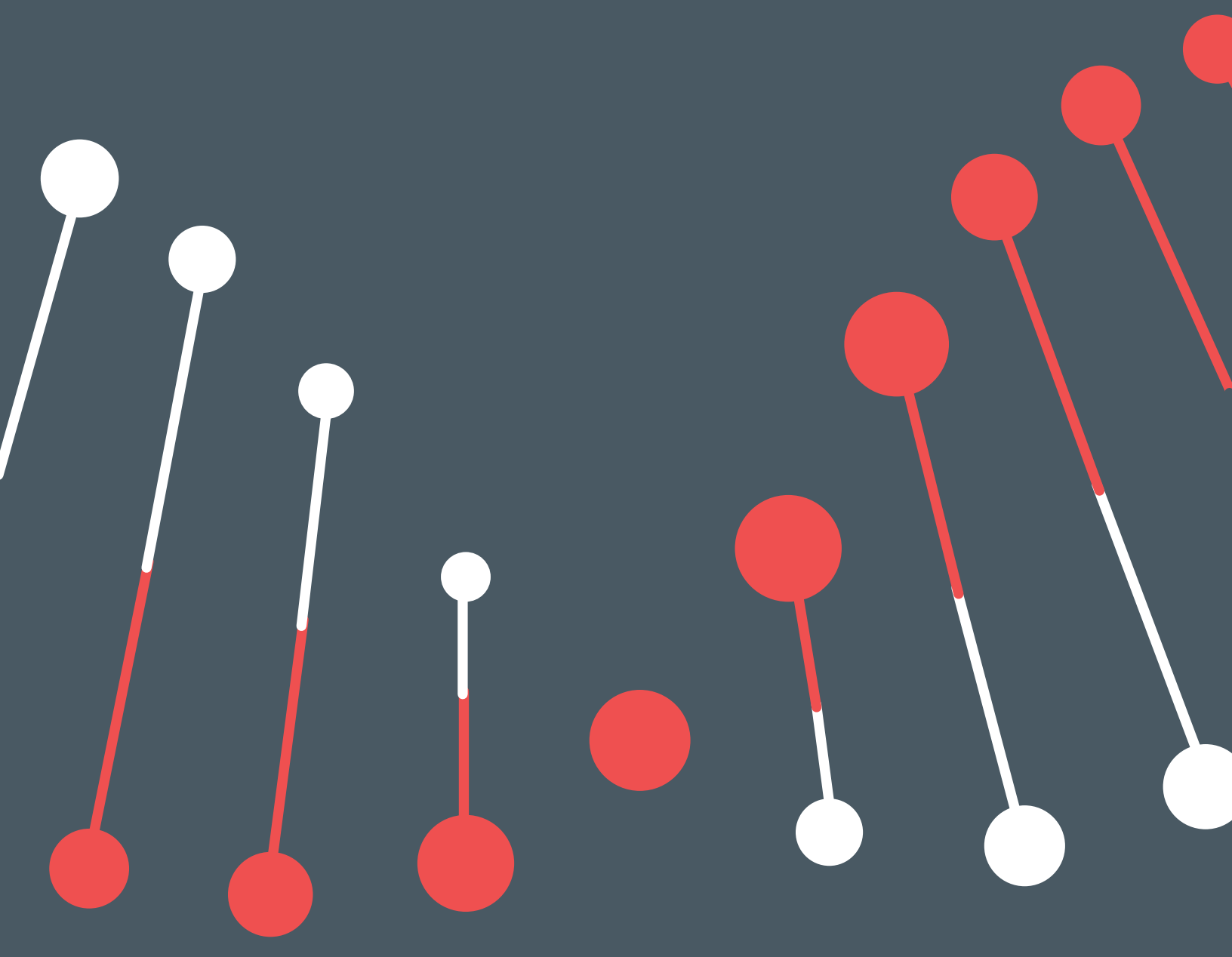# perfectstrain

Myogenics LLC

The K20 Center for Educational and Community Renewal is a statewide education research and development center which promotes innovative learning through school-university-community collaborations. Our mission is to cultivate a collaborative network engaged in research and outreach that creates and sustains innovation and transformation through leadership development, shared learning, and authentic technology integration.

The K20 Center's Virtual Learning Experiences (VLE) development team is tasked with creating game-based learning experiences to be used in undergraduate courses at The University of Oklahoma. The experiences are designed and developed by a small team working with volunteer University professors.

TABLE OF CONTENTS

The purpose of this guide is to support the effective integration of "Perfect Strain" into your classroom teaching. The teacher's guide is designed to help you in the following ways:

Gain Familiarity with the game

This guide provides an overview of all the scenarios, which should help you tether the scenario to lesson content.

Extend Lessons

This guide offers additional activities and links that will help you extend or consolidate the scenario objectives.
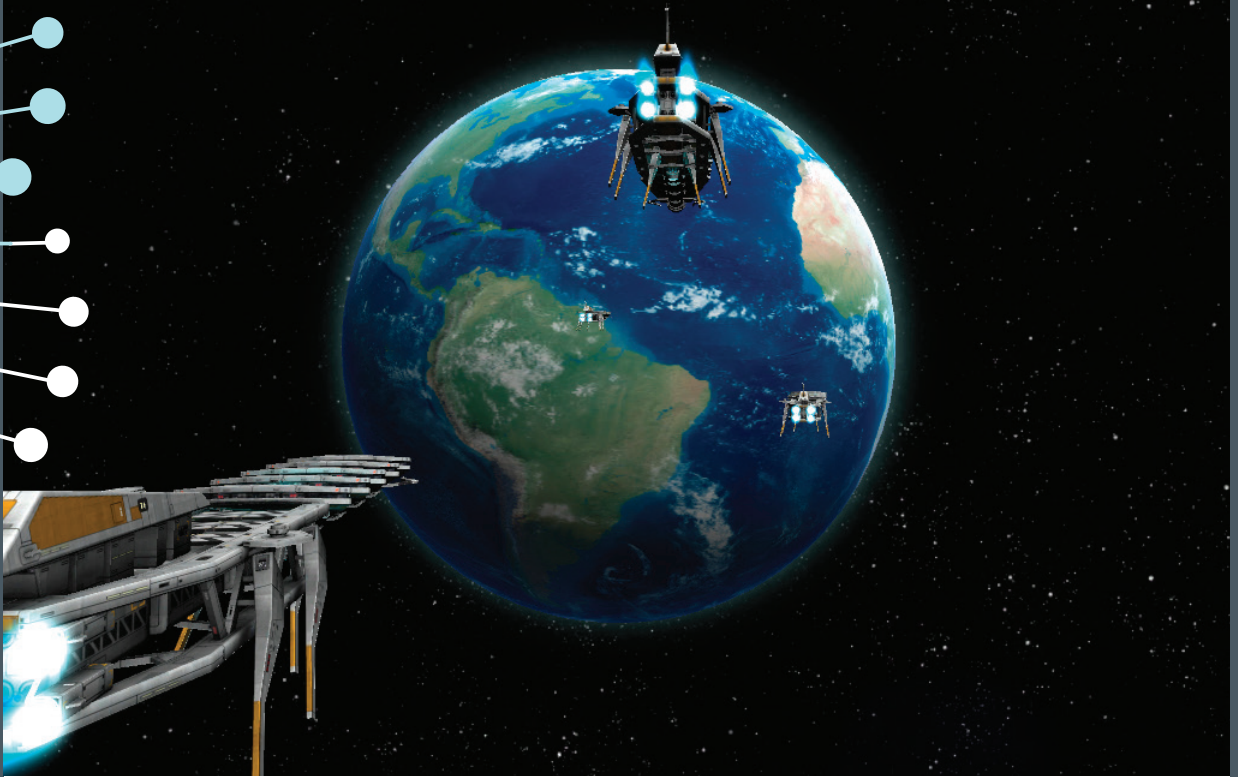
ABOUT THE GAME

PURPOSE

This instruction focuses on conceptual understanding of evolution and natural selection, paying particular attention to learners' common misconceptions (as identified by college professors). The objectives of this instruction are as follows.

The student will be able to:
- Describe how natural selection works
- Describe selection pressure
- Define mutation
- Define genetic variation
- Define genetic fitness
- Avoid expressing essentialism when describing evolution
- Describe that organisms are not made with a purpose

GAME NARRATIVE

The year is 3023 and the Earth has been abandoned. Energy consumption and the mass harvesting of natural resources have caused the Earth's surface to be completely uninhabitable, forcing humanity to begin colonizing space. The player takes the role of a microbiologist working for Myogenetics LLC, a multi-national corporation operating from space. Myogenetics is hiring microbiologists to attempt to develop strains of bacteria that can be launched to the surface, in order to help clean the severely polluted Earth. The player will be responsible for using a variety of tools, operating under a strict budget generously provided by Myogenetics and finding the perfect strain of bacteria to clean up humanity's troubled home world.

HOW TO USE THE GAME

Perfect Strain works as a supplement to classroom or online teaching methods. This game **is not** intended to teach natural selection to students who have no background in biology; instead, it is intended as an supplementary activity that can be assigned instead of homework or other practice activities. While many students may struggle with the abstract nature of natural selection, this game offers a rich interactive environment and a unique way for students to visualize and interact with the process through artificial selection. Since natural selection is a process without agency, Perfect Strain focuses on relating the processes in artificial selection to natural selection to avoid reinforcing common misconceptions.

In Perfect Strain players have the opportunity to observe evolution at a greatly accelerated rate. Players will be tasked with breeding a strain of bacteria holding a specific genetic trait; watching these bacteria in a petri dish as they grow, reproduce, and mutate. In addition to observation, students will have a menu of tools that apply selection pressure to the culture, mirroring real-world scientific techniques. Each mission will require breeding strains of bacteria that are increasingly complex and demand more selection pressure used in tandem."

The primary source of instruction in this game is provided by in-game feedback.

PLAYING THE GAME

Perfect Strain is divided into five missions. Each mission introduces new elements of natural selection. The missions are designed to build on one another, adding new concepts as the game progresses. Each mission has a single goal to breed a specific type of bacteria. They must be played in sequence. When a player successfully completes a mission they will be taken back to the mission selection screen to choose another mission, where they may elect to re-do a mission they've already completed or progress to the next level. If the player does not successfully complete the mission they are taken back to mission selection screen and cannot proceed until they are successful.

TUTORIAL

When the player begins the first mission they will be presented a tutorial that explains the mechanics of the game as well as the user interface. The tutorial is given in two sections, a "new hire packet" that introduces the mechanics of the game and a series of tutorial messages that guide the player through user interface, i.e. the selection pressure tools and other dashboard controls at their disposal. The new hire packet contains graphics and text explaining the basic mechanics of the game. Each tutorial message introduces an element of the user interface.

Students should be instructed to read the tutorials carefully to avoid later confusion. Tutorials require the student to take an action in the game to continue. For most players this tutorial should be all that is required to learn the game. The tutorial is available for consultation at all times during the game.
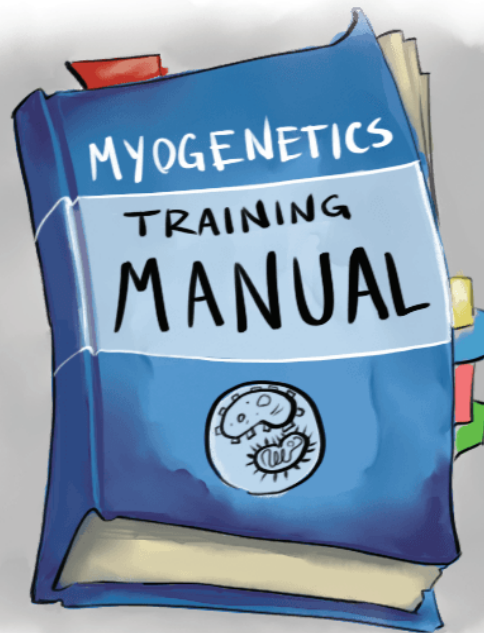
perfectstrain

Mission Selection

Options

USER INTERFACE

Mission Goal
The goal for each mission can be found in this panel. During challenges this panel will display the player's progress toward completion.

New Hire Packet (Help)
This button will open the new hire packet. It explains the mechanics of the game and also contains the introduction video and glossary of scientific terms. It can be accessed at any time during gameplay, and opening the packet will automatically pause the game.

Budget
The budget serves as a timer from the start of each mission, counting down one dollar for every second of gameplay, regardless of activity. Each time the player uses a tool, a certain amount is deducted from the budget; tools' 'cost' is listed above each on the menu. The budget countdown pauses automatically when feedback or questions are interjected in gameplay (see Questions, 5.2.11), or the player may pause the game and budget countdown manually (see Pause Button 5.2.10). If the budget is depleted below $400 before the mission is accomplished, the mission "fails" and the player must try again. This panel shows the budget for each mission. It costs $1 a second to run each mission. When the budget drops below $400 (the cost to use the vacuum tool) the mission will end.

BUDGET: $1700

MISSION OBJECTIVE

Bacteria
Bacteria in the petri dish look like this.
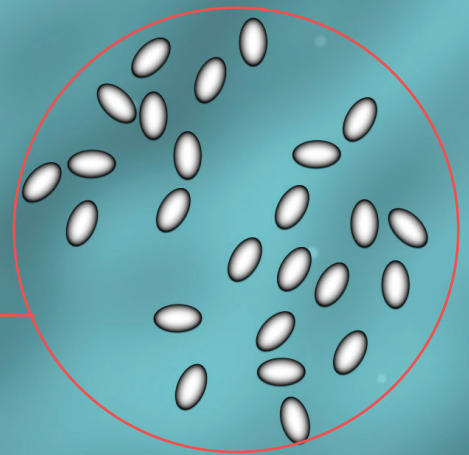
Petri Dish
Taking up most of the screen is a three dimensional rendering of the petri dish. This 3D image will help the student to understand how the bacteria are moving and the population changing over time.
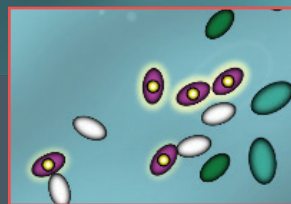
Targeted Bacteria
When the player clicks on a tool all bacteria resistant to that tool will be marked with a yellow tag. They will not take damage from that tool.

Desired Bacteria
Bacteria that hold the desired trait in a mission will be surrounded by a pulsing visual effect to differentiate them from other bacteria.

Options Menu
This button will open the options menu. This menu contains volume control and also allows the player to return to the mission selection screen.

Population Fitness
These bars measure the fitness of the bacteria in the petri dish. That is, how many offspring the population has.

Desired Fitness
This bar shows the fitness of the desired strain of bacteria.

Other Fitness
This bar shows the fitness of the rest of the bacteria.

Population totals
This section describes how many bacteria are currently in the petri dish.

Desired Bacteria Total
This total shows the number of desired bacteria for this mission, and the trait required.

Other Bacteria Total
This total shows the number of other bacteria.

FITNESS

50	100
ANTIBIOTIC RESISTANCE	OTHER BACTERIA

ANTIBIOTIC
$ 100

UV LIGHT
$ 100

CHILLER
$ 100

HEATER
$ 100

Ag SILVER
$ 100

29 THRESHER
$ 100

VACUUM
$ 100

PLANET SURFACE

78%   29

⏸ PAUSE

Tools
This section shows all tools that can be used on the bacteria in the petri dish. Available tools will be in color. Unavailable tools will be greyed out.

Clean Percentage
This bar measures the percentage of the zone you have cleaned.

Planet view
This screen shows a view of the planet. In the beginning of each mission the planet will be covered in a cloud of pollution. When the player uses the vacuum to send bacteria to the planet it will clear as the bacteria clean up.

Bacteria Population on Surface
This number shows how many bacteria are alive on the surface. The longer bacteria survive the more they will clean up the planet.

Pause Button
Clicking this button will pause the game, and the budget countdown will stop. Clicking it again will resume the game.

$ 100

HEATER
$ 100

Ag SILVER
$ 100

29 THRESHER
$ 100

VACUUM
$ 100

PLANET SURFACE

78%   29

When do bacterial mutations occur? Select all that are correct.

During an individual's lifetime.

✓ During reproduction when genes are replicated.
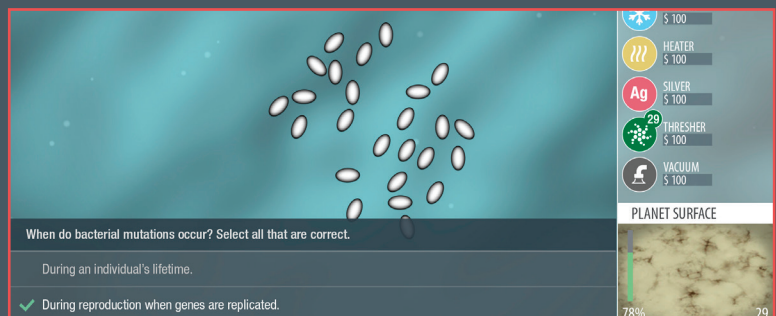
Questions
The player will trigger questions as they play the game. The questions form the majority of the evaluation of the player's understanding within the game. They take the form of multiple choice, true/false, and concept map questions. Questions answered correctly add extra money to the budget countdown, allowing more time and tool use. Incorrect answers do not affect the budget.

MECHANICS
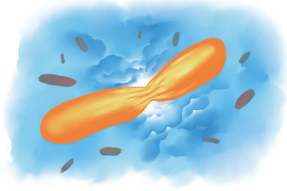
Reproduction

All bacteria reproduce after a short interval. When bacteria reproduce they split into two identical daughter cells.
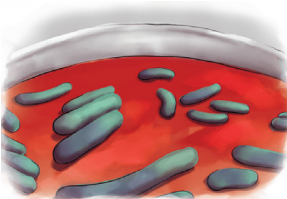
Mutations

Some daughter cells will be mutants. Mutants hold different traits from their parents. Mutant bacteria will leave a glowing trail for a short time after they develop, and those with the desired attributes will display a glowing outline when the player chooses/applies a selection pressure tool.
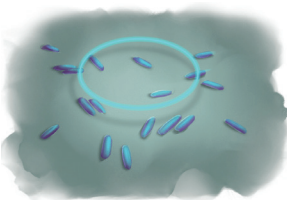
Tools

Players use tools to interact with the bacteria in the petri dish. Each tool acts as a selection pressure and makes a certain trait beneficial. When the player selects a tool from the tool menu, it will highlight all bacteria resistant to that tool with a yellow marker. Bacteria that have mutated into the desired strain will be distinguished by a glowing yellow outline.

Antibiotic Syringe

The antibiotic syringe injects a solution into an area of the petri dish which damages the bacteria. Bacteria which develop antibiotic resistance take no damage from this tool. All tools except the thresher last for 10 seconds then automatically deactivate.
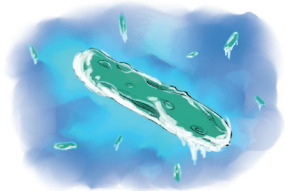
Chiller

The chiller tool lowers the temperature in an area of the petri dish. Bacteria within this affected zone will move and reproduce slowly.

Heater

This tool raises the temperature, causing bacteria to move and reproduce more quickly.
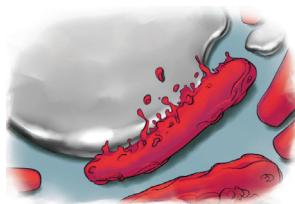
Silver Nanoparticles

The silver nanoparticles have two effects on bacteria within its affect. It damages bacteria and also has the chance to deactivate a bacteria's antibiotic resistance trait.
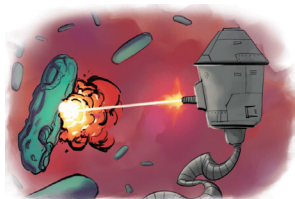
Thresher

This tool works differently from the others. Instead of having a large area of affect, the player places small thresher robots. These robots will target the closest bacteria and destroy them on contact. The thresher robots will deactivate and leave the petri dish once they've destroyed 10 bacteria.
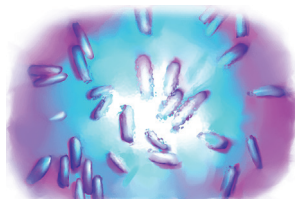
UV Lamp

The UV lamp bathes an area in power ultraviolet radiation. Bacteria within its affect will take damage, and also have a higher chance of mutations occurring during reproduction. Unlike all other tools, the UV area has two outlined areas, the directly-affected area (where all bacteria without UV resistance die off) and an outer perimeter in which bacteria may mutate.
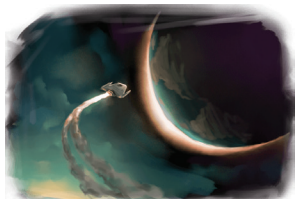
Vacuum

The vacuum tool collects bacteria and sends them to the planet's surface. This tool must be used to successfully complete each mission by taking a sample of the desired strain. It is the most expensive tool and therefore can only be used 2-4 times in a mission.

Solar Flare

In missions 4 and 5 the solar flare event will occur. This event will disable the Thresher tool for a period of time, raising the difficulty level of the mission.

Difficulty

Each mission has a lower budget total than the previous, steadily ramping up the difficulty and requiring the player to make more strategic use of their tools to succeed. In missions 4 and 5, the introduction of the solar flare will force the player to use different tools to affect the bacteria than they might otherwise. In mission 4 the desired trait is randomly selected from the mission goals of the previous three missions. In Mission 5, a more difficult desired trait than previous missions, vigorous, is required in addition to the penultimate challenge of the lowest budget and potential solar flares.

MISSIONS

MISSION 1
Introduction

Topics Addressed: Define fitness, define mutations, describe selection pressure, and describe that organisms are not made with a purpose (teleology).

In the first mission the player will be responsible for cleaning up Zone 1, Greenland. Due to the hole in the ozone layer over the North Pole the area is heavily irradiated with UV, making bacteria that resist these effects necessary. The desired strain for this mission is bacteria with antibiotic resistance.

Players will be introduced to the theme and basic mechanics of the game. They will have access to only three tools, the Thresher, the UV Lamp, and the Vacuum.

Solutions: The strategy most likely to lead to success is using the UV Lamp to increase the rate of mutation. Once UV resistant traits develop the player can use the lamp freely to cull other bacteria. They may also use the thresher tool if the population gets too high, to quickly lower the population.

Evaluation: The learner will receive assessment questions to test their understanding of fitness, mutation, selection pressure, and their understanding of the purposes these serve within the grander scheme of natural selection.

Questions for Mission 1: pg 23-26

MISSION 2
Perfect Strain

Topics Addressed: Define Genetic variation, define Natural Selection, review selection pressure, mutations, and fitness

In the second mission the player will focus on Zone 2, the area in and around Houston, Texas. This area is heavily contaminated with medical waste. Bacteria with antibiotic resistance are necessary to clean up this area.

Players will have access to all tools from the previous mission and will be introduced to the antibiotic tool in this mission.

Solutions: In this mission the best strategy is to begin by using the UV Lamp to encourage mutations. After antibiotic resistance has developed, they should switch to the antibiotic syringe to cull other bacteria. They can also make use of UV lamp to cull, but should use the thresher less often as it is harder to control.

Evaluation: The learner will receive assessment questions to test their understanding of genetic variation, natural selection, selection pressure, mutations, and fitness.

Questions for Mission 2: pg 27-31

ZONE 03

For this mission, you will be cleaning a large mining operation located in Adelaide, Australia. Because of the large silver deposits in the area, bacteria with high silver resistance will be necessary to successfully remove the pollution from the area.

CONTINUE
Development Build
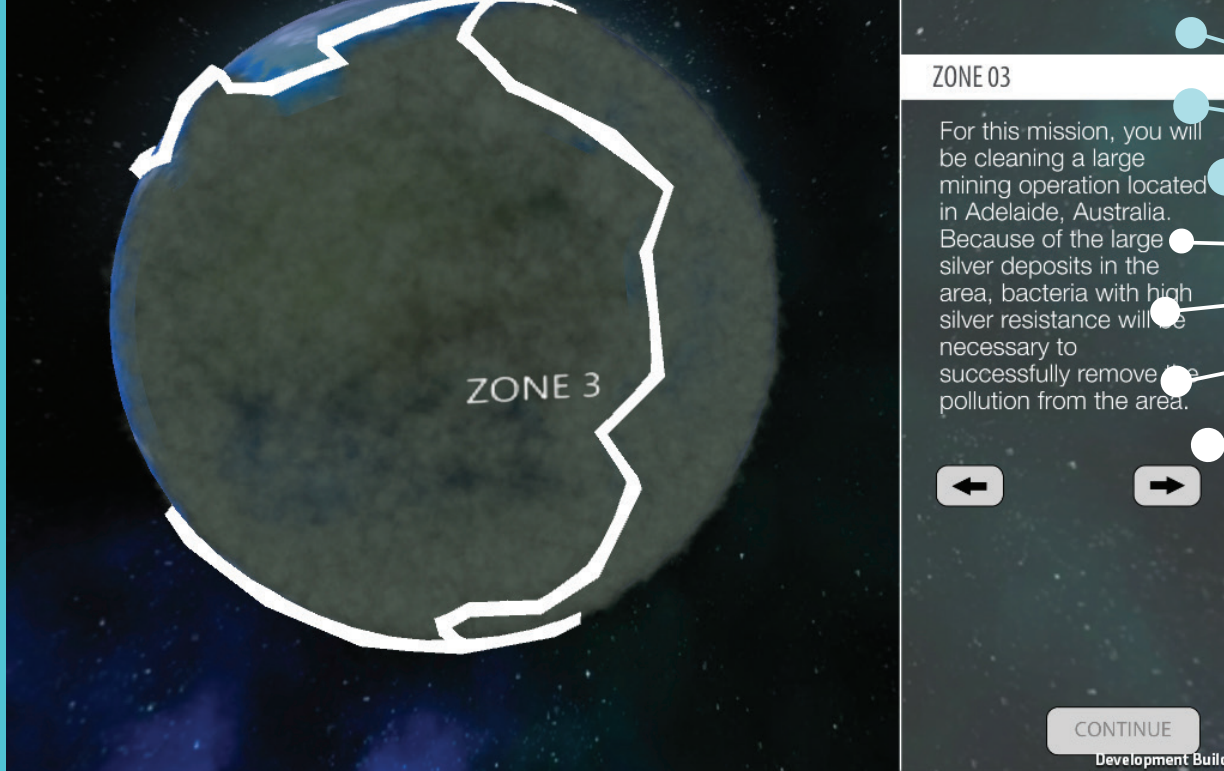
MISSION 3
So Fit

Topics Addressed: Review of Natural Selection, selection pressure, mutations, Genetic variation, Fitness, and describe that organisms are not made with a purpose.

In this mission the players will be cleaning Zone 3, centered on a large silver mining facility in Adelaide, Australia. The player will need to encourage bacteria with resistance to silver nanoparticles to successfully complete this mission.

Players will have access to all tools from the previous missions and will be introduced to the silver nanoparticles tool.

Solutions: In this mission the best strategy is to encourage mutations with the UV Lamp. When the desired strain appears, use the silver nanoparticles to cull other bacteria without harming the desired strain.

Evaluation: The learner will receive assessment questions to test their understanding of natural selection, selection pressure, genetic variation, fitness, and teleology.

Questions for Mission 3: pg 32-37

ZONE 04

This mission will focus on one of the most heavily contaminated spots left on the planet. We are still awaiting exact details from our sensors to determine the desired trait. The information should be ready when you accept this mission.

CONTINUE
Development Build
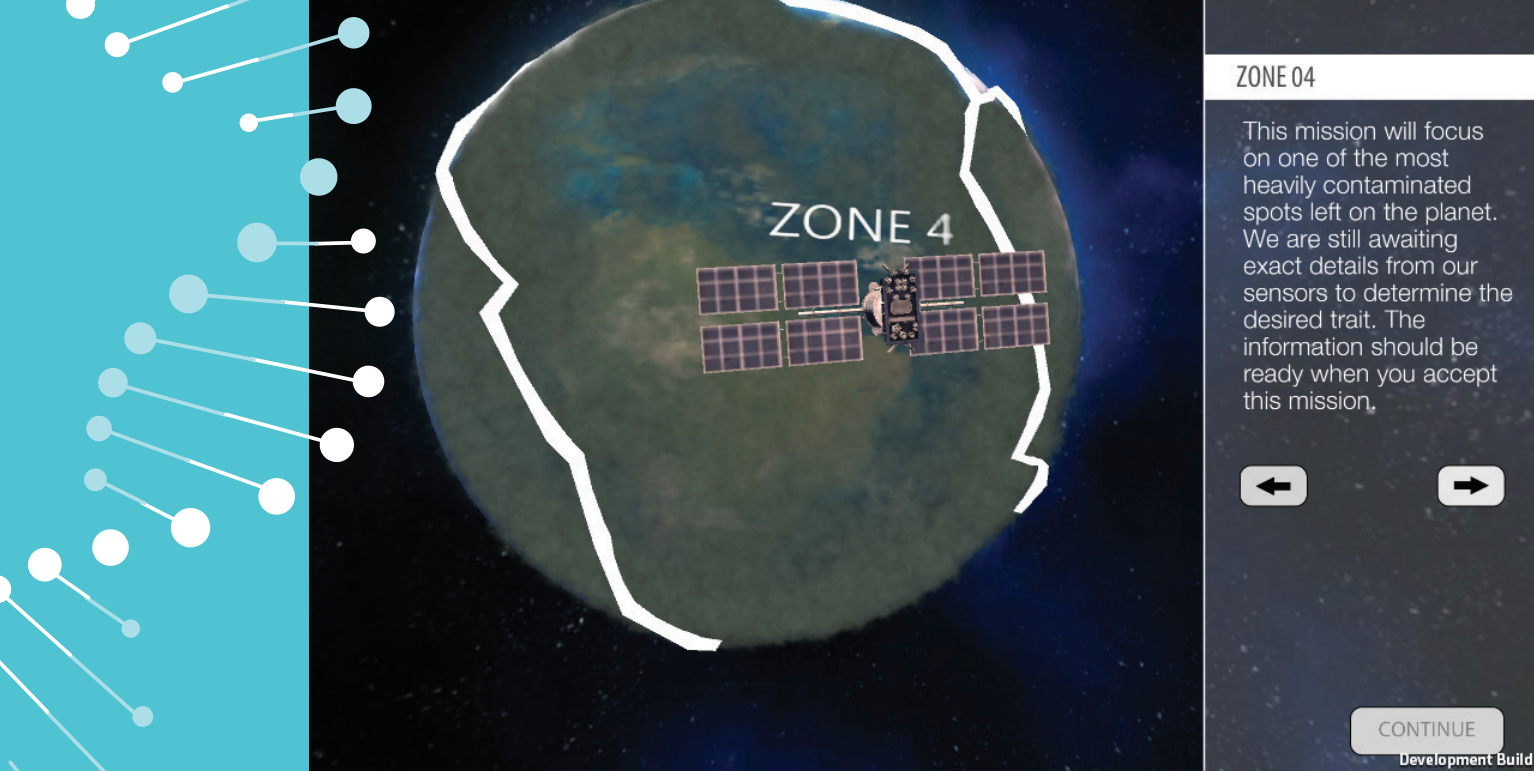
MISSION 4
Philosophy and Solar Flares

Topics Addressed: Explanation of the misconception of essentialism, review of teleology, selection pressure, and natural selection

The location of this mission is chosen from a short list when the player begins the mission. This ensures that the desired trait will be different in each mission. The locations and respective goals are as follows

1. South Pole Station in Antarctica is cooking in ultraviolet radiation. The player must breed another strain with resistance to ultraviolet radiation.

2. Tokyo, Japan has rogue colonies of nanorobots that target any foreign objects. The player must breed a strain with physical resistance.

3. London, England has huge levels of medical waste. The player must breed a strain with antibiotic resistance.

4. Alamos, Mexico is tainted with silver nanoparticles. The player must breed a strain with silver resistance.

Players will have access to the heater and chiller tools, giving them the complete arsenal of tools for this game. However, this mission also introduces the solar flare, an event that will shut down one of the player's tools for a period of time.

Solutions: In this mission the player use what they learned in the previous missions to complete this one. They should make use of the heater to encourage the desired strain once it appears, and use their other tools to cull as necessary.

Evaluation: The learner will receive assessment questions to test their understanding of essentialism, teleology, natural selection, and selection pressure.

Questions for Mission 4: pg 38-41

ZONE 05

This mission will see you tasked with cleaning up the largest concentration of pollution on Earth, the Great Pacific garbage patch. Bacteria must be fast-moving to quickly traverse highly contaminated areas.

CONTINUE
Development Build
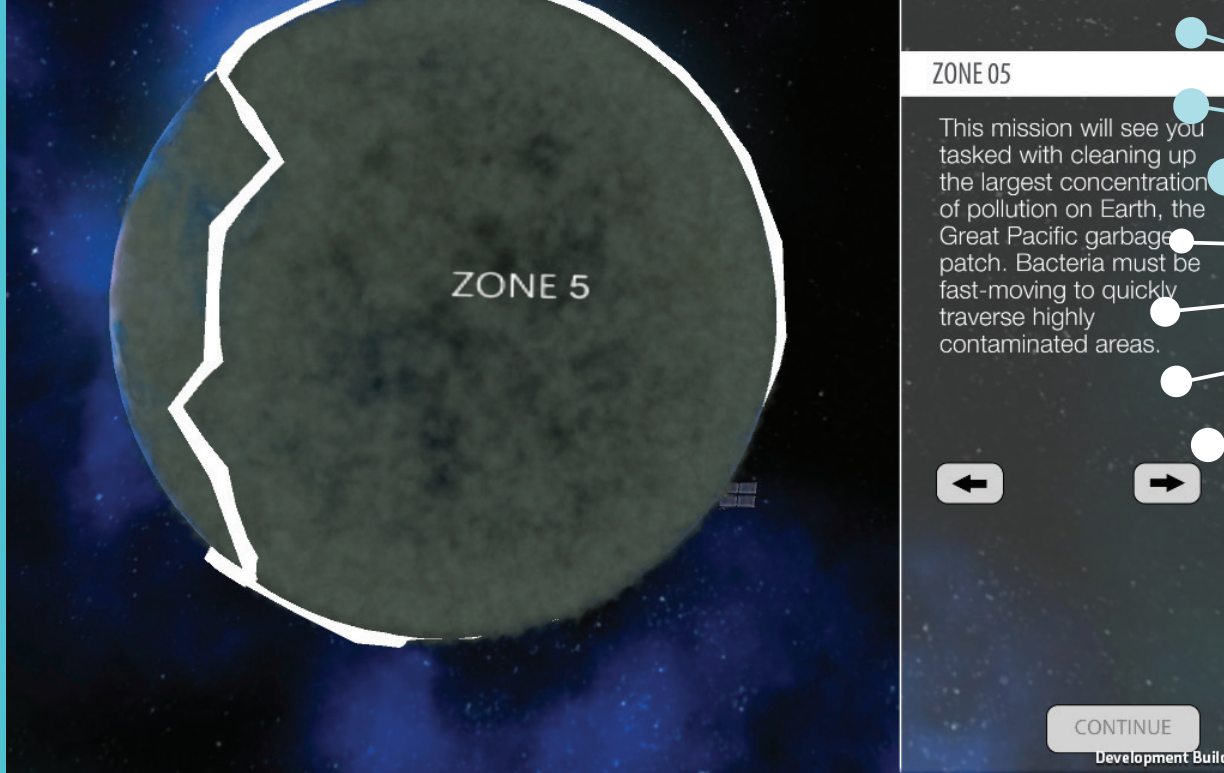
MISSION 5
Need for Speed

Topics Addressed: Review of all academic content

Mission 5 takes place in the Great Pacific garbage patch. Bacteria must be fast-moving to escape the patches of heavy contamination there. The vigorous trait is required for success.

The player can use every tool in this mission. They will also once again face the solar flare.

Solutions: To encourage the vigorous trait the player must first encourage the trait to appear by increasing reproduction and mutation rates with the heater and UV lamp. After the trait appears they must manage the petri dish very carefully. Culling the other bacteria will require the player to strategically play tools to avoid wiping out the vigorous bacteria. To succeed the best strategy is to place the heater over as large a group of vigorous bacteria as possible, and using the other tools to carefully cull around the desired population.

Evaluation: The learner will receive assessment questions to test their understanding of all academic goals.

Questions for Mission 5: pg 42-49

FURTHER RESOURCES

ADDITIONAL RESOURCES

Understanding Evolution
Understanding Evolution is a non-commercial, education website, teaching the science and history of evolutionary biology. This site is here to help you understand what evolution is, how it works, how it factors into your life, how research in evolutionary biology is performed, and how ideas in this area have changed over time.

http://evolution.berkeley.edu/evolibrary/home.php

Evolution Education by NCSE
The National Center for Science Education (NCSE) is a not-for-profit, membership organization providing information and resources for schools, parents, and concerned citizens working to keep evolution and climate science in public school science education. We educate the press and public about the scientific and educational aspects of controversies surrounding the teaching of evolution and climate change, and supply needed information and advice to defend good science education at local, state, and national levels. Our 5000 members are scientists, teachers, clergy, and citizens with diverse religious and political affiliations.

http://ncse.com/evolution

Tree of Life Web Project
The Tree of Life is a collection of webpages illustrating the evolutionary tree of organisms, and presenting information about the characteristics of thousands of different groups of organisms. Each ToL page focuses on one particular group. It includes a phylogenetic tree or taxon list for the subgroups contained within the current group. The tree or taxon list is also one of the principal means of navigation along the branches of the Tree of Life: it has links to deeper parts of the tree (toward the root) and to finer parts of the tree (toward the tips). Below the tree may be various topics, including an introduction to the group, characteristics of members of the group, internet and literature references, etc.

http://tolweb.org/tree/

BioInteractive
The Howard Hughes Medical Institute is a science philanthropy whose mission is to advance biomedical research and science education for the benefit of humanity. We empower exceptional scientists and students to pursue fundamental questions about living systems. Their BioInteractive project includes teaching guides, animations, virtual labs, and apps that focus on all aspects of biological science.

http://www.hhmi.org/biointeractive

ACTIVITIES

Squirrelmapper
Students will learn to identify squirrels and begin to record data on the types of squirrels found around them. The students will then be able to record their data on the Squirrel Mapper website and view the observations of people in other locations. This activity can also be used to show how the environment (and humans!) can be used to select which organisms are most "successful", based on their characteristics.

http://squirrelmapper.org/

Case Studies:
Natural Selection and Darwin's Finches

This web site is a companion to Evolutionary Analysis, 3rd edition by Scott Freeman and Jon Herron. It includes resources to help you succeed in your studies of evolutionary biology. This exercise will allow you to verify the conclusions arrived at by scientists regarding the beak lengths of Darwin's finches.

http://wps.prenhall.com/esm_freeman_evol_3/0,8018,849374-,00.html

EXTENSIONS

To transfer the instruction the learner receives in the game we suggest using an in-class discussion soon afterward to review what the learner's learned and cement their understanding. Suggested questions for the class include:

1) How does the artificial selection in the game differ from natural selection in reality?

2) What are examples of selection pressure caused by nature? Compare those with selection pressure caused by humans.

You may use the discussion raised by these two questions to introduce the Hardy-Weinberg Equilibrium. This equation is based on five assumptions. The violation of any of these indicates that evolution is happening. **They include:**

- Mating is Random – no one individual is more attractive than any other

- There is an infinite population size, resources are unlimited

- There are no mutations

- Individuals are not moving in or out of the population

- There are no genotypes that have an advantage - all individuals have equal fitness

Exploring each of these assumptions, such as discussing captive breeding programs or low population species, can introduce real-world context to the learner's understanding of natural selection.

3) Based on one of the selection pressures

discussed in the previous question, what do you think the results of natural selection on a population would look like?

This question can also be used to introduce the concept of coevolution, in which organisms that share an environment develop traits that rely on one another, such as the monarch butterfly larvae and milkweed plant. It can also be used to discuss convergent evolution, where evolution leads to the development of similar features in different species. The streamlined shape of marine fish and mammals, compared to the body plan of sharks and dolphins, reflect this element of evolution.

4) How does the scientific meaning of fitness differ from how it is used commonly?

5) How do mutations as depicted in the game differ from how they are often depicted in the media?

This question can be a jumping off point for further research on science in the news. Learners could research information on the spread of bacteria and viruses and the development of antibiotic resistance.

GLOSSARY

Allele   Different forms of the same gene in the same position along the chromosome of an individual.

Antibiotic   Antibiotics are chemical compounds that block the growth and reproduction of bacteria.

Artificial Selection   Selection by humans for breeding of useful traits from the natural variation among an organism.

Bacteria   Unicellular organisms that lack a nucleus.

Binary Fission   To reproduce bacteria replicate their DNA then grow to nearly double their original size. Then they divide in half producing two identical daughter cells.

Daughter Cell   Either of the two identical cells formed from the division of parent cell during binary fission.

Fitness   The ability of an individual to survive and reproduce viable offspring in its specific environment.

Genes   Genes are coded DNA instructions that control the production of proteins within the cell.

Genetic Variation   Differences in the alleles of genes between individuals in a population

Mutation   Mutations are any changes in the genetic material of an organism.

Natural Selection   Process by which individuals that are better suited to their environment survive and reproduce most successfully.

Population   A group of individuals of the same species that live in the same area. The bacteria in the petri dish make up a population.

Selection Pressure   Any element in a population's environment that makes certain traits more beneficial than others.

Strain   A variation in a particular species that possesses minor differences but still remains distinguishable. In each mission your goal is to breed a strain with a specific trait.

Trait   A specific characteristic that varies from one individual to another. Antibiotic resistance and slow reproduction speed are traits different bacteria may hold.

QUESTIONS KEY

FITNESS QUESTIONS [MISSION 1]

An individual with high fitness is stronger than other individuals in the population.	
True	Incorrect. In biology, fitness measures an individual's ability to pass on its genes, not physical strength.
False	Correct.

Fitness is a measure of:	
The reproductive rate of a population.	Correct.
The mutation rate of a population.	Incorrect. Fitness measures how often a population reproduces.
The physical health of a population.	Incorrect. When speaking scientifically, fitness refers to an individual's ability to pass on its genes.

Select all that apply. An individual with high fitness…	
Will reproduce more often than individuals with lower fitness.	Correct.
Will have more offspring than individuals with low fitness.	Correct.
Lives longer.	Not necessarily. Fitness only measures an individual's ability to pass on its genes. If an individual has a long lifetime but does not reproduce it will still have a low fitness.

MUTATION QUESTIONS [MISSION 1]

When do bacterial mutations occur?	
During an individual's lifetime	Incorrect. Mutations occur during reproduction.
During reproduction when genes are replicated.	Correct.
Whenever an individual needs help overcoming a selection pressure.	Incorrect. Traits caused by mutations may be beneficial against a selection pressure but they do not occur in response to a selection pressure.

Mutations usually result in new, beneficial traits.	
True.	Not exactly. The changes in genes caused by mutations are random, so they could be harmful, neutral, or beneficial.
False.	Correct.

Select all that apply. Mutations can lead to...	
Beneficial traits.	Correct.
Harmful traits.	Correct.
Neutral traits.	Correct.
Individuals becoming a new species.	Incorrect. An individual cannot become a new species during its lifetime. Mutations can only lead to new traits appearing during reproduction.

SELECTION PRESSURE QUESTIONS [MISSION 1]

Selection pressure makes certain ___ more beneficial than others.	
traits	Correct.
individuals	Incorrect. Selection pressure makes some traits more beneficial, individuals without it will have difficulty reproducing.
environments	Incorrect. Selection pressure is caused by environments. It makes certain traits more beneficial.

Selection pressure leads to some traits becoming more common.	
True.	Correct.
False.	Incorrect. Certain traits can become more beneficial to populations facing a specific selection pressure. Individuals within the population who possess those traits will thrive and reproduce more successfully than those without.

Which of the following are examples of selection pressure? Select all that apply.	
Fitness	Incorrect. Selection pressures are elements of the environment that affect what traits in a population are beneficial.
Mutation Rate	Incorrect. Selection pressures are elements of the environment that affect what traits in a population are beneficial.
Exposure to light	Correct.
Temperature	Correct.

TELEOLOGY QUESTIONS [MISSION 1]

Populations tend to change over time.	
True.	Correct.
False.	Incorrect. Populations are not working toward a definite goal, but due to natural selection are always undergoing change.

What does a population look like after a selection pressure is applied to it?	
The population has moved toward its goal.	Incorrect. Populations do not have consciousness or goals. They undergo changes due to the undirected process of natural selection.
The population will always die out.	Incorrect. Due to genetic variation, some individuals may have beneficial traits and not die out in response to selection pressure.
The population will display a different proportion of traits.	Correct.

Which is correct?	
Population -> Time -> Identical Population	Incorrect. Populations change over time as random mutations occur.
Population -> Goal -> Desired Population	Incorrect. Populations do not have desires and do not move toward specific goals. Natural selection is an undirected process that usually results in individuals adapted to their environment by making individuals with certain traits more likely to survive and reproduce.
Population -> Selection Pressure -> New Population	Correct.

GENETIC VARIATION QUESTIONS [MISSION 2]

Which of the following reflects genetic variation in nature?	
A population of bacteria with many traits..	Correct.
A population of bacteria with only one trait.	Incorrect. Genetic variation leads to a population with a variety of traits.
A population of bacteria with the majority holding one trait with a few unique individuals.	Incorrect. Genetic variation leads to a population with a variety of traits.

What is genetic variation?	
The principal that some individuals in a population hold different traits than others.	Correct.
The principal that individuals in a population hold the same traits.	Incorrect. Individuals in a population hold different traits. Variety is the norm.
The principal that the individuals in a population rarely differ from a single type.	Incorrect. Genetic variation leads to a population with a variety of traits.

Populations are made up of identical individuals.	
True.	Incorrect. While individuals may seem similar, variations at the genetic level make each unique.
False.	Incorrect. While individuals may seem similar, variations at the genetic level make each unique.

NATURAL SELECTION QUESTIONS [MISSION 2]

What are the potential results of natural selection on a population? Select all that apply.

A population that will die out in response to environmental changes	Correct.
More individuals holding traits that are advantageous in their environment.	Correct.
Only strong individuals will be left alive.	Incorrect. Natural selection leads to the survival of bacteria best adapted to the environment, not necessarily the strongest.

Natural selection results in physically stronger populations.

True.	Incorrect. The results of natural selection are populations better adapted to their environments. This may not always mean they are physically stronger.
False.	Correct.

Which of the following is correct?

Individual -> Natural Selection -> Adapted Individual	Incorrect. Natural selection results in changes to populations, not individuals.
Population -> Natural Selection -> Adapted Population	Correct.
Population -> Natural Selection -> Population.	Incorrect. Natural selection results in a population that has undergone changes and adapted to its environment.

SELECTION PRESSURE QUESTIONS [MISSION 2]

Selection pressure is any element in the environment that causes some traits in a population to be more beneficial than others.	
True.	Correct.
False.	Incorrect. Anything from weather to predators to famine can act as selection pressure.

Selection pressure causes:	
Some traits to become beneficial.	Correct.
Some individuals to become stronger.	Incorrect. Selection pressure makes some traits more beneficial. It doesn't make individuals stronger.
A population to die out.	Incorrect. Selection pressure lowers the fitness of some individuals, but due to genetic variation some individuals may have beneficial traits and survive.

Select all that apply. Selection Pressure results in...	
Some traits becoming beneficial.	Correct.
Some traits becoming neutral.	Correct.
Some traits becoming harmful.	Correct.
New traits appearing.	Incorrect. Traits do not appear because of selection pressure, but are the natural results of mutations.

MUTATIONS QUESTIONS [MISSION 2]

Select all that apply. Mutations...	
Occur during an individual's lifetime.	Incorrect. In bacteria mutations only occur during reproduction.
Can be harmful, beneficial, or neutral.	Correct.
May cause new traits to develop.	Correct.
Are any changes to an individual's genes.	Correct.

Mutations occur during an individual's lifetime.	
True.	Incorrect. In bacteria mutations only occur during reproduction.
False.	Incorrect. In bacteria mutations only occur during reproduction.

What are the results of a mutation?	
The daughter cell displays a new trait.	Correct.
The daughter cell is always stronger than its parent.	Incorrect. Mutations are random. They can have neutral or even harmful effects.
The daughter cell is always weaker than its parent.	Incorrect. Mutations can have beneficial effects.

FITNESS QUESTIONS [MISSION 2]

What does fitness measure?

An individual's ability to pass on its genes.	Correct.
The strength of an individual.	Incorrect. Fitness measures how often an individual passes on its genes through reproduction. It doesn't measure how strong an individual is.
How evolved an individual is.	Incorrect. It doesn't measure how evolved something is. Fitness measures how often an individual passes on its genes through reproduction.

A population with high fitness will reproduce more often than a population with low fitness.

True.	Incorrect. Fitness measures how often a population reproduces. One with low fitness will reproduce more slowly than a population with high fitness.
False.	Correct.

Select all that apply.

Populations with high fitness reproduce more often than populations with low fitness.	Correct.
Populations with low fitness reproduce more slowly than population with high fitness.	Correct.
Populations with low fitness are weaker than those with high fitness.	Incorrect. Fitness measures reproductive rate, not relative strength.

NATURAL SELECTION QUESTIONS [MISSION 3]

Successful artificial selection, such as that practiced by microbiologists to modify bacterial strains, depends on which of the following? Select all that apply.	
Microbiologists must be able to selectively breed the individuals with the most desirable traits.	You don't have all the right answers. For artificial selection to occur the population must have a desired trait that is passed to its daughter cells and breeders must be able to select for individuals with the desirable trait.
Some individuals must have more desirable genetic traits that lead to greater reproduction than others.	You don't have all the right answers. For artificial selection to occur the population must have a desired trait that is passed to its daughter cells and breeders must be able to select for individuals with the desirable trait.
When individuals with desirable traits are bred, their traits must be passed on to their daughter cells.	You don't have all the right answers. For artificial selection to occur the population must have a desired trait that is passed to its daughter cells and breeders must be able to select for individuals with the desirable trait.

Natural selection leads to a population better adapted to their environment.	
True.	Correct.
False.	Incorrect. The results of natural selection are adapted populations holding beneficial traits to their environment.

What does natural selection require to occur? Select all that apply.	
Selection pressure	Correct.
Time	Correct.
A goal	Incorrect. Natural selection isn't a process with a goal or an end. There will always be selection pressures acting on a population.

SELECTION PRESSURE QUESTIONS [MISSION 3]

Which of the following are selection pressures? Select all that apply.	
Extreme temperatures	Correct.
Limited resources	Correct.
Reproduction speed	Incorrect. This is a trait. Selection pressures are elements in the environment that make some traits more beneficial than others.
Predators	Correct.
Difficult terrain	Correct.

Selection pressures are traits that an individual has that affect its environment.	
True.	Incorrect. Selection pressures are elements of the environment that make some traits more beneficial than others.
False.	Correct

Selection pressure	
Leads to natural selection.	Correct.
Fulfills a population's genetic goals.	Incorrect. Populations don't have genetic goals and only change in response to selection pressure.
Will always increase a population's fitness.	Incorrect. Selection pressures can make some traits more or less beneficial than others, but it won't always increase the fitness of a population.

MUTATION QUESTIONS [MISSION 3]

A mutation appears when it is most useful for an individual.	
True.	Incorrect. Mutations do not try to supply what an individual needs, they are random events.
False.	Correct.

Mutations	
Always result in stronger individuals.	Incorrect. Mutations can cause detrimental traits to appear.
Occur during an individual's life in response to environmental changes.	Incorrect. In bacteria mutations only occur during reproduction.
Can lead to the appearance of new traits.	Correct.

When do mutations occur?	
During reproduction.	Correct.
In response to environmental change.	Incorrect. Mutations occur during reproduction.

GENETIC VARIATION QUESTIONS [MISSION 3]

A population is composed of similar individuals with only a few outliers.

True.	Incorrect. While individuals in a population are similar, they naturally show genetic variation among their peers.
False.	Correct.

How does genetic variation lead to natural selection?

A variety of traits ensures that some individuals will survive and thrive under selection pressure, leading to a population adapted to its environment.	Correct.
A variety of traits ensures mutations occur more often.	Incorrect, traits don't affect when mutations occur.
Genetic variation ensures populations are similar and will adapt in the same way.	Incorrect. Genetic variation leads to populations with varied traits.

Which of the following are true?

Individuals in a population hold different traits.	Correct.
Individuals in a population all match a certain type.	Incorrect. Due to genetic variation individuals are all slightly different, genetically.
Selection pressure leads to certain traits becoming more common.	Correct.

FITNESS QUESTIONS [MISSION 3]

What is the best definition of fitness in evolutionary theory?

The ability of a population to survive in any environment, compared to other populations.	Incorrect. Fitness is measured relative to other individuals in the same population.
The ability of an individual to survive and reproduce in any potential environment, compared to other individuals.	Incorrect. Fitness is measured within a certain environment.
The ability of a species to survive compared to other species.	Incorrect. Fitness is measured for an individual relative to other individuals of the same species.
The ability of an individual to survive and reproduce in a certain environment, compared to other individuals.	Correct.
The ability of a species to survive over time, compared to other species.	Incorrect. Fitness is measured for an individual relative to other individuals of the same species and it is measured within a certain environment.

Individuals with high fitness will pass on their traits more often than individuals with low fitness.

True	Correct.
False.	Incorrect. Individuals with high fitness reproduce more often, leading to greater chances to pass on their traits.

Which of the following is true? Select all that apply.

Fitness measures a population's ability to reproduce.	Correct.
Populations with high fitness are more evolved than other populations.	Incorrect. High fitness would denote the population is more adapted to the environment, not that is more genetically advanced or evolved.
Populations with low fitness may have trouble replacing their numbers.	Correct.
Fitness can be used to measure how adapted a population is to its environment.	Correct.

TELEOLOGY QUESTIONS [MISSION 3]

What will the population of bacteria look like if you only use the thresher tool?

Individuals who already possess physical resistance traits will reproduce most often and the population will change.	Correct.
Bacteria would have a variety of traits, none would dominate.	Incorrect. The population would change in response to the selection pressure from the thresher tool. Physical resistance would become more common.
The population would not be any different.	Incorrect. Populations change over time, especially in response to selection pressure like the thresher. Physical resistance would become more common.

Species always develop toward more advanced forms.

True	Incorrect. Species do not necessarily become more advanced, but become more adapted to their environments.
False.	Correct.

Populations

Work toward definite ends.	Incorrect. Natural selection is an undirected process that results in populations adapted to their environment, it has no end.
Always evolve to more advanced forms.	Incorrect. Natural selection doesn't result in more advanced individuals, just ones better adapted to their environment.
Constantly undergo change as the environment changes.	Correct.

ESSENTIALISM QUESTIONS [MISSION 4]

A species is composed of a group of identical individuals. Variations from this type are unusual.	
True.	Incorrect. Although individuals within the same species will have many traits in common, genetic variation means that each individula is different from the rest.
False.	Correct.

How do individuals in a population compare with one another?	
They are essentially the same.	Incorrect. Individuals differ on a genetic level from one another and hold different traits.
They always have the same fitness.	Incorrect. Due to genetic variation individuals can have different fitness due to holding different traits.
They are different from one another.	Correct.

Species...	
Represent a single unchanging type.	Incorrect. Populations and individuals within a species vary from one another
Represent a group of related but distinct individuals.	Correct.
Represent a similar group with rare variations.	Incorrect. Variation within a species is the norm.

TELEOLOGY QUESTIONS [MISSION 4]

How do individuals respond to changes in their environment?	
The entire species will change.	Incorrect. A species doesn't change all at once in response to environmental changes, only populations in the whole.
They will develop new traits to adapt to the changes.	Incorrect. Individuals cannot develop new traits during their life time, and cannot develop new traits in response to their environment.
individuals that hold beneficial traits in this environment will have higher fitness.	Correct.

The goal of all species is to evolve to more complex forms.	
True.	Incorrect. Species don't have goals. Evolution is an undirected process.
False.	Correct.

A genetically diverse population of individuals...	
can adapt more easily to their environment.	Correct.
Will become more adapted to their environment because the want to survive.	Incorrect. Populations don't have goals or wants, but may adapt over generations due to natural selection.
Changes all at once to adapt to their environment.	Incorrect. Populations will adapt over generations due to natural selection.

SELECTION PRESSURE QUESTIONS [MISSION 4]

natural selection = population + ___ + genetic variation	
Selection Pressure	Correct.
Fitness	Incorrect. The actions of selection pressure on a genetically varied population leads to natural selection. Fitness measures an individual's ability pass on its genes.
Reproduction	Incorrect, but close. While reproduction is necessary for a species' survival, the process of natural selection requires selection pressure to be placed on a genetically varied population.

Mutations have the largest effect on the process of natural selection.	
True.	Incorrect. While mutations are important processes for the appearance of new traits, without selection pressure the population would have no force for change acting upon it.
False.	Correct.

How does selection pressure differ in artificial selection compared to natural selection?	
Selection pressure is controlled by the breeder in artificial selection.	Correct.
In artificial selection mutations don't happen randomly.	Incorrect. Mutations are still random and rare occurrences during artificial selection.
In artificial selection fitness is not important.	Incorrect. Fitness is incredibly important during artificial selection. Increasing fitness will result in more of the desired population appearing.

NATURAL SELECTION QUESTIONS [MISSION 4]

A trait becomes common in a population because:	
This trait helps an individual live longer and successfully reproduce.	Correct.
This trait is always beneficial and leads to increased fitness.	Incorrect. Environmental changes can turn a beneficial trait neutral or even harmful.
This trait always develops in response to environmental changes.	Incorrect. Individuals don't develop traits in response to their environment. Natural selection will result in individuals that already have those traits reproducing more successfully and becoming more common.

The results of natural selection are populations better adapted to their environment.	
True.	Correct.
False.	Incorrect. Due to natural selection individuals that have beneficial traits are more likely to reproduce successfully, resulting in a population better adapted to its environment.

How do populations change over time?	
The proportion of traits that lead to survival and reproduction will increase in a population.	Correct.
Their fitness will drop.	Incorrect. Over time a population will become adapted to its environment, raising its fitness.
All individuals will become identical.	Incorrect. Due to genetic variation individuals with a variety of traits will always be present.

NATURAL SELECTION QUESTIONS [MISSION 5]

How does artificial selection differ from natural selection?	
Artificial selection results in more mutations.	Incorrect. Artificial selection does not cause more mutations than natural selection.
Artificial selection results in specific traits appearing.	Correct.
Artificial selection doesn't use selection pressure.	Incorrect. Selection pressure is required for both processes, but for artificial selection the pressure isn't a random occurrence.

Natural Selection stops when an individual evolves.	
True.	Incorrect. Natural selection is an unceasing process. It does not end.
False.	Correct.

Natural Selection is the process by which populations become adapted to their environment.	
True.	Correct.
False.	Incorrect. The results of natural selection is a population of individuals that is adapted to their environment.

SELECTION PRESSURE QUESTIONS [MISSION 5]

What are the results of selection pressure?	
A population with a different proportion of traits.	Correct.
A stronger population.	Incorrect. Population "strength" is a meaningless measure. Selection pressure will cause a shift in the proportion of traits in the population.
A population with low fitness.	Incorrect. Selection pressure usually selects for traits that lead to individuals with increased fitness.

Selection pressure results in a population with traits beneficial to an environment with that pressure.	
True.	Correct.
False.	Incorrect. Selection pressures results in a population with traits that are beneficial in that environment.

What are the results of selection pressure? Select all that apply.	
Individuals with harmful traits will become uncommon.	Correct.
Individuals with beneficial traits will become common.	Correct.
Populations with high fitness will become common.	Correct.
Populations with low fitness will become common.	Incorrect. Populations with low fitness will become less common since they do not reproduce as successfully as those with high fitness.

MUTATION QUESTIONS [MISSION 5]

What is a mutation? Select all that apply.	
Any change in an individual that makes it different from its parent.	Correct.
A change to an individual's genes.	Correct.
The development of a new species	Incorrect. A mutation doesn't create a new species, just an individual different from its parent.

Mutations are any change in an individual that creates a new species.	
True.	Incorrect. A mutation doesn't create a new species, just an individual different from its parent.
False.	Correct.

What is a mutation?	
Any change in an individual that makes it different from its parent.	Correct.
An individual becoming a more advanced form during its life.	Incorrect. Mutations are any change that makes an individual different from its parent, they only occur during reproduction.
The development of a new species	Incorrect. A mutation doesn't create a new species, just an individual different from its parent.

GENETIC VARIATION QUESTIONS [MISSION 5]

Individuals in a species share a common gene pool, but may not all have identical traits.	
True.	Correct.
False.	Incorrect. A species is not uniform, but are composed of individuals different from one another.

In a species, any individual that varies from a common type is unusual.	
True.	Incorrect. Differences between individuals of a species are the norm.
False.	Correct.

Select all that apply. Populations...	
Are made up of variations of a single species.	Correct.
Differ from one another.	Correct.
Are made of a single type.	Incorrect. Populations are made of individuals with varied traits.

MUTATION QUESTIONS [MISSION 5]

What is a mutation? Select all that apply.	
Any change in an individual that makes it different from its parent.	Correct.
A change to an individual's genes.	Correct.
The development of a new species	Incorrect. A mutation doesn't create a new species, just an individual different from its parent.

Mutations are any change in an individual that creates a new species.	
True.	Incorrect. A mutation doesn't create a new species, just an individual different from its parent.
False.	Correct.

What is a mutation?	
Any change in an individual that makes it different from its parent.	Correct.
An individual becoming a more advanced form during its life.	Incorrect. Mutations are any change that makes an individual different from its parent, they only occur during reproduction.
The development of a new species	Incorrect. A mutation doesn't create a new species, just an individual different from its parent.

FITNESS QUESTIONS [MISSION 5]

What effect does low fitness have on a population?	
They will reproduce less often.	Correct.
They will die off more quickly.	Incorrect. Low fitness will lower the rate of reproduction, not how often things will die.
Their mutation rate will drop.	Incorrect. Low fitness doesn't affect mutations. This population will reproduce less often.
They will become weaker.	Incorrect. Fitness doesn't measure the strength of a population, only its reproduction rate.

Fitness is a good measure of a population's ability to survive.	
True.	Correct.
False.	Incorrect. Fitness measures how often a population reproduces. The more individuals in a population the more likely it is to survive.

Which environmental elements could negatively affect fitness? Select all that apply.	
A heatwave.	Correct.
A sudden freeze.	Correct.
The introduction of a new predator.	Correct.
An increase in resources.	Incorrect. Increasing resources would increase a population's fitness by making all individuals more likely to survive and reproduce.

ESSENTIALISM QUESTIONS [MISSION 5]

Why don't all populations immediately die out when their environment changes?	
They guide evolution towards adapting to the changes.	Incorrect. Evolution is not a directed process.
Populations are often composed of many genetically diverse individuals, allowing some individuals to survive the changes.	Correct.
They reproduce more quickly to overcome any changes.	Incorrect. Populations cannot change themselves in response to environment changes.

Populations survive environmental changes due to genetic variation.	
True.	Correct.
False.	Incorrect. Thanks to genetic variation some individuals will survive due to the diversity of traits in the population.

Select all that apply. When the environment in which a population lives changes:	
Previously harmful traits may become beneficial	Correct.
Previously beneficial traits may become neutral.	Correct.
The proportion of traits in the population will change.	Correct.
Fitness will drop as the population will not have individuals adapted to this change.	Incorrect. Due to genetic variation numerous traits are present in a population, allowing it to flexibly adapt to changes in the environment.

TELEOLOGY QUESTIONS [MISSION 5]

Species have goals.	
True.	Incorrect. It is a common misconception that species move toward goals. Due to natural selection species are constantly undergoing changes, but it is not a directed process.
False.	Correct.

Natural selection is a directed process.	
True.	Incorrect. Natural selection has no ultimate goal, it is the culmination of tiny changes caused by a species interacting with its environment over generations.
False.	Correct.

Select the true statements:	
Species change over time.	Correct.
Traits become more common if they are beneficial.	Correct.
Individuals in a population will adapt to a new environment.	Incorrect. Individuals either have genetic traits that allow them to survive or they do not. They cannot change existing traits simply because they need them to adapt.
Over time species take on more advanced forms.	Incorrect. Natural selection isn't a goal-oriented process, and doesn't necessarily lead to the appearance of more advanced individuals.

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