Connecting Concepts:

Interactive Lessons in Biology

Computer-based biology tutorials produced collaboratively by the T^4 Biology Project, Division of Information Technology, and instructors of Introductory Biology 151-152 at the University of Wisconsin-Madison.

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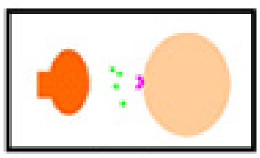
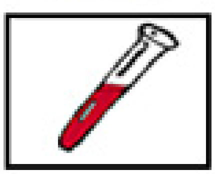
Animal Physiology
Lesson: Homeostasis

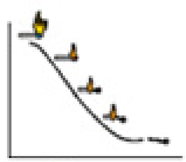
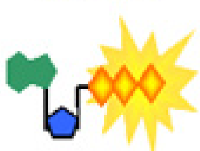
Topic	Summary	What Students Do
TOPIC 1:  Ben's Bad Day	Students follow a student named Ben through his day. Along the way, they interpret Ben's various physiological reactions and determine how his organs and organs systems interact to maintain homeostasis.	• encounter realistic yet humorous situations leading to changes in Ben's blood pressure, pH, glucose, osmolarity, and body temperature • select physiological inputs to restore Ben's homeostasis in each situation
TOPIC 2:  Ben's Homeostasis: the Inside Story	Students dive deep inside Ben to see how messenger molecules of the nervous and endocrine systems carry signals throughout his body.	• step through animations of signaling between nervous and endocrine systems and target organs • label events in a signal relay between the brain, pituitary gland, and kidney • classify descriptions of neurotransmitters or hormones based on properties such as receptor specificity and delivery to target organs
TOPIC 3:  Does Ben Have Diabetes?	Students learn about negative feedback regulation of glucose and play the role of doctor to determine if Ben has diabetes.	• learn about symptoms and causes of diabetes • step through an animation depicting feedback regulation by insulin • complete a case study in which they: o examine Ben's symptoms and family history of diabetes o interpret the result of his glucose tolerance test o answer questions about his condition and treatment options

Animal Physiology

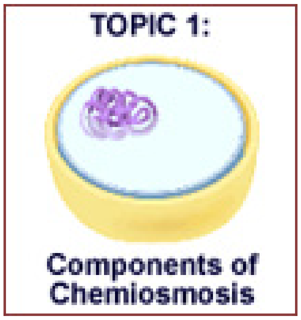
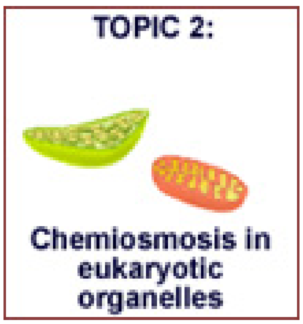
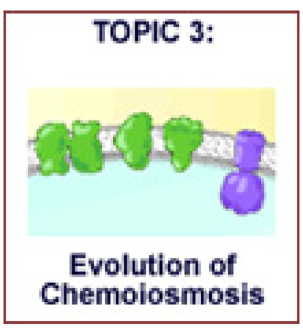
Lesson: Signal Transduction

Topic	Summary	What Students Do
TOPIC 1:  Components & Events	Students examine generalized components and events of signal transduction, first using the helpful metaphor of a pool game and then, the Fight-or-Flight response.	• observe animations of signal transduction in the game of pool, in the organ systems of a student, and in a liver cell responding to adrenaline • identify components (receptor, intermediaries, target) and events (signal engagement, relay, and interaction with target) in each animation
TOPIC 2:  Intracellular Signal Transduction	Students delve further into signal transduction with a journey into the olfactory neuron of a mosquito. They look at how lactic acid in human sweat triggers a cellular and behavioral mosquito response.	• step through an animation of the pathway • reconstruct the sequence of events in the pathway • conduct experiments testing chemical inhibitors of the pathway and the behavior of mosquitoes with mutations in the pathway • identify molecular amplification and regulatory events • explain the advantages of complexity and regulation in the pathway
TOPIC 3:  Implications in Human Health	Using their knowledge of signal transduction, students look at estrogen signaling and the potential role that dioxins play in disrupting this pathway in endometriosis.	• learn about the normal female reproductive cycle and symptoms of endometriosis • step through an animation depicting estrogen signaling in a uterine cell • complete an investigation of the effects of dioxin on the pathway in which they: o interpret data from experiments o select a model that incorporates experimental results o explain how dioxin could disrupt the reproductive cycle

Cell Biology
Lesson: Thermodynamics

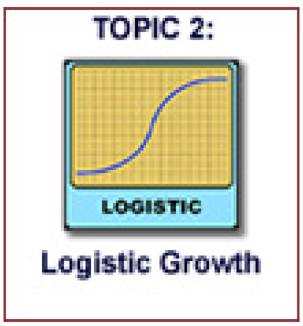
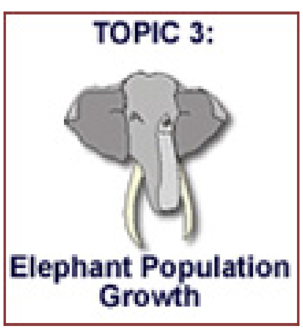
Topic	Summary	What Students Do
TOPIC 1:  Why Cells Need Energy	Students help a paramecium living in a Petri dish to collect enough energy to survive and reproduce.	• learn about cellular processes that require energy
TOPIC 2:  Energy Conversions	Students follow energy conversions in *Euglena,* during photosynthesis, respiration, and cell work.	• review definitions and properties of endergonic and exergonic processes • explain, in qualitative terms, free energy changes in the universe, photosynthesis, respiration and cell work • identify the type of work (chemical, mechanical, etc.) being done in a number of cellular processes
TOPIC 3:  ATP	Students solve a mystery: where does ATP's energy go in the glutamine synthetase reaction?	• "interview" molecules to learn how ATP's energy was released and absorbed in the ATP-coupled reaction • reconstruct events leading to and from a high energy reaction intermediate • identify which molecules (reactants, products, enzyme) got some of ATP's energy
TOPIC 4:  Enzymes	Students must hire an enzyme for the job of catalyst from a set of candidates that may be exaggerating their qualifications	• evaluate the claims of each enzyme to determine if they violate the chemical and thermodynamic properties of enzymes
TOPIC 5:  Summary	Students compare the energetics of photosynthesis, cellular respiration, and cellular work.	• complete a review table that summarizes the energy inputs, outputs, free energy change, etc. of these processes

Cell Biology
Lesson: Chemiosmosis

Topic	Summary	What Students Do
	Students look at the components of chemiosmosis in the bacterium, *Paracoccus denitrificans.*	• step through animations of electron transport, proton gradient, and ATP synthase
	Students construct chemiosmosis pathways in mitochondria and chloroplasts.	• select the correct components (electron donor and acceptor, ETC, ATP synthase) and place them in the appropriate subcellular location • apply concepts about redox reactions, concentration gradients, and energetics to explain how chemiosmosis fits in a cell's overall metabolism • complete review table that summarizes properties of chemiosmosis in organelles and *Parcocculs denitificans*
	Students follow the evolution of chemiosmosis and the role it played in the evolution of cellular life.	• learn about chemical and cellular changes on early earth • analyze the efficiency of early forms of chemiosmosis • compare mechanisms of oxygenic and nonoxygenic photosynthesis • evaluate metabolic advantages of several endosymbiotic relationships

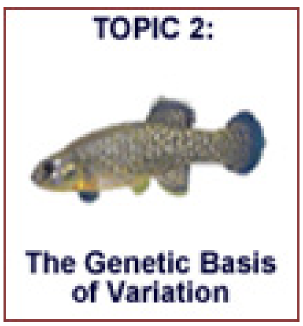
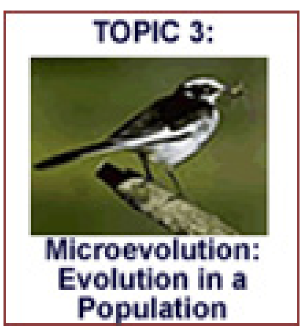
Ecology

Lesson: Population Dynamics

Topic	Summary	What Students Do
	Students conduct a study of a zebra mussel population in a fictional lake and present their findings during a virtual teleconference.	• review qualitative descriptions of growth curves from the exponential and logistic models • collect, plot, and fit data to a model • answer questions about populations at other localities by calculating r_{max}, t, and N using their data
	Students review the math and biology behind the logistic growth model with the help of a fish population.	• complete interactive explorations of: o density-dependence and carrying capacity o the difference between r (*realized intrinsic rate of increase* or *per capita growth rate*), r_{max}, (*maximum intrinsic rate of increase*), and dN/dt (*population growth rate*) o how growth rate changes over time, while r decreases • summarize and compare properties of exponential and logistic growth
	Students follow the growth of the Kruger National Park elephant population from 1903-1996. While following the history of the population, students calculate values using the logistic equation.	complete a case study in which they: • learn the biological and sociopolitical history of the KNP elephants • calculate dN/dt, N, and 1-(N/K) over time • explain how assumptions of logistic growth affect the shape of the curve • evaluate how well the KNP population fits the logistic model

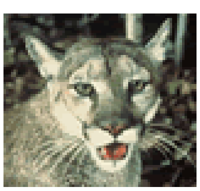
Evolution

Lesson: Natural Selection

Topic	Summary	What Students Do
	Students follow Darwin on a virtual field trip around the world in order to debunk three common misconceptions about natural selection.	• complete interactive explorations of each misconception and explain that: o fitness involves not only survival, but also reproduction o selection is not random o populations, not individuals, evolve • construct a definition of natural selection
	Students play the game, “Fitness Fever” to look at the underlying genetic variation that natural selection acts upon.	• learn about three single-locus traits known to be acted on by natural selection in animals, plants and bacteria • rate the fitness of genotypes given an environmental context • select changes that enhance the fitness of an organism
	Students play the role of predators on moths on a tree trunk. Then, they play the role of biologist, analyzing the changing gene frequencies of the moth population and determining if the population evolved over three generations	• collect data by “eating” moths • calculate gene frequencies for each phenotype over three generations • interpret graphs of their data to determine if microevolution occurred • explain how selection acts on populations

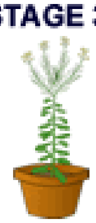
Evolution

Lesson: Species & Speciation

Topic	Summary	What Students Do
TOPIC 1:  Discovering Species	Students determine if 5 frog populations should be considered separate species using criteria of three of the species concepts: biological, morphological, and phylogenetic.	• describe why species are continuous over time and space • review definitions of three species concepts with strengths and weaknesses of each • analyze traits to sort populations into species based on 3 species concepts • use the terms: Biological, Phylogenetic, and Morphological Species Concepts phylogenetic tree, reproductive isolation
TOPIC 2:  Patterns of Speciation	Students think about speciation events at several points along the phylogeny of the plant genus *Fuchsia*	• interpret phylogenies and geographical distributions to determine speciation patterns • integrate the concepts of continental drift with speciation • analyze hypotheses as they explain patterns of speciation • use the terms: allopatry, sympatry, adaptive radiation, gene flow, vicariance, polyploidy
TOPIC 3:  The Importance of Being Species	Students look at speciation case studies. They are asked to think critically about evidence they collect to answer questions within the following contexts: Mosquito case: Does the evidence support separating one species into more than one species? Panther case: Does the evidence show that the FL panther is unique enough to conserve? (also useful for **conservation** lessons)	• interpret real data on *Anopheles quadrimaculatus* species complex and the Florida panther, including: o morphological traits o haplotypes o population histories o ecology o molecular phylogenies o hybridization o geographic distributions • define species in “real life” situations • make a conservation decision based on concepts in species and speciation

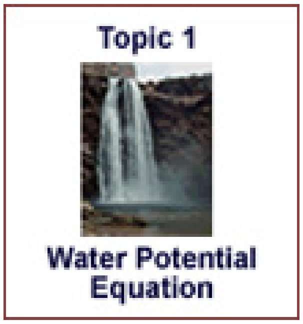
Genetics

Lesson: Biotechnology

Topic	Summary	What Students Do
STAGE 1:  **Determine Which Gene**	Students work with a mentor, Jane, on a virtual research project in which they create a genetically modified crop plant. In the first stage, they determine which gene to over-express to increase Vitamin E levels in canola plants.	• explain the relationship between phenotype and genotype in the context of a biochemical pathway • analyze the effect of a rate-determining step on the overall productivity of a pathway
STAGE 2:  **Get the Gene**	Students find and analyze the sequence of the G-TMT (γ-tocopherol methyltransferase) gene in a simulated version of a genomic database. They amplify the sequence using PCR.	• identify sequence landmarks, including translation start and stop, polyadenylation, etc. • map functional regions of a gene sequence, including coding sequence, 3' UTR, etc. • select appropriate primers for amplifying a sequence using PCR
STAGE 3:  **Transform Plants with Gene**	Students transform canola plants with the G-TMT gene using *Agrobacterium* and determine if over-expression results in altered phenotype.	• learn principles and procedures for transformation using *Agrobacterium* • select the appropriate genetic components and orientation of components in an expression construct for the G-TMT gene • reconstruct the sequence of events and explain the efficiencies of the transformation/selection process • evaluate data from 2 genetically engineered plants and explain variability in the results

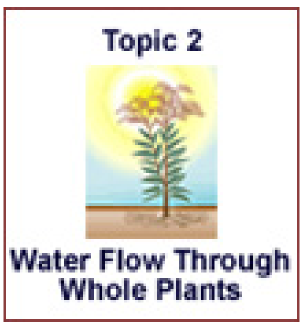
Plant Biology
Lesson: Water Relations

Topic | **Summary** | **What Students Do**



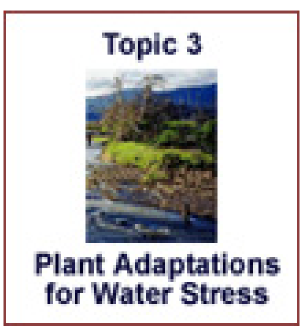
Students investigate water potential in various, real-life situations. They review components of the water potential equation with the help of "Professor Waterman".

- descriptions of solute and pressure potential and the water potential equation
- how to predict the movement of water under various conditions
- gain experience using the water potential equation
- use the terms: solute potential, pressure potential, gravity potential



Students follow movement of water through a plant from the soil to the atmosphere. They calculate water potential at each of 5 locations in the soil-plant-atmosphere continuum.

- predict the value and direction of ψ_s and ψ_p in different parts of a plant, given information about physical conditions
- calculate ψ_w for soil, root cell, xylem, mesophyll cell, leaf air space, and atmosphere



Students help a restoration ecologist choose plants that will grow at Alamitos Creek, California, based on plant adaptations for dry conditions and the concept of water potential.

complete an applied research project in which they:

- review concepts pertaining to plant adaptations for dry conditions
- construct a checklist of criteria for plants adapted to grow at Alamitos Creek
- select 3 plants that meet criteria for growth at Alamitos Creek using inventories of real data for 9 plants