Module *(Estimated time to cover module sections)*	**Where can I cover this in my Biology curriculum?** **Highlights?**	**Pennsylvania Keystone Eligible Content**	**Next Generation Science Standards** ***HS-LS1*** *From Molecules to Organisms: Structures and Processes* ***HS-LS2*** *Ecosystems: Interactions, Energy and Dynamics* ***HS-LS3*** *Heredity: Inheritance and Variation of Traits* ***HS-LS4*** *Biological Evolution: Unity and Diversity*	**Other Resources** *(Websites, related activities, etc.)*
What is Genomics? *Each video plus questions - 15 min each for the Intro video and 3 application videos*	This module begins with a video introducing the genome and how it is studied by researchers. Three short videos highlight applications of genomics to food, biodiversity and health care. Intro video can be used in typical unit on DNA & Protein Synthesis; start of mitosis or meiosis when discussing chromosomes, homologous pairs, etc.	BIO.B.1.2.2 Explain the functional relationships between DNA, genes, alleles, and chromosomes and their roles in inheritance.	HS LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. HS LS1.A: Structure and Function *Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1) *All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which	Excellent video introducing genomics and its uses: http://www.ontariogenomics.ca/about/what-genomics Genetic Variation unit: http://learn.genetics.utah.edu/content/variation/

			carry out most of the work of cells. (HS-LS1-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS3-1.) *Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2)	
3 application videos plus jigsaw activity - 40 min **Video: Food** **Video: Biodiversity**	Students could "jigsaw" these three videos--students will be assigned to watch one of three videos. They will then meet with other students who watched the same video to answer the questions. Finally, students will be put in mixed groups with the responsibility of teaching their classmates what they learned. *Food could be incorporated during Genetics unit; Plant Reproduction; whenever talking about natural selection/artificial selection; or in whichever unit you cover genetic engineering. GMO's is a hot topic of discussion and lends itself well to incorporating ethical and societal issues. *Biodiversity and the concept of DNA Barcoding might be used in studying evolution and classification; at the very start of the year when introducing life and its diversity; or when talking about DNA/DNA Technology and identifying organisms by their DNA.	BIO.B.2.4.1 Explain how genetic engineering has impacted the fields of medicine, forensics, and agriculture (i.e. selective breeding, gene splicing, cloning, genetically modified organisms, gene therapy)	HS **LS1.A: Structure and Function** Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3) HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	Cracking Your Genetic Code http://www.pbs.org/wgbh/nova/body/cracking-your-genetic-code.html (also available by searching YouTube) Nova: Personal DNA Testing (12 min.) http://www.pbs.org/wgbh/nova/sciencenow/0302/01.htm (also available by searching YouTube) NOVA: Cracking The Code (8 min) http://www.pbs.org/wgbh/nova/body/cracking-the-code-of-life.html Select segment 11- Family Disease (also available by searching YouTube)

Video: Health	*Health fits well with either DNA & Protein Synthesis or Genetics units, especially if you discuss genetic screening, which is a hot topic of discussion and lends itself well to incorporating ethical and societal issues. This is especially true with the resurgence of 23 & Me and the popularity of DNA testing related to personal genetics and ancestry related information.			
Tour of the Genome	This module describes genome structure and how it relates to function. It uses videos to introduce and visually represent the human genome. In small groups, students investigate how problems with genome structure can result in genetic diseases.		HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.	Tour of Basic Genetics animations: http://learn.genetics.utah.edu/content/basics/
Genome Overview *Intro video plus discussion plus questions - 25 min.*	This introductory video fits well with DNA & Protein Synthesis or the first time you talk about chromosomes. It is a clear and entertaining look at these topics and sets the stage nicely for further detail and discussion. We would not recommend this as the main instructional video by which they learn the material--it's too fast and with too little detail--but it can be a great intro and conclusion video. Students could go back after the unit and see how much more they understand.	BIO.B.1.2.1 Describe how the process of DNA replication results in the transmission and/or conservation of genetic information. BIO.B.2.2.1 Describe how the processes of transcription and translation are similar in all organisms.		Excellent animations on DNA and Genes at: http://learn.genetics.utah.edu/content/molecules/ For example: What is a chromosome? http://learn.genetics.utah.edu/content/chromosomes/intro/
Chromosome Close-	This eye opening video fits well to help introduce DNA & Protein Synthesis, Genetics or the first	BIO.B.1.2.2 Explain the functional relationships between DNA, genes, alleles, and		Available along with other animations and tutorials at DNA Interactive

up *Video, discussion and questions 20 min*	time you talk about chromosomes. Students will never think of a chromosome in the same way again! You could also use this when talking about evolution, in terms of gene duplication followed by mutation to one of the genes. It also discusses DNA repeats. It is important for teachers to reassure students that they do not need to learn the specific genes and their locations; the idea is to get an appreciation for the many different kinds of genes and non-coding regions that can be located on one short segment of a chromosome.	chromosomes and their roles in inheritance.		http://www.dnai.org/c/index.html (Select - Genome / Tour) Video on how gene duplication can lead to evolutionary innovation: http://www.hhmi.org/biointeractive/making-fittest-birth-and-death-genes
Packaging DNA *Video, discussion and questions- 10 min*	This video can easily be used when first talking about DNA or chromosomes. It can also be used as a lead in to epigenetics and modification of histones.	BIO.B.1.2.2 Explain the functional relationships between DNA, genes, alleles, and chromosomes and their roles in inheritance.		Epigenetics unit: http://learn.genetics.utah.edu/content/epigenetics/ Great videos and animations at NOVA Science Now: http://www.pbs.org/wgbh/nova/body/epigenetics.html
Chromosome Arrangement *Video, discussion and questions 20 min*	Video can easily be used when first talking about DNA or chromosomes or Mitosis. Be sure to walk students through the experiments and what would have been seen depending on which model was correct and why.	BIO.B.1.2.2 Explain the functional relationships between DNA, genes, alleles, and chromosomes and their roles in inheritance.	HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.	

Genome Structure and Disease *Do these all together - 40-100 min depending on how you have your students present their findings* **Karyotyping** **Activity** **Resources for Genetic Disorders**	Karyotyping background and activity could be done during Meiosis or Genetics units, although having students also diagram how the mistake would have happened would help them understand the process of meiosis even better. You might assign each group/student a picture of a normal and abnormal karyotype; have them determine the abnormality (match with the list) first and then do the research. Teachers should emphasize that there is a difference between chromosomal disorders and genetic disorders caused by a gene mutation. The disorders discussed in the Activity are all caused by chromosomal abnormalities. The link in the "Additional Resources" section includes both kinds. The primate chromosome comparison activity in the right column could be used as part of your Evolution unit when discussing evidence for evolution.	BIO.B.2.1.2 Describe processes that can alter composition or number of chromosomes (i.e. crossing over, nondisjunction, duplication, translocation, deletion, insertion, and inversion). BIO.B.3.2.1 Interpret evidence supporting the theory of evolution (i.e. fossil, anatomical, physiological, embryological, biochemical, and universal genetic code).	HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors HS-LS1.A: Structure and Function All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS -LS1-1.) HS-LS1.B: Growth and Development of Organisms In multicellular organisms' individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic	Chromosome and Karytotypes Unit: http://learn.genetics.utah.edu/content/chromosomes/ Karyotyping Activities: http://www.biology.arizona.edu/human_bio/activities/karyotyping/karyotyping.html http://learn.genetics.utah.edu/content/chromosomes/karyotype/ Primate Chromosome Comparison; Compare chromosomes of human, gorilla, chimp, and orangutan: http://www.utsouthwestern.edu/edumedia/edufiles/education_training/programs/stars/chromosome-analysis.pdf Genetic Disorders: 1. https://www.genome.gov/10001204/specific-genetic-disorders/ 2. https://ghr.nlm.nih.gov/condition 3. http://learn.genetics.utah.edu/content/disorders/

			material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4) LS3.A: Inheritance of Traits. Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1)	
DNA Sequencing *Background readings & discussion - 45-60 min.*	This module explains why DNA sequencing information is important for the biological sciences. It provides a brief description of the technical challenges of DNA sequencing. Students learn the basic principles of sequencing-by-synthesis, which is a widely used next-generation sequencing (NGS) technology. Students will do an online activity			How PCR works http://www.DNAlc.org/resources/animations/pcr.html http://learn.genetics.utah.edu/content/labs/pcr/ DNA Sequencing: http://www.hhmi.org/biointeractive/disease/Sequence_Assembly/01.html

Activity - 45 min	that simulates sequencing strings of DNA. This unit can be covered during a DNA Technology unit or added as a very relevant example to your DNA replication unit, since sequencing relies on the principles of DNA replication.			(Read slides 1-17 and watch the videos on slides 2, 6 and 17) How Sanger Sequencing works http://www.wiley.com/college/pratt/0471393878/student/animations/dna_sequencing/index.html http://www.dnalc.org/resources/animations/cycseq.html http://www.dnalc.org/view/15479-Sanger-method-of-DNA-sequencing-3D-animation-with-narration.html Visit HHMI for DNA Sequencing
What Makes a Cell a Cell? A Bioinformatics Experiment *Introductory video and discussion - 15-20 min*	The same genome is in every cell of your body. Yet different cells in different parts of your body look and act very differently. The activity explores several databases that are used by bioinformaticians and other scientists for their research. The activity, organized by topics, is presented such that students progress from more simple to more complex database exploration. The topics expose students to human health-related databases as well as to databases for multiple species, which can be used for comparative genomics. Watch a video that describes one way a bioinformatician could approach the question: How does the same genome produce		HS-LS3.B: Variation of Traits In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) Environmental factors also affect expression of traits, and hence affect the probability of	Stem Cells unit: http://learn.genetics.utah.edu/content/stemcells/

	different types of cells? The video introduction fits well in a unit on DNA and Protein Synthesis or Reproduction & Development when talking about differentiation of cells during embryonic development. You could use this to start off a cell unit but it does require some knowledge/language of DNA and gene expression.		occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2), (HS-LS3-3)	
Sickle Cell Disease *20 min. Minimum, including discussion - 60 minutes if more questions added using graphics on the site*	This could be done in a unit on genetics or when talking about DNA and protein synthesis and mutations. It could also be done as part of population genetics and evolution. Students utilize the 1000 Genomes database for this activity. "The 1000 Genomes Project ran between 2008 and 2015. The goal of the 1000 Genomes Project was to find most genetic variants with frequencies of at least 1% in the populations studied" from around the world. (http://www.1000genomes.org/about)		HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.	
Genome Size *25-45 min, including discussion, questions and whether you have students do the calculations and any additional searching.*	This is a great short activity to do with your class when you first start talking about DNA and protein synthesis or when you first mention chromosomes before Mitosis. Students utilize the Animal Genome Size database, "a comprehgensive catalogue of animal genome size data"(great images of different animals and C values flash by on top left!) http://www.genomesize.com/			

Huntington's Disease *40-50 minutes with introduction and discussion*	The OMIM website is a treasure chest of information about genetic traits and genetic disorders and is great to use during Genetics, after the students have some background on DNA and gene expression. This site has a ton more to offer and is connected to the National Center for Biotechnology Information's (NCBI website http://www.ncbi.nlm.nih.gov/) You could definitely expand this to a full period or more activity.			Tutorial for OMIM available at: http://www.openhelix.com/OMIM
Cystic Fibrosis *40-60 minutes with introduction and discussion.*	This could be done at many places in the year - during discussions of protein structure during DNA & protein synthesis or during Genetics. The Uniprot site that students will use is amazing - it contains almost everything that is known about the structure and function of every protein that has been catalogued! It is well worth spending time to learn what is there and spend a day or two there with your class.			Uniprot tutorials: https://www.youtube.com/channel/UCkCR5RJZCZZoVTQzTYY92aw
Breast Cancer *20-30 minutes with introduction and discussion*	This can be done during Cell Cycle and Cancer / Mitosis unit, during DNA & Protein Synthesis or during Genetics. You could also do this during a Biochemistry unit when covering Protein Structure and include the concept of "domains". The NCBI Gene site that students will use and its various linked sites is another amazing resource for everything connected to DNA, genes and proteins. Again, it is well worth spending time to learn what			NCBI tutorials available at: http://www.ncbi.nlm.nih.gov/guide/training-tutorials/ Watch video clip, NOVA: Cracking The Code (8 min) http://www.pbs.org/wgbh/nova/body/cracking-the-code-of-life.html (Select- Watch the

BRCA1 *30-40 minutes with introduction and discussion*	is there and spend a day or two there with your class. The HomoloGene database that students will also use allows you to see what species share genes that are thought to be "homologs" - similar in structure and evolutionary origin. Try looking at the Protein information - it is especially interesting to see which domains are conserved between species.			Program. Select segment 11- Family Disease) After watching the clip, discuss the following questions with the whole class or in small groups: (5-10 min) Should Alana get BRCA genetic testing for breast/ovarian cancer susceptibility genes? If she tests positive, what options are available to her? If she tests negative, does that mean that she will never develop breast or ovarian cancer?
Bioinformatics: What? Why? Who? *Video plus discussion - 20min* *45-50 min for all activities that follow (they can be done in 5-15 minute chunks)*	Introductory video could be used in a DNA Technologies unit. The same is true for all of the activities that follow in this section. Please note that the last problem in the "Real Problems" section renews itself with a different problem when you reload the page!			

RNA Sequencing: Up Close with the Data	RNA plays an important role in biological systems as the intermediary between DNA and proteins. By measuring the RNA in a cell or tissue, we gain insight into the cell/tissue's function. RNA-sequencing (RNA-seq) is a relatively new technology that allows us to measure RNA in a sample with a high degree of accuracy. In this module we are going to discuss the data generated by an RNA-seq experiment.			
RNA-seq Data *Readings, short video and discussion - 20 min* **Gene expression** **Find new genes** **Detect changes in RNA splicing**	This section could be done in your DNA & Protein Synthesis unit or a DNA Technologies unit. It has good basic core content. Great gene expression graphic Nice video on RNA splicing (introns/exons)			mRNA Processing Case Study: http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=849&id=849
RNA-seq Analysis *10-15 min reading and discussion*	This section could be done in your DNA & Protein Synthesis unit or a DNA Technologies unit. It has good basic core content.			

Read Alignment / Mapping **Basic alignment** **Multimappers (repeated sequences)** **Spliced alignment** *Reading and discussion 15-20 min*	This section and those that follow in the rest of the module may be more suited for AP Biology level courses or in an elective course on Genetics/Genomics, etc. They could also be used to help differentiate instruction in an Honors Biology classroom. It has clear graphics and explanations and ends with creative and challenging activities.			
Gene quantification **Simple quantification** **Alternative splicing** *Reading and discussion 10-15 min*				
RNA-seq in the World *Reading and discussion 10-15 min*	These examples and the accompanying information in the teacher section would be of interest in any level Biology class when covering DNA and gene expression			

Activities *10-20 min each* **RNA-seq Activity 1** **RNA-seq Activity 2** **RNA-seq Activity 3** **RNA-seq Activity 4** **RNA-seq Advanced Activity**	The questions that accompany the activities would be great to do in small groups and then as a whole class, using the diagrams in the slideshow to help lead the discussion.			
Browsing Genomes	This could be done as part of a DNA Technology unit, when covering Classification and Diversity of Life or when covering the Immune System. It could also be done at the end of the unit on DNA & Protein Synthesis since it nicely incorporates most of that unit.		HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment	The Center for Disease Control has excellent life cycle diagrams of all parasitic infections! http://www.cdc.gov/parasites/

Toxoplasmosis *10 min reading and discussion*	This is a short general introduction to Toxoplasma.		HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations	
ToxoDB *Video and discussion* *15-20 min*	This section contains a short 5 minute video tutorial that uses a clear analogy to shopping at Amazon.		HS-LS4.C: Adaptation Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2) Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically , behaviorally , and physiologically well suited to survive and reproduce in a specific environment. That is, the differential surv iv al and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3),(HS-	

			LS4-4) Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5) Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5)	
GBrowse *Video and discussion - 25 min.*	This section contains a 12 minute tutorial demonstrating how to use a genome browser within the Toxo DB database. Speaker uses a nice analogy with Google Maps. In addition to be a clearly explained tutorial that is very applicable to other genome browsers, it is an excellent review of chromosomes, genes, introns/exons.			How to get more interesting data sets at any of the Databases? Under tracks, select - Transcript Expression Evidence - look for data sets of interesting topics More activities: http://workshop.eupathdb.org/athens/2011/index.php?page=schedule
The following sections				

should be done together and will take 30-45 min of browsing and discussion				
Open ToxoDB with GBrowse	This section gets you started on the activity involving two genes found in the ToxoDB database. It requires use of the terminology surrounding DNA structure, gene expression and also from the previous RNA Sequencing module.			The coding strand (sense strand or non-template strand) is the DNA strand which has the same base sequence as the RNA transcript produced (with thymine replaced by uracil). During transcription, RNA Pol II binds the non-coding strand (antisense strand, template strand, or transcribed strand) and transcribes their sequence to synthesize an RNA transcript with complementary bases. By convention, the coding strand is the strand used when displaying a DNA sequence. It is presented in the 5' to 3' direction. https://en.wikipedia.org/wiki/Coding_strand
Locate RNA Sequence Data	This section help you pull up data involving which RNA is being transcribed by which genes, on which days and in which host (cat, human) in the infection cycle of Toxoplasma.			
Interpreting a Coverage Plot	It is really exciting to actually work with this type of sophisticated data in a way that is made readily understandable for high school			

	students!			
Questions	These will be challenging questions - you will need to gauge the format (individual, small group, whole class) that you use with your class. Every wrong answer will provide a window of opportunity for some excellent discussions and further questions.			