DNA structure and function, DNA replication, damage to DNA, and chromosomal structure. 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 what is included in each part.

DNA Structure and Function

This section includes a basic description of the structure of DNA, including nucleotides, base pairing, and the double-helix nature of the molecule. It also has an interview with James Watson regarding his role in the discovery of the DNA double helix. Coding and noncoding regions of DNA are discussed, along with information regarding the human genome. Toward the end of the section, there are several lecture chapter references that relate to how DNA is used for evolutionary comparisons between organisms.

DNA Replication

Along with excellent basic and advanced animations of DNA replication, this section includes a look at mistakes that are made and repaired during DNA replication, as well as theories about the causes of cancer as they relate to DNA replication.

Damage to DNA

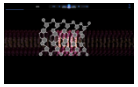
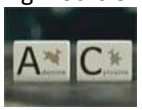
The section includes information about mutations and trinucleotide repeats, both of which lead to some human diseases. The resources included here discuss causes and rates of mutations, the cause of trinucleotide repeats, and diseases associated with both.

Eukaryotic Chromosome Structure

Eukaryotic chromosomes differ from prokaryotic chromosomes both in the packaging of DNA for the nucleus and the presence of telomeres. This section includes resources pertaining to the basics of eukaryotic DNA packaging (including histones and nucleosomes), details about eukaryotic telomeres, and problems associated with DNA replication and telomeres. An interactive click-and-learn activity is included that provides a mini lesson on telomere structure and function.

DNA Structure and Function

This table includes HHMI animations, video clips, interactives, and lecture material pertaining to DNA Structure and Function.
All of these resources can be accessed via www.BioInteractive.org and via Holiday Lectures on Science DVDs.
Note: The DNA animations are the only resources not available on DVD. They can be streamed or downloaded via www.BioInteractive.org/dna/animations.html.
If you have downloaded this document from BioInteractive.org, simply click on the thumb print photo or lecture title to open the resource.

Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
Viral Outbreak (2010)	Infectious Diseases	Animation	The Chemical Structure of DNA 	DNA's chemical properties can be harnessed for a variety of biotechnology applications. (2 min. 45 sec.)
	DNA*	Animation	Building Blocks of DNA 	Adenine (A), cytosine (C), guanine (G), and thymine (T) are the components of nucleotides that make up DNA. (26 sec.)
	DNA*	Animation	Chargaff's Ratio 	In 1950, Erwin Chargaff published a paper stating that in the DNA of any given species, the ratio of adenine to thymine is equal, as is the ratio of cytosine to guanine. This became known as Chargaff's ratio, and it was an important clue for solving the structure of DNA. (48 sec.)
	DNA*	Animation	Watson Constructing Base Pair Models 	During the process of trying to elucidate the structure of DNA, James Watson made some cardboard models to try to understand how DNA nucleotides are paired. It helped him visualize how hydrogen atoms of paired nucleotides interact with each other to form a symmetrical structure that fits the double-helix model. (1 min. 42 sec.)

Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
	DNA*	Animation	Paired DNA Strands 	DNA has a double-helix structure. If untwisted, DNA looks like two parallel strands. Each strand has a linear sequence of A, C, G, and T. The precise order of the letters carries the coded instructions. One strand is a complementary image of the other: A always pairs with T, and C always pairs with G. (1 min. 18 sec.)
	DNA*	Animation	Coding Sequence in DNA 	Of the 3 billion letters in the human genome, only 1% directly code for proteins. Of the rest, about 25% make up genes and their regulatory elements. The functions of the remaining letters are still unclear. (1 min. 4 sec.)
The Double Life of RNA (1995)	RNA	Lecture	Lecture 1: Catalysis, Chemical and Biochemical, Ch. 26	Q&A: Does DNA have catalytic properties? (52:33–55:09)
Evolution: Constant Change and Common Threads (2005)	Evolution	Lecture	Lecture 2: Selection in Action, Ch. 9–12	Mendelian inheritance pattern: A one-gene trait. (10:44–16:24) *This segment uses corn to illustrate the importance of a single gene to an organism*
Evolution: Constant Change and Common Threads (2005)	Evolution	Lecture	Lecture 3: Fossils, Genes, and Embryos, Ch. 26–27	Organisms share molecular pathways and enzymes. (34:55-36:06) *This segment explains that organisms share DNA as a basis for heredity.*
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 1: Reading Genes and Genomes, Ch. 4	Geneticists are interested in human variation. (6:18–7:59)
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 1: Reading Genes and Genomes, Ch. 17	Q&A: Does "junk" DNA cause problems in interpreting the genome? (26:45–27:32)
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 1: Reading Genes and Genomes, Ch. 22	How big is the human genome? (33:08–34:22)
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 1: Reading Genes and Genomes, Ch. 23	New York's 5th Avenue as the human genome? (34:22–38:43)

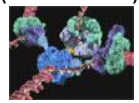
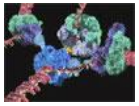
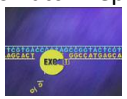
Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 1: Reading Genes and Genomes, Ch. 24–28	Finding genes in the genome. (38:43–45:55). *This segment discusses genes in the human genome: the number, the location, and the homology between other vertebrates.*
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 3: Human Genomics: New Guide for Medicine, Ch. 4–6	Observing what nature has already perturbed. (5:38–10:04) *Included is a discussion about the similarity of DNA between two people.*
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 3: Human Genomics: New Guide for Medicine, Ch. 7–8	Human origins and why we have little genetic variation. (10:04–13:49) *This segment traces human migration by looking at genetic variation.*
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Interactive Click and Learn	Using DNA to Trace Human Migration  *Resource title on DVD:* Origins of Modern Humans	All living humans originated from populations of ancestors who migrated out of Africa less than 100,000 years ago. Learn how scientists have used genetic markers to trace the migration routes and origins of modern human populations. (19 slides)
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 3: Human Genomics: New Guide for Medicine, Ch. 9–12	What differences do genetic variations make? (13:49–20:47) *These chapters discuss the role of SNPs in various human diseases.*
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 3: Human Genomics: New Guide for Medicine, Ch. 14–16	Filling in life's matrix: Genes, phenotypes, and SNPs. (22:44–29:03) *This section includes examples of genetic bases of human phenotype variation.*
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 4: The Strength of Families: Solving Rett Syndrome, Ch. 12–14	X-chromosome inactivation. (14:26–18:11) *These three chapters explain X-chromosome inactivation and include an animation.*
Exploring Biodiversity: The Search for New Medicines (2009)	Biodiversity	Lecture	Lecture 1: From Venoms to Drugs, Ch. 14	Phylogenetic tree of cone snails. (19:32–21:42)
Exploring Biodiversity: The Search for New Medicines (2009)	Biodiversity	Lecture	Lecture 1: From Venoms to Drugs, Ch. 17	Hunting specialization and phylogenetic tree. (22:56–24:20)
Exploring Biodiversity: The Search for New Medicines (2009)	Biodiversity	Lecture	Lecture 2: Shedding Light on an Invisible World, Ch. 27	Q&A: How do bacteria survive in extreme environments? (30:17–31:40)

Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
Exploring Biodiversity: The Search for New Medicines (2009)	Biodiversity	Lecture	Lecture 3: Biodiversity at a Snail's Pace, Ch. 27–30	3-D Structure of toxin peptides. (37:39–43:37) *This segment includes an example of proteins with similar structures but different functions.*
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 1: Reading Genes and Genomes, Ch. 29–31	Human and mouse comparisons: The mouse as a model for humans. (45:55–50:03) *This segment compares human genomes with mouse genomes.*
Exploring Biodiversity: The Search for New Medicines (2009)	Biodiversity	Lecture	Lecture 3: Biodiversity at a Snail's Pace, Ch. 31	Convergent evolution between toxin superfamilies. (43:38–45:17)
Exploring Biodiversity: The Search for New Medicines (2009)	Biodiversity	Lecture	Lecture 3: Biodiversity at a Snail's Pace, Ch. 32	Molecular basis for venom divergence. (45:18–46:11)
Evolution: Constant Change and Common Threads (2005)	Evolution	Lecture	Lecture 4: From Butterflies to Humans, Ch. 35–37	What can we learn about human evolution? (40:10–45:07) *These chapters illustrate how DNA is used to study human evolution and our relatedness to chimps.*
AIDS: Evolution of an Epidemic (2007)	Infectious Disease	Lecture	Lecture 3: Drugs and HIV Evolution, Ch. 6–8	The first antiretroviral used to fight AIDS. (7:43–10:52) *This segment explains the mechanism of AZT as it relates to gene expression. An animation is also included.*

DNA Replication

This table includes HHMI animations, video clips, interactives, and lecture material pertaining to DNA Replication.
All of these resources can be accessed via www.BioInteractive.org and via Holiday Lectures on Science DVDs.
Note: The DNA animations are the only resources not available on DVD. They can be streamed or downloaded via www.BioInteractive.org/dna/animations.html.
If you have downloaded this document from BioInteractive.org, simply click on the thumb print photo or lecture title to open the resource.

Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
	DNA*	Animation	DNA Replication (Schematic) 	The structure of DNA, discovered by James Watson and Francis Crick, suggests a mechanism of replication. The double helix unwinds, and each strand acts as a template for the construction of the new DNA molecule. (50 sec.)

Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
	DNA*	Animation	DNA Replication (Basic Detail) 	Using information from molecular research, this 3-D animation shows how DNA is replicated at the molecular level. It involves an enzyme that unwinds the DNA, and other enzymes that copy the two resulting strands. (1 min. 6 sec.)
	DNA*	Animation	DNA Replication (Advanced Detail) 	Both strands of the DNA double helix act as templates for the new DNA strands. Incoming DNA is unraveled by the enzyme helicase, resulting in the 3′ strand and the 5′ strand. The 3′ strands and the 5′ strands are replicated by a DNA polymerase enzyme but in different ways. (2 min. 32 sec.)
The Double Life of RNA (1995)	RNA	Lecture	Lecture 4: Life at the End of the Chromosome: Another RNA Machine, Ch. 3–9	Human chromosomes and their replication and telomeres. (2:03–22:57) *This segment includes a detailed look at DNA replication in humans and the function of telomeres at the end of eukaryotic chromosomes.*
The Double Life of RNA (1995)	RNA	Lecture	Lecture 4: Life at the End of the Chromosome: Another RNA Machine, Ch. 10–17	Replication problems at the ends of the DNA strand. (22:57–46:14) *This segment explains the problem associated with telomeres and the role of the enzyme telomerase while connecting the concepts with research methods.*
AIDS: Evolution of an Epidemic (2007)	Infectious Disease	Lecture	Lecture 3: Drugs and HIV Evolution, Ch. 21	Q&A: Does AZT also affect cellular replication? (21:54–22:28)
Learning from Patients: The Science of Medicine (2003)	Cancer	Animation	Mismatch Repair 	This animation illustrates how mistakes made during DNA replication are repaired. (1 min. 22 sec.)
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 1: Research Mechanics: Putting the Brakes on Cancer, Ch. 18–25	Theories on what causes cancer (27:07–43:08) *This clip illustrates the role of mutations in cancer, why DNA replication is not perfect, and an example of a human cancer.*

Damage to DNA

This table includes HHMI animations, video clips, interactives, and lecture material pertaining to damage that occurs to DNA.
All of these resources can be accessed via www.BioInteractive.org and via Holiday Lectures on Science DVDs.
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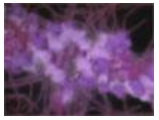
Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 1: Reading Genes and Genomes, Ch. 18	Q&A: Are most diseases caused by small changes in DNA? (27:32–28:58)
	DNA*	Animation	Damage to DNA Leads to Mutation 	Reactive molecules, such as free radicals, and solar ultraviolet radiation can lead to mutations in DNA. Most mutations are corrected, but in rare cases, mutations can accumulate and cause diseases such as cancer. (1 min. 6 sec.)
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 3: Human Genomics: New Guide for Medicine, Ch. 17	Q&A: Are mutation rates different in different species? (29:03–30:34)
Scanning Life's Matrix: Genes, Proteins, and Small Molecules (2002)	Genomics and Chemical Genetics	Lecture	Lecture 3: Human Genomics: New Guide for Medicine, Ch. 18	Q&A: Has the mutation rate increased with a larger human population? (30:34–31:38)
AIDS: Evolution of an Epidemic (2007)	Infectious Disease	Lecture	Lecture 2: AIDS and the HIV Life Cycle, Ch. 35	Q&A: Do mutations cause changes in the HIV envelope protein? (50:26–52:05)
Constant Change and Common Threads (2005)	Evolution	Lecture	Lecture 1: Endless Forms Most Beautiful, Ch. 31–35	The odds of a mutation producing a black-coated mouse. (45:52–51:49) *This segment shows how mutation rate is associated with selection and evolution.*
Constant Change and Common Threads (2005)	Evolution	Lecture	Lecture 1: Endless Forms Most Beautiful, Ch. 36	Q&A: How does the mutation arise? (51:49–52:45)
Constant Change and Common Threads (2005)	Evolution	Lecture	Lecture 3: Fossils, Genes, and Embryos, Ch. 42	Q&A: How do major changes in gene structure occur? (51:00–52:05)
Constant Change and Common Threads (2005)	Evolution	Lecture	Lecture 4: From Butterflies to Humans, Ch. 44	Q&A: Are gene control region mutations more likely? (55:48–57:11)

Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 1: Research Mechanics: Putting the Brakes on Cancer, Ch. 18–25	Theories on what causes cancer. (27:07–43:08) *This clip illustrates the role of mutations in cancer, why DNA replication is not perfect, and an example of a human cancer.*
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 1: Research Mechanics: Putting the Brakes on Cancer, Ch. 32	Q&A: How do mutagens cause such specific mutations? (52:03–52:56)
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 2: Chaos to Cure: Basic Research to Patients, Ch. 13	Using stool samples to detect mutations. (20:57–27:02)
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 2: Chaos to Cure: Basic Research to Patients, Ch. 17	Q&A: What are the body's defenses against cancer? (25:55–27:02)
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 2: Chaos to Cure: Basic Research to Patients, Ch. 22–26	Cancer cells have altered chromosomes. (32:43–38:54) *This segment discusses chromosomal translocations, with a look at leukemia and Gleevec as a treatment option.*
Learning from Patients: The Science of Medicine (2003)	Neuroscience	Animation	Trinucleotide Repeat 	Slippage during DNA replication can lead to expanding sections of repeating nucleotides. Watch this animation to see how this problem occurs. (1 min. 7 sec.)
Learning from Patients: The Science of Medicine (2003)	Cancer	Lecture	Lecture 3: A Healthy Nervous System: Delicate Balance, Ch. 11–13	CAG trinucleotide repeat expansion causes SCA1. (19:41–23:56) *This segment discusses the role of the number of repeats as it relates to age of disease onset.*

Eukaryotic Chromosome Structure

This table includes HHMI animations, video clips, interactives, and lecture material pertaining to eukaryotic chromosome structure.
All of these resources can be accessed via www.BioInteractive.org and via Holiday Lectures on Science DVDs.
Note: The DNA animations are the only resources not available on DVD. They can be streamed or downloaded via www.BioInteractive.org/dna/animations.html.
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Holiday Lecture	BioInteractive Topic	Resource Type	Resource	Resource Summary
	DNA*	Animation	DNA Packaging 	DNA is tightly packed in the nucleus of every cell. DNA wraps around special proteins called histones, which form loops of DNA called nucleosomes. These nucleosomes coil and stack together to form fibers called chromatin. Chromatin in turn forms larger loops and coils to form chromosomes. (1 min. 43 sec.)
The Double Life of RNA (1995)	RNA	Interactive Click and Learn	Structure and Function of Telomeres  *Resource title on DVD:* Telomeres Revisited	This mini lesson covers the research on telomeres that has happened since the 1995 Holiday Lectures. (17 slides)
The Double Life of RNA (1995)	RNA	Lecture	Lecture 4: Life at the End of the Chromosome: Another RNA Machine, Ch. 3–9	Human chromosomes and their replication and telomeres. (2:03–22:57) *This segment includes a detailed look at DNA replication in humans and the function of telomeres at the end of eukaryotic chromosomes.*
The Double Life of RNA (1995)	RNA	Lecture	Lecture 4: Life at the End of the Chromosome: Another RNA Machine, Ch. 10–17	Replication problems at the ends of the DNA strand. (22:57–46:14) *This clip explains the problem associated with telomeres and the role of the enzyme telomerase while connecting the concepts with research methods.*