EVOEXPLORER

An scaffolded inquiry-based interactive learning application aimed at remediating misconceptions in natural selection

A MASTER'S RESEARCH PROJECT BY ANNIE TSENG

Wireframe / User Flow
March 12, 2018

CONTENTS

EVOEXPLORER

An inquiry-based learning application
on topics in evolution.

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EVOEXPLORER

An inquiry-based learning application
on topics in evolution.

E-mail jane.doe@mail.utoronto.ca

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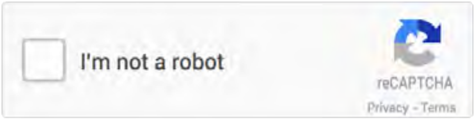

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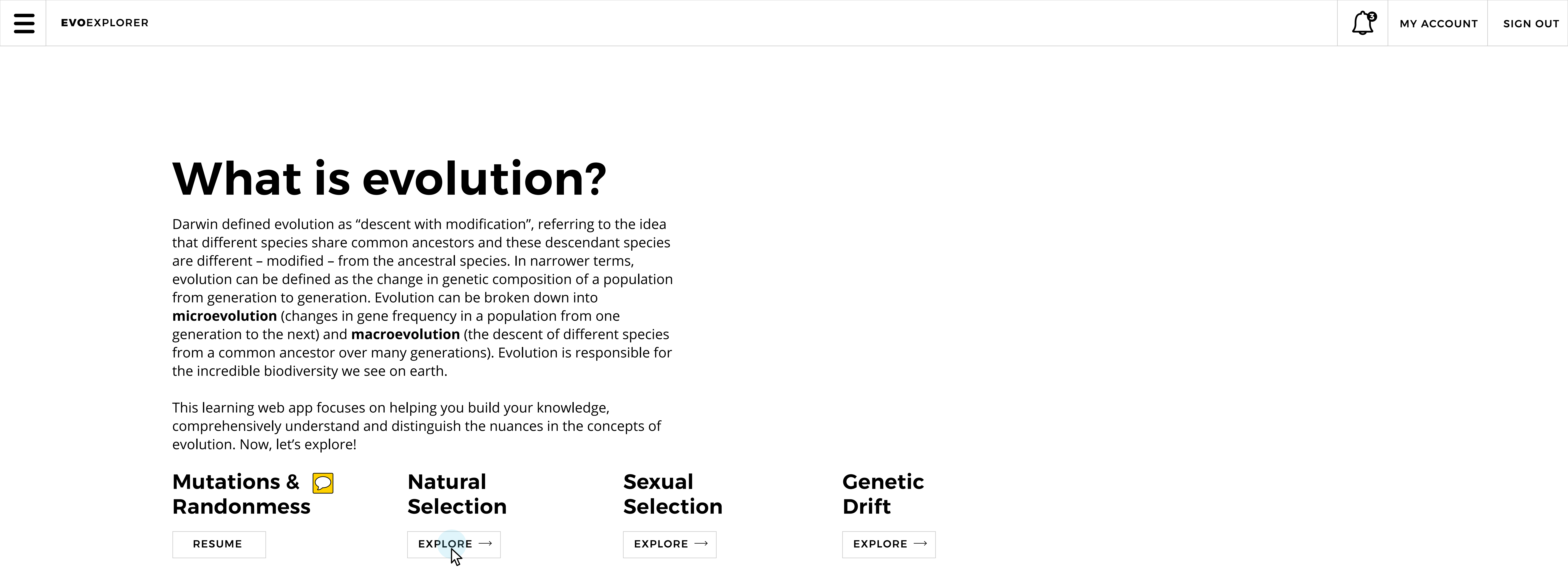


What is evolution?

Darwin defined evolution as “descent with modification”, referring to the idea that different species share common ancestors and these descendant species are different – modified – from the ancestral species. In narrower terms, evolution can be defined as the change in genetic composition of a population from generation to generation. Evolution can be broken down into **microevolution** (changes in gene frequency in a population from one generation to the next) and **macroevolution** (the descent of different species from a common ancestor over many generations). Evolution is responsible for the incredible biodiversity we see on earth.

This learning web app focuses on helping you build your knowledge, comprehensively understand and distinguish the nuances in the concepts of evolution. Now, let’s explore!

Mutations & Randonmess

Natural Selection

Sexual Selection

Genetic Drift

Natural selection: Adaptive evolution

In biology, **adaptation** has two meanings: it can refer to a state that has evolved because it enhances a population's relative **reproductive success**, and it can also refer the process that produces that state. Natural selection is the only mechanism that consistently results in adaptations. Natural selection describes a process in which some individuals with certain inherited traits survive and reproduce at higher rates compared to other individuals *due* to those inherited traits. In response to selection, genetic traits that improve reproductive success increase in frequency (in the population) over many generations. In other words, natural selection works on **heritable phenotypic variation** to produce adaptive change.

With a growing human population and increasing global urbanization, human activities have significant impacts on many organisms. In this web learning application, we will consider how human activities may provide selection for or against organismal traits.

Learning outcomes:

- Define the concept of natural selection
- Identify the necessary conditions for natural selection to occur: 1) genetic variation 2) heritability and 3) differential survival
- Describe how generation time may affect adaptation by natural selection

PRE-QUIZ

How well do you know natural selection?

CASE STUDY 1

Heritability as a requirement for adaptation

CASE STUDY 2

Genetic variation as a requirement for adaptation

CASE STUDY 3

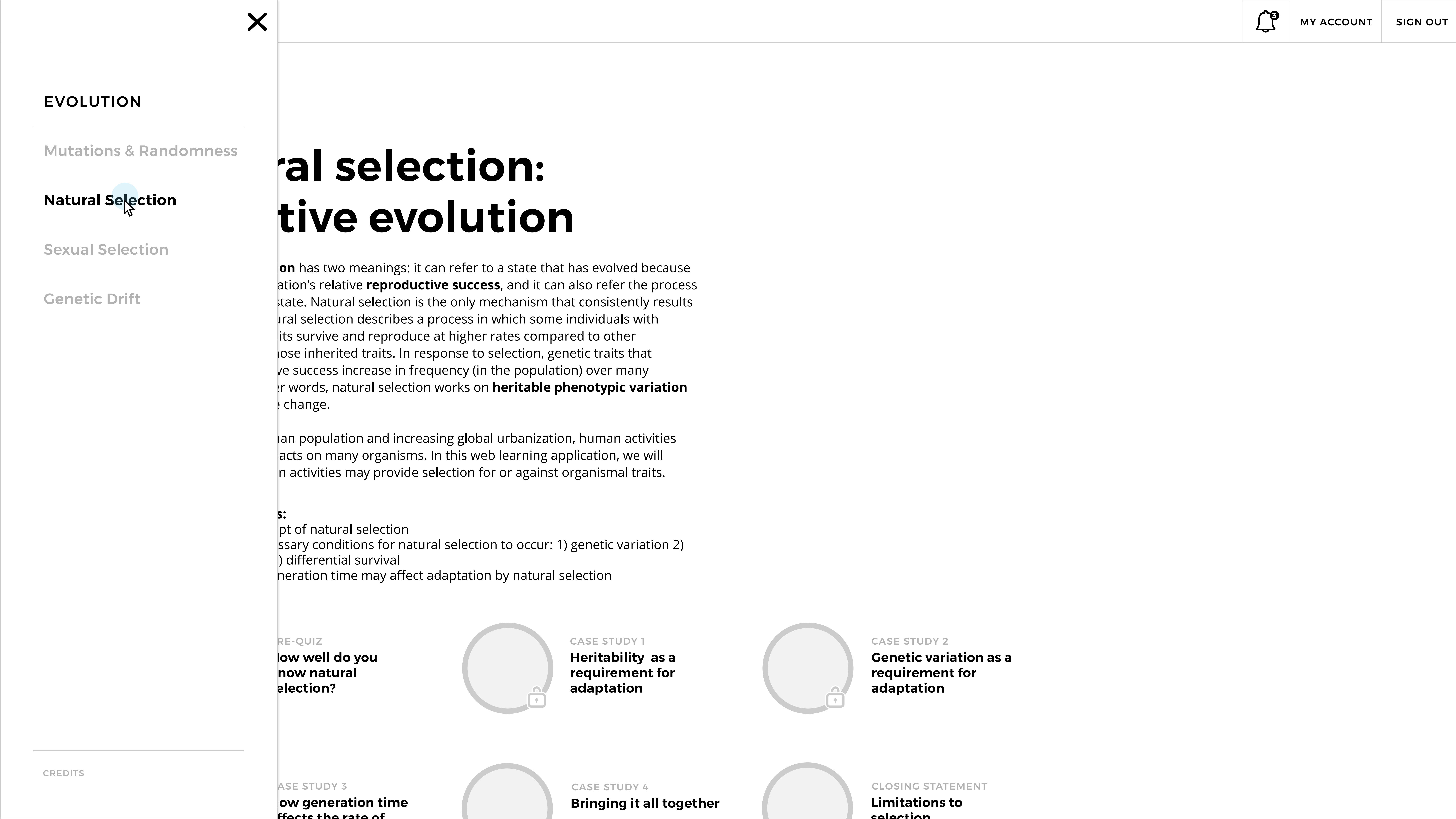
How generation time affects the rate of

CASE STUDY 4

Bringing it all together

CLOSING STATEMENT

Limitations to selection



EVOLUTION

Mutations & Randomness

Natural Selection

Sexual Selection

Genetic Drift

CREDITS

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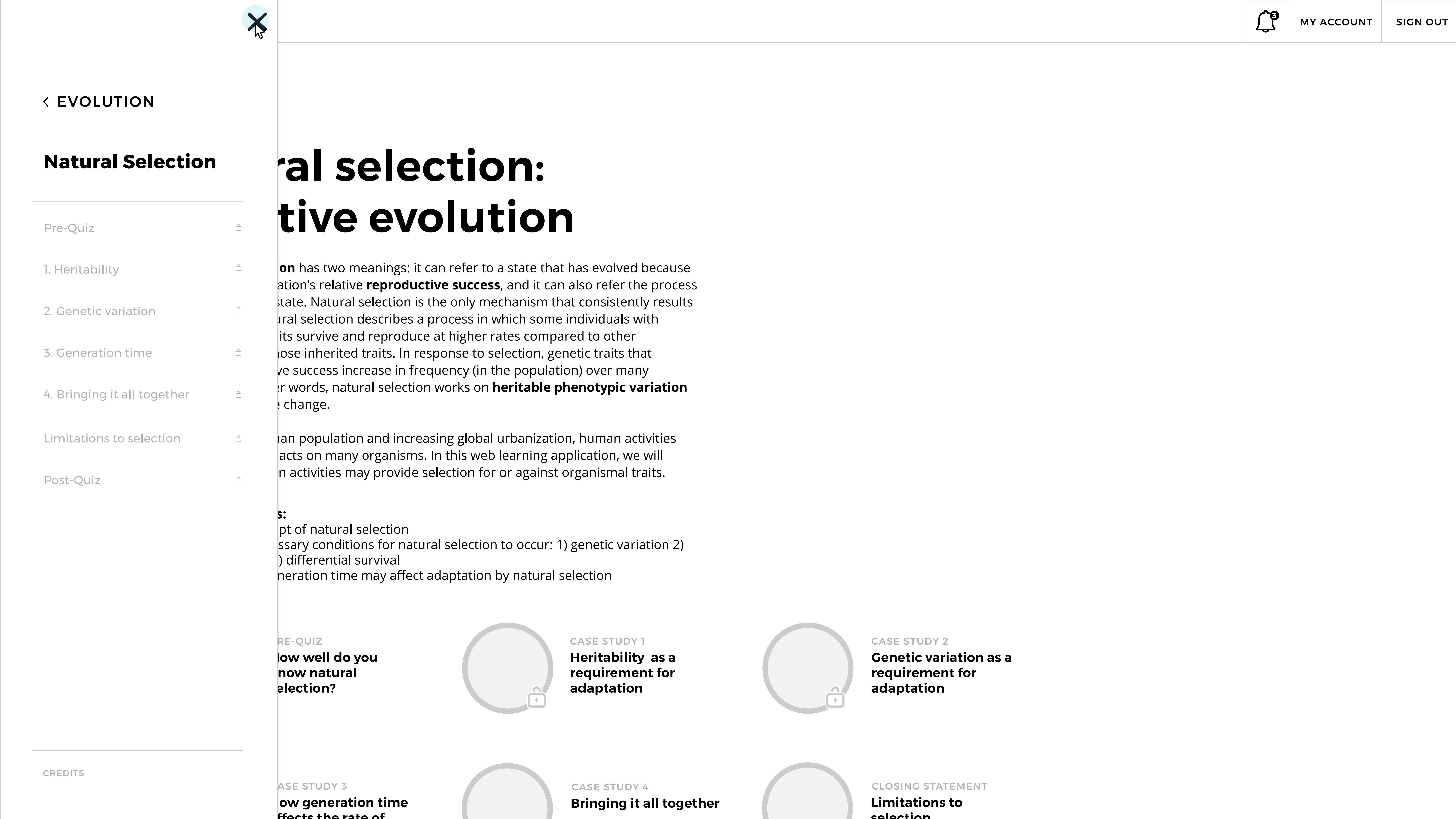

‹ EVOLUTION

Natural Selection

- Pre-Quiz
- 1. Heritability
- 2. Genetic variation
- 3. Generation time
- 4. Bringing it all together
- Limitations to selection
- Post-Quiz

CREDITS

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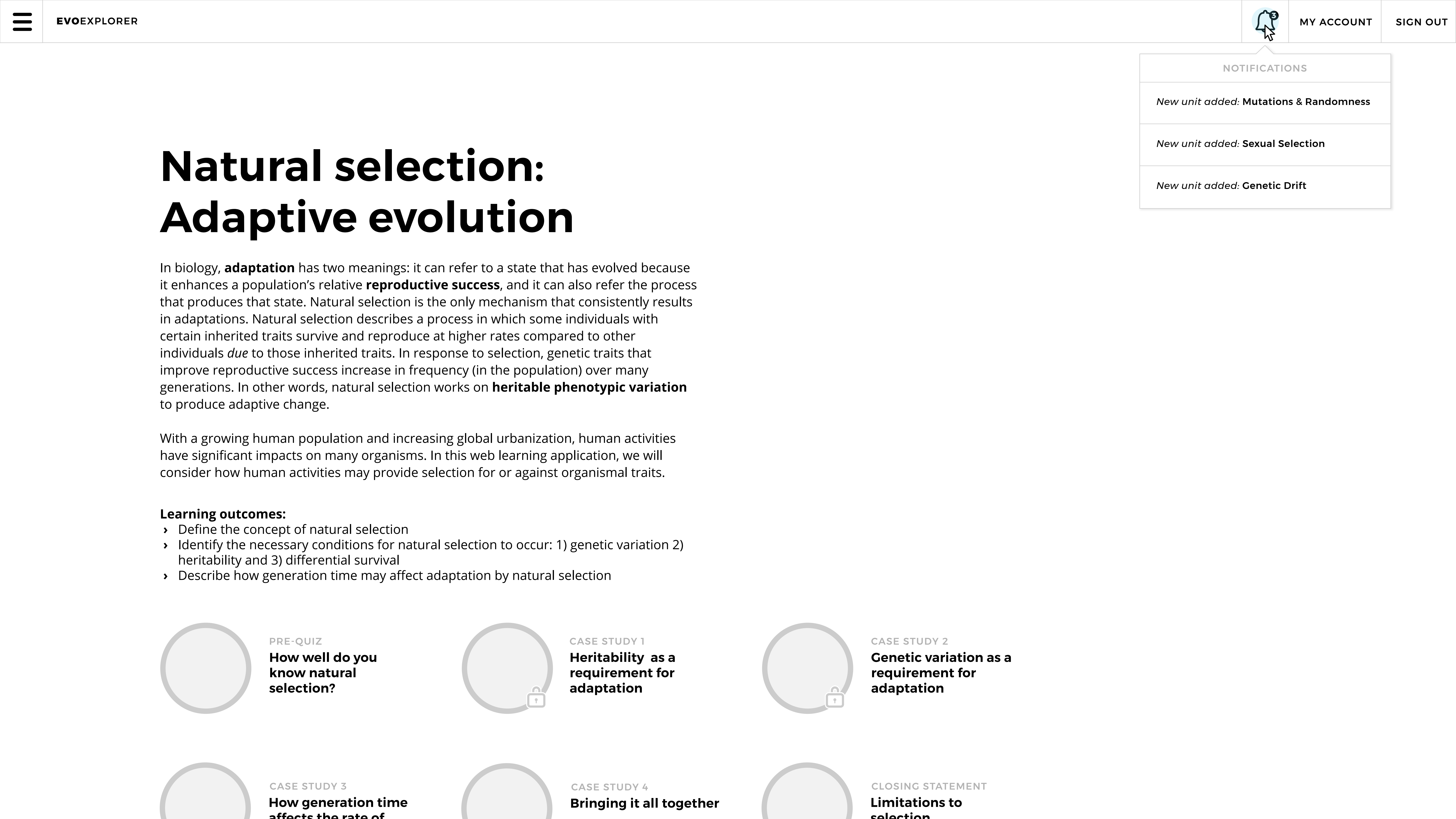

NOTIFICATIONS

New unit added: **Mutations & Randomness**

New unit added: **Sexual Selection**

New unit added: **Genetic Drift**

Natural selection: Adaptive evolution

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MY PROFILE

MY LIBRARY

HISTORY

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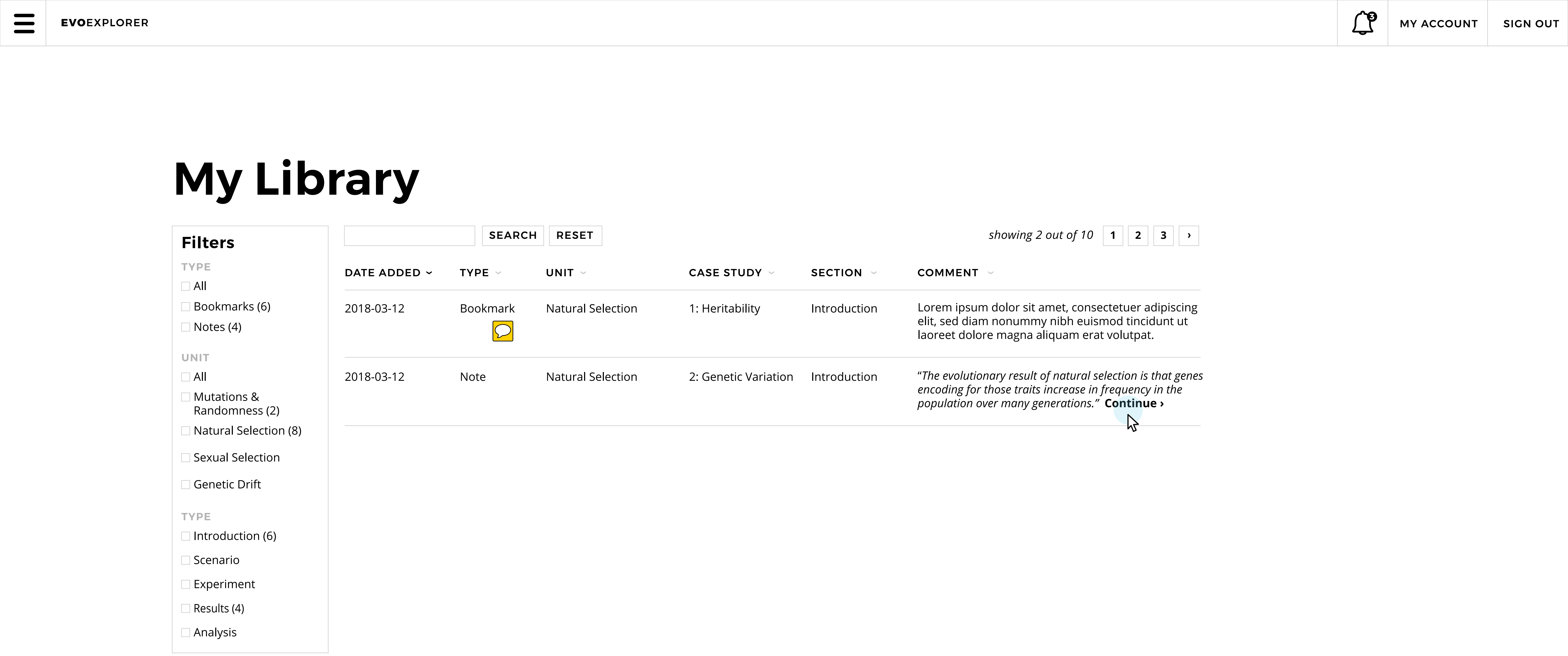

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Filters

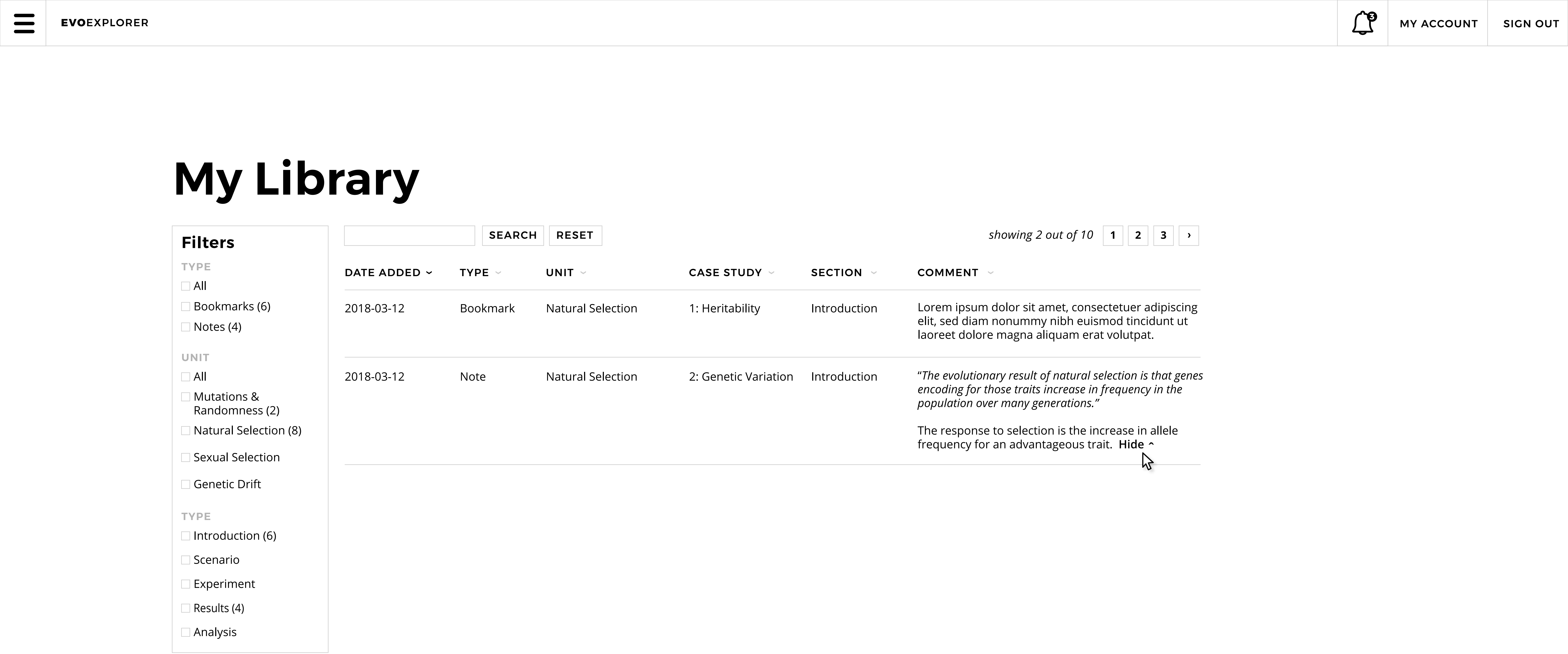
TYPE
- ☐ All
- ☐ Bookmarks (6)
- ☐ Notes (4)

UNIT
- ☐ All
- ☐ Mutations & Randomness (2)
- ☐ Natural Selection (8)
- ☐ Sexual Selection
- ☐ Genetic Drift

TYPE
- ☐ Introduction (6)
- ☐ Scenario
- ☐ Experiment
- ☐ Results (4)
- ☐ Analysis

showing 2 out of 10 1 2 3 ›

DATE ADDED ˅	TYPE ˅	UNIT ˅	CASE STUDY ˅	SECTION ˅	COMMENT ˅
2018-03-12	Bookmark 💬	Natural Selection	1: Heritability	Introduction	Lorem ipsum dolor sit amet, consectetuer adipiscing elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat.
2018-03-12	Note	Natural Selection	2: Genetic Variation	Introduction	*"The evolutionary result of natural selection is that genes encoding for those traits increase in frequency in the population over many generations."* **Continue ›**



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2018-03-12	Note	Natural Selection	2: Genetic Variation	Introduction	*“The evolutionary result of natural selection is that genes encoding for those traits increase in frequency in the population over many generations.”* The response to selection is the increase in allele frequency for an advantageous trait. **Hide**

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START

PRE-QUIZ

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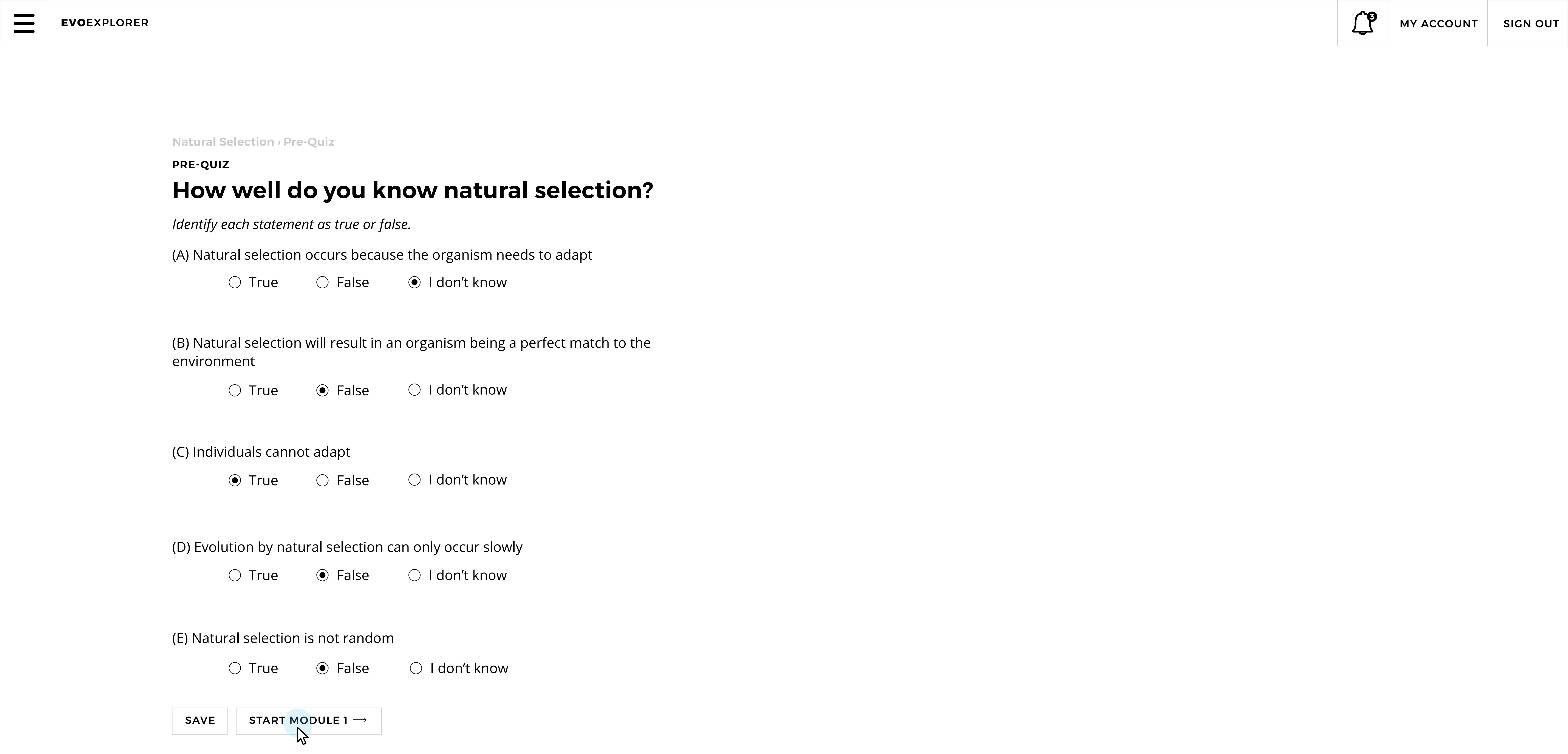
Limitations to selection



Natural Selection › Pre-Quiz

PRE-QUIZ

How well do you know natural selection?

Identify each statement as true or false.

(A) Natural selection occurs because the organism needs to adapt

○ True ○ False ● I don't know

(B) Natural selection will result in an organism being a perfect match to the environment

○ True ● False ○ I don't know

(C) Individuals cannot adapt

● True ○ False ○ I don't know

(D) Evolution by natural selection can only occur slowly

○ True ● False ○ I don't know

(E) Natural selection is not random

○ True ● False ○ I don't know

Natural Selection › Heritability

Heritability as a requirement for adaptation

Natural selection is a process that occurs within a population over many generations. Therefore, natural selection only leads to evolutionary change in a population if the traits that are selected for or against are heritable.

BEGIN CASE STUDY 1 ⟶

Natural Selection › Heritability › Scenario

CASE STUDY 1

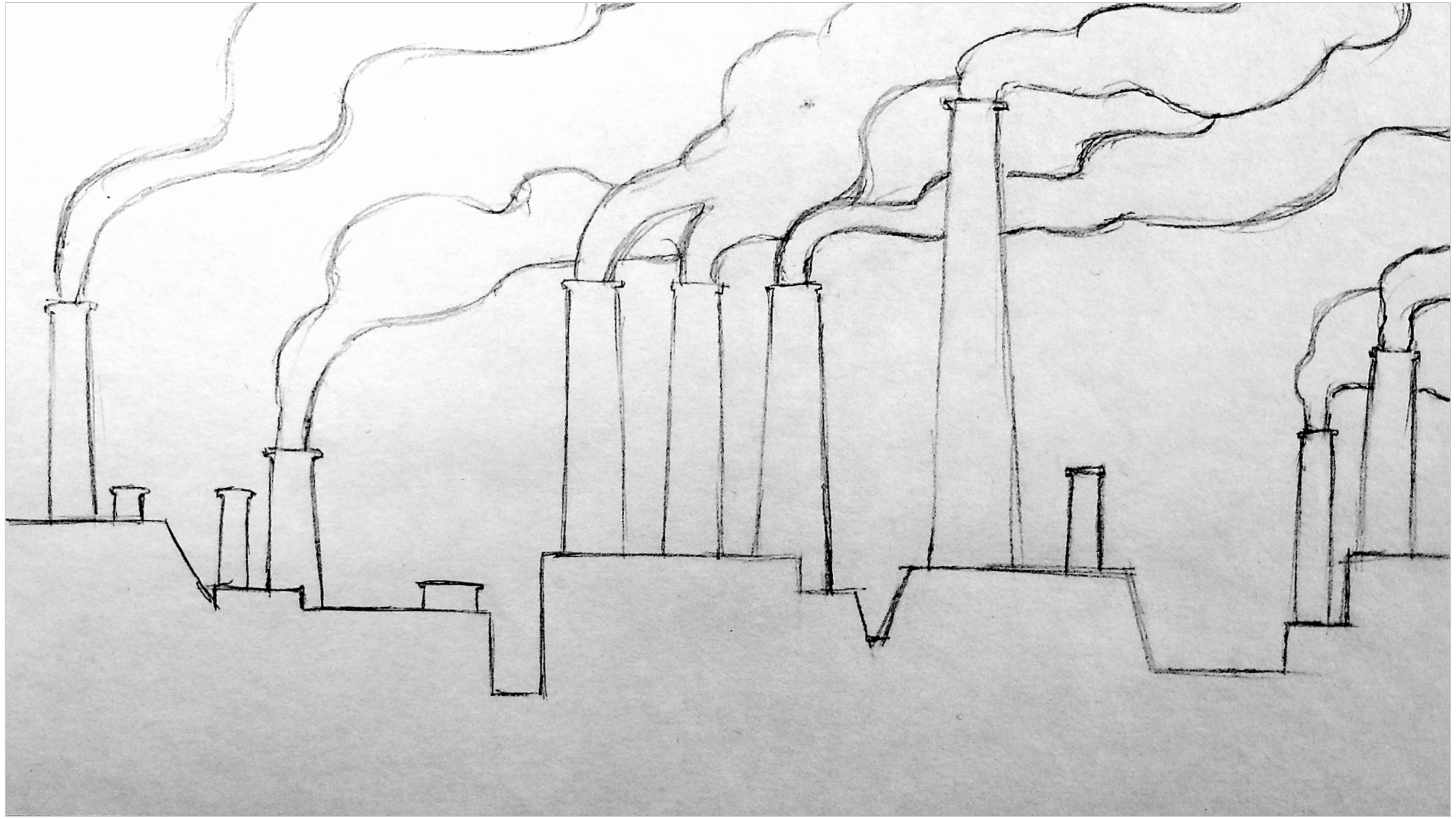
Moth populations during the Industrial Revolution

The Industrial Revolution was a transition from hand production methods to machines, new chemical manufacturing, and steam-powered factories. It began in Great Britain and occurred in the period from the 18th to 19th century.

While it increased the standard of living for the general population, it also led to a significant and sudden increase in levels of smoke pollution due to coal consumption in factories.

⟵ PREVIOUS

NEXT ⟶



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‹ NATURAL SELECTION

CASE STUDY 1

Heritability as a requirement for adaptation

Introduction ●

Scenario ○

Prediction

Experiment

Analysis

CREDITS

ritability › Scenario

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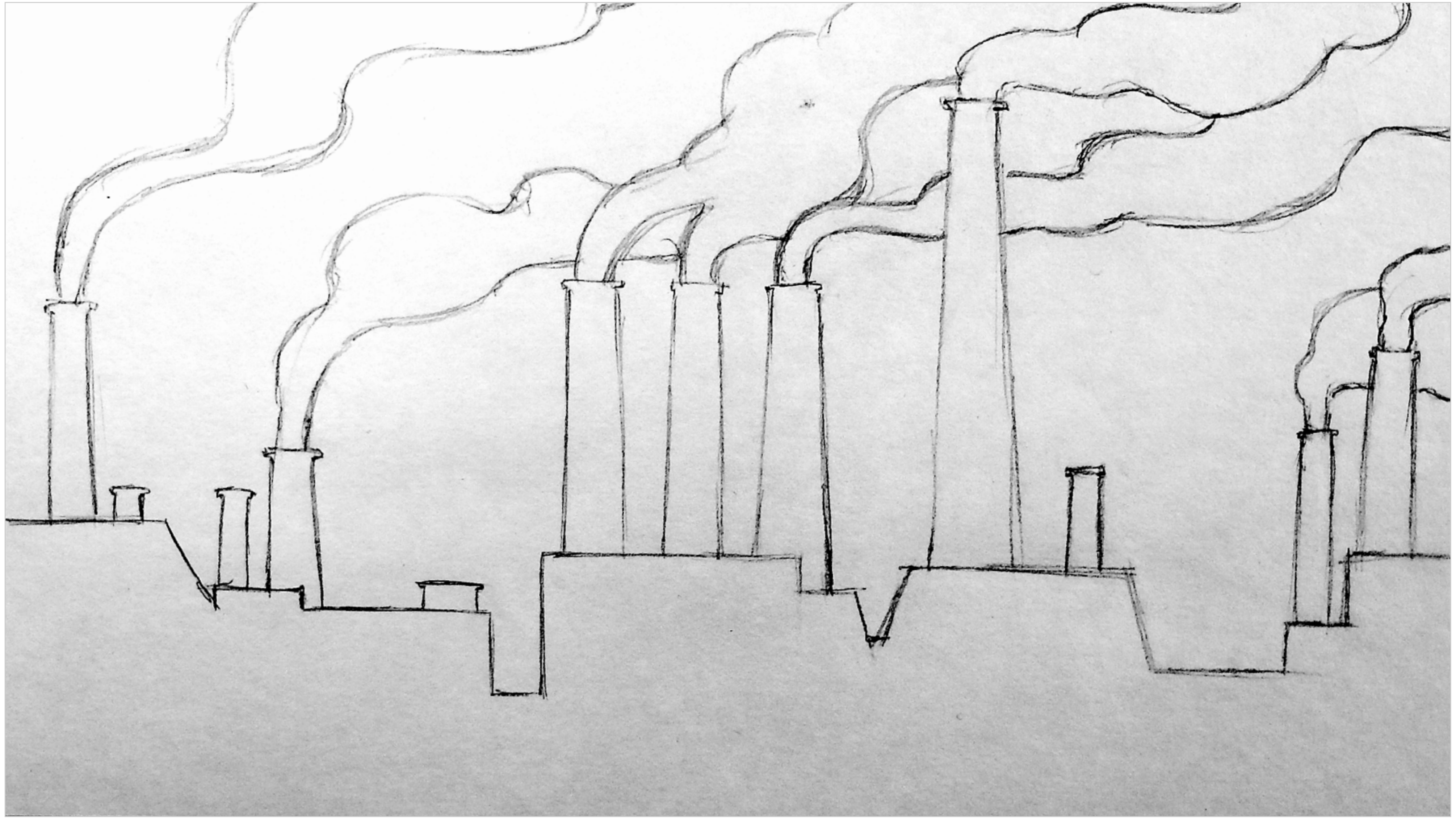

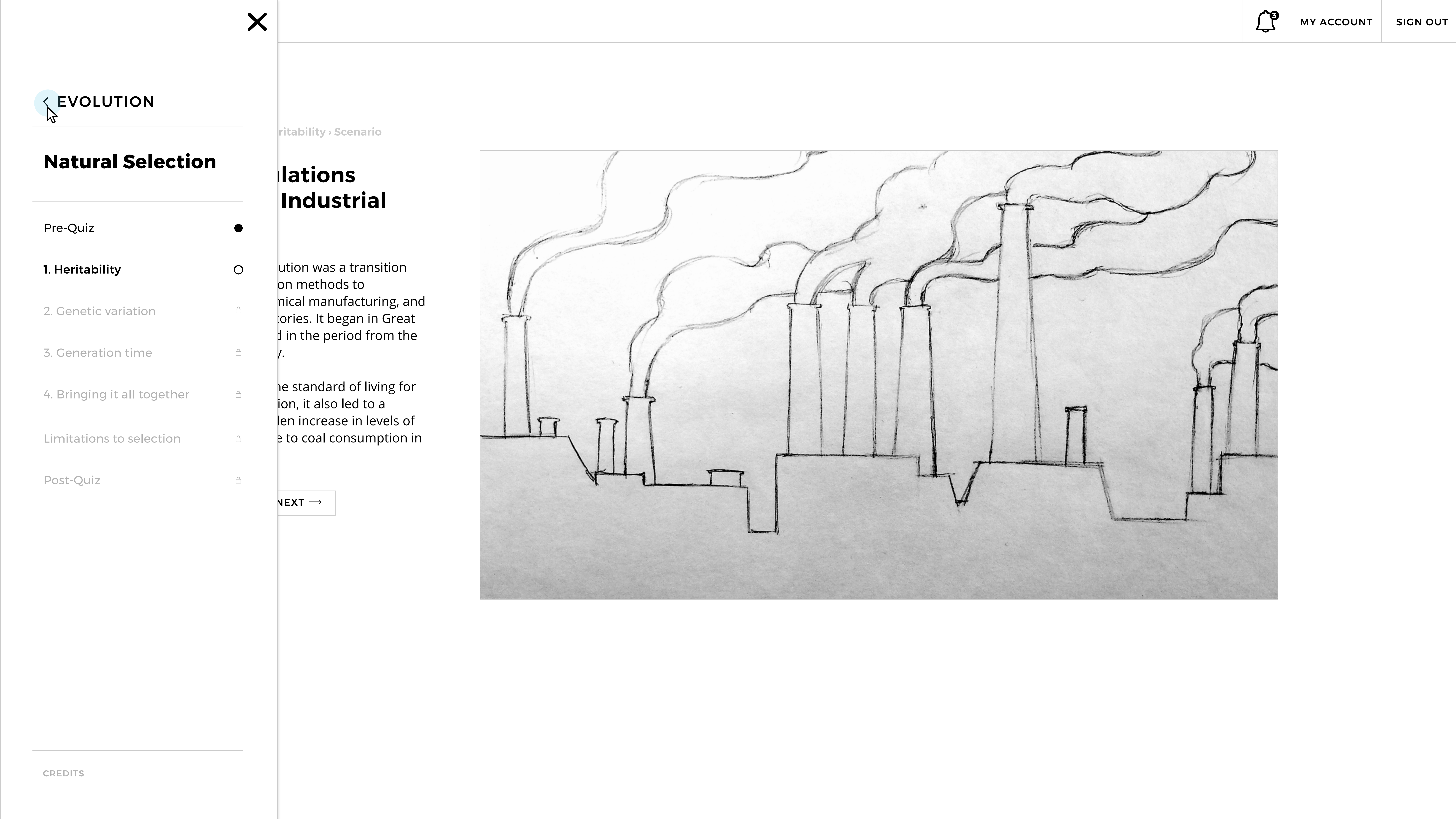

Natural Selection

Pre-Quiz ●

1. Heritability ○

2. Genetic variation 🔒

3. Generation time 🔒

4. Bringing it all together 🔒

Limitations to selection 🔒

Post-Quiz 🔒

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EVOLUTION

- Mutations & Randomness
- **Natural Selection**
- Sexual Selection
- Genetic Drift

CREDITS

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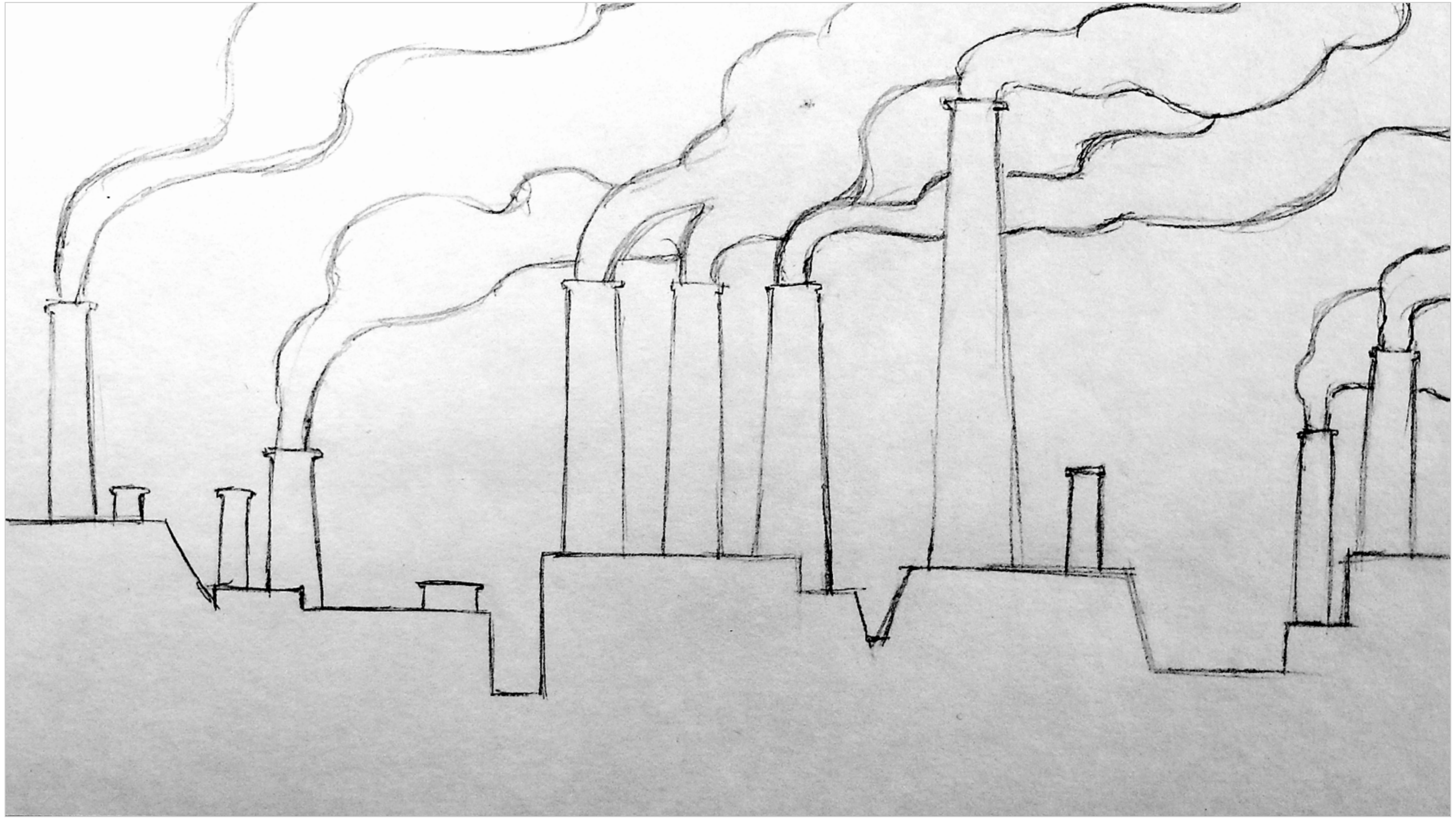

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PRE-QUIZ
How well do you know natural selection?

RESUME

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EVOEXPLORER

MY ACCOUNT

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Natural Selection › Heritability › Scenario

CASE STUDY 1

Moth populations during the Industrial Revolution

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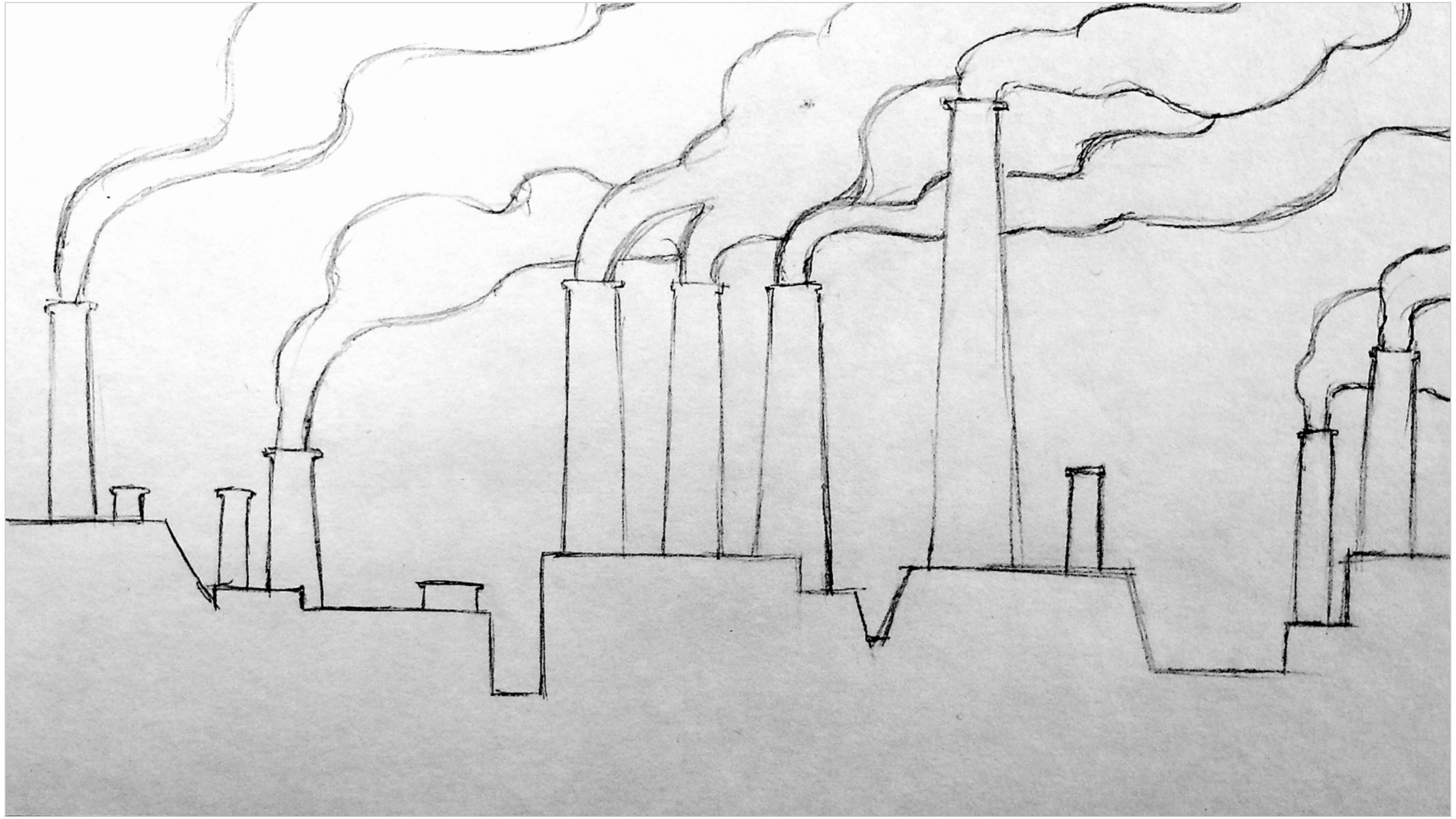
⟵ PREVIOUS

NEXT ⟶



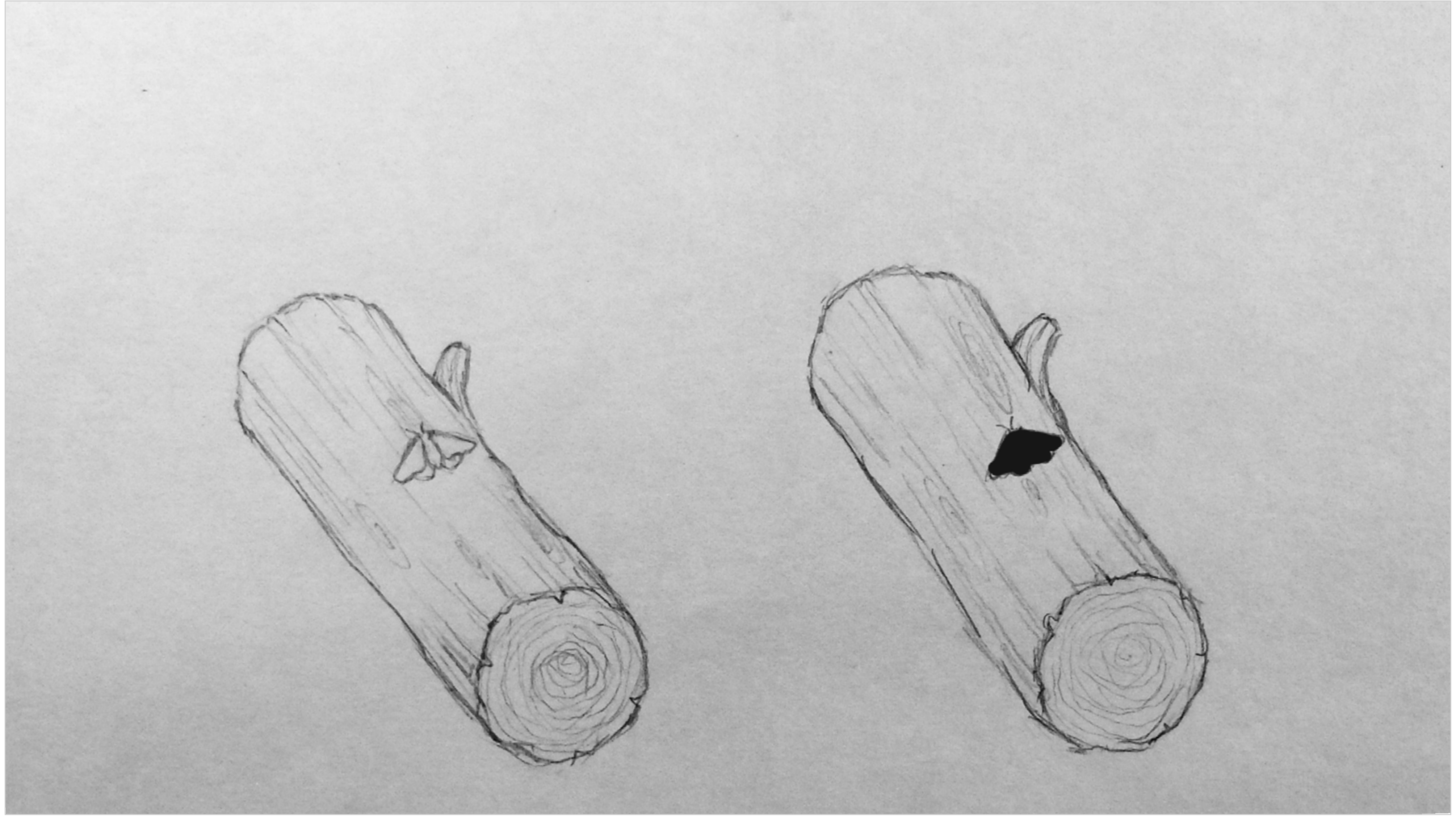
Natural Selection › Heritability › Scenario

CASE STUDY 1

Moth populations during the Industrial Revolution

Before the Industrial Revolution, numbers of black peppered moths were lower in the population compared to light-coloured moths which were better able to camouflage against the light-coloured lichens and English tree bark

← PREVIOUS NEXT →



Natural Selection › Heritability › Scenario

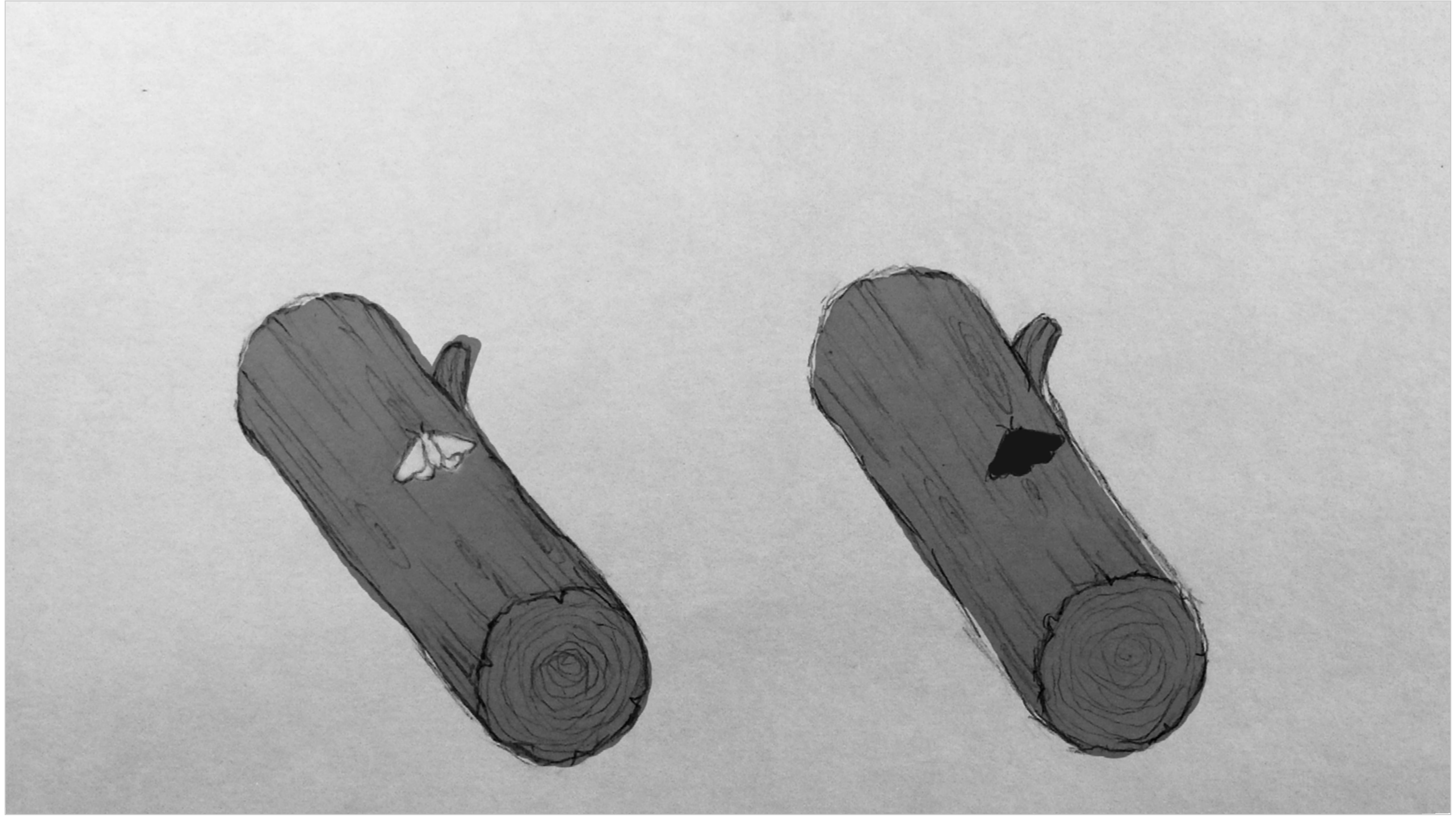
CASE STUDY 1

Moth populations during the Industrial Revolution

However, within the first few decades of the Industrial Revolution in England, the trees darkened due to the soot emitted from coal-burning factories and light-coloured lichens died from toxic emissions.

Light-coloured moths no longer blended in with the darkened environment and were easily preyed upon by birds, whereas, dark-coloured moths were able to camouflage. This led to an increase of the dark-coloured moth in the population, peaking at 98% within approximately 50 years.

⟵ PREVIOUS NEXT ⟶



Natural Selection › Heritability › Scenario › Predict

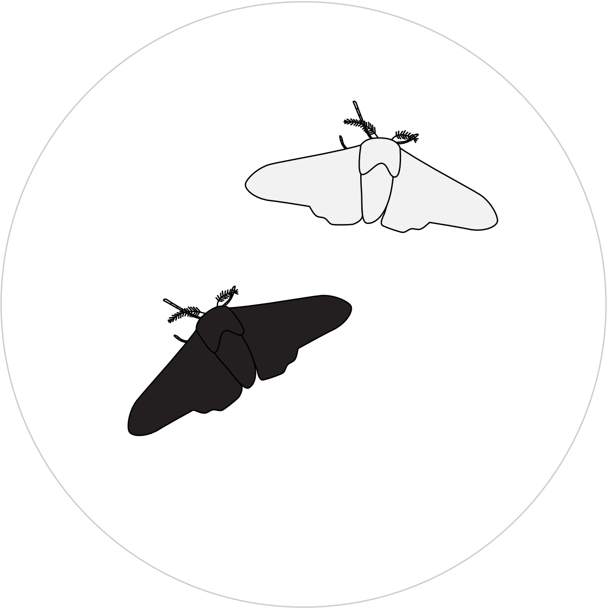
CASE STUDY 1

Predict

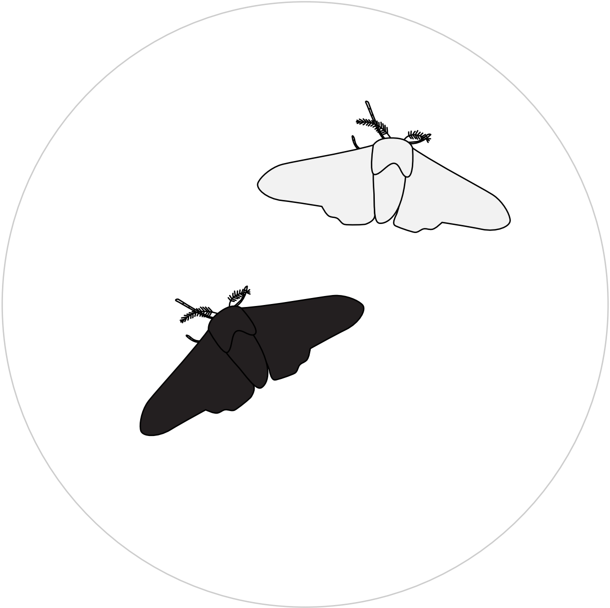
Specific alleles are responsible for either colour (dark or light) that we see in the peppered moths, meaning that both dark and light coloured traits are heritable.

Now as a scientist, you are fascinated by how heritability of colour will affect the population as time passes after the Industrial Revolution. You decide to consider two possible scenarios...

⟵ PREVIOUS PREDICT ⟶



Population A: If colour is **heritable**, what do you think will happen?



Population B: If colour is **non-heritable**, what do you think will happen?

EVOEXPLORER   3   MY ACCOUNT   SIGN OUT

Natural Selection › Heritability › Scenario › Predict

CASE STUDY 1

Predict: Population A

At the end of the Industrial Revolution, moth population A consisted of 90% dark coloured moths. In this population, colour is *heritable*. Due to efforts to reduce atmospheric pollution, the barks of trees have become light again and light-coloured lichens are flourishing. What colour do you expect to see most of in the moth population after a few decades of reduced pollution?

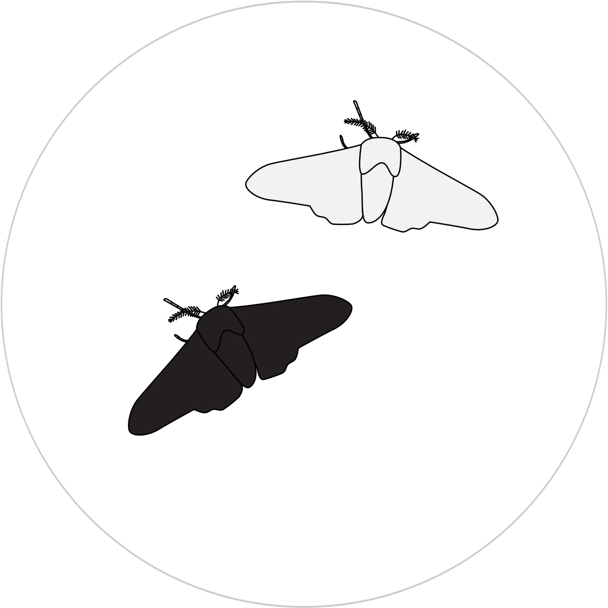
need a hint ?

○ No significant change

● Decrease in the percentage of population with dark colours; increase in the percentage of population with light colours

○ Increase in the percentage of population with dark colours
Decrease in the percentage of population with light colours

⟵ PREVIOUS   SAVE   PART B ⟶



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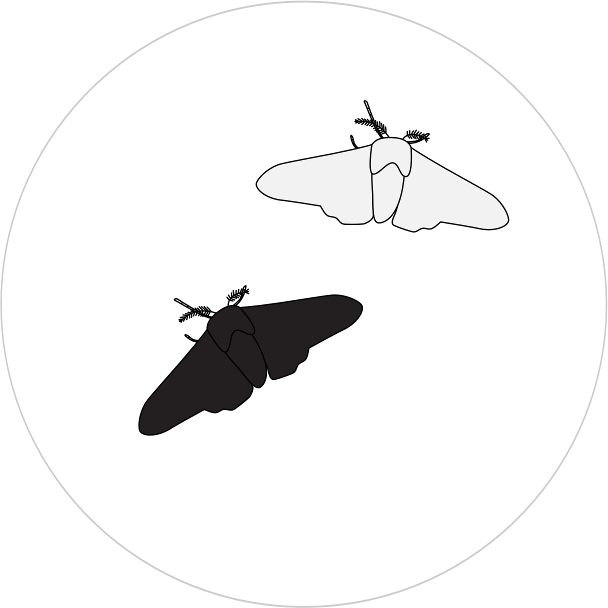


Population B: If colour is **non-heritable**, what do you think will happen?

Natural Selection › Heritability › Scenario › Predict

CASE STUDY 1

Predict: Population B

At the end of the Industrial Revolution, a hypothetical moth population B consisted of 50% dark coloured moths. In this population, dark and light colour traits were *non-heritable*. What colour do you expect to see most of in the moth population after a few decades following the Industrial Revolution in which the pollution is reduced (light-coloured tree bark and light-coloured lichens)?

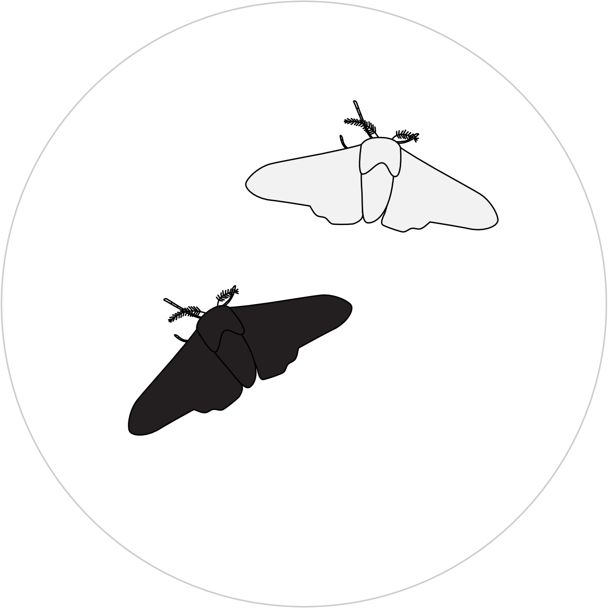
need a hint ?

● No significant change

○ Decrease in the percentage of population with dark colours; increase in the percentage of population with light colours

○ Increase in the percentage of population with dark colours
Decrease in the percentage of population with light colours

← PREVIOUS SAVE LET'S EXPLORE →



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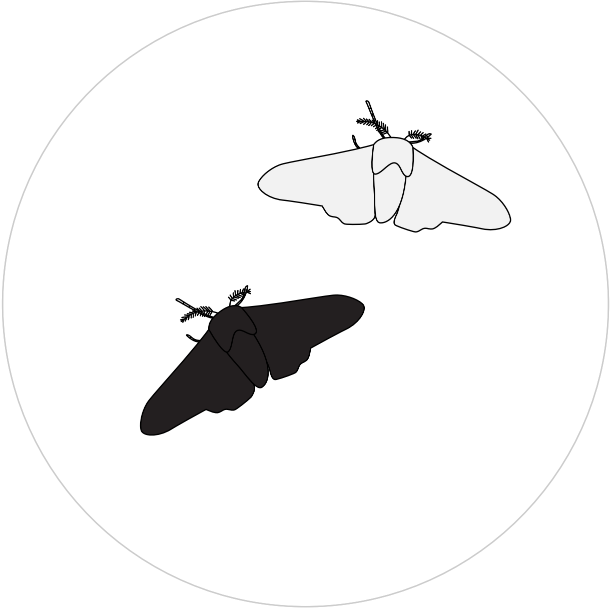


Population B: If colour is **non-heritable**, what do you think will happen?

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

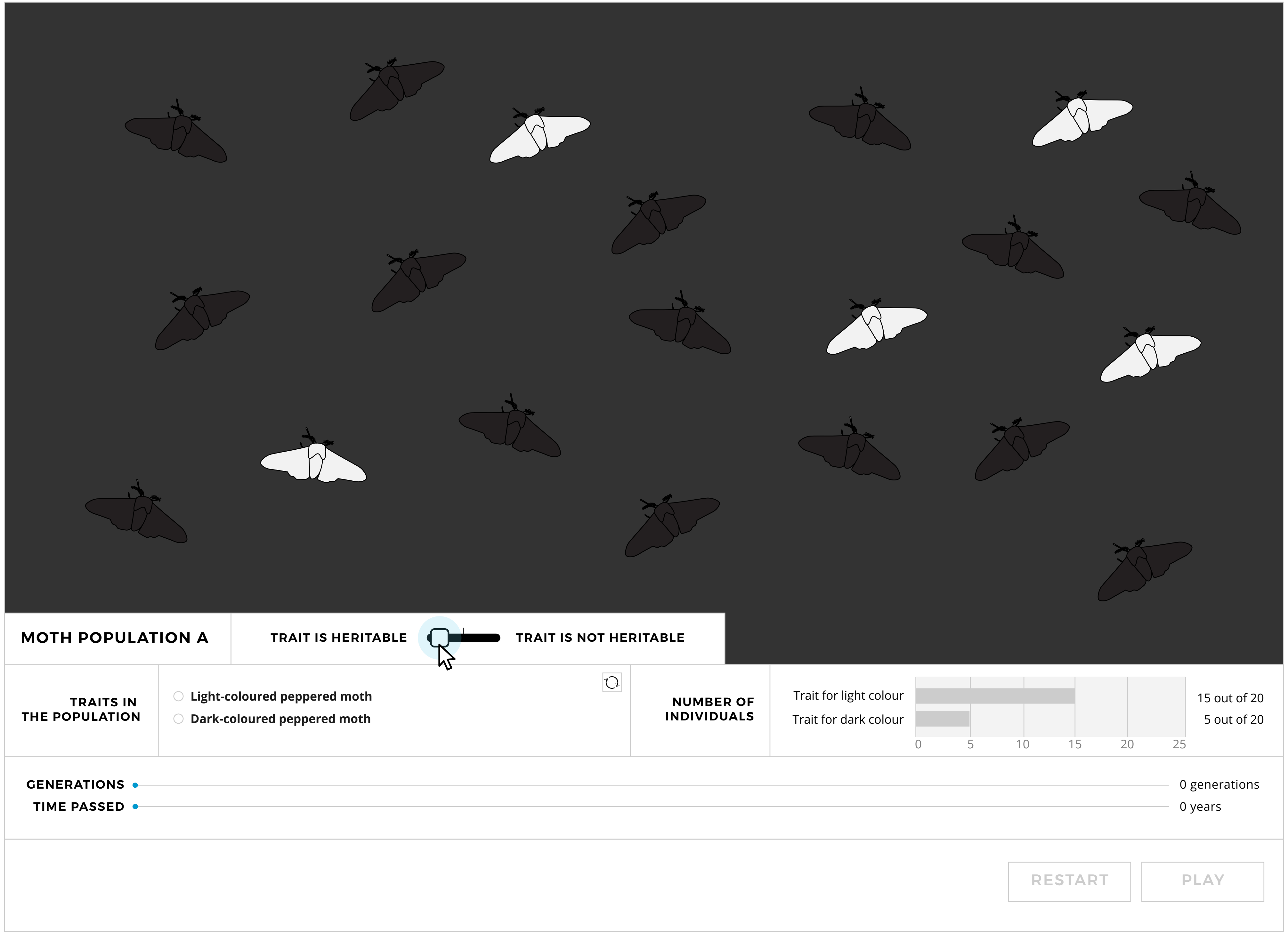
Experiment A

First, let’s look at population A in which colour is heritable.

At the end of the Industrial Revolution, the moth population consisted of 90% dark coloured moths. Due to efforts to reduce atmospheric pollution, the barks of trees have become light again and light-coloured lichens are flourishing.

First, adjust the toggle to “trait is heritable”.

← PREVIOUS NEXT →



MOTH POPULATION A TRAIT IS HERITABLE TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION

- ○ Light-coloured peppered moth
- ○ Dark-coloured peppered moth

NUMBER OF INDIVIDUALS

Trait for light colour	15 out of 20
Trait for dark colour	5 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

RESTART PLAY

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

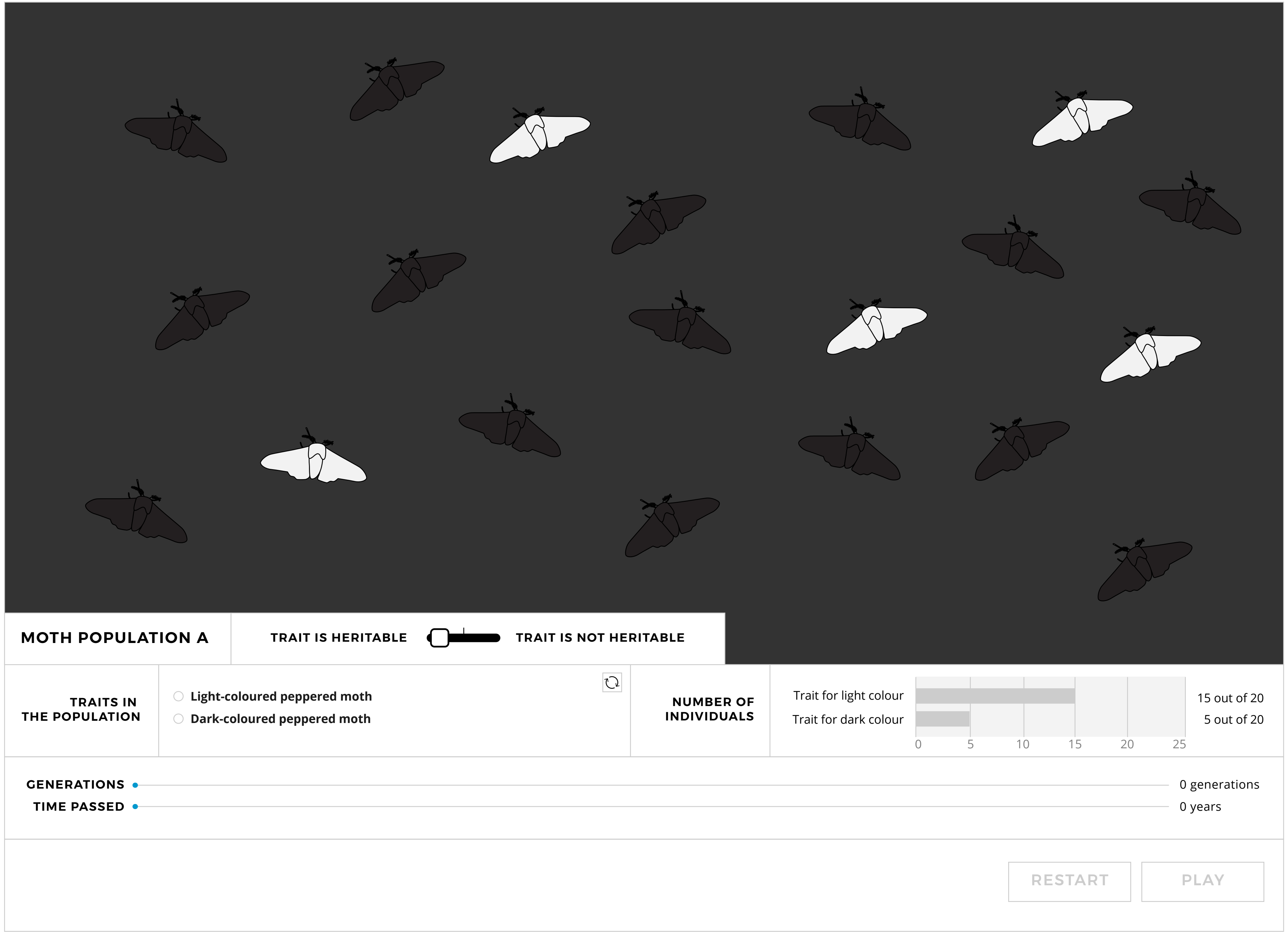
Experiment A

First, let's look at population A in which colour is heritable.

At the end of the Industrial Revolution, the moth population consisted of 90% dark coloured moths. Due to efforts to reduce atmospheric pollution, the barks of trees have become light again and light-coloured lichens are flourishing.

First, adjust the toggle to "trait is heritable".

⟵ PREVIOUS NEXT ⟶



○ Light-coloured peppered moth
○ Dark-coloured peppered moth

Trait for light colour	15 out of 20
Trait for dark colour	5 out of 20

GENERATIONS 0 generations
TIME PASSED 0 years

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Experiment A

You predicted that if the trait is heritable, then *there would be an increase in the percentage of population with dark colours and a decrease in the percentage of population with light colours.*

Peppered moths have a generation time of one year. To observe the overall trend, you decide to collect data on the moth population for the next 24 years following the end of the Industrial Revolution as the tree barks have become lighter.

Record how many individuals in the population are light coloured and dark coloured in the starting population (generation 0). Click "play" and pause every 2 years to continue collecting data.

CASE STUDY 1 NOTEBOOK | DATA LOG

Population A Data

Generation #:

Number of individuals | **Trait**

Select an option − +

ADD NEW DATA | SAVE

← PREVIOUS | PART B →

MOTH POPULATION A

TRAIT IS HERITABLE | TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION

○ Light-coloured peppered moth

○ Dark-coloured peppered moth

NUMBER OF INDIVIDUALS

Trait for light colour	🟩	5 out of 20
Trait for dark colour	▨	15 out of 20

0 5 10 15 20 25

GENERATIONS — 0 generations

TIME PASSED — 0 years

RESTART | PLAY

CASE STUDY 1

Experiment A

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Record how many individuals in the population are light coloured and dark coloured in the starting population (generation 0). Click “play” and pause every 2 years to continue collecting data.

CASE STUDY 1 NOTEBOOK | DATA LOG

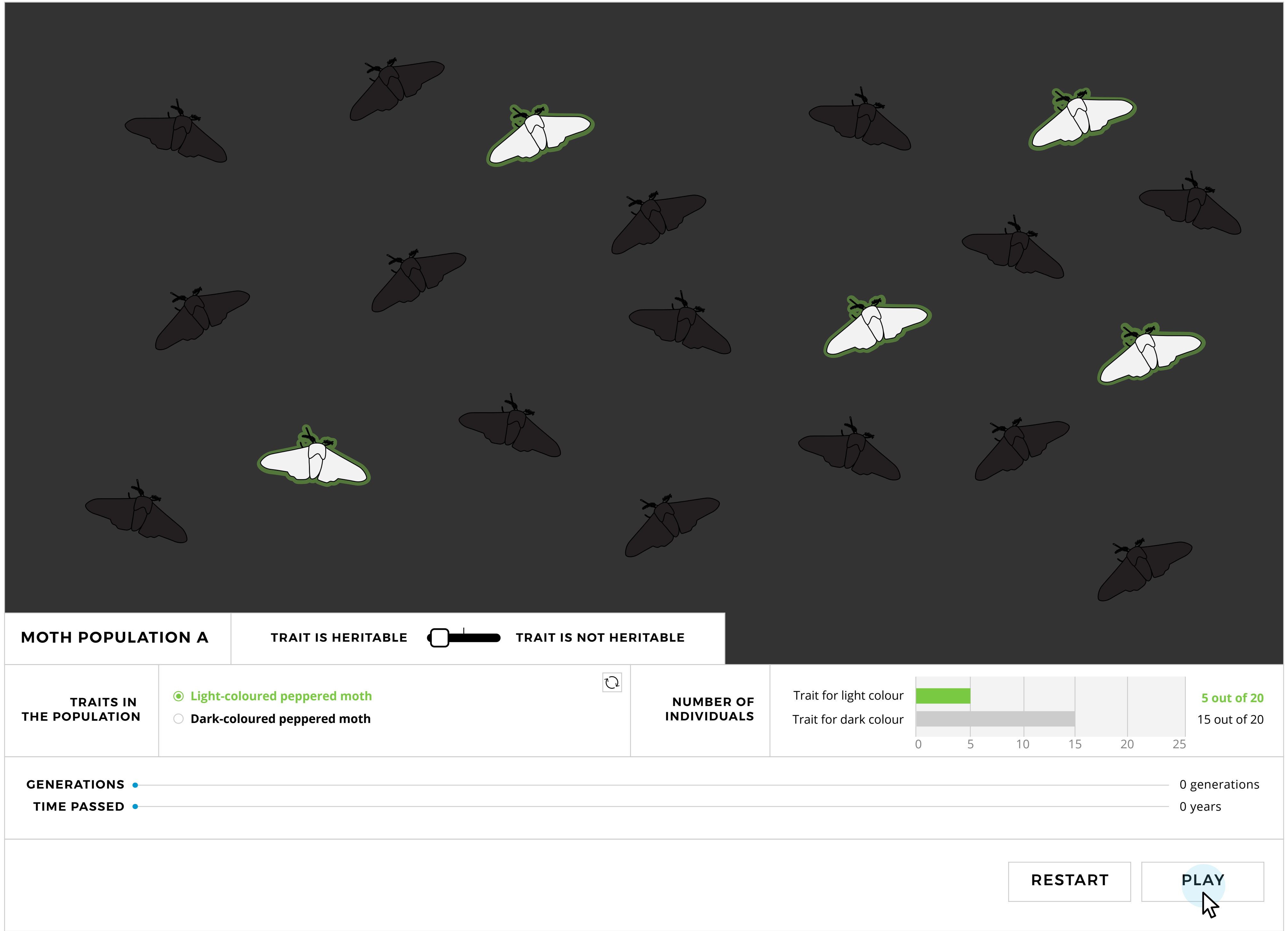
Population A Data

Generation #: 0

Number of individuals	**Trait**
5	Light colour
15	Dark colour

ADD NEW DATA SAVE

← PREVIOUS PART B →



MOTH POPULATION A

TRAIT IS HERITABLE / TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION

● Light-coloured peppered moth

○ Dark-coloured peppered moth

NUMBER OF INDIVIDUALS

Trait for light colour	5 out of 20
Trait for dark colour	15 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Experiment A

You predicted that if the trait is heritable, then *there would be an increase in the percentage of population with dark colours and a decrease in the percentage of population with light colours.*

Peppered moths have a generation time of one year. To observe the overall trend, you decide to collect data on the moth population for the next 24 years following the end of the Industrial Revolution as the tree barks have become lighter.

Record how many individuals in the population are light coloured and dark coloured in the starting population (generation 0). Click “play” and pause every 2 years to continue collecting data.

CASE STUDY 1 NOTEBOOK | **DATA LOG**

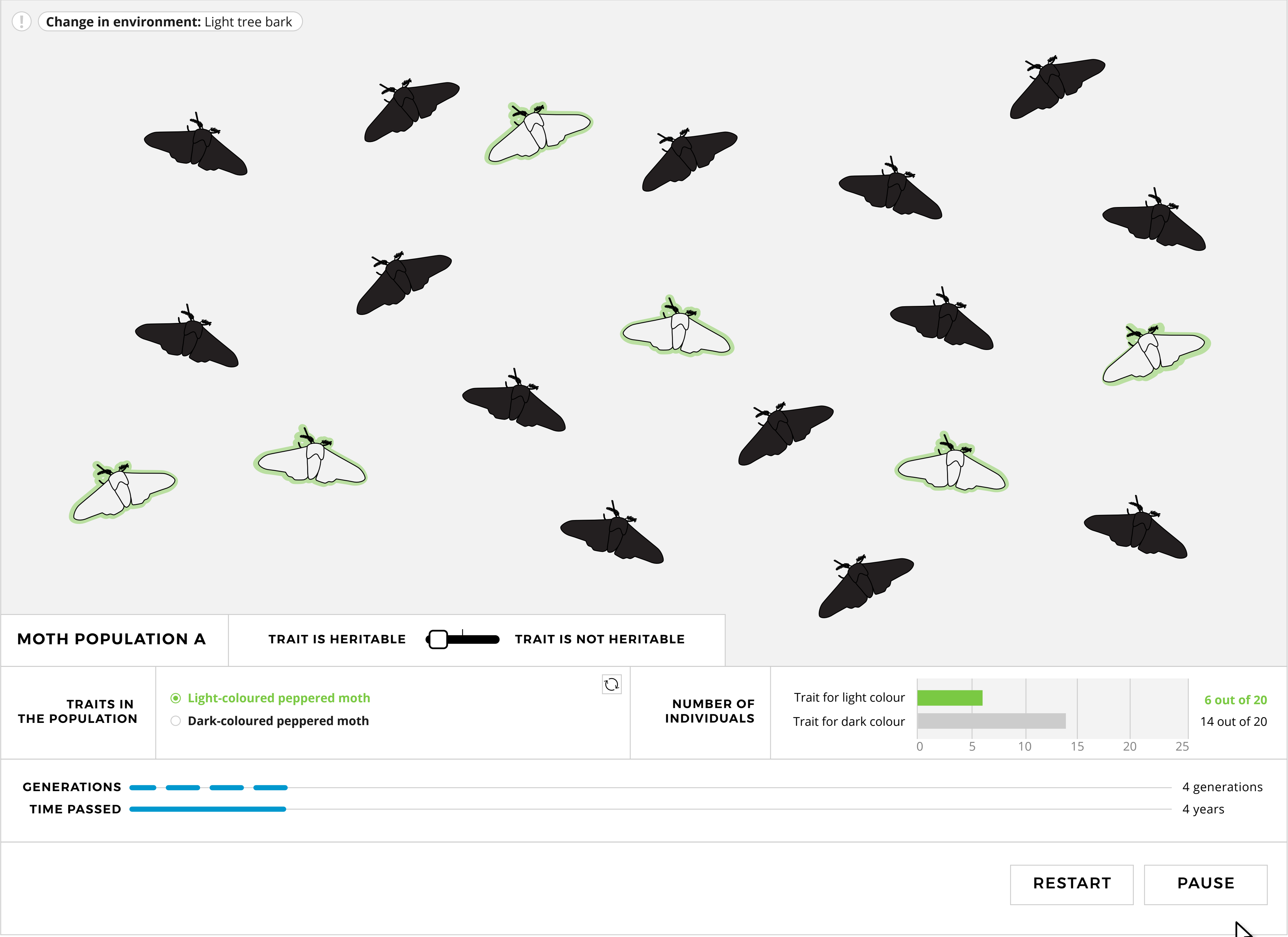
Population A Data

Generation #: 4

Number of individuals	**Trait**
6	Light colour
14	Dark colour

ADD NEW DATA SAVE

← PREVIOUS PART B →



Change in environment: Light tree bark

MOTH POPULATION A

TRAIT IS HERITABLE ● TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION

● Light-coloured peppered moth
○ Dark-coloured peppered moth

NUMBER OF INDIVIDUALS

GENERATIONS 4 generations

TIME PASSED 4 years

RESTART PAUSE

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Experiment A

You predicted that if the trait is heritable, then *there would be an increase in the percentage of population with dark colours and a decrease in the percentage of population with light colours.*

Peppered moths have a generation time of one year. To observe the overall trend, you decide to collect data on the moth population for the next 24 years following the end of the Industrial Revolution as the tree barks have become lighter.

Record how many individuals in the population are light coloured and dark coloured in the starting population (generation 0). Click "play" and pause every 2 years to continue collecting data.

CASE STUDY 1 NOTEBOOK | DATA LOG

Population A Data

Generation #: 24

Number of individuals	**Trait**		
22	Light colour ⌄	−	+
1	Dark colour ⌄	−	+

ADD NEW DATA | SAVE

⟵ PREVIOUS | PART B ⟶

MOTH POPULATION A

TRAIT IS HERITABLE ● TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION
- ● Light-coloured peppered moth
- ○ Dark-coloured peppered moth

NUMBER OF INDIVIDUALS

Trait for light colour	22 out of 23
Trait for dark colour	1 out of 23

GENERATIONS: 24 generations

TIME PASSED: 24 years

RESTART | PLAY

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Experiment B

Let's look at population B in which colour is non-heritable.

Consider a hypothetical scenario in which population B at the end of the Industrial Revolution consisted of 50% dark coloured moths.

Adjust the toggle to "trait is non-heritable".

⟵ PREVIOUS   NEXT ⟶

MOTH POPULATION B

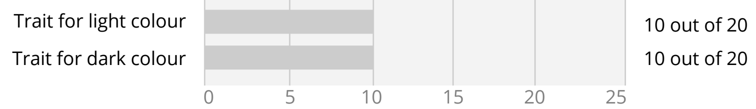
TRAIT IS HERITABLE ● TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION

○ Light-coloured peppered moth

○ Dark-coloured peppered moth

NUMBER OF INDIVIDUALS



GENERATIONS 0 generations

TIME PASSED 0 years

RESTART   PLAY

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

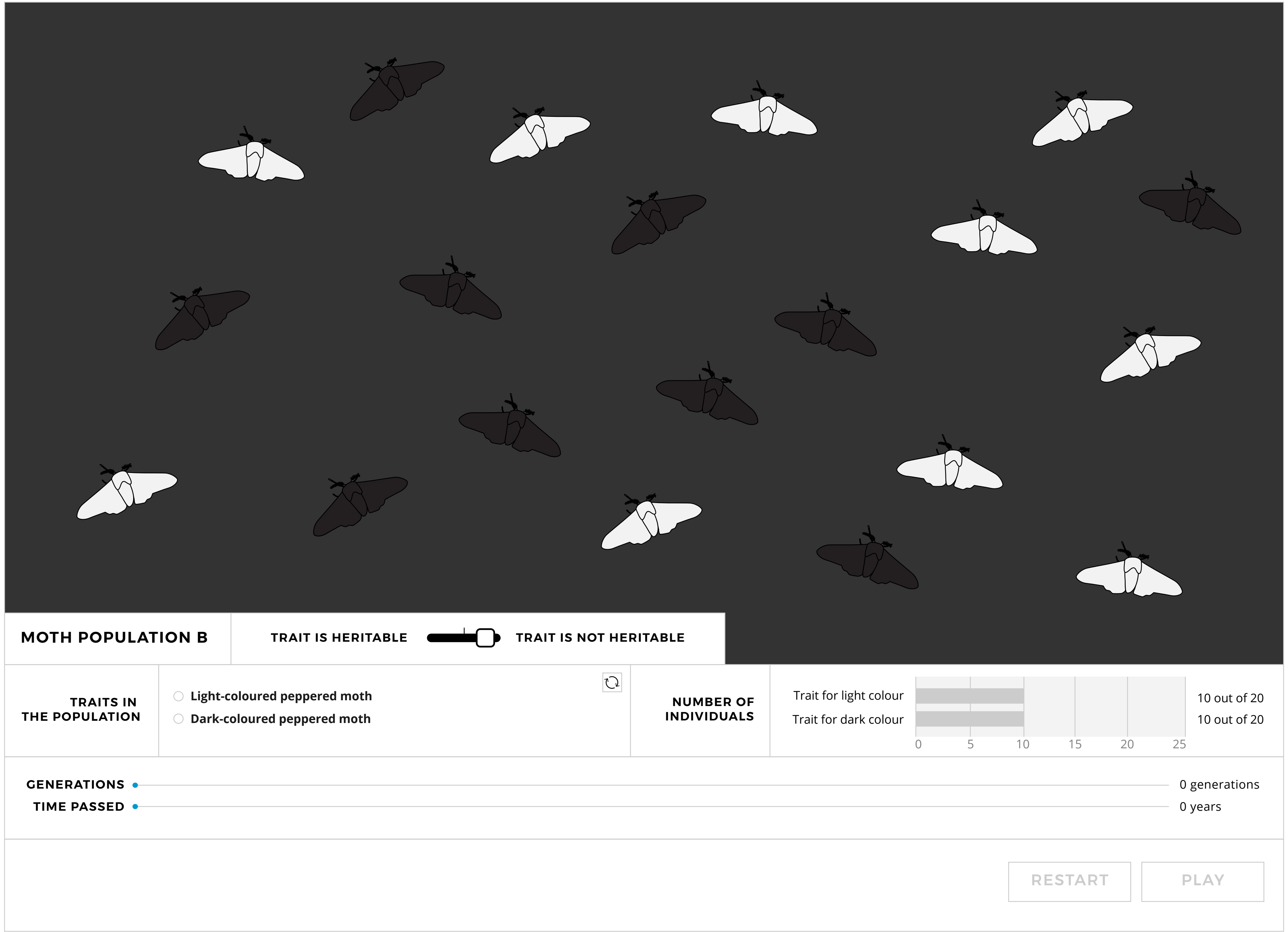
Experiment B

Let's look at population B in which colour is non-heritable.

Consider a hypothetical scenario in which population B at the end of the Industrial Revolution consisted of 50% dark coloured moths.

Adjust the toggle to "trait is non-heritable".

⟵ PREVIOUS NEXT ⟶



○ Light-coloured peppered moth
○ Dark-coloured peppered moth

Trait for light colour	10 out of 20
Trait for dark colour	10 out of 20

GENERATIONS 0 generations
TIME PASSED 0 years

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Experiment B

You predicted that if the trait is non-heritable, then *there would no significant difference.*

Peppered moths have a generation time of one year. To observe the overall trend, you decide to collect data on the moth population for the next 24 years following the end of the Industrial Revolution as the tree barks have become lighter.

Record how many individuals in the population are light coloured and dark coloured in the starting population (generation 0). Click “play” and pause every 2 years to continue collecting data.

CASE STUDY 1 NOTEBOOK | DATA LOG

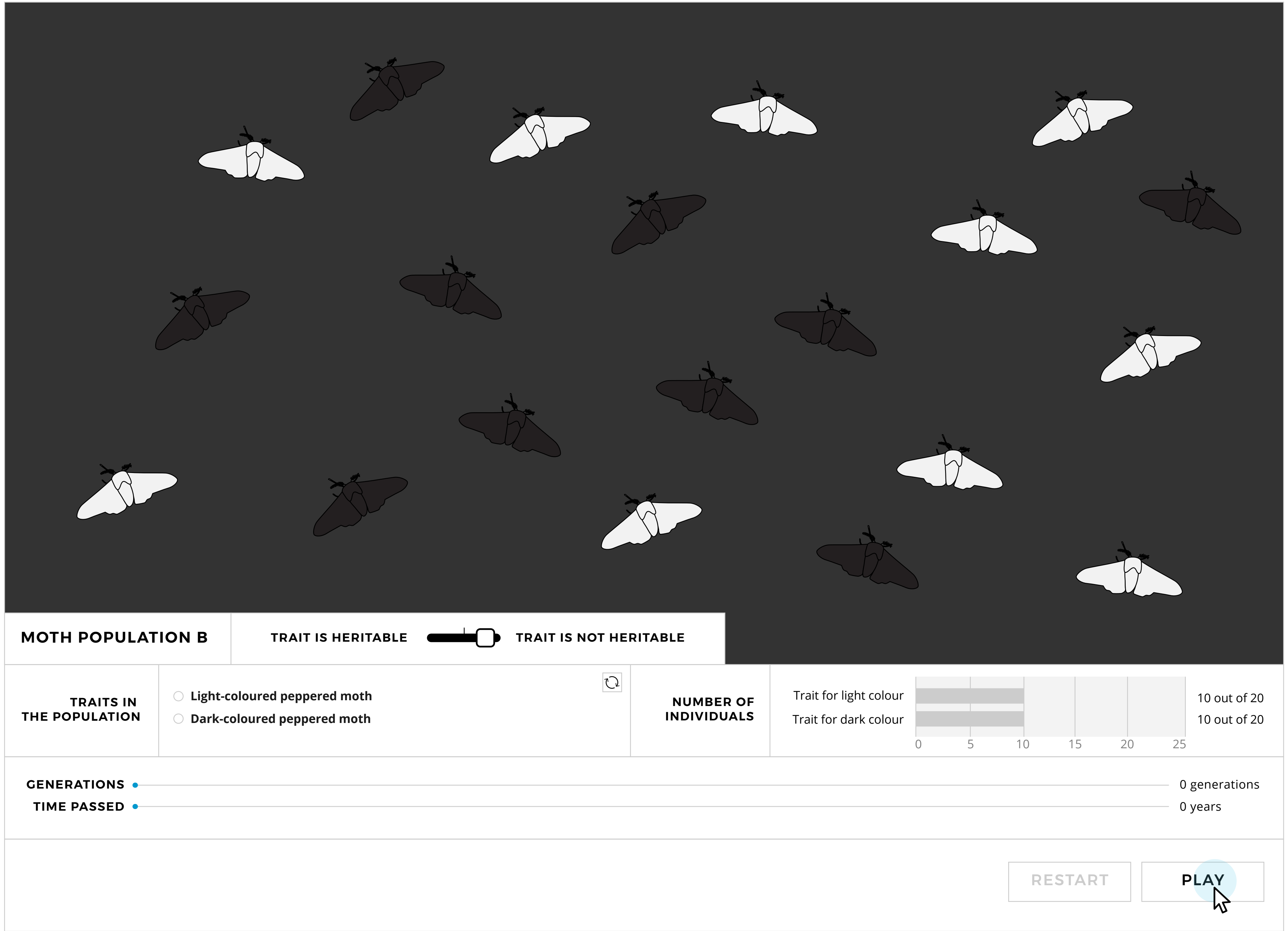
Population B Data

Generation #: 0

Number of individuals	**Trait**
10	Light colour
10	Dark colour

ADD NEW DATA SAVE

← PREVIOUS RESULTS →



MOTH POPULATION B

TRAIT IS HERITABLE — TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION
○ Light-coloured peppered moth
○ Dark-coloured peppered moth

NUMBER OF INDIVIDUALS

Trait for light colour	10 out of 20
Trait for dark colour	10 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

RESTART PLAY

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Experiment B

You predicted that if the trait is non-heritable, then *there would no significant difference.*

Peppered moths have a generation time of one year. To observe the overall trend, you decide to collect data on the moth population for the next 24 years following the end of the Industrial Revolution as the tree barks have become lighter.

Record how many individuals in the population are light coloured and dark coloured in the starting population (generation 0). Click "play" and pause every 2 years to continue collecting data.

CASE STUDY 1 NOTEBOOK | DATA LOG

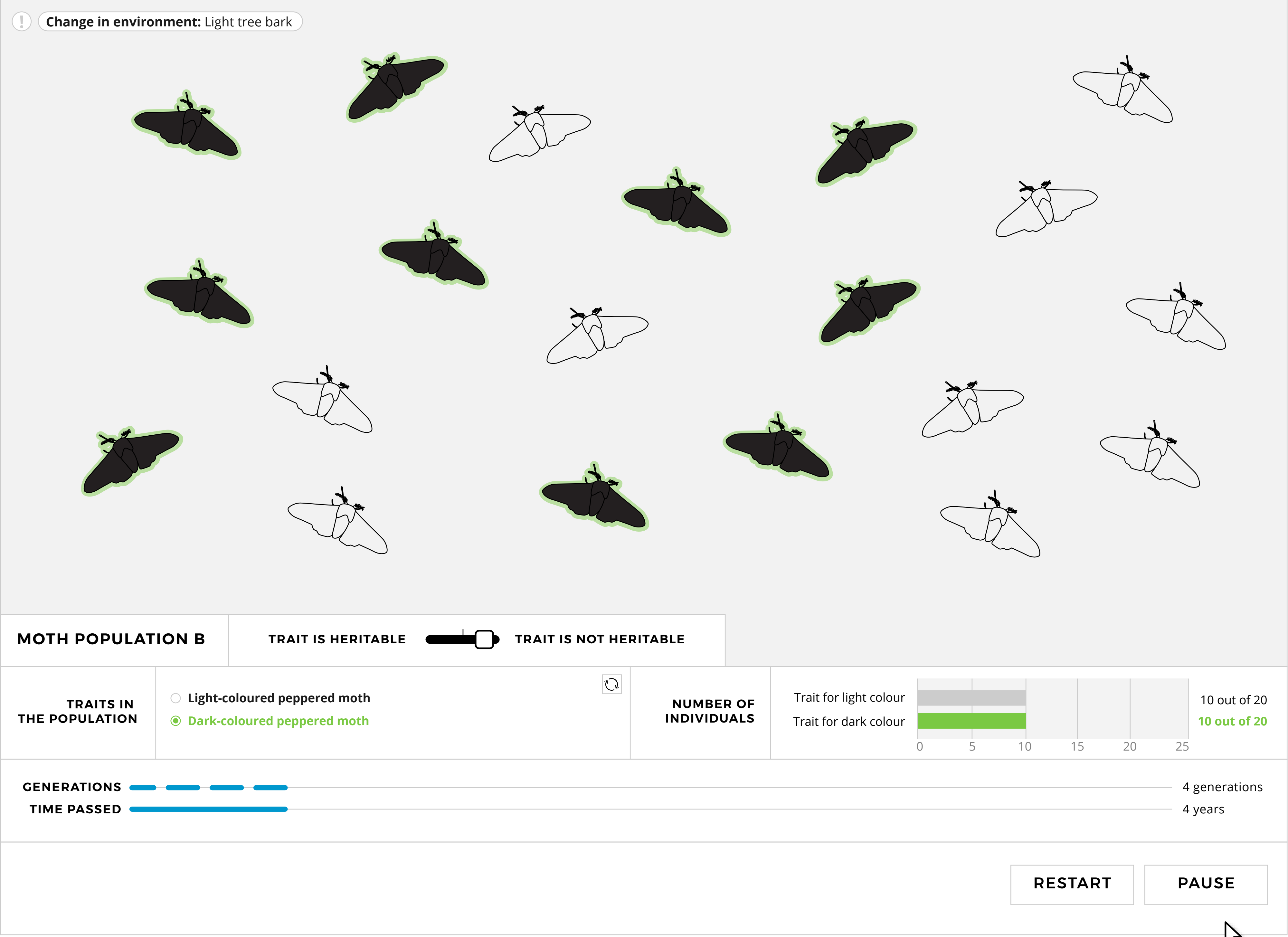
Population B Data

Generation #: 4

Number of individuals	**Trait**
10	Light colour
10	Dark colour

ADD NEW DATA SAVE

← PREVIOUS RESULTS →



Change in environment: Light tree bark

MOTH POPULATION B

TRAIT IS HERITABLE ● TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION

○ Light-coloured peppered moth

● Dark-coloured peppered moth

NUMBER OF INDIVIDUALS

Trait for light colour: 10 out of 20

Trait for dark colour: 10 out of 20

GENERATIONS: 4 generations

TIME PASSED: 4 years

Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Experiment B

You predicted that if the trait is non-heritable, then *there would no significant difference.*

Peppered moths have a generation time of one year. To observe the overall trend, you decide to collect data on the moth population for the next 24 years following the end of the Industrial Revolution as the tree barks have become lighter.

Record how many individuals in the population are light coloured and dark coloured in the starting population (generation 0). Click "play" and pause every 2 years to continue collecting data.

CASE STUDY 1 NOTEBOOK | DATA LOG

Population B Data

Generation #: 24

Number of individuals	**Trait**
12	Light colour
9	Dark colour

ADD NEW DATA SAVE

← PREVIOUS RESULTS →

MOTH POPULATION B

TRAIT IS HERITABLE / TRAIT IS NOT HERITABLE

TRAITS IN THE POPULATION

○ Light-coloured peppered moth

● Dark-coloured peppered moth

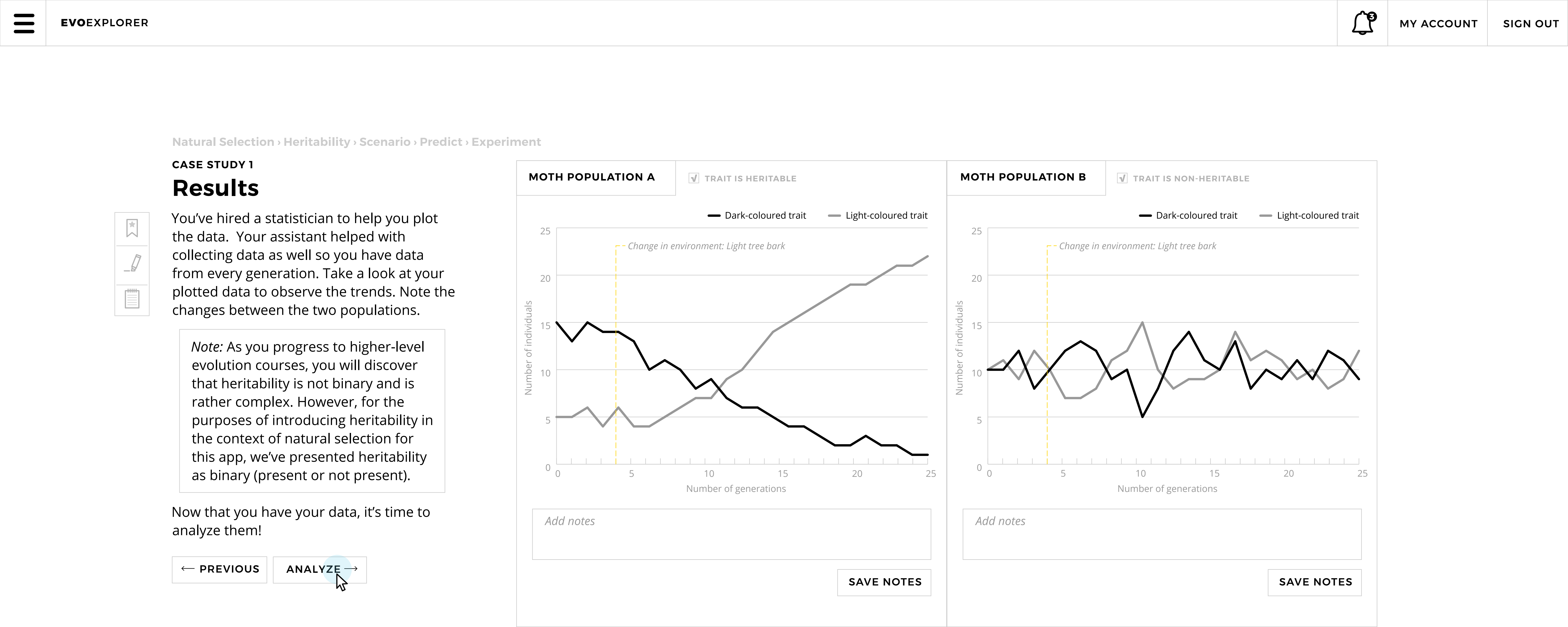
NUMBER OF INDIVIDUALS

Trait for light colour: 12 out of 21

Trait for dark colour: 9 out of 21

GENERATIONS: 24 generations

TIME PASSED: 24 years



Natural Selection › Heritability › Scenario › Predict › Experiment

CASE STUDY 1

Results

You've hired a statistician to help you plot the data. Your assistant helped with collecting data as well so you have data from every generation. Take a look at your plotted data to observe the trends. Note the changes between the two populations.

> *Note:* As you progress to higher-level evolution courses, you will discover that heritability is not binary and is rather complex. However, for the purposes of introducing heritability in the context of natural selection for this app, we've presented heritability as binary (present or not present).

Now that you have your data, it's time to analyze them!

⟵ PREVIOUS   ANALYZE ⟶

EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Heritability › Scenario › Predict › Experiment › Analysis

CASE STUDY 1

Analysis

MY PREDICTIONS

In scenario A, you predicted that there would be an increase in the percentage of population with dark colours and a decrease in the percentage of population with light colours.

In scenario B, you predicted that there would be no significant change

1. Were your predictions correct or incorrect?

○ Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

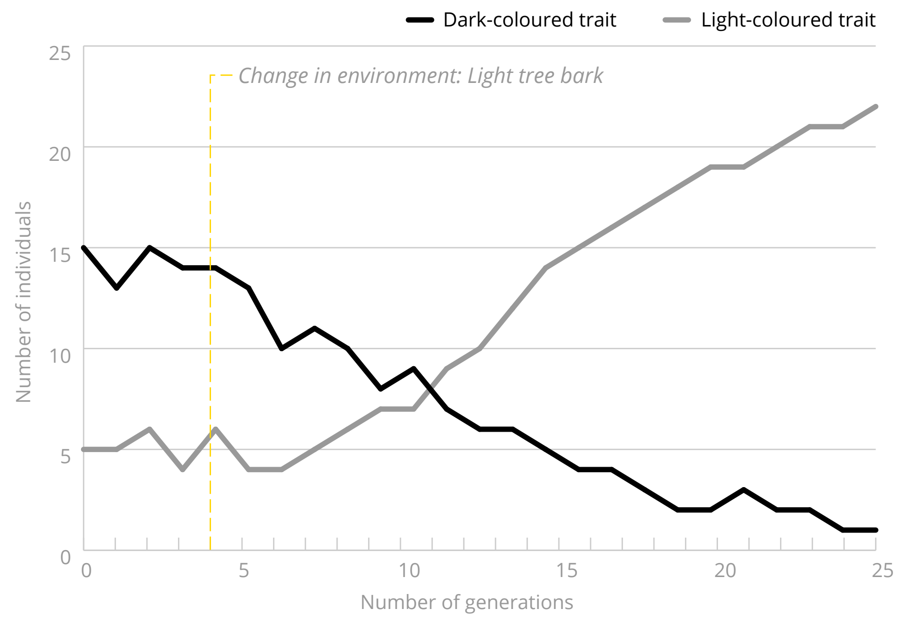
● Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

⟵ PREVIOUS | SAVE | NEXT CASE ⟶

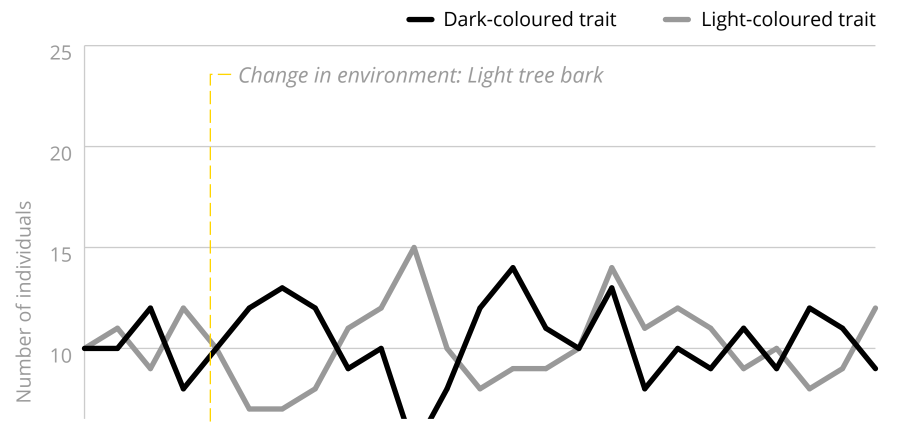
CASE STUDY 1 NOTEBOOK | EXPERIMENT RESULTS | NOTES



Experiment A Observations

☑ TRAIT IS HERITABLE

I observed that population A consists of mostly ligh-coloured moths after 24 years because the heritable trait can be selected for.



Experiment B Observations

☑ TRAIT IS NON-HERITABLE

Moth population B remains approximately 50% dark despite selection pressure because the trait can’t be selected for (could still potentially get light-coloured moths).

Natural Selection › Genetic Variation

Genetic variation as a requirement for adaptation

Natural selection is a process in which individuals with certain heritable traits have greater relative survival rates and reproductive success in a specific environment due to those traits. The evolutionary result of natural selection is that alleles encoding selected traits increase in frequency in the population over many generations. In other words, while natural selection does act on individuals, the evolutionary change caused by natural selection is only apparent when considering a population of organisms over time.

The phenotypic variation we can perceive may reflect **genetic variation** which is the difference between individuals in the composition of their genes and other DNA sequences. However, not all phenotypic variation results from genetic differences and therefore is not heritable. Thus, only **phenotypic variation with a genetic basis** provides the raw material for evolutionary change and is an essential prerequisite for evolution by natural selection.

BEGIN CASE STUDY 2 ⟶

Natural Selection › Genetic Variation

Genetic variation as a requirement for adaptation

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BEGIN CASE STUDY 2 ⟶

Genetic variation as a requirement for adaptation

TIP
Click here to add comments

1

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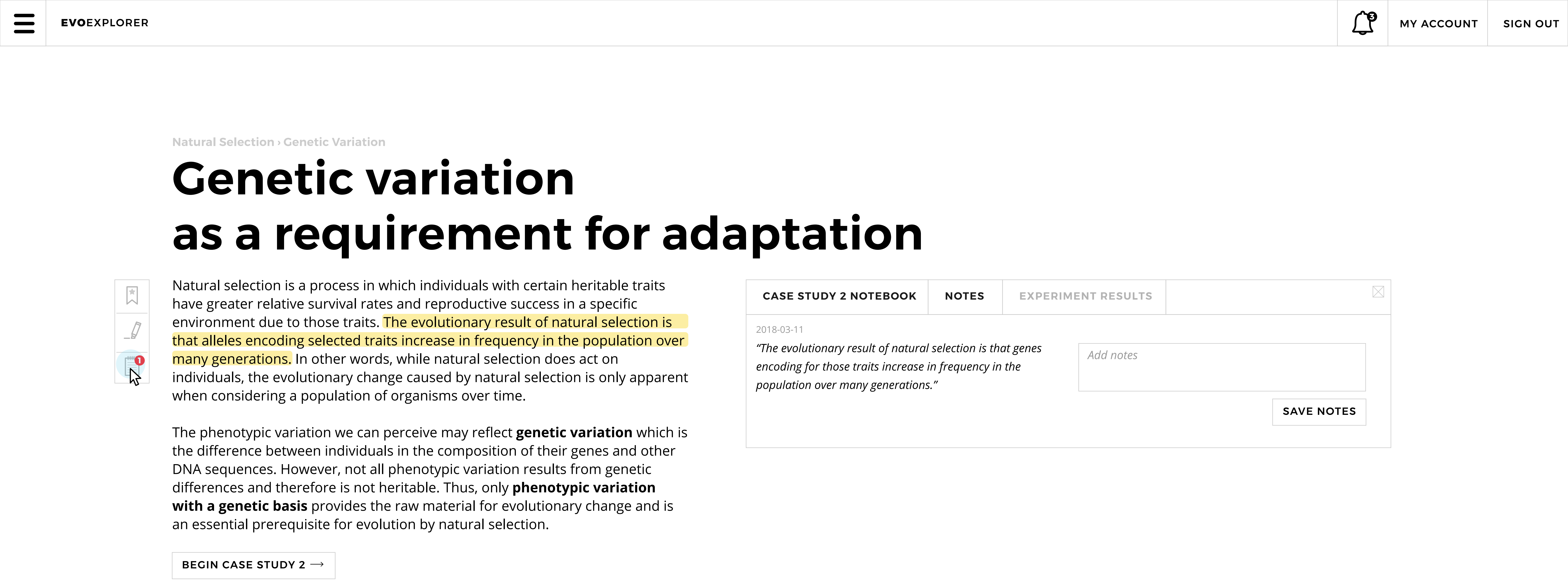
BEGIN CASE STUDY 2 ⟶



Natural Selection › Genetic Variation

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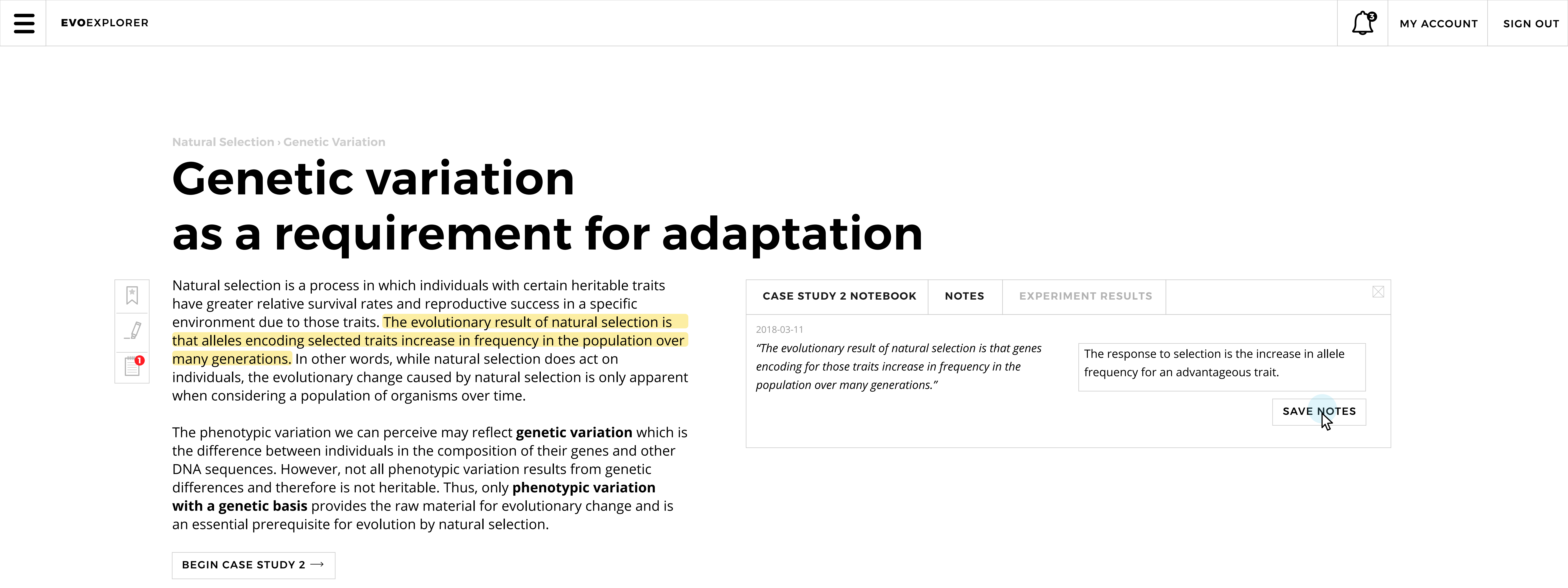
2018-03-11

"The evolutionary result of natural selection is that genes encoding for those traits increase in frequency in the population over many generations."



Natural Selection › Genetic Variation

Genetic variation
as a requirement for adaptation

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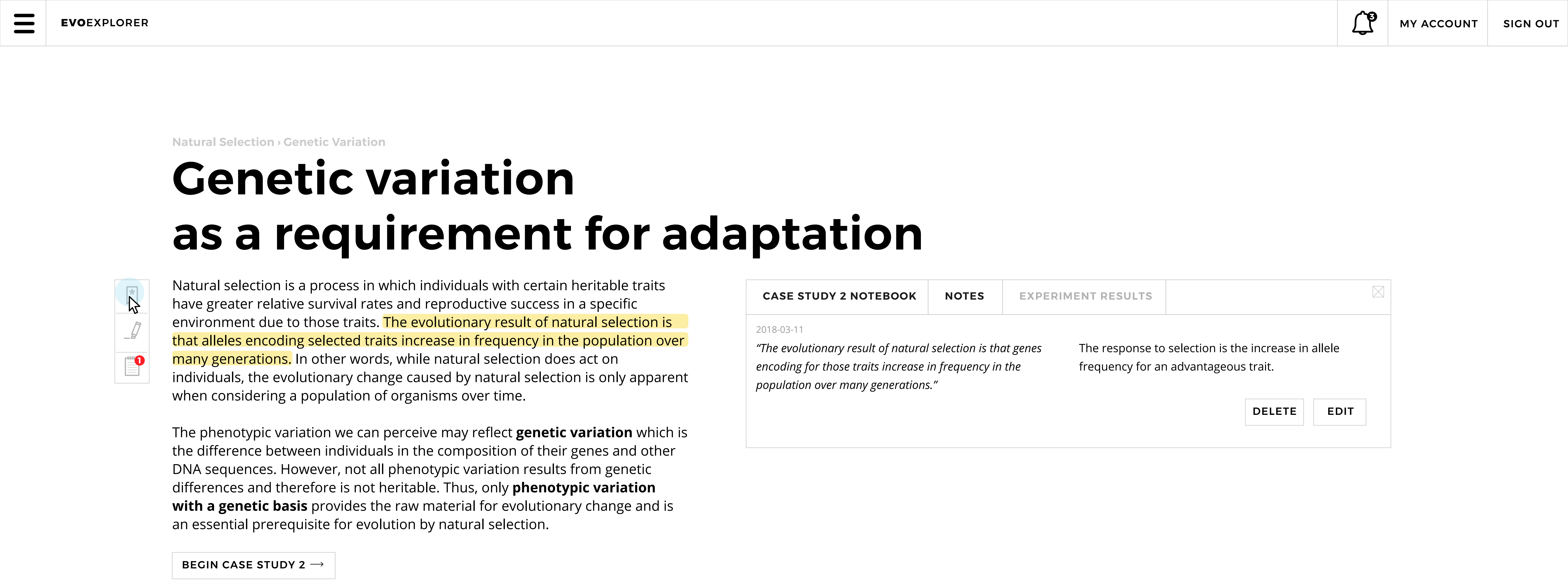
2018-03-11

"The evolutionary result of natural selection is that genes encoding for those traits increase in frequency in the population over many generations."

The response to selection is the increase in allele frequency for an advantageous trait.



Natural Selection › Genetic Variation

Genetic variation as a requirement for adaptation

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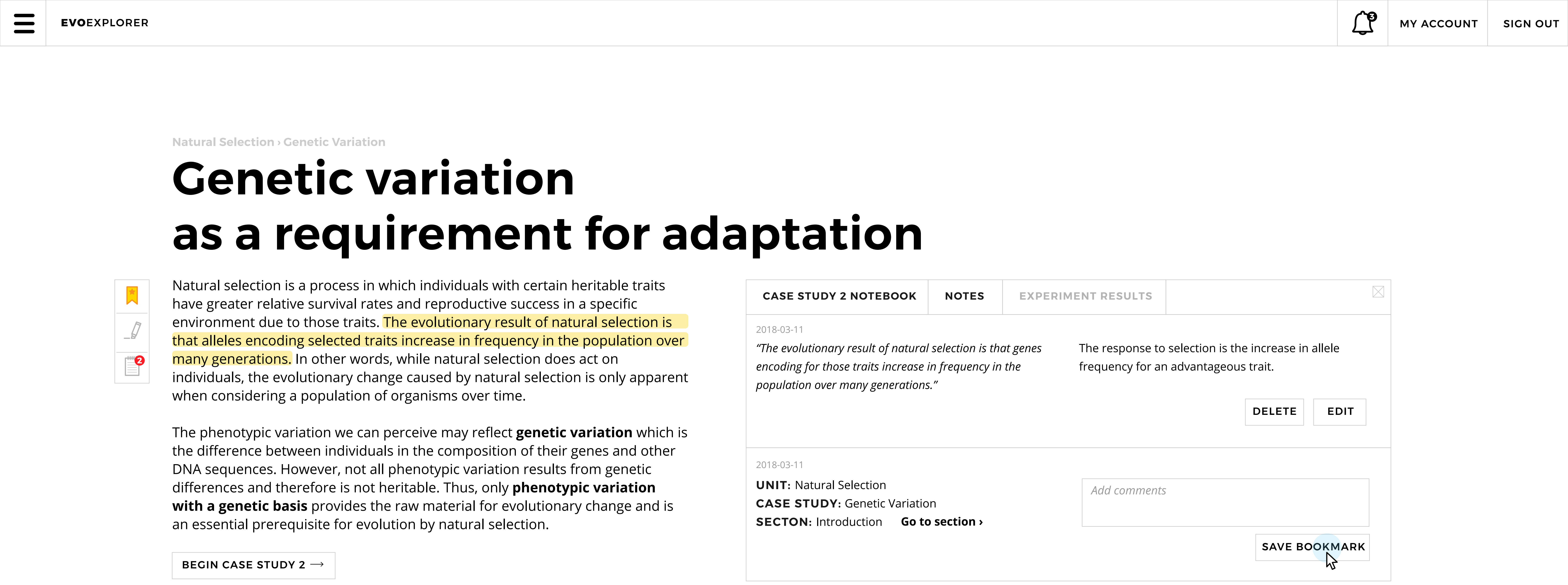

Natural Selection › Genetic Variation

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The response to selection is the increase in allele frequency for an advantageous trait.

2018-03-11

UNIT: Natural Selection
CASE STUDY: Genetic Variation
SECTON: Introduction **Go to section ›**

Add comments

Natural Selection › Genetic Variation

Genetic variation as a requirement for adaptation

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BEGIN CASE STUDY 2 ⟶

CASE STUDY 2 NOTEBOOK | **NOTES** | EXPERIMENT RESULTS

2018-03-11

"The evolutionary result of natural selection is that genes encoding for those traits increase in frequency in the population over many generations."

The response to selection is the increase in allele frequency for an advantageous trait.

DELETE EDIT

2018-03-11

UNIT: Natural Selection
CASE STUDY: Genetic Variation
SECTON: Introduction **Go to section ›**

DELETE EDIT

Natural Selection › Genetic Variation

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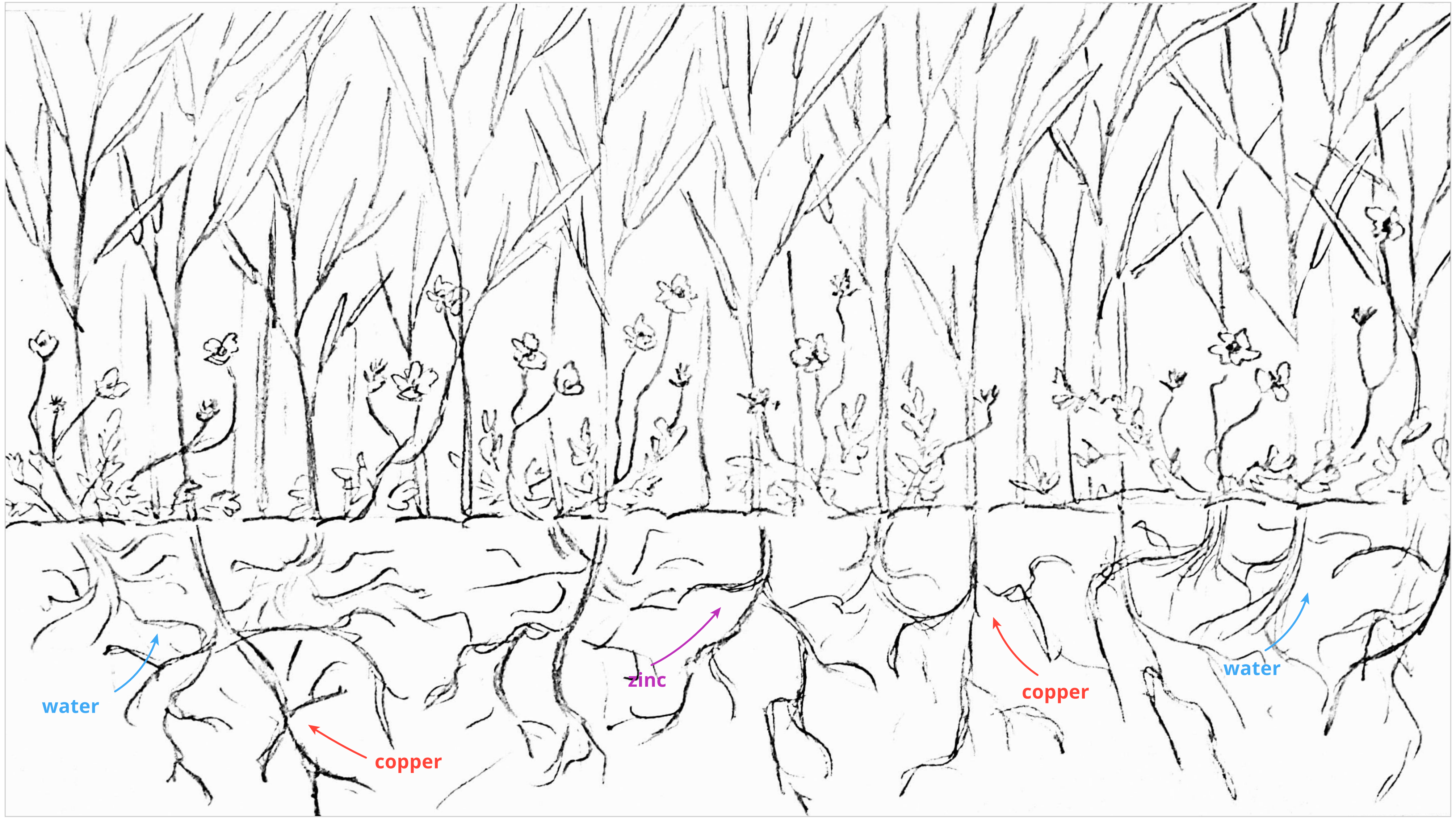
BEGIN CASE STUDY 2 ⟶

CASE STUDY 2

Plant populations near mines

Heavy metals, such as copper, zinc and nickel, at low amounts, are micronutrients for plants. However, toxic levels of heavy metals can occur either naturally or due to human activities such as mining.

⟵ PREVIOUS NEXT ⟶



Natural Selection › Genetic Variation › Scenario

CASE STUDY 2

Plant populations near mines

Surprisingly, soils polluted with heavy metals are never completely bare, and it is possible to find plants capable of growing and reproducing in places like mine dumps (tailings) despite the environmental stress. Although some species of grasses have shown potential to rapidly evolve tolerance to the toxic levels of heavy metals, other species have not.

⟵ PREVIOUS NEXT ⟶

Natural Selection › Genetic Variation › Scenario › Predict

CASE STUDY 2

Predict

Now as a scientist, you are curious about how genetic variation will affect the population as time passes after environmental change. You have found an *uncontaminated* area with two populations of plants.

Management at a nearby mining site has plans to start dumping mine tailings in this area, so you decide to investigate these two populations of plants and observe what happens after the soil becomes contaminated with toxic amounts of copper.

← PREVIOUS

PREDICT →

Population A has greater genetic variation and a genetic trait for copper tolerance is present in a very small percentage of the population.

Population B has lower genetic variation and has no genetic trait for copper-tolerance is present.

EVOEXPLORER MY ACCOUNT SIGN OUT

Natural Selection › Heritability › Scenario › Predict

CASE STUDY 2

Predict: Population A

What will happen to **population A** once the workers start dumping mine tailings in the uncontaminated area, for

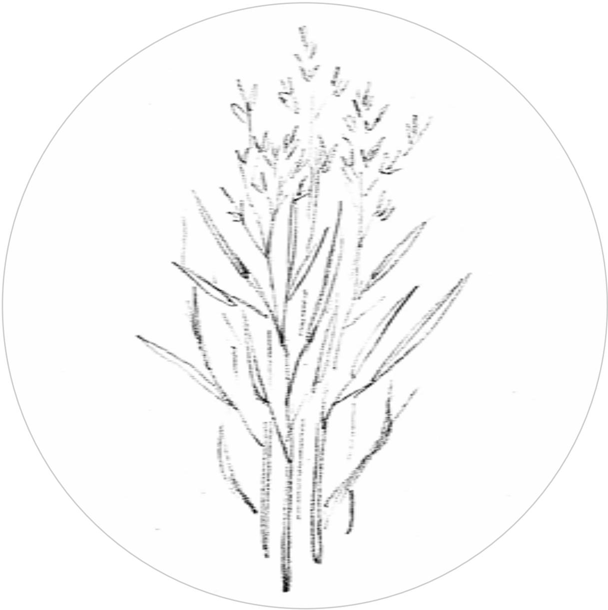
a) the first following generation?
b) after a couple generations?

need a hint ?

● Individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance

○ Individuals die indiscriminately, and after a couple generations, the population size will diminish

⟵ PREVIOUS SAVE PART B ⟶



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Population B has lower genetic variation and has no genetic trait for copper-tolerance is present.

EVOEXPLORER MY ACCOUNT SIGN OUT

Natural Selection › Heritability › Scenario › Predict

CASE STUDY 2

Predict: Population B

What will happen to **population B** once the workers start dumping mine tailings in the uncontaminated area, for

a) the first following generation?
b) after a couple generations?

need a hint ?

○ Individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance

● Individuals die indiscriminately, and after a couple generations, the population size will diminish

⟵ PREVIOUS SAVE LET'S EXPLORE⟶

Population A has greater genetic variation and a genetic trait for copper tolerance is present in a very small percentage of the population.

Population B has lower genetic variation and has no genetic trait for copper-tolerance is present.

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK DATA LOG

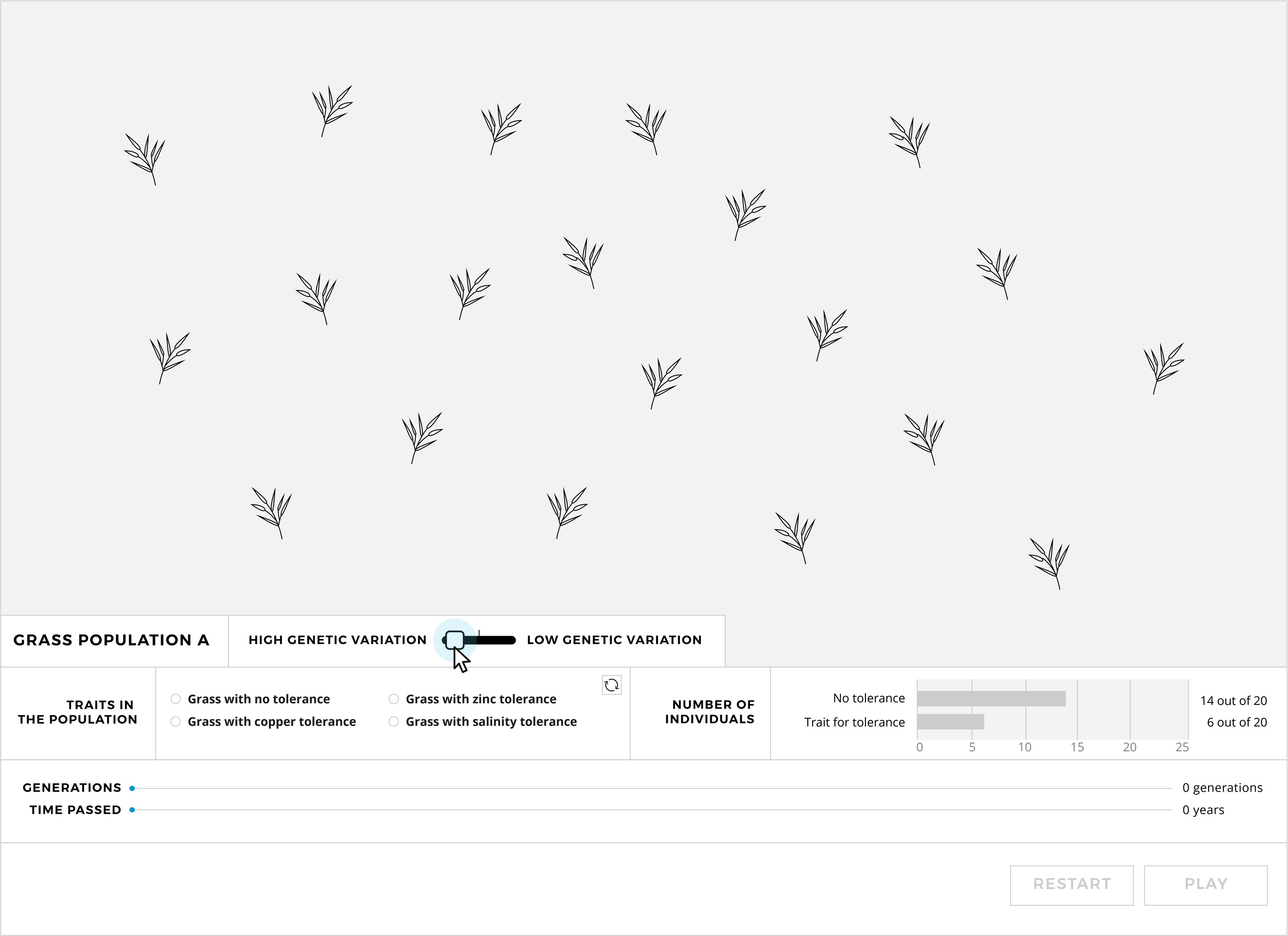
Population A Data

Generation #: ☐

Number of individuals ☐ **Trait** *Select an option* ⌄ − +

ADD NEW DATA SAVE

⟵ PREVIOUS NEXT ⟶



GRASS POPULATION A HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION
○ Grass with no tolerance
○ Grass with zinc tolerance
○ Grass with copper tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS
No tolerance 14 out of 20
Trait for tolerance 6 out of 20

GENERATIONS 0 generations
TIME PASSED 0 years

RESTART PLAY

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK | DATA LOG

Population A Data

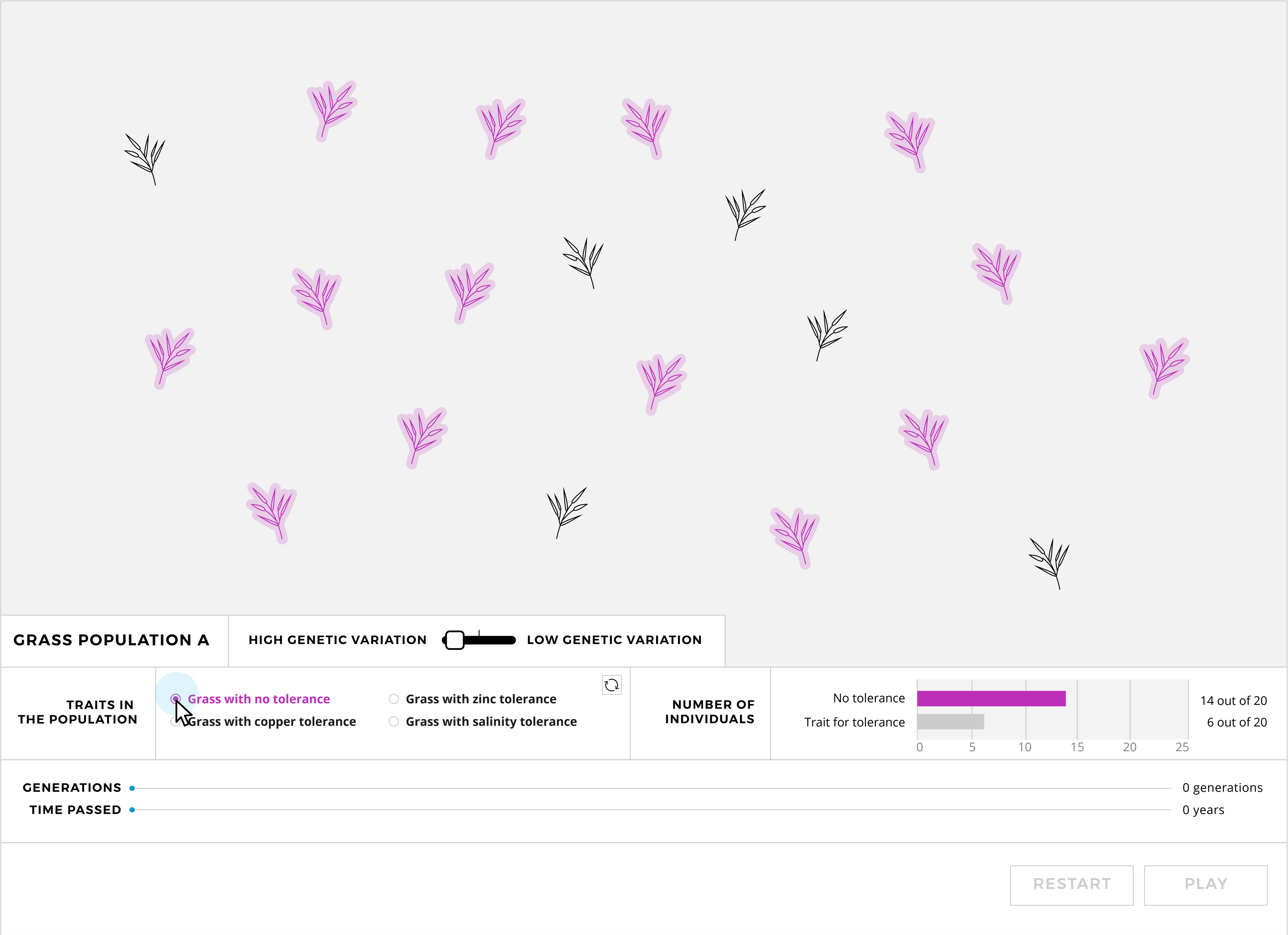
Generation #:

Number of individuals **Trait**

Select an option − +

ADD NEW DATA SAVE

← PREVIOUS NEXT →



GRASS POPULATION A

HIGH GENETIC VARIATION ● LOW GENETIC VARIATION

TRAITS IN THE POPULATION

● Grass with no tolerance

○ Grass with copper tolerance

○ Grass with zinc tolerance

○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

14 out of 20

6 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

RESTART PLAY

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK | DATA LOG

Population A Data

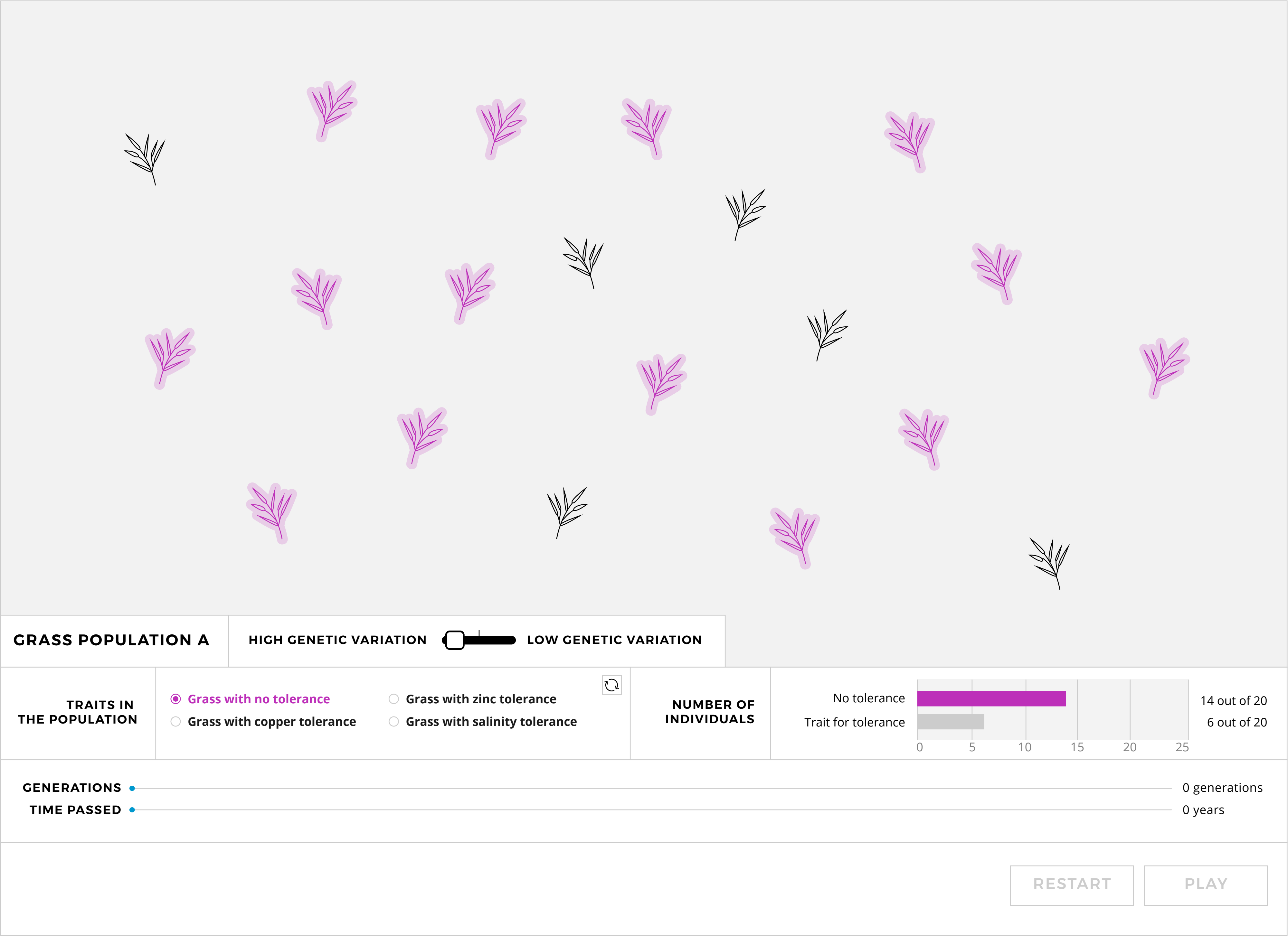
Generation #: 0

Number of individuals	**Trait**
14	*Select an option*

- No tolerance
- Copper tolerance
- Zinc tolerance
- Salinity tolerance

− + SAVE

← PREVIOUS NEXT →



GRASS POPULATION A

HIGH GENETIC VARIATION ● LOW GENETIC VARIATION

TRAITS IN THE POPULATION

- ● Grass with no tolerance
- ○ Grass with copper tolerance
- ○ Grass with zinc tolerance
- ○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	14 out of 20
Trait for tolerance	6 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK DATA LOG

Population A Data

Generation #: 0

Number of individuals	**Trait**
14	No tolerance

ADD NEW DATA SAVE

← PREVIOUS NEXT →

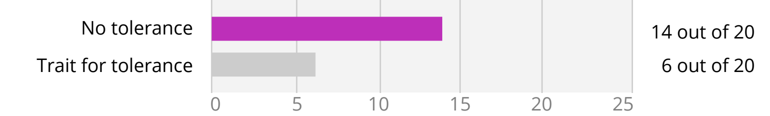
GRASS POPULATION A

HIGH GENETIC VARIATION ○ LOW GENETIC VARIATION

TRAITS IN THE POPULATION

- ● Grass with no tolerance
- ○ Grass with zinc tolerance
- ○ Grass with copper tolerance
- ○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS



No tolerance	14 out of 20
Trait for tolerance	6 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

RESTART PLAY

EVOEXPLORER

3 MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK | DATA LOG

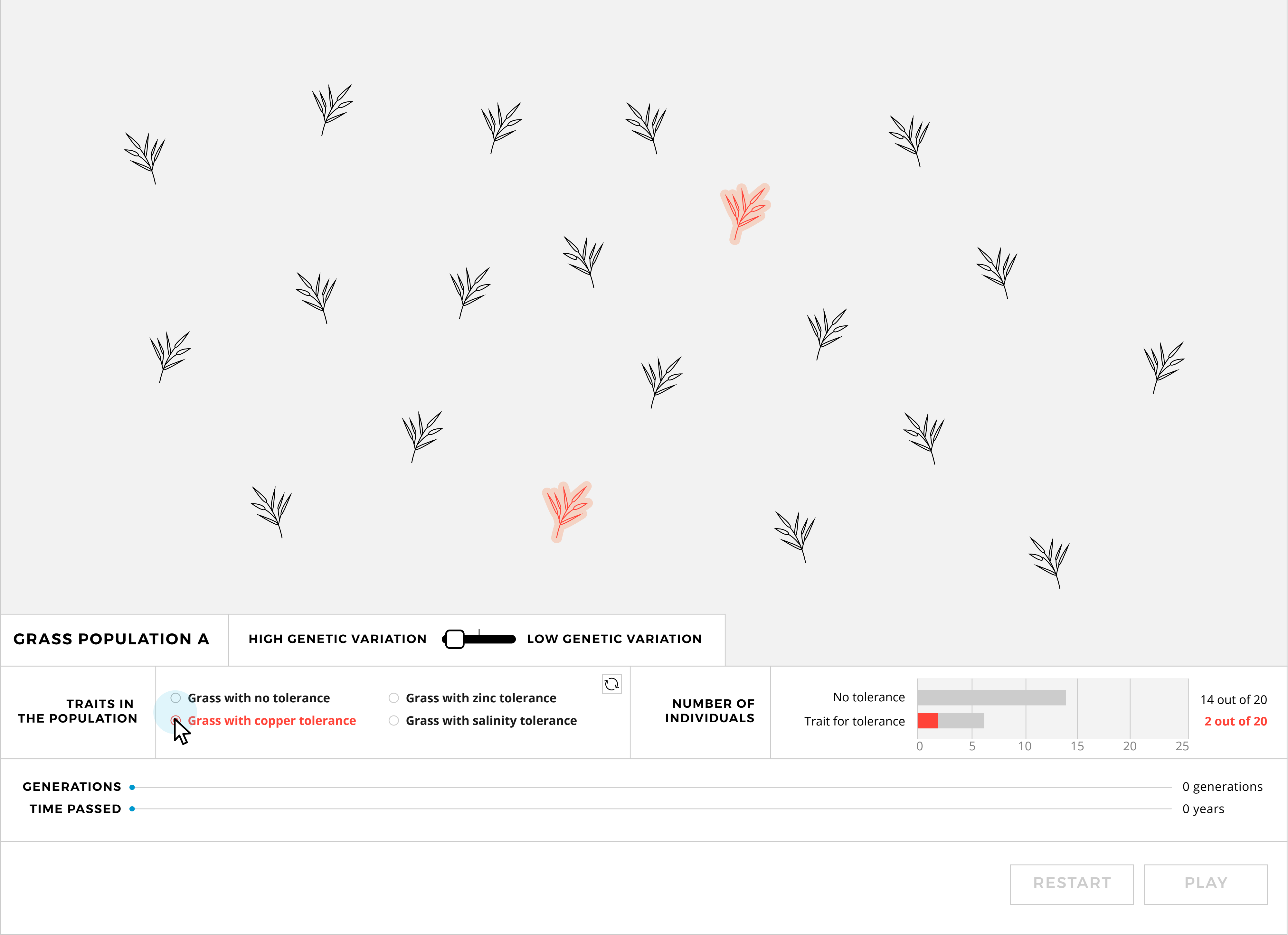
Population A Data

Generation #: 0

Number of individuals	**Trait**		
14	No tolerance	−	+
	Select an option	−	+

ADD NEW DATA SAVE

← PREVIOUS NEXT →



GRASS POPULATION A

HIGH GENETIC VARIATION LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	14 out of 20
Trait for tolerance	2 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

RESTART PLAY

☰ **EVO**EXPLORER

3 MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK DATA LOG

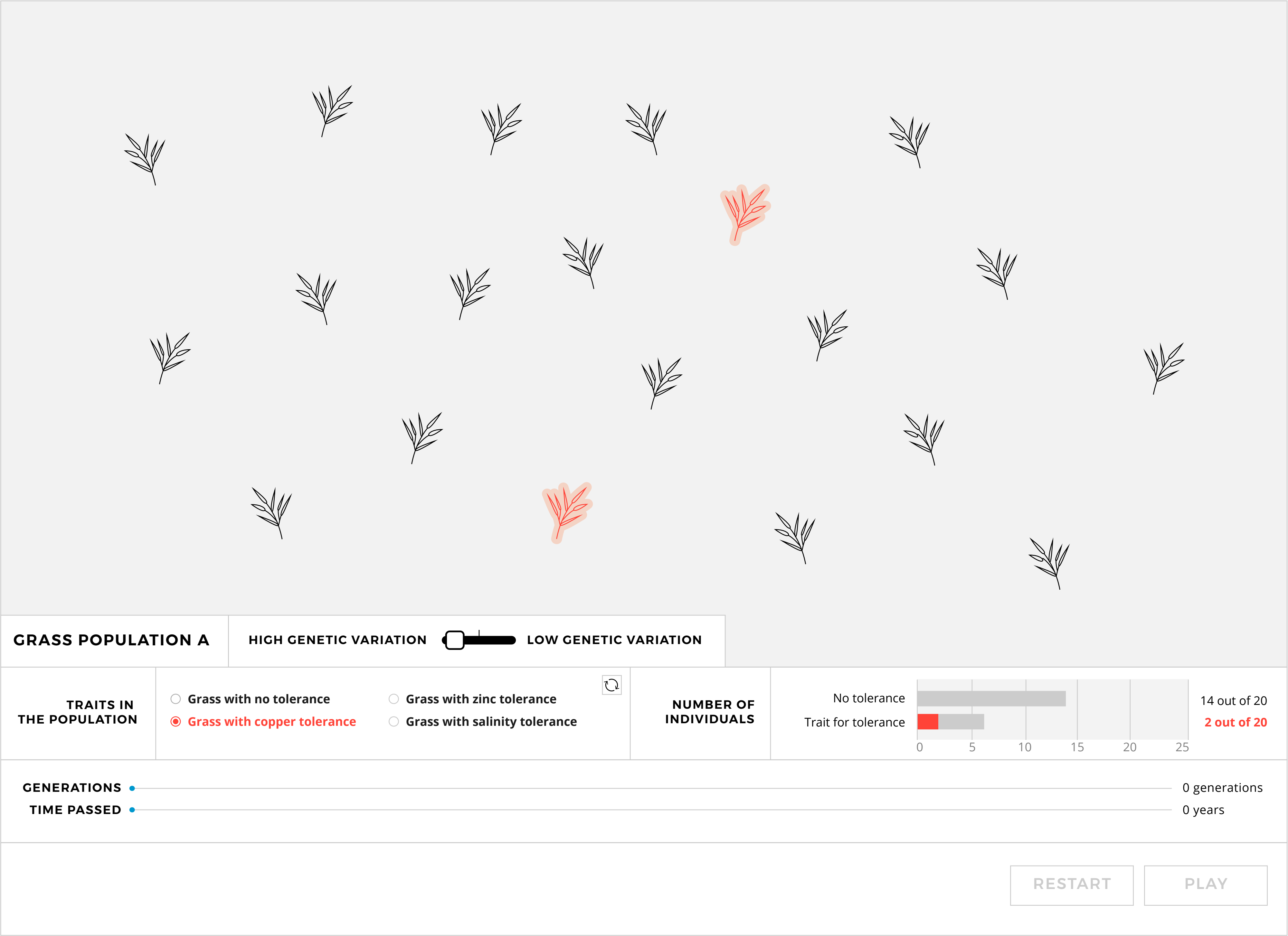
Population A Data

Generation #: 0

Number of individuals	**Trait**		
14	No tolerance	−	+
2	Copper tolerance	−	+

ADD NEW DATA SAVE

← PREVIOUS NEXT →



TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	14 out of 20
Trait for tolerance	2 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

EVOEXPLORER   MY ACCOUNT   SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK   DATA LOG

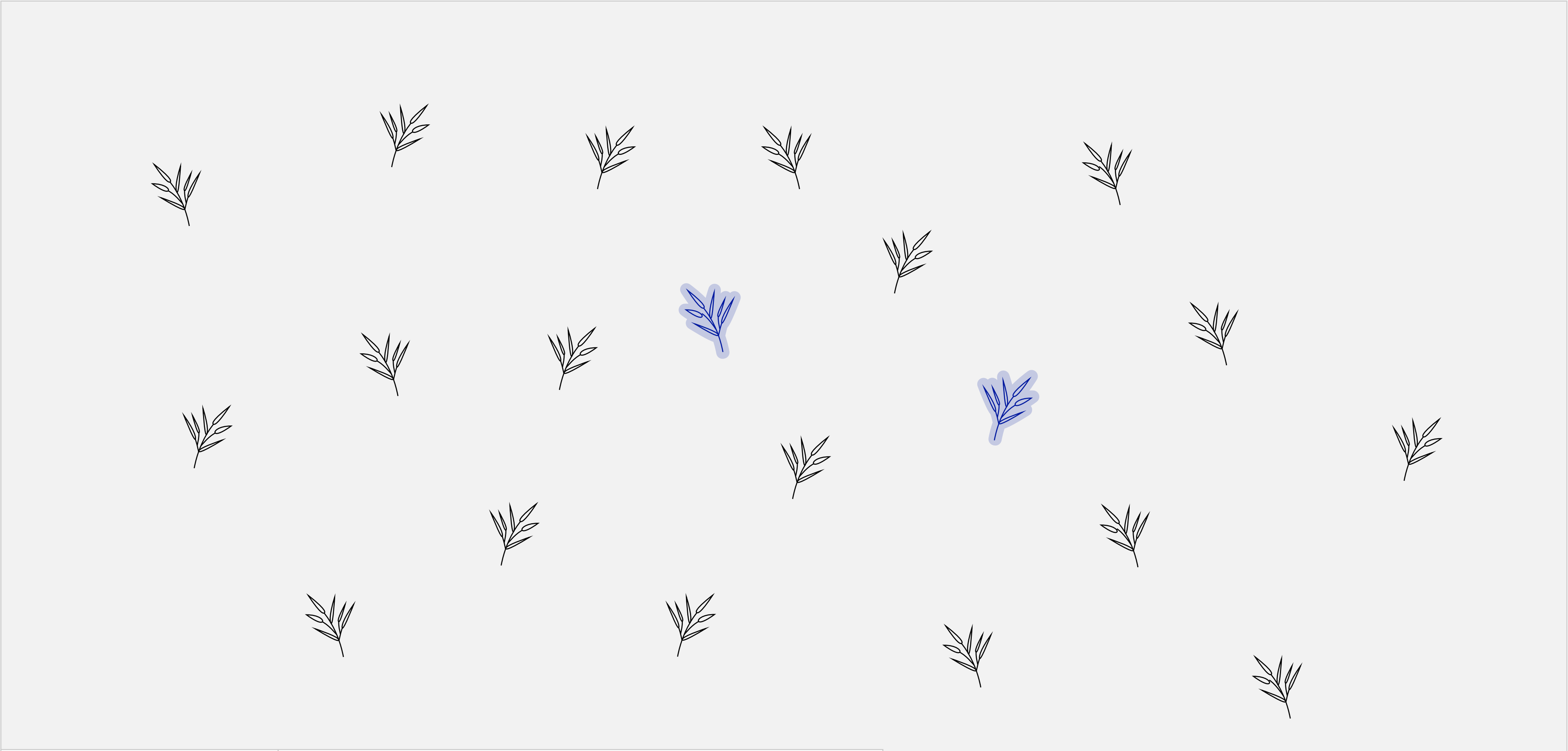
Population A Data

Generation #: 0

Number of individuals	**Trait**		
14	No tolerance	−	+
2	Copper tolerance	−	+
	Select an option	−	+

ADD NEW DATA   SAVE

← PREVIOUS   NEXT →



GRASS POPULATION A   HIGH GENETIC VARIATION   LOW GENETIC VARIATION

TRAITS IN THE POPULATION

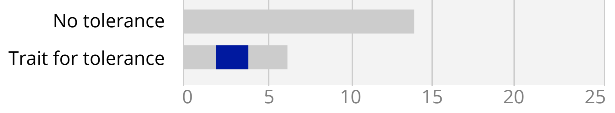
○ Grass with no tolerance

○ Grass with copper tolerance

● Grass with zinc tolerance

○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS



14 out of 20

2 out of 20

GENERATIONS   0 generations

TIME PASSED   0 years

RESTART   PLAY

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK | DATA LOG

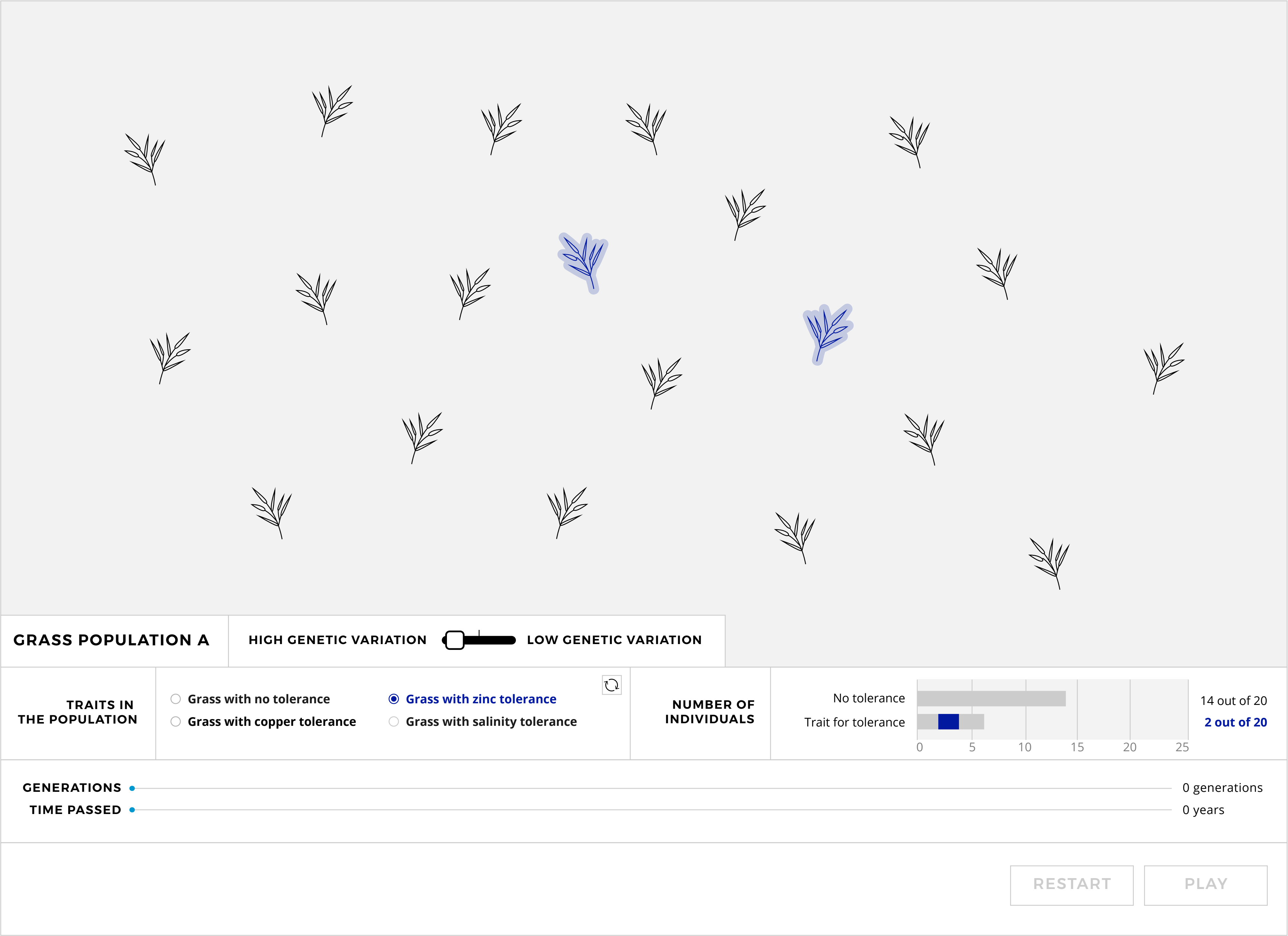
Population A Data

Generation #: 0

Number of individuals	Trait
14	No tolerance
2	Copper tolerance
2	Zinc tolerance

ADD NEW DATA SAVE

← PREVIOUS NEXT →



GRASS POPULATION A

HIGH GENETIC VARIATION ● LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with zinc tolerance
○ Grass with copper tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	14 out of 20
Trait for tolerance	2 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK | DATA LOG

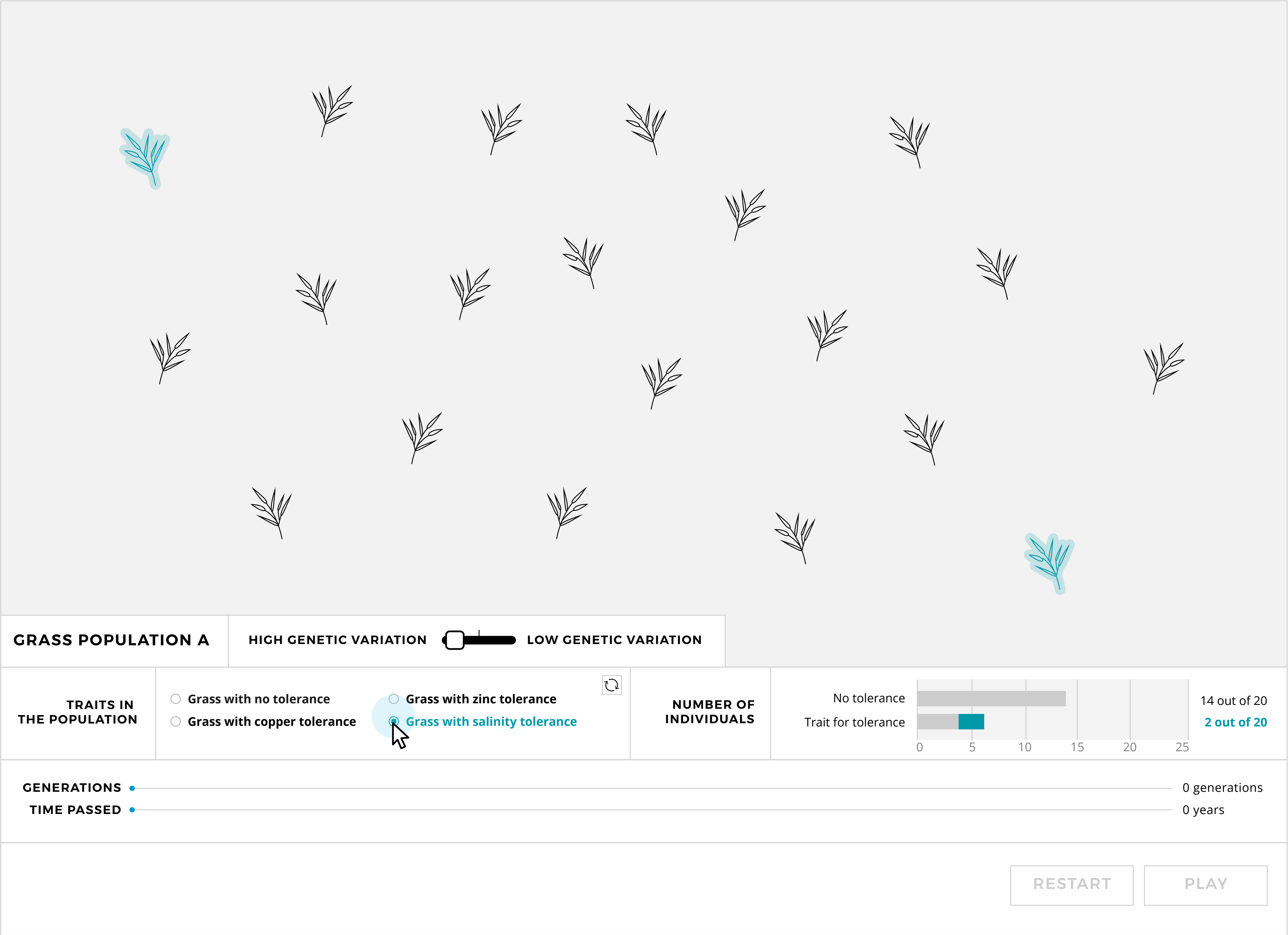
Population A Data

Generation #: 0

Number of individuals	**Trait**
14	No tolerance
2	Copper tolerance
2	Zinc tolerance
	Select an option

ADD NEW DATA | SAVE

← PREVIOUS | NEXT →



GRASS POPULATION A

HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance

○ Grass with copper tolerance

○ Grass with zinc tolerance

● Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance: 14 out of 20

Trait for tolerance: 2 out of 20

GENERATIONS: 0 generations

TIME PASSED: 0 years

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

First, let's look at **grass population A** which has greater genetic variation.

Adjust the toggle for greater genetic variation in order to observe grass population A.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK DATA LOG

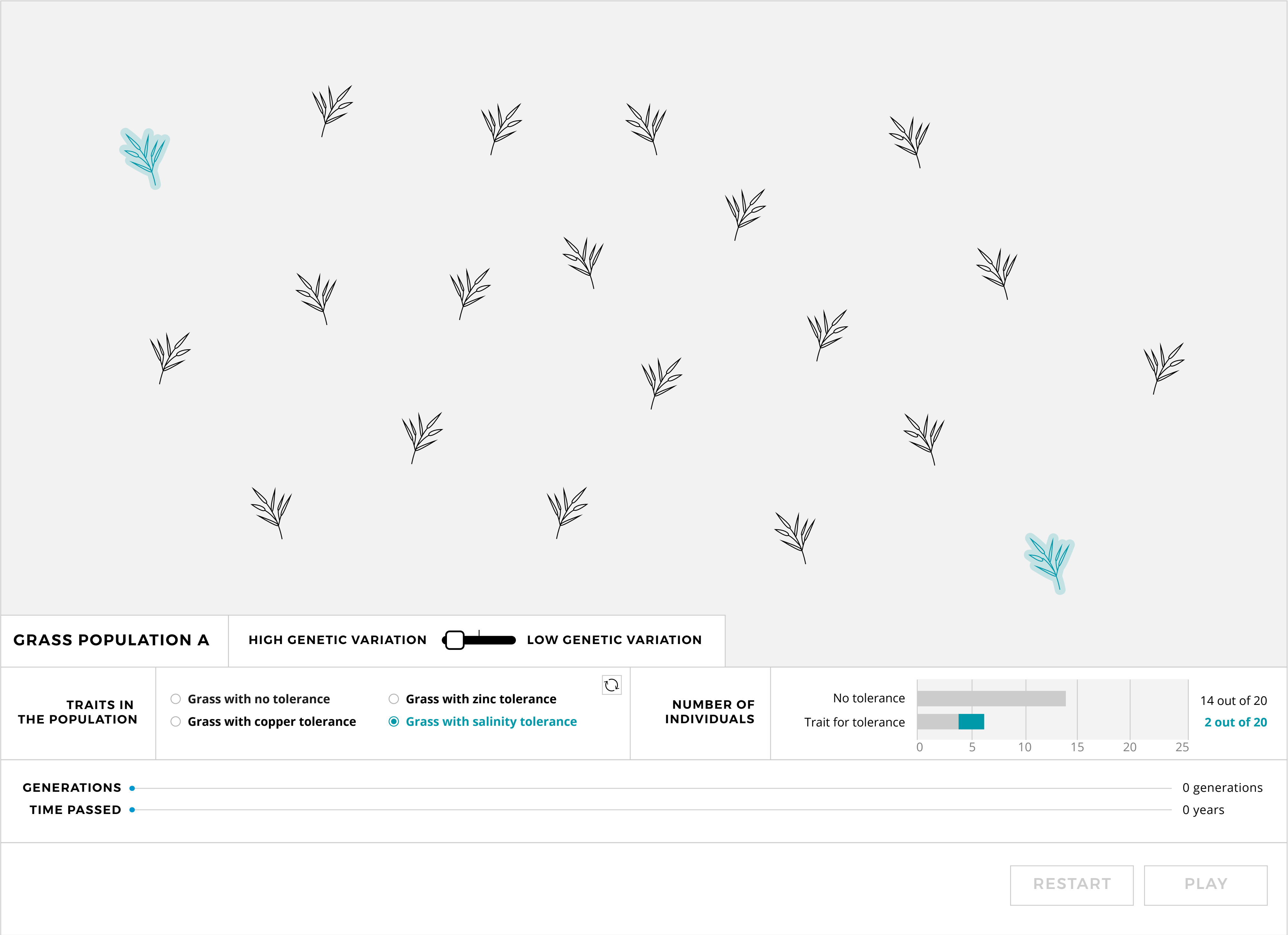
Population A Data

Generation #: 0

Number of individuals	**Trait**
14	No tolerance
2	Copper tolerance
2	Zinc tolerance
2	Salinity tolerance

ADD NEW DATA SAVE

← PREVIOUS NEXT →



GRASS POPULATION A

HIGH GENETIC VARIATION / LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
○ Grass with copper tolerance
○ Grass with zinc tolerance
● Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance: 14 out of 20
Trait for tolerance: 2 out of 20

GENERATIONS: 0 generations
TIME PASSED: 0 years

EVOEXPLORER MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK DATA LOG

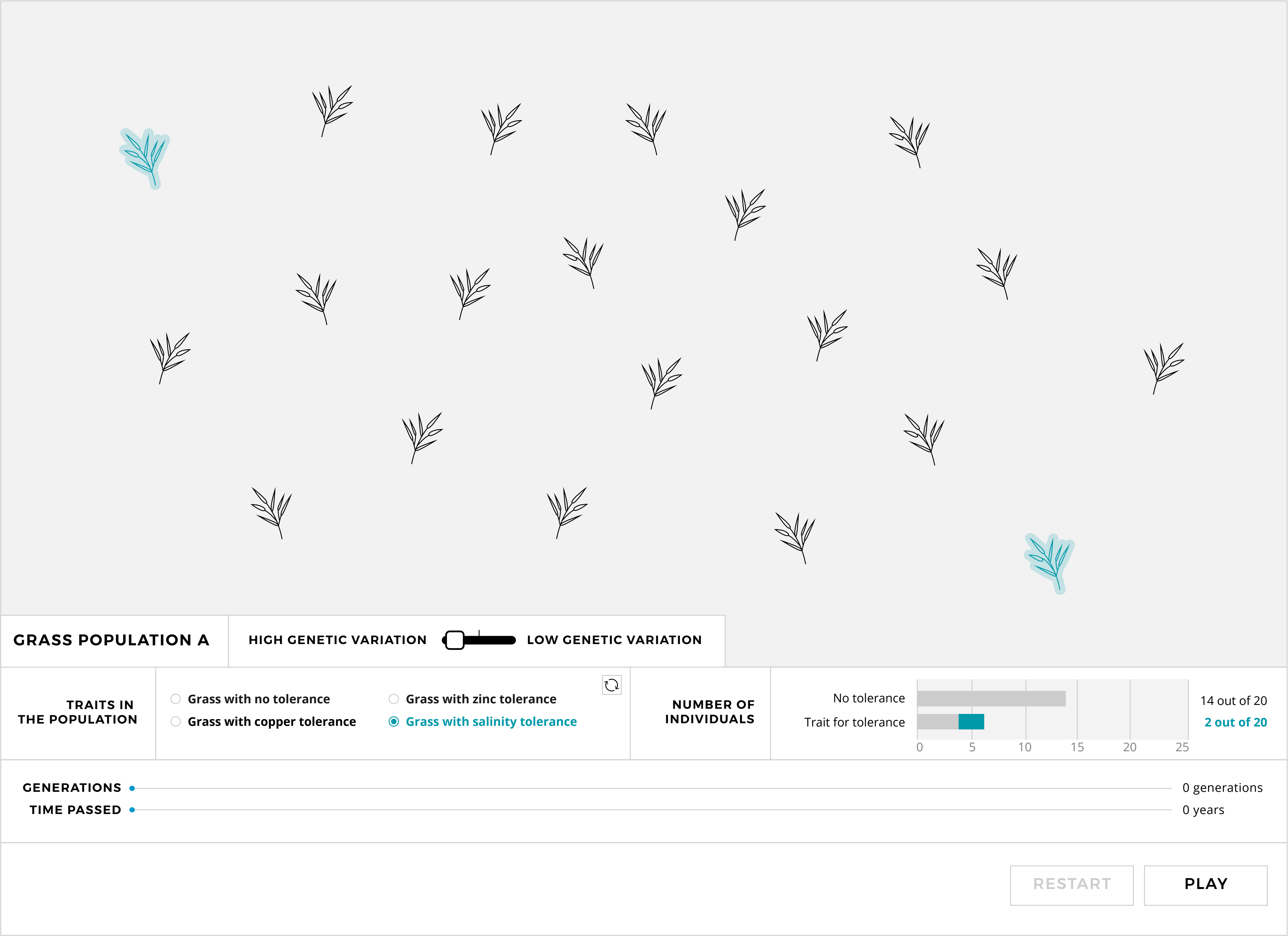
Population A Data

Generation #: 0

Number of individuals	**Trait**
14	No tolerance
2	Copper tolerance
2	Zinc tolerance
2	Salinity tolerance

ADD NEW DATA SAVE

← PREVIOUS PART B →



GRASS POPULATION A

HIGH GENETIC VARIATION LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
○ Grass with copper tolerance
○ Grass with zinc tolerance
● Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	14 out of 20
Trait for tolerance	2 out of 20

GENERATIONS 0 generations

TIME PASSED 0 years

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

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CASE STUDY 2 NOTEBOOK DATA LOG

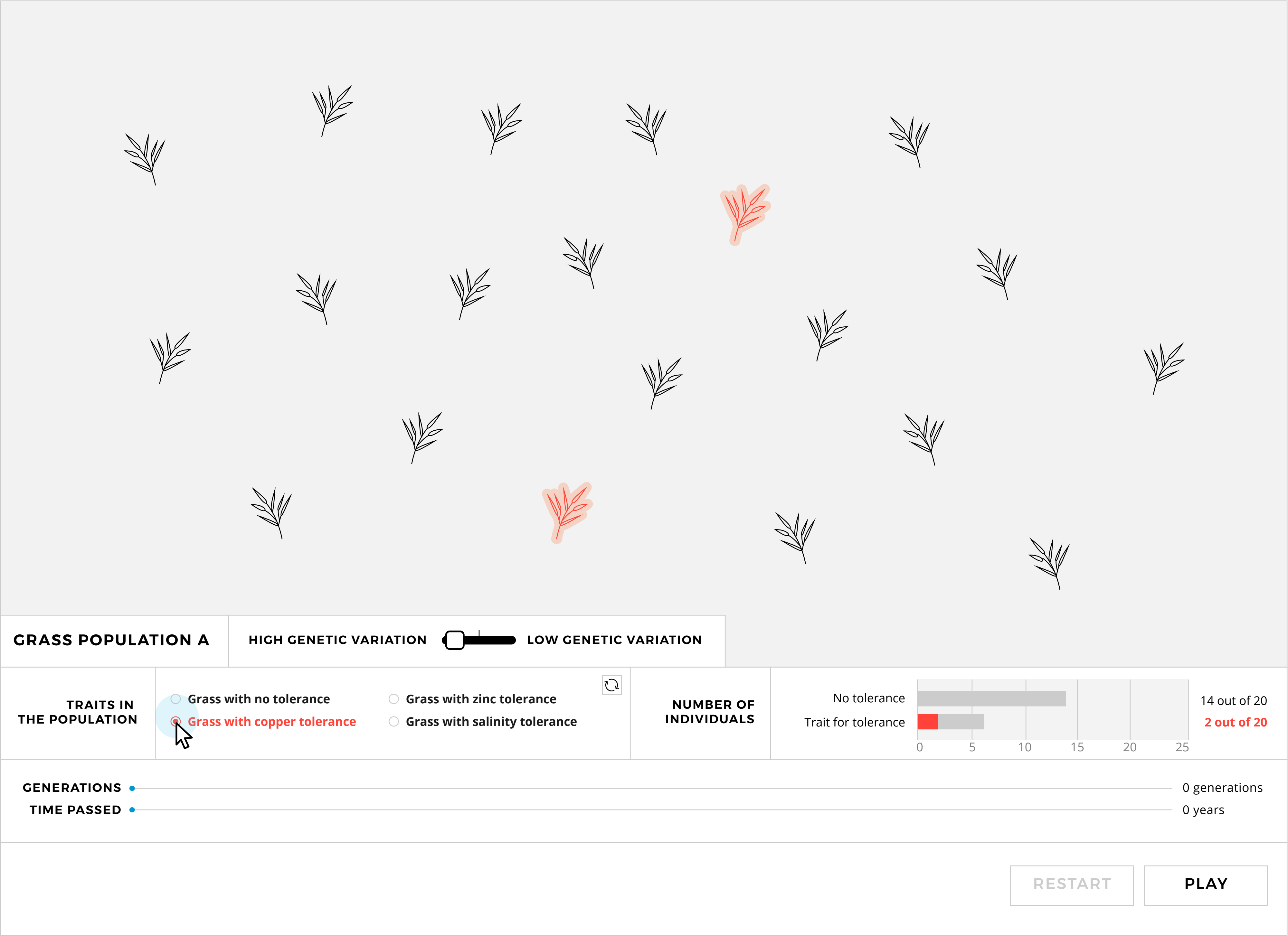
Population A Data

Generation #: 0

Number of individuals	**Trait**
14	No tolerance
2	Copper tolerance
2	Zinc tolerance
2	Salinity tolerance

ADD NEW DATA SAVE

← PREVIOUS PART B →



Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

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Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

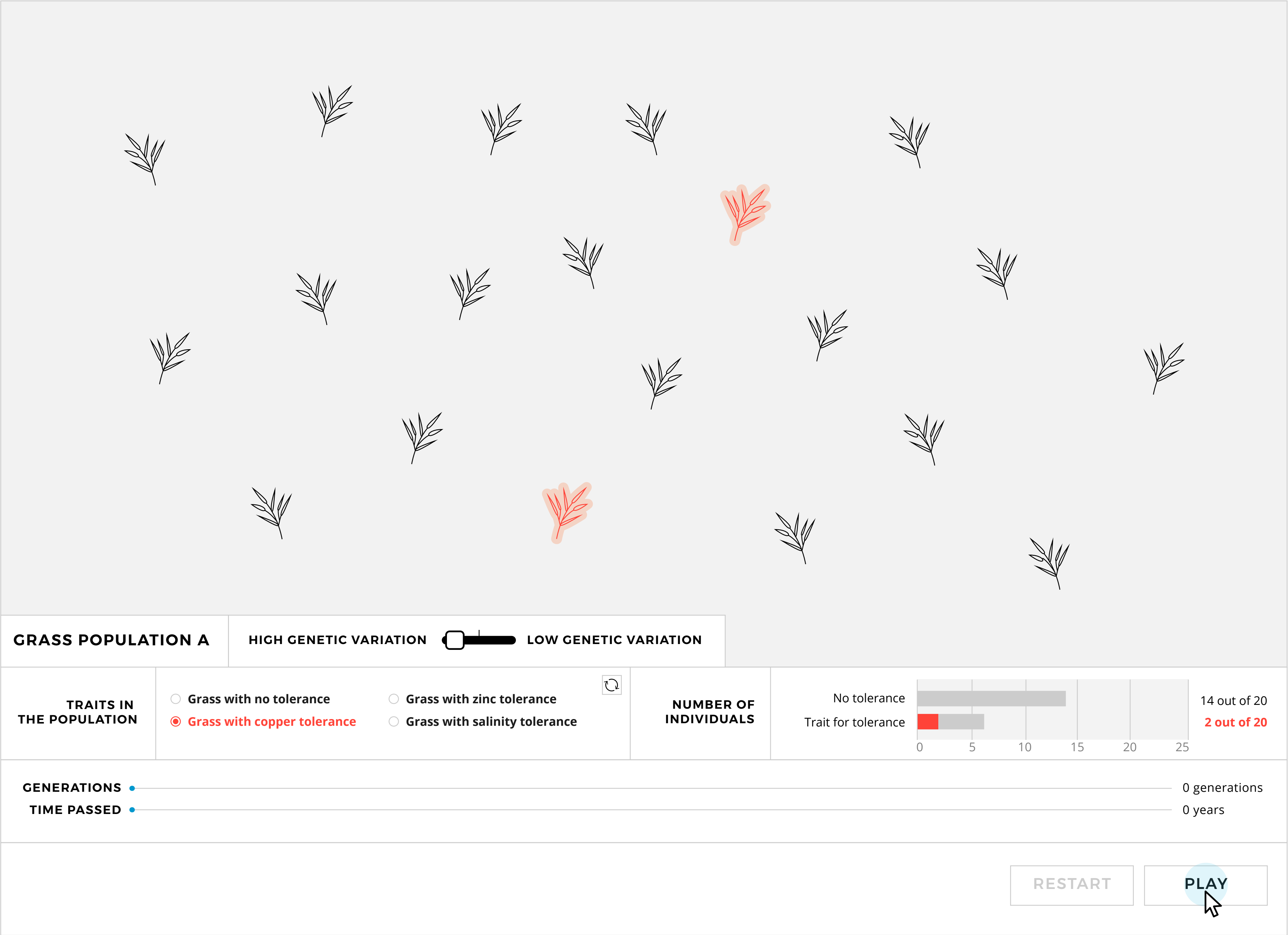
CASE STUDY 2 NOTEBOOK DATA LOG

Population A Data

Generation #: 0

Number of individuals	**Trait**
14	No tolerance
2	Copper tolerance
2	Zinc tolerance
2	Salinity tolerance

ADD NEW DATA SAVE



GRASS POPULATION A

HIGH GENETIC VARIATION LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance: 14 out of 20
Trait for tolerance: 2 out of 20

GENERATIONS: 0 generations
TIME PASSED: 0 years

← PREVIOUS PART B →

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click "play" and pause every 2 generations to record how many individuals in the population have or don't have copper tolerance.

CASE STUDY 2 NOTEBOOK DATA LOG

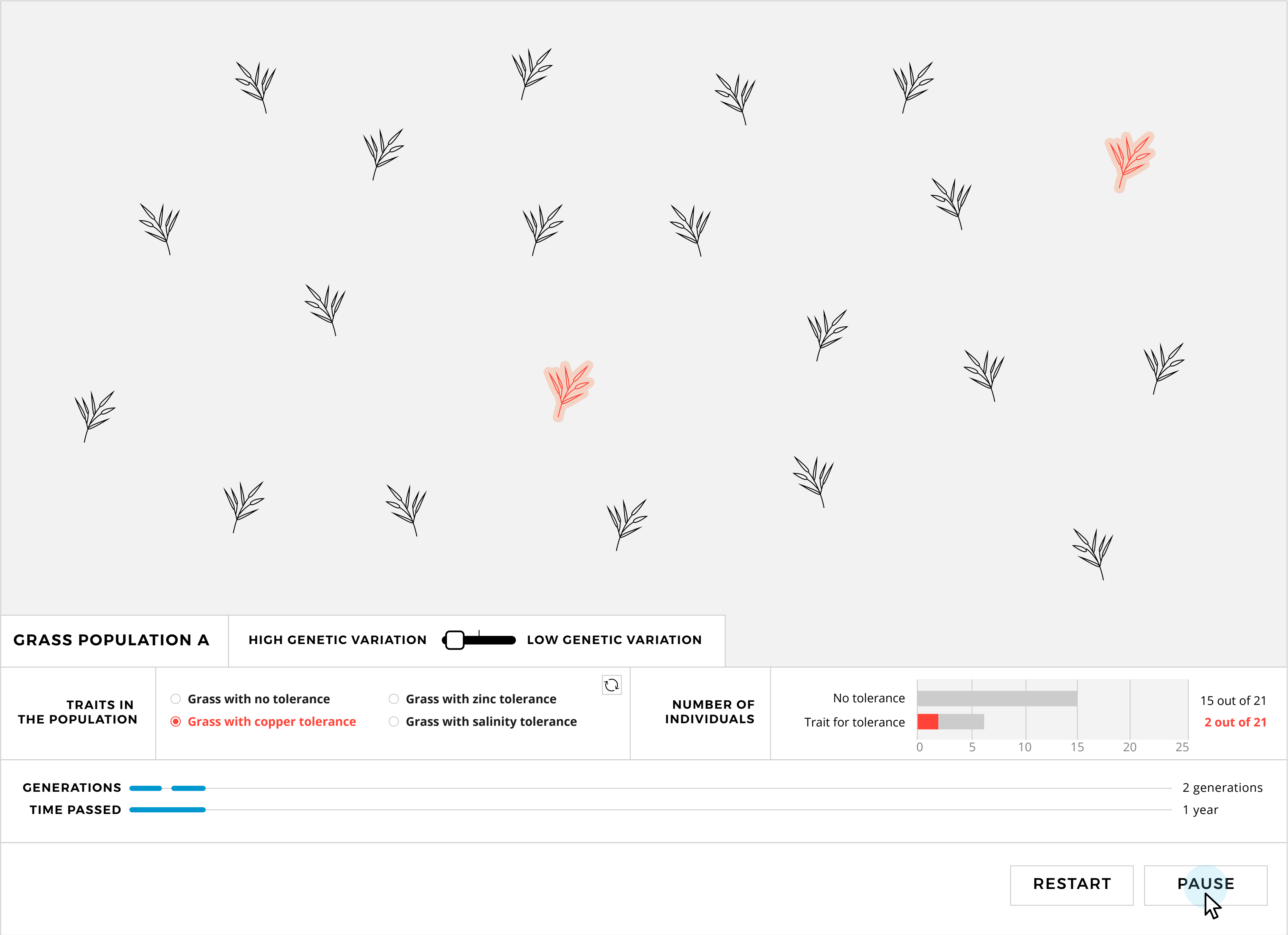
Population A Data

Generation #: 0

Number of individuals	**Trait**
14	No tolerance
2	Copper tolerance
2	Zinc tolerance
2	Salinity tolerance

ADD NEW DATA SAVE

← PREVIOUS PART B →



GRASS POPULATION A

HIGH GENETIC VARIATION LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	15 out of 21
Trait for tolerance	2 out of 21

GENERATIONS 2 generations
TIME PASSED 1 year

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK DATA LOG

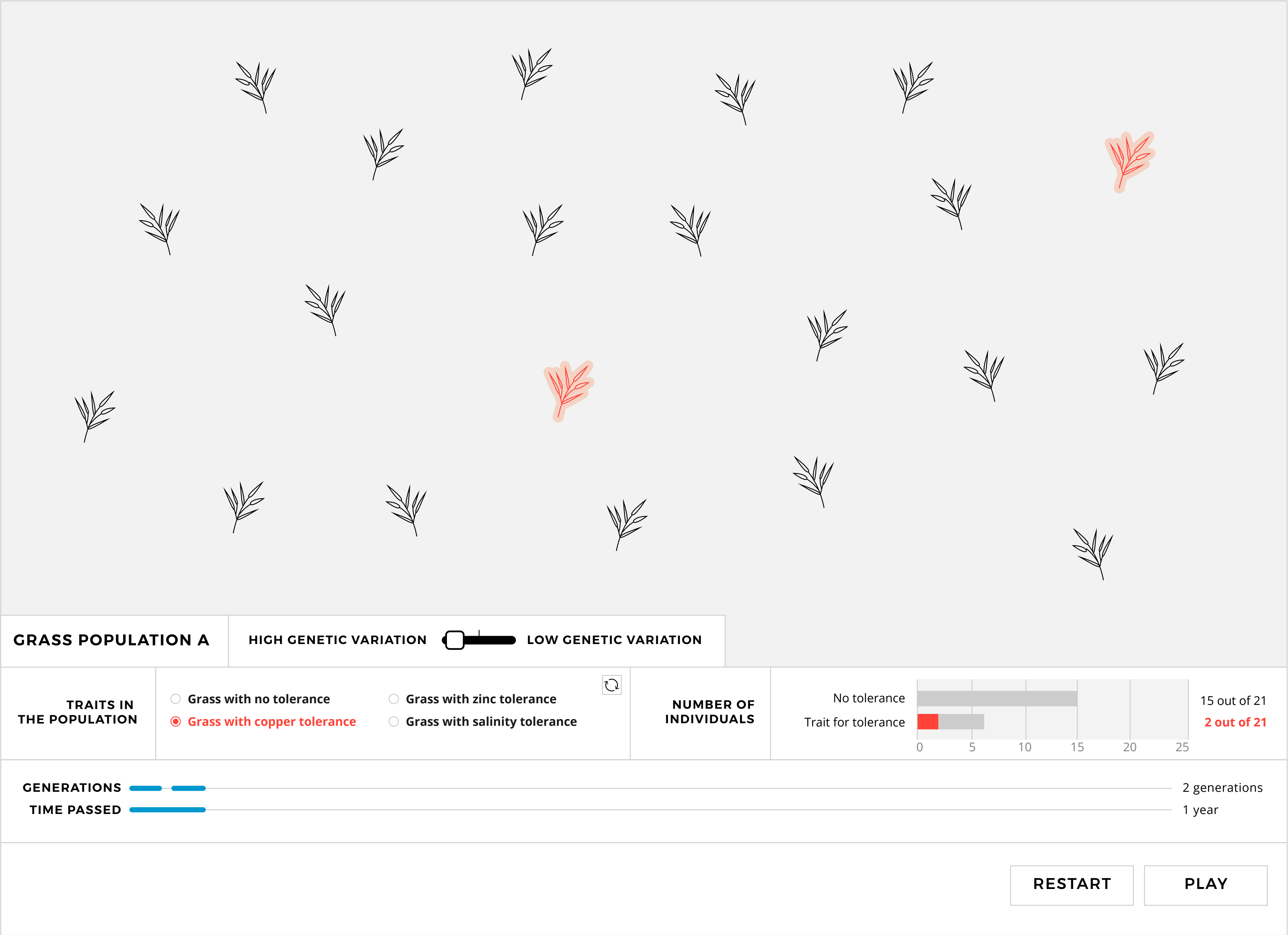
Population A Data

Generation #: 0

Number of individuals	**Trait**		
14	No tolerance	−	+
2	Copper tolerance	−	+
2	Zinc tolerance	−	+
2	Salinity tolerance	−	+

ADD NEW DATA SAVE

⟵ PREVIOUS PART B ⟶



GRASS POPULATION A

HIGH GENETIC VARIATION LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	15 out of 21
Trait for tolerance	2 out of 21

GENERATIONS 2 generations

TIME PASSED 1 year

RESTART PLAY

EVOEXPLORER

MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK DATA LOG

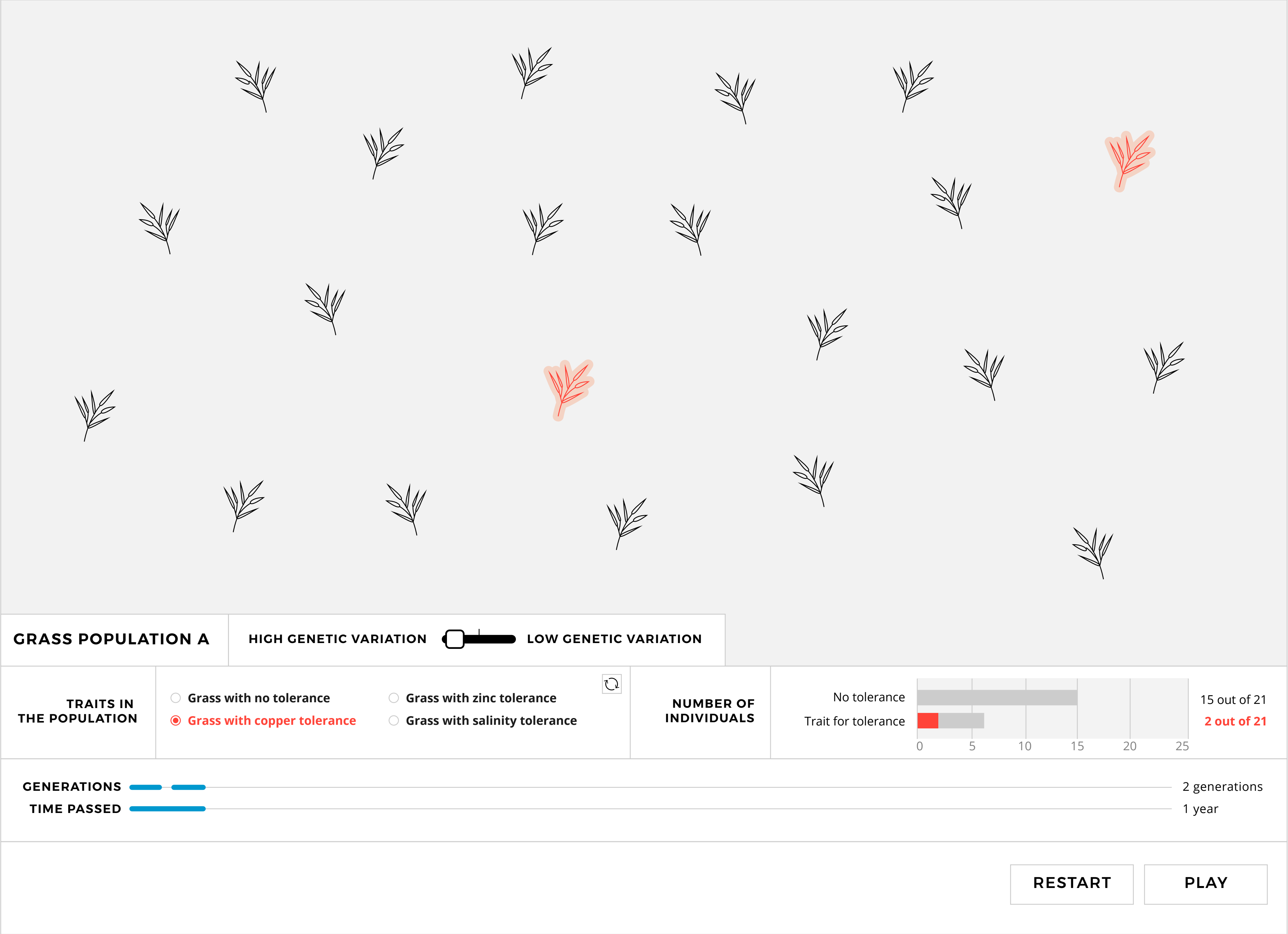
Population A Data

Generation #: ☐

Number of individuals ☐ **Trait** Select an option − +

ADD NEW DATA SAVE

← PREVIOUS PART B →



TRAITS IN THE POPULATION
○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS
No tolerance 15 out of 21
Trait for tolerance 2 out of 21

GENERATIONS 2 generations
TIME PASSED 1 year

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click "play" and pause every 2 generations to record how many individuals in the population have or don't have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

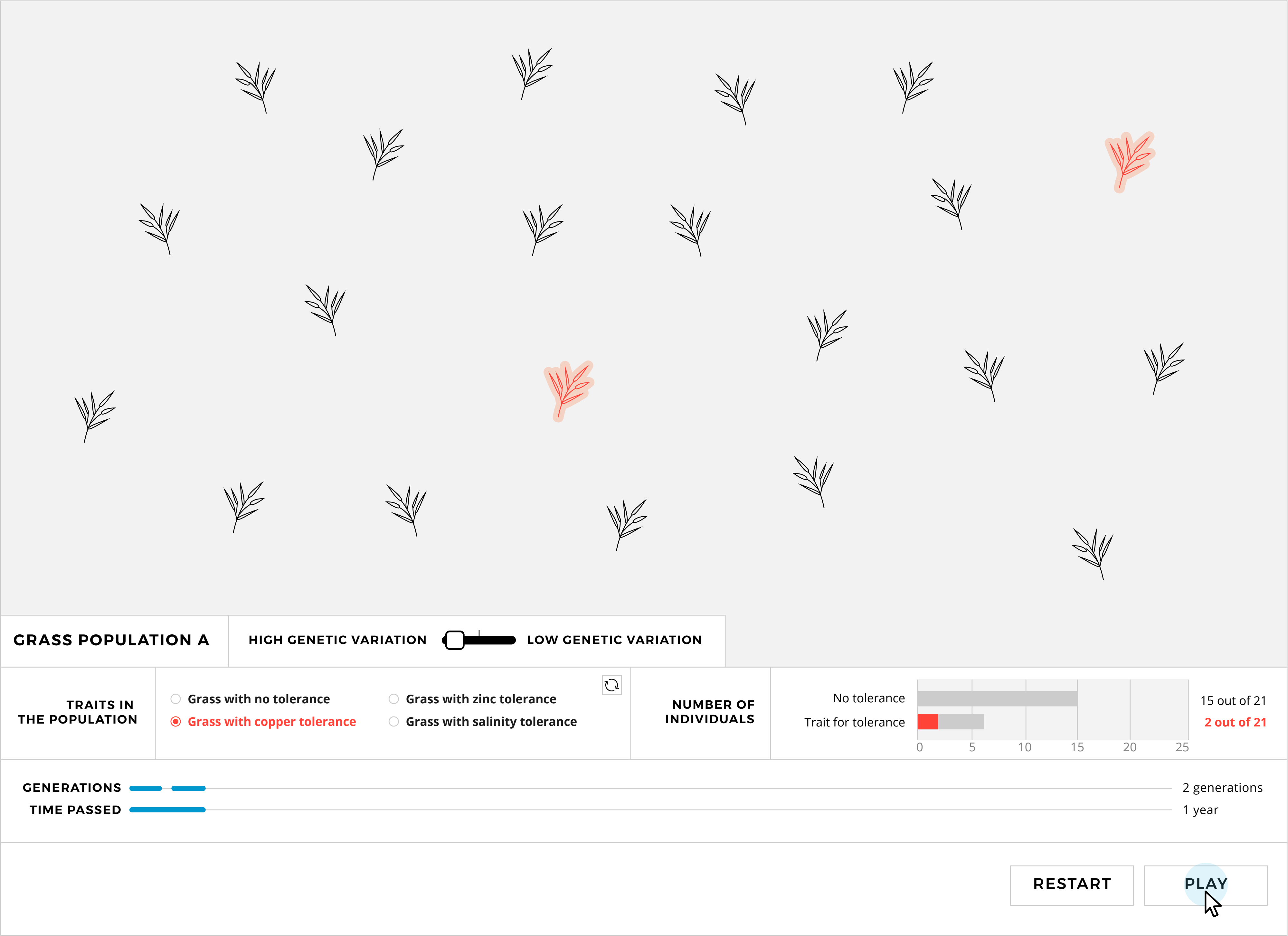
Population A Data

Generation #: 2

Number of individuals	**Trait**
15	No tolerance
2	Copper tolerance

ADD NEW DATA SAVE

← PREVIOUS PART B →



GRASS POPULATION A

HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	15 out of 21
Trait for tolerance	2 out of 21

GENERATIONS 2 generations

TIME PASSED 1 year

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

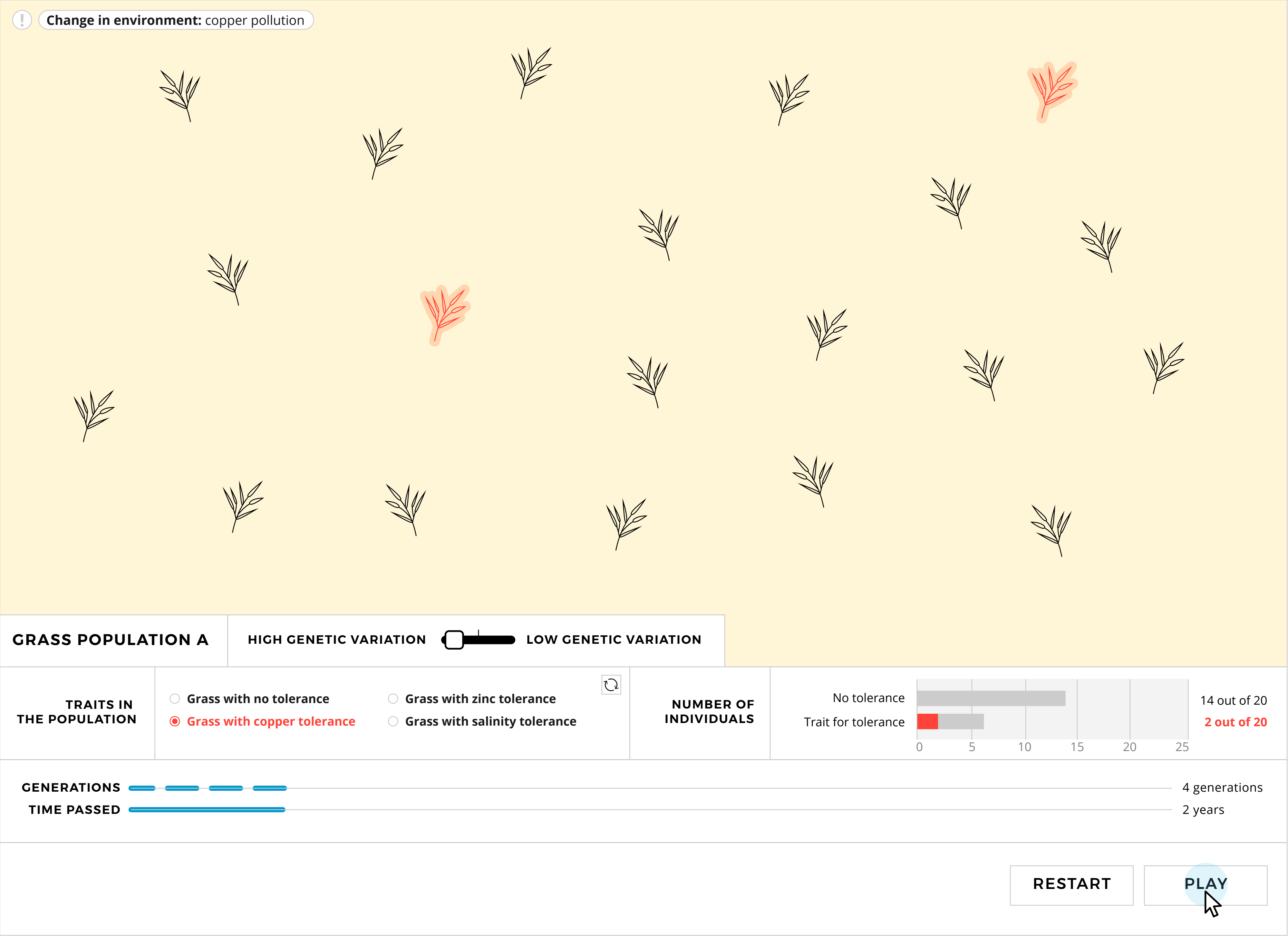
Population A Data

Generation #: 4

Number of individuals	**Trait**
14	No tolerance
2	Copper tolerance

ADD NEW DATA   SAVE

← PREVIOUS   PART B →



Change in environment: copper pollution

GRASS POPULATION A

HIGH GENETIC VARIATION / LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance

● Grass with copper tolerance

○ Grass with zinc tolerance

○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance: 14 out of 20

Trait for tolerance: 2 out of 20

GENERATIONS: 4 generations

TIME PASSED: 2 years

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

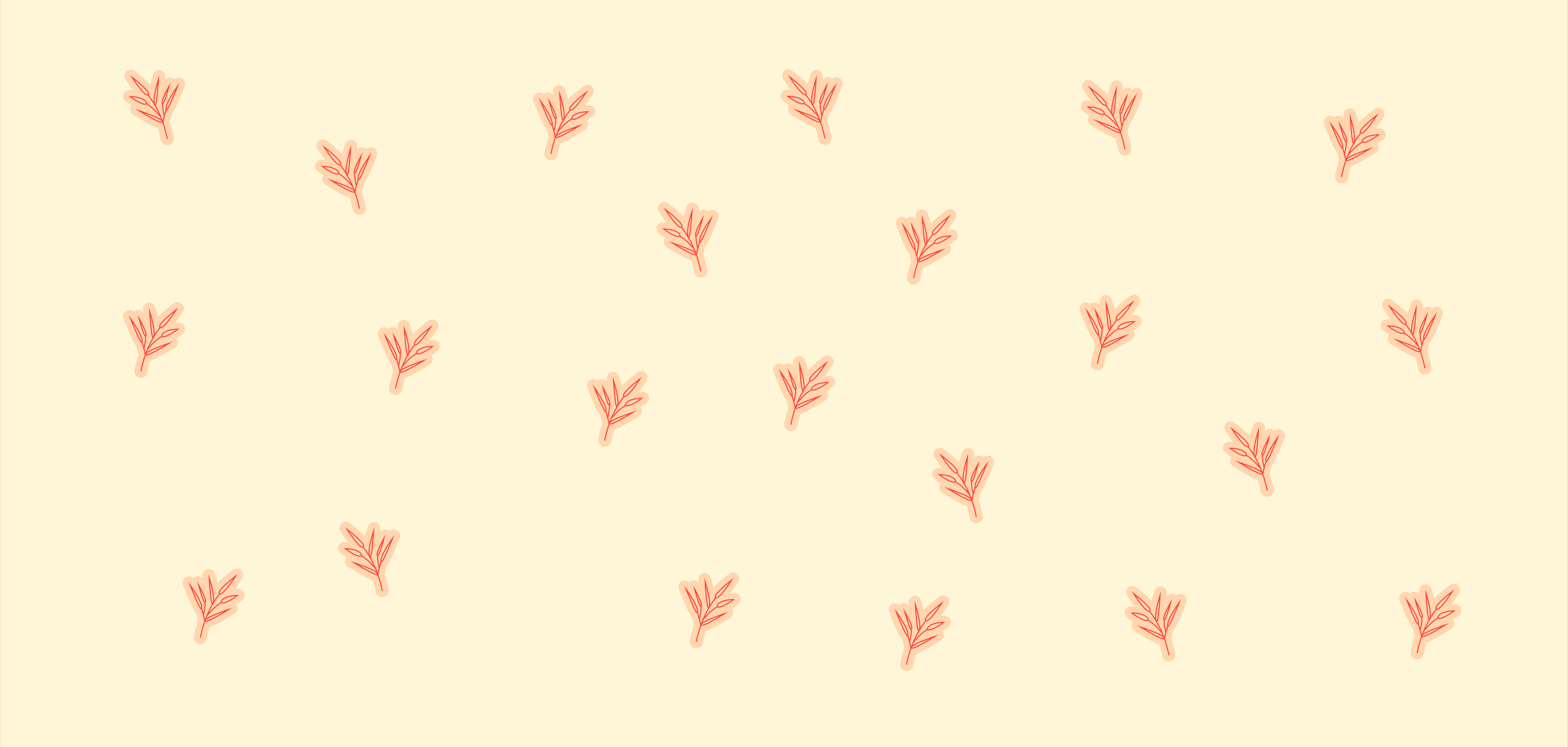
Population A Data

Generation #: 20

Number of individuals	**Trait**
0	No tolerance ⌄ − +
22	Copper tolerance ⌄ − +

ADD NEW DATA   SAVE

← PREVIOUS   PART B →

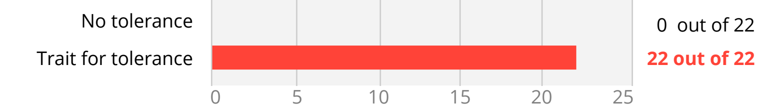


GRASS POPULATION A   HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS



GENERATIONS 20 generations

TIME PASSED 10 years

RESTART   PLAY

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

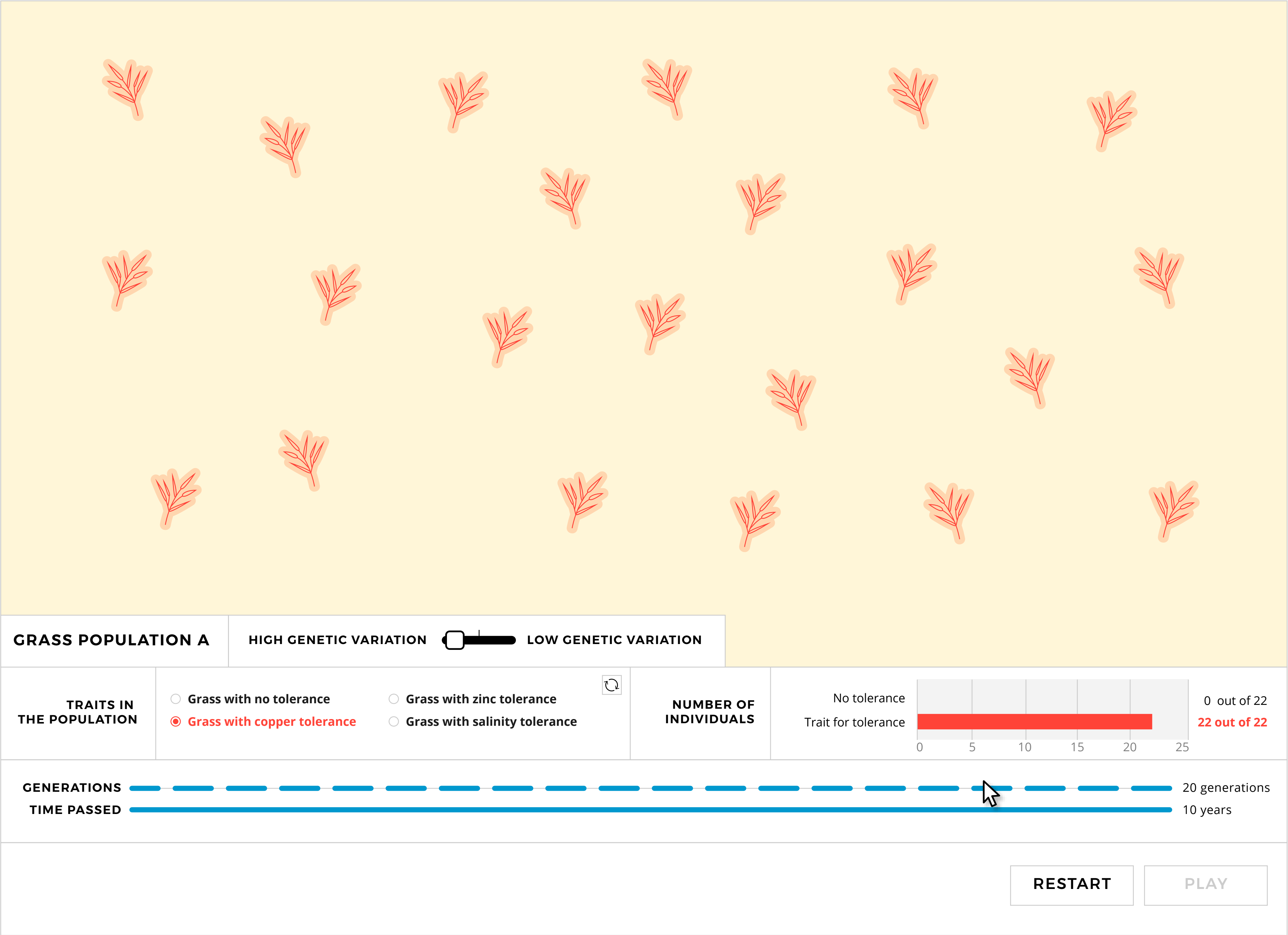
Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

Population A Data

Generation 0 edit	14 with no tolerance 2 with copper tolerance
Generation 2 edit	14 with no tolerance 4 with copper tolerance
Generation 4 edit	14 with no tolerance 2 with copper tolerance
Generation 6 edit	10 with no tolerance 3 with copper tolerance
Generation 8 edit	8 with no tolerance 7 with copper tolerance

← PREVIOUS PART B →



○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

No tolerance: 0 out of 22
Trait for tolerance: 22 out of 22

20 generations
10 years

TIP
You can drag the time bars here to review each generation

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

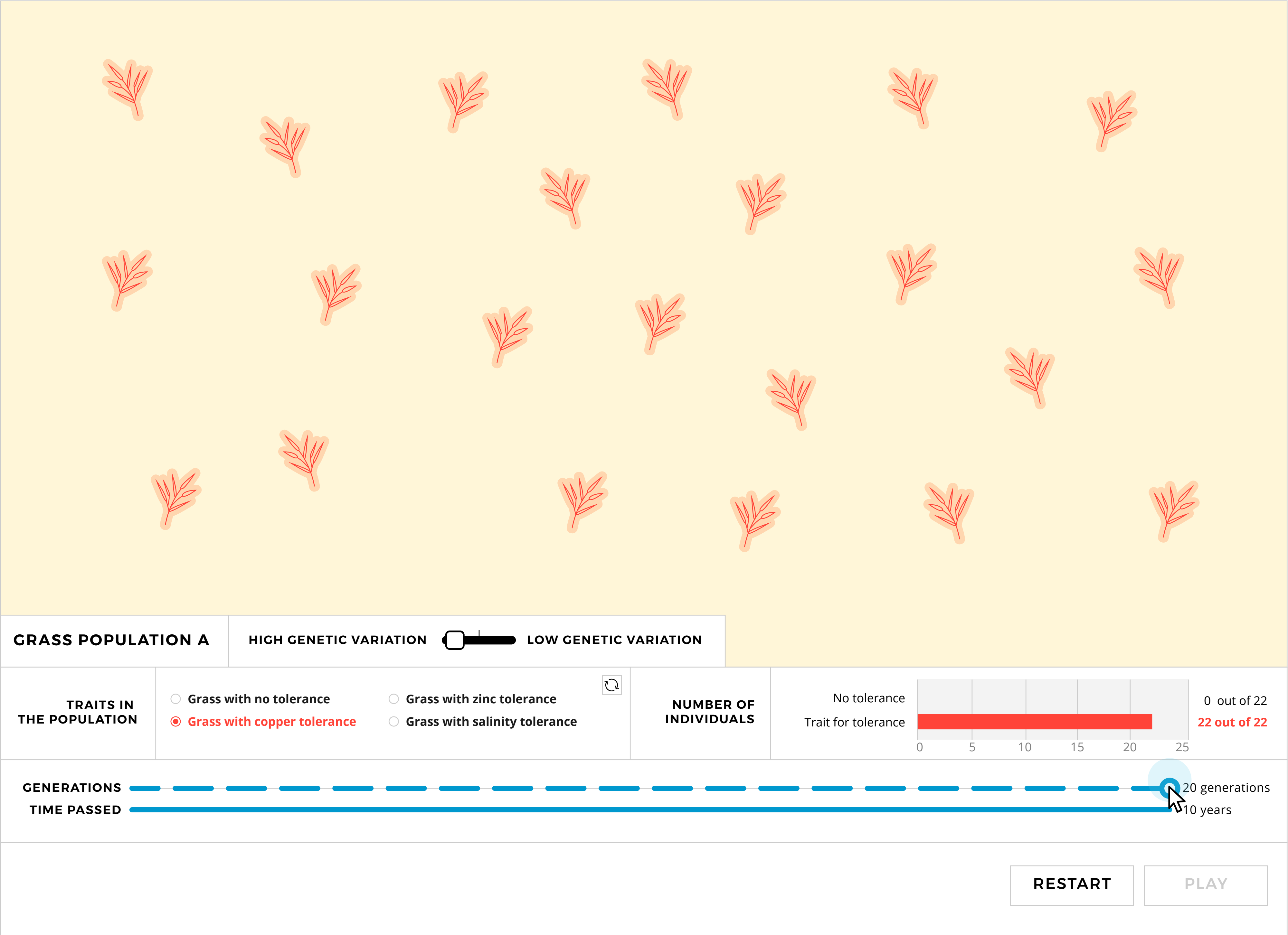
This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

Population A Data

Generation 0 edit	14 with no tolerance 2 with copper tolerance
Generation 2 edit	14 with no tolerance 4 with copper tolerance
Generation 4 edit	14 with no tolerance 2 with copper tolerance
Generation 6 edit	10 with no tolerance 3 with copper tolerance
Generation 8 edit	8 with no tolerance 7 with copper tolerance



GRASS POPULATION A

HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance: 0 out of 22
Trait for tolerance: 22 out of 22

GENERATIONS: 20 generations
TIME PASSED: 10 years

RESTART PLAY

← PREVIOUS PART B →

EVOEXPLORER

MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

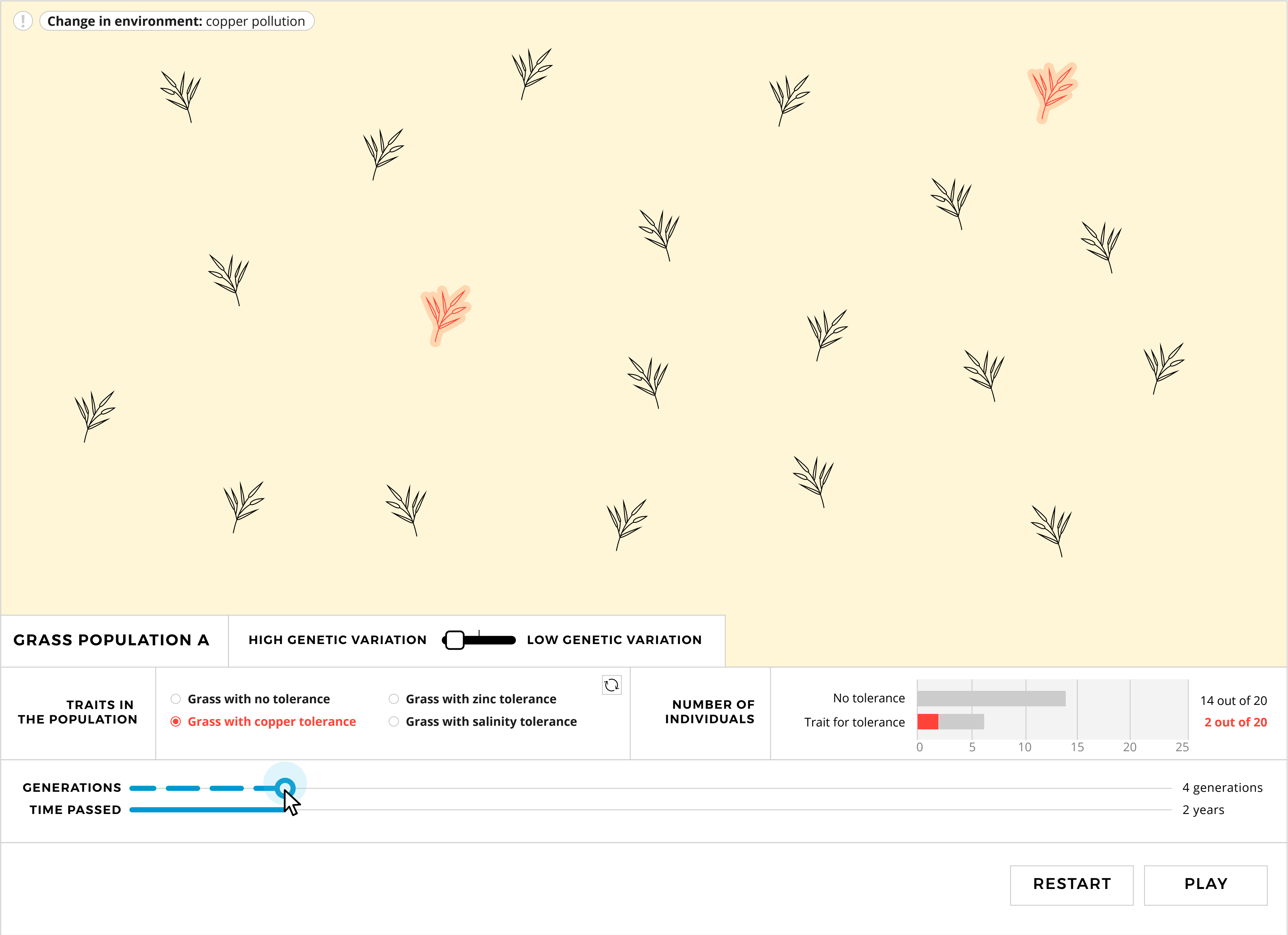
Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK | DATA LOG

Population A Data

Generation 0 edit	14 with no tolerance 2 with copper tolerance
Generation 2 edit	14 with no tolerance 4 with copper tolerance
Generation 4 edit	14 with no tolerance 2 with copper tolerance
Generation 6 edit	10 with no tolerance 3 with copper tolerance
Generation 8 edit	8 with no tolerance 7 with copper tolerance

⟵ PREVIOUS PART B ⟶



Change in environment: copper pollution

GRASS POPULATION A

HIGH GENETIC VARIATION ⬤━━ LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance: 14 out of 20
Trait for tolerance: 2 out of 20

GENERATIONS: 4 generations
TIME PASSED: 2 years

RESTART PLAY

☰ **EVO**EXPLORER 🔔3 MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

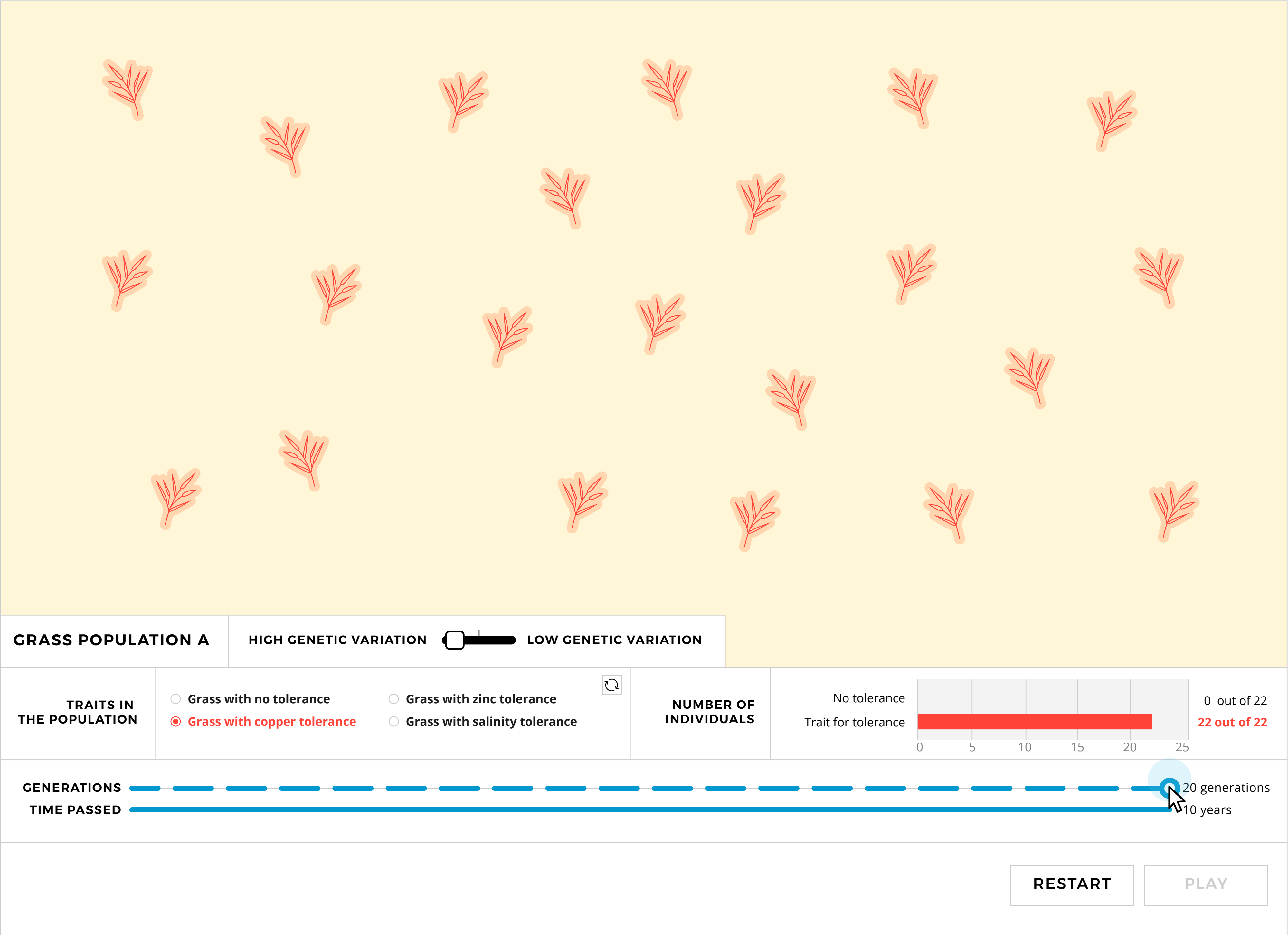
Click "play" and pause every 2 generations to record how many individuals in the population have or don't have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

Population A Data

Generation 0 edit	14 with no tolerance 2 with copper tolerance
Generation 2 edit	14 with no tolerance 4 with copper tolerance
Generation 4 edit	14 with no tolerance 2 with copper tolerance
Generation 6 edit	10 with no tolerance 3 with copper tolerance
Generation 8 edit	8 with no tolerance 7 with copper tolerance

← PREVIOUS | PART B →



GRASS POPULATION A

HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	0 out of 22
Trait for tolerance	22 out of 22

GENERATIONS 20 generations

TIME PASSED 10 years

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

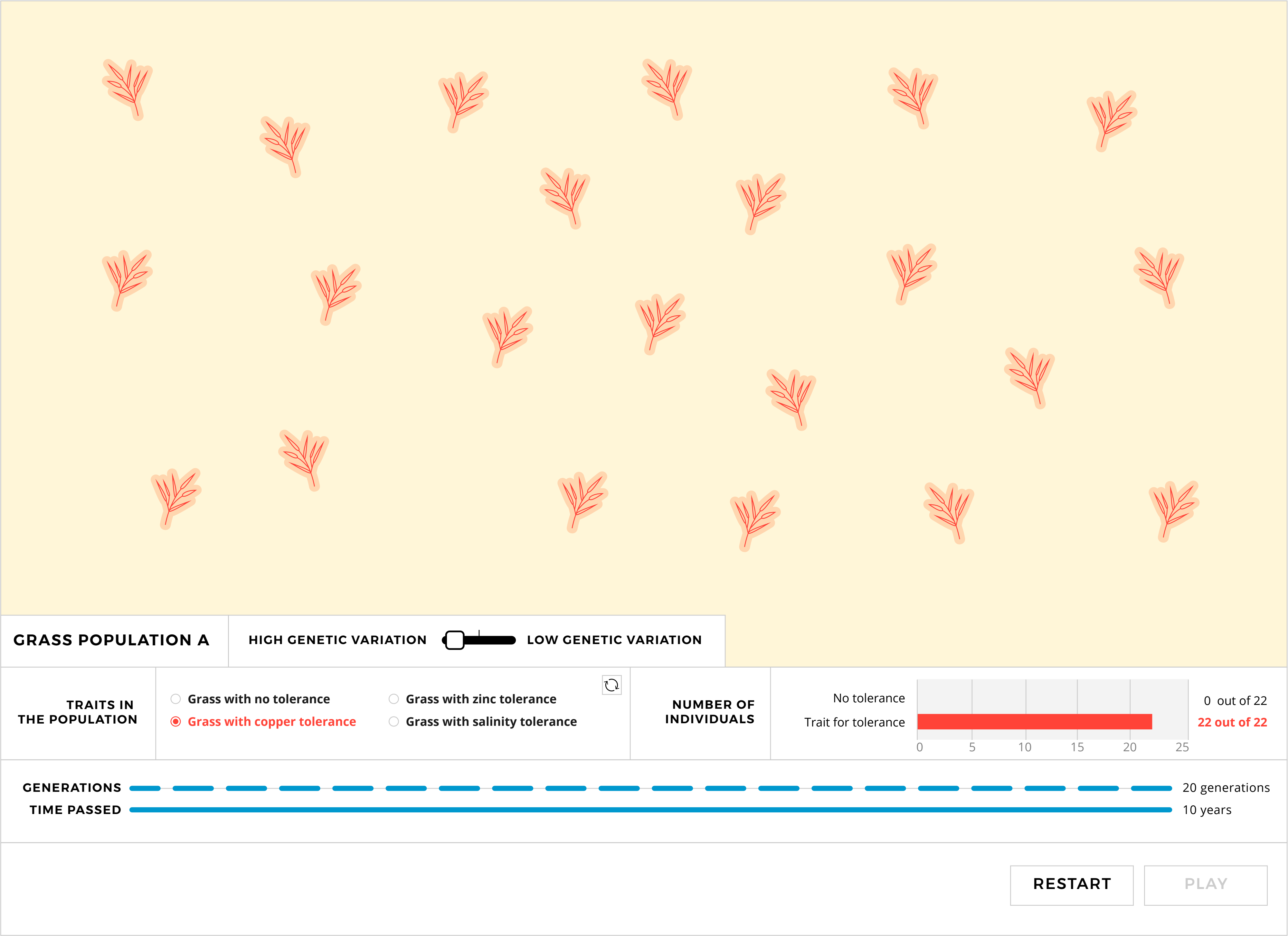
Click "play" and pause every 2 generations to record how many individuals in the population have or don't have copper tolerance.

CASE STUDY 2 NOTEBOOK | DATA LOG

Population A Data

Generation 0 edit	14 with no tolerance 2 with copper tolerance
Generation 2 edit	14 with no tolerance 4 with copper tolerance
Generation 4 edit	14 with no tolerance 2 with copper tolerance
Generation 6 edit	10 with no tolerance 3 with copper tolerance
Generation 8 edit	8 with no tolerance 7 with copper tolerance

⟵ PREVIOUS PART B ⟶



TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance		0 out of 22
Trait for tolerance	🟥	22 out of 22

GENERATIONS 20 generations

TIME PASSED 10 years

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

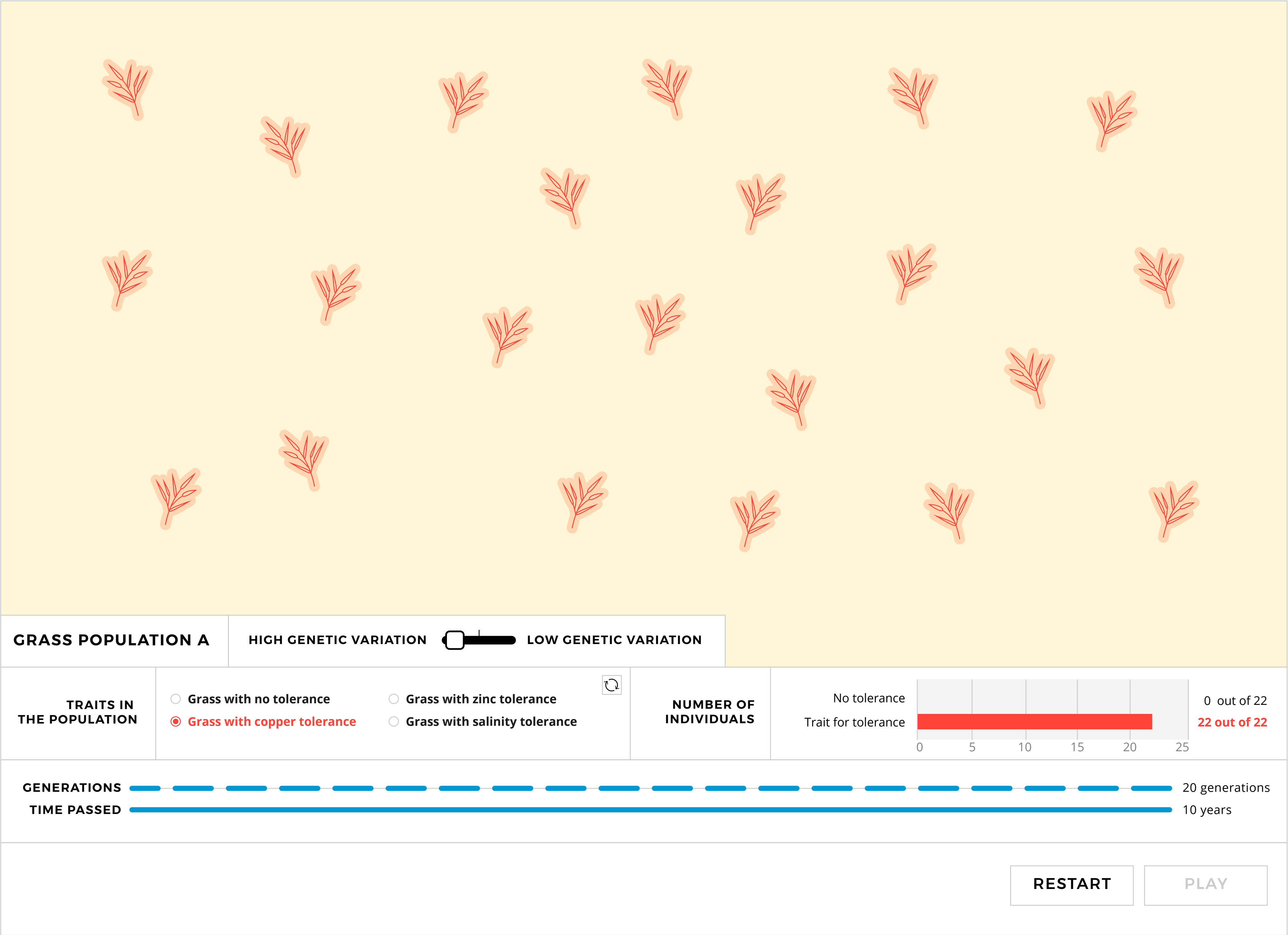
Click "play" and pause every 2 generations to record how many individuals in the population have or don't have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

Population A Data

Generation 0 save	14 with no tolerance 2 with copper tolerance
Generation 2 edit	14 with no tolerance 4 with copper tolerance
Generation 4 edit	14 with no tolerance 2 with copper tolerance
Generation 6 edit	10 with no tolerance 3 with copper tolerance
Generation 8 edit	8 with no tolerance 7 with copper tolerance

← PREVIOUS
PART B →



GRASS POPULATION A
HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION
○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS
No tolerance: 0 out of 22
Trait for tolerance: 22 out of 22

GENERATIONS: 20 generations
TIME PASSED: 10 years

RESTART
PLAY

EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK | DATA LOG

Population A Data

Generation 0 edit	14 with no tolerance 2 with copper tolerance
Generation 2 edit	14 with no tolerance 4 with copper tolerance
Generation 4 edit	14 with no tolerance 2 with copper tolerance
Generation 6 edit	10 with no tolerance 3 with copper tolerance
Generation 8 edit	8 with no tolerance 7 with copper tolerance

← PREVIOUS

PART B →

GRASS POPULATION A

HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance

● Grass with copper tolerance

○ Grass with zinc tolerance

○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	0 out of 22
Trait for tolerance	22 out of 22

GENERATIONS — 20 generations

TIME PASSED — 10 years

RESTART

PLAY

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment A

You predicted that in population A, *individuals with copper tolerance will survive in the first generation, and after a couple generations, the population will consist of mostly individuals with copper tolerance.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click “play” and pause every 2 generations to record how many individuals in the population have or don’t have copper tolerance.

CASE STUDY 2 NOTEBOOK | DATA LOG

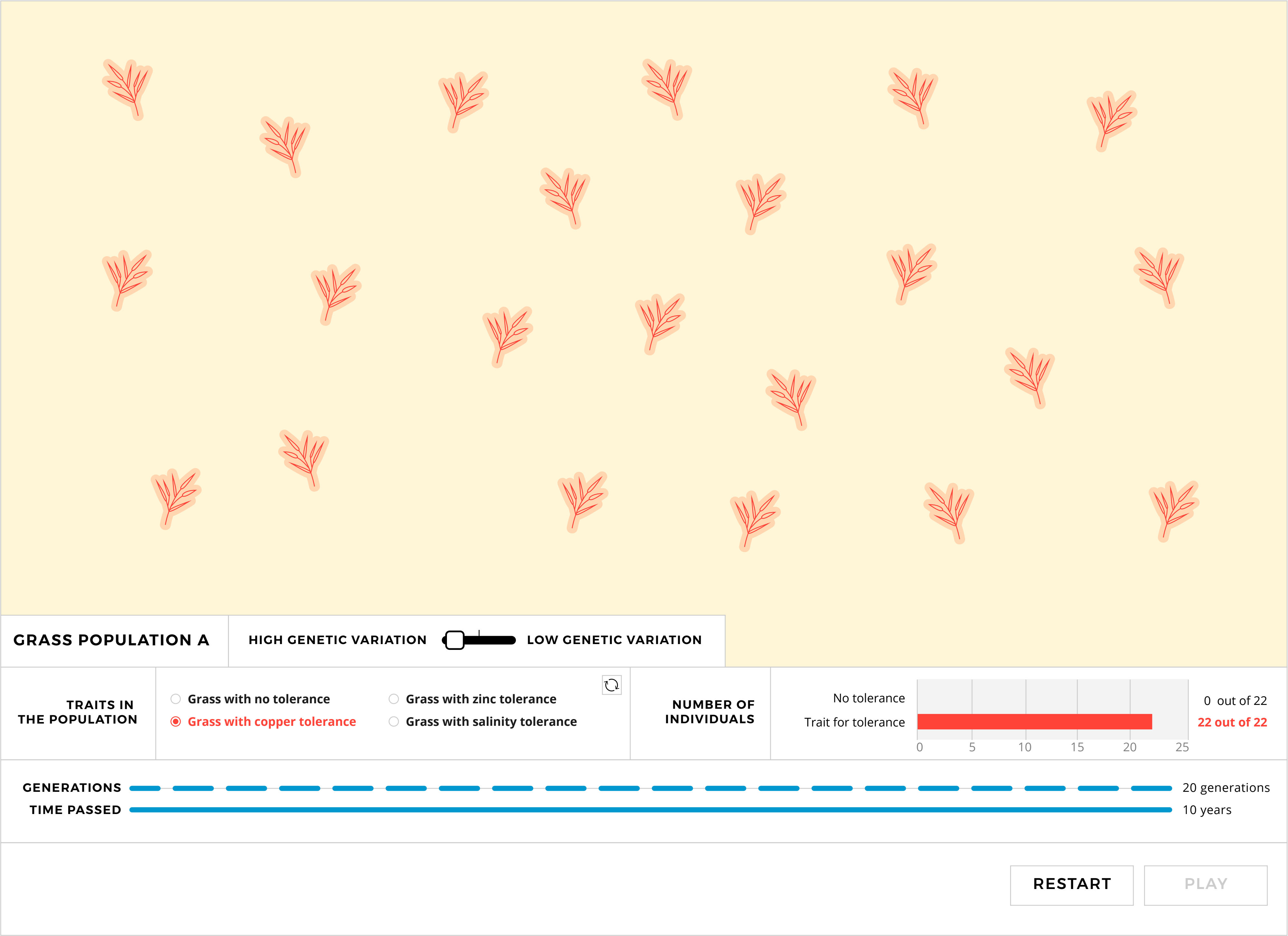
Population A Data

Generation #: 20

Number of individuals	**Trait**
0	No tolerance
22	Copper tolerance

ADD NEW DATA SAVE

← PREVIOUS PART B →



GRASS POPULATION A

HIGH GENETIC VARIATION / LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	0 out of 22
Trait for tolerance	22 out of 22

GENERATIONS 20 generations

TIME PASSED 10 years

EVOEXPLORER

3

MY ACCOUNT

SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment B

First, let's look at **grass population B** which has greater genetic variation.

Adjust the toggle for lower genetic variation in order to observe grass population B.

Select traits in the population to see what traits are present in the starting population and how many individuals have them. Record them in your notebook.

CASE STUDY 2 NOTEBOOK DATA LOG

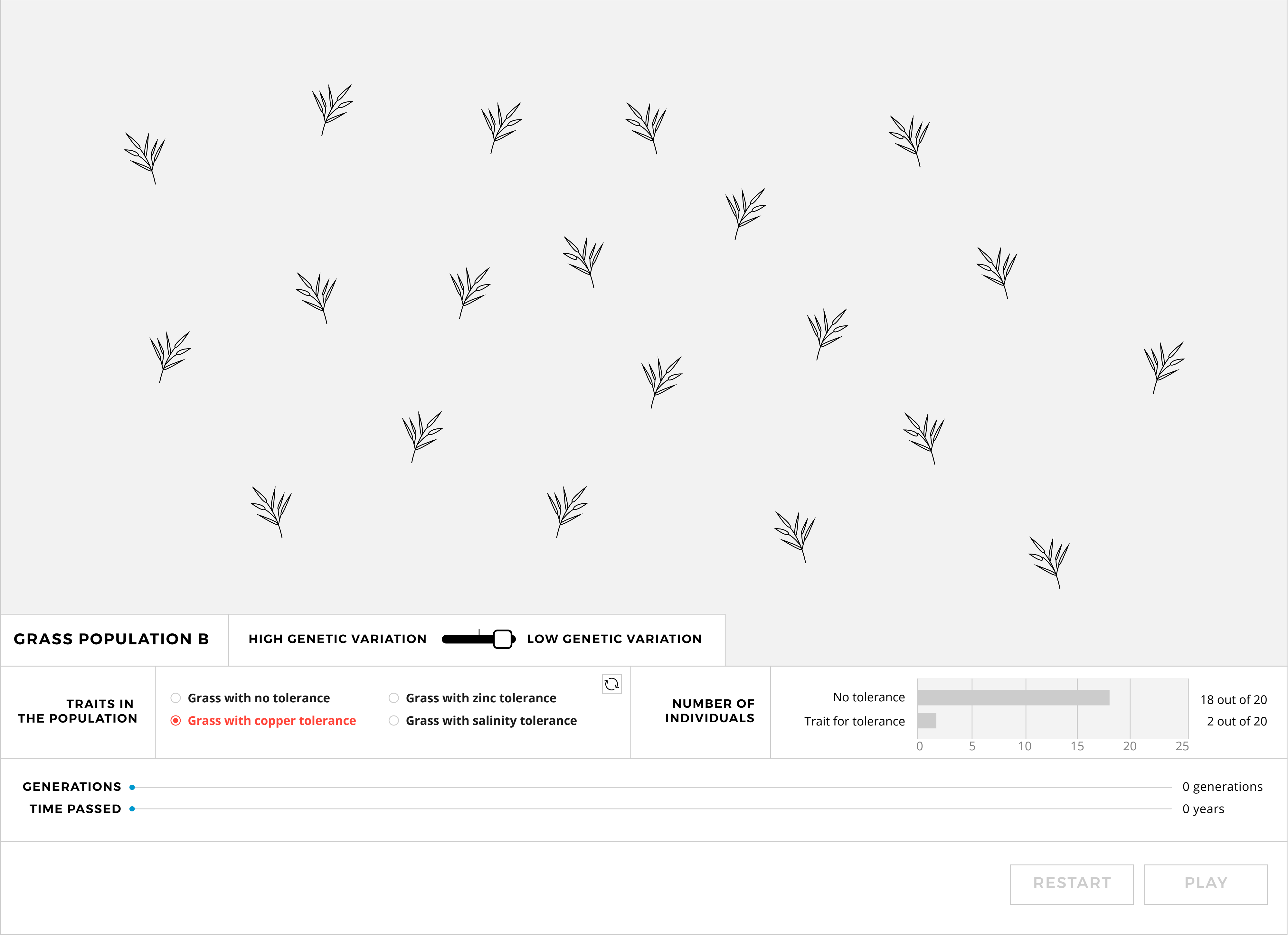
Population B Data

Generation #: 0

Number of individuals	**Trait**
18	No tolerance
0	Copper tolerance
0	Zinc tolerance
2	Salinity tolerance

ADD NEW DATA SAVE

← PREVIOUS NEXT →



Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment B

You predicted that in population B, *individuals will die indiscriminately, and after a couple generations, the population size will diminish.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click "play" and pause every 2 generations to record how many individuals in the population have or don't have copper tolerance.

CASE STUDY 2 NOTEBOOK | DATA LOG

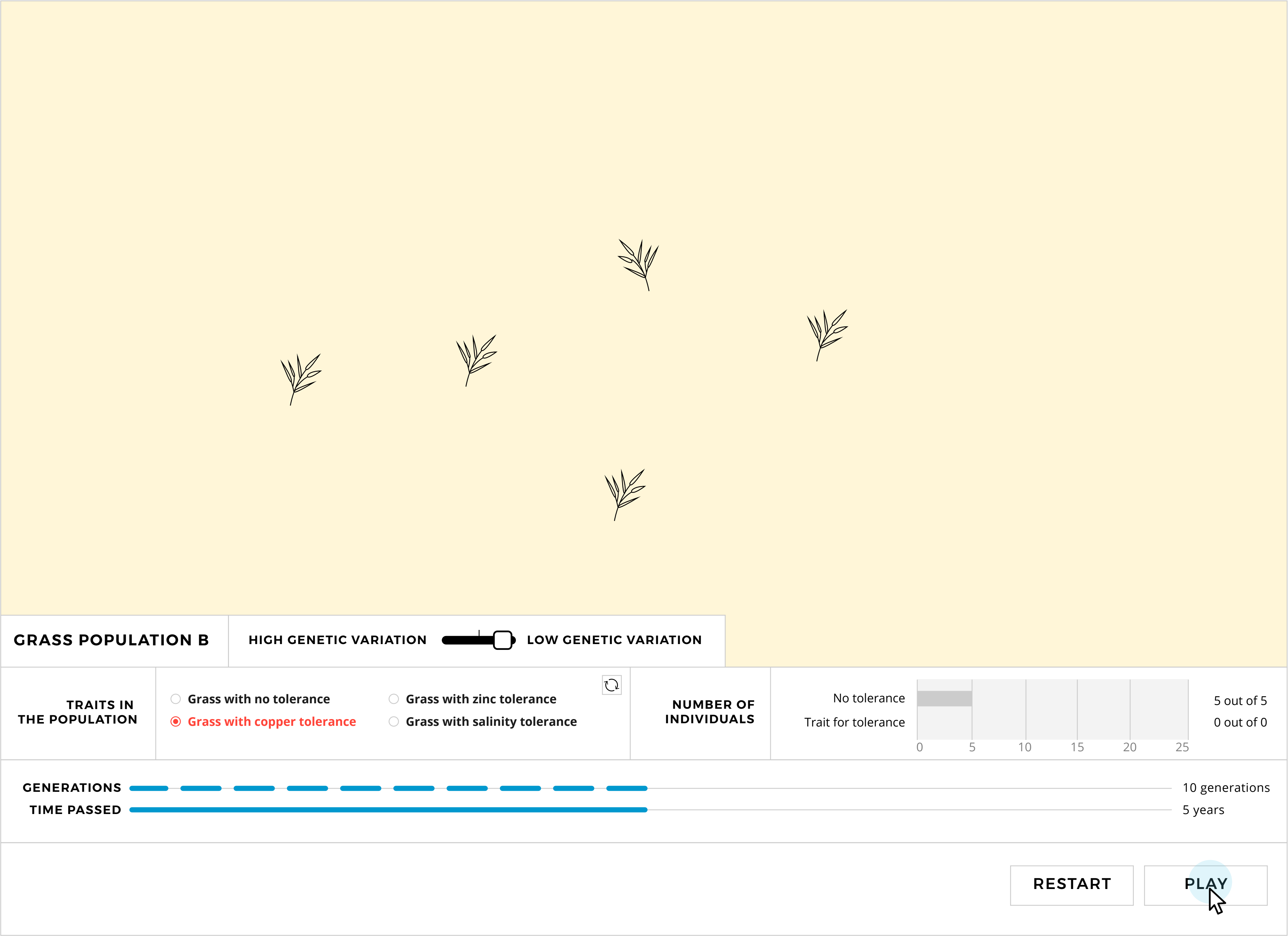
Population A Data

Generation #: 10

Number of individuals	Trait
5	No tolerance
0	Copper tolerance

ADD NEW DATA | SAVE

← PREVIOUS | RESULTS →



GRASS POPULATION B

HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance	5 out of 5
Trait for tolerance	0 out of 0

GENERATIONS: 10 generations

TIME PASSED: 5 years

RESTART | PLAY

EVOEXPLORER

MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

Experiment B

You predicted that in population B, *individuals will die indiscriminately, and after a couple generations, the population size will diminish.*

This grass population has a generation time of 26 weeks. To observe the overall trend, you decide to collect data on the grass population for the next 10 years both before and after soil contamination with copper wastes.

Click "play" and pause every 2 generations to record how many individuals in the population have or don't have copper tolerance.

CASE STUDY 2 NOTEBOOK | **DATA LOG**

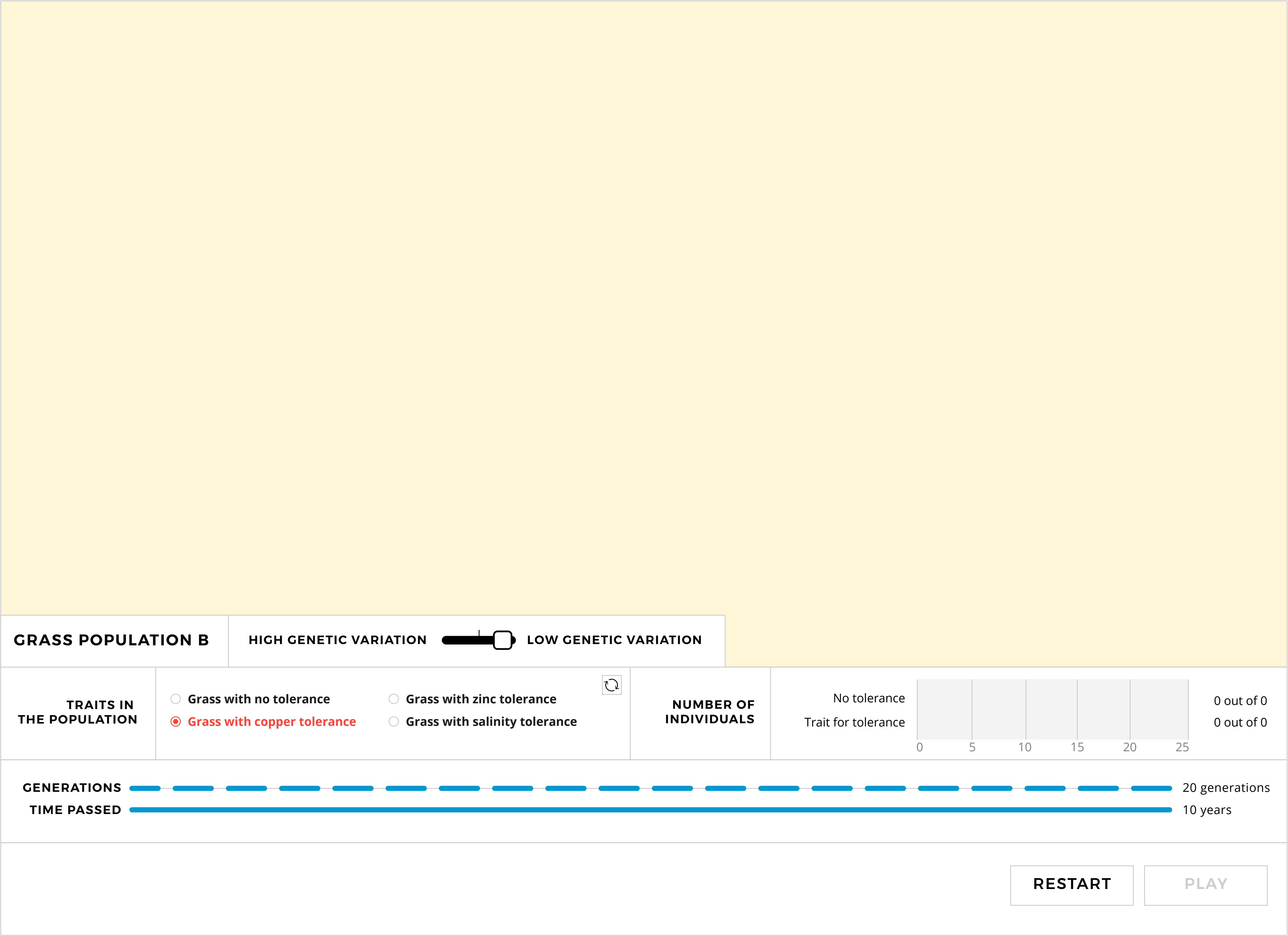
Population A Data

Generation #: 20

Number of individuals	**Trait**
0	No tolerance
0	Copper tolerance

ADD NEW DATA SAVE

← PREVIOUS RESULTS →



GRASS POPULATION B

HIGH GENETIC VARIATION — LOW GENETIC VARIATION

TRAITS IN THE POPULATION

○ Grass with no tolerance
● Grass with copper tolerance
○ Grass with zinc tolerance
○ Grass with salinity tolerance

NUMBER OF INDIVIDUALS

No tolerance: 0 out of 0
Trait for tolerance: 0 out of 0

GENERATIONS: 20 generations
TIME PASSED: 10 years

☰ **EVO**EXPLORER

🔔 3 MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment

CASE STUDY 2

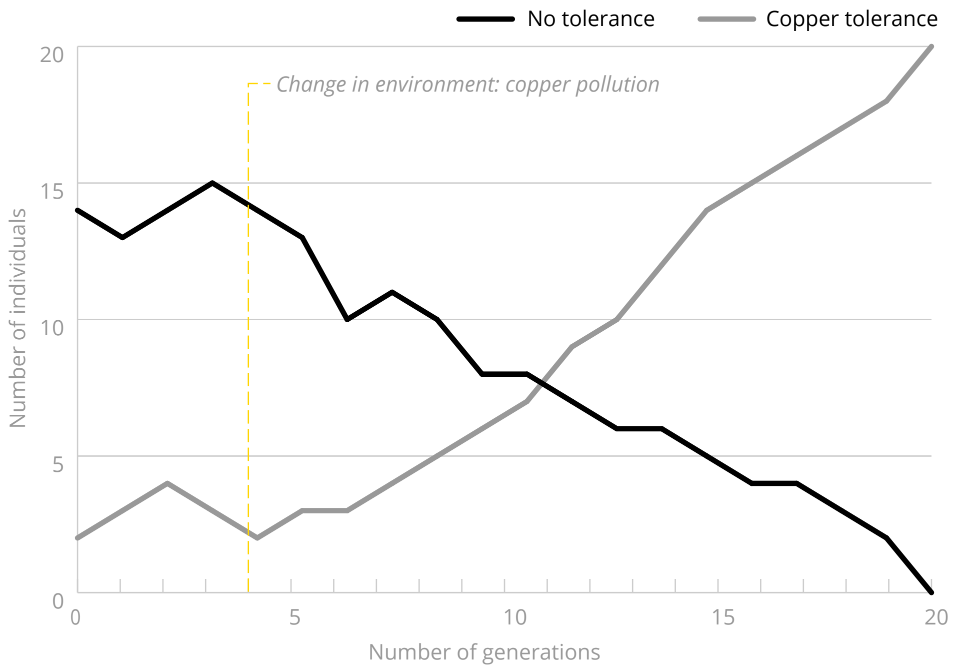
Results

You’ve hired a statistician to help you plot the data. Your assistant helped with collecting data as well so you have data from every generation. Take a look at your plotted data to observe the trends. Note the changes between the two populations.

Now that you have your data, it’s time to analyze them!

⟵ PREVIOUS ANALYZE ⟶

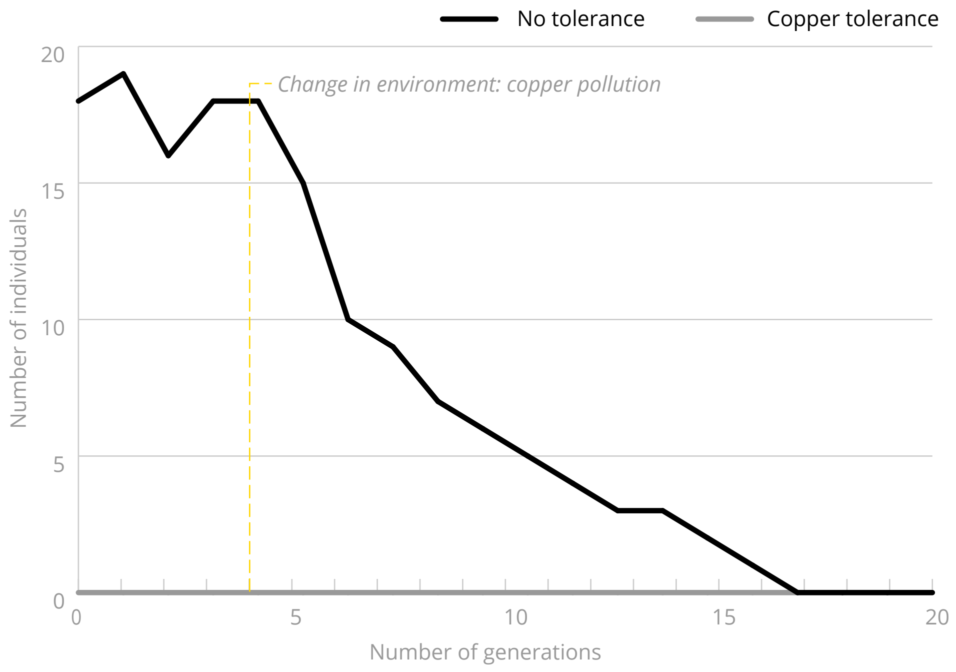
GRASS POPULATION A ☑ HIGH GENETIC VARIATION



Add notes

SAVE NOTES

GRASS POPULATION B ☑ LOW GENETIC VARIATION



Add notes

SAVE NOTES

EVOEXPLORER

3 MY ACCOUNT SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment › Analysis

CASE STUDY 2

Analysis

MY PREDICTIONS

In scenario A, you predicted that copper tolerant individuals in population A will survive, whereas individuals in population B will die indiscriminately.

In scenario B, you predicted that copper tolerant individuals in population A will increase (and individuals in with no tolerance will die off), whereas individuals in population B will die indiscriminately and the whole population will diminish completely.

1. Were your predictions correct or incorrect?

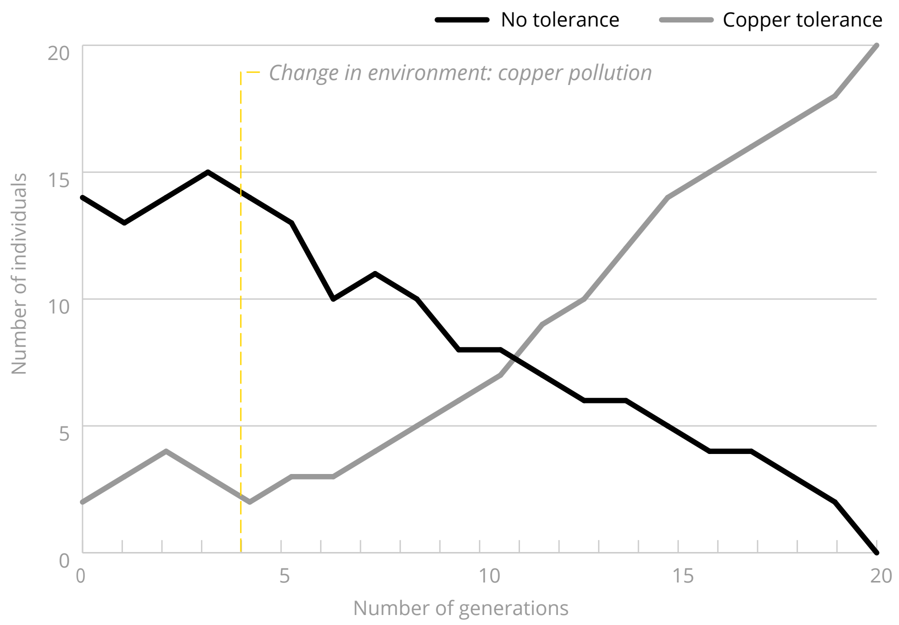
○ Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

● Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

CASE STUDY 1 NOTEBOOK | EXPERIMENT RESULTS | NOTES



Experiment A Observations

☑ HIGH GENETIC VARIATION

I observed that A has greater genetic variation, therefore copper tolerance is present in a very small percentage of the population. When the population is placed in soil with medium-high copper content, individuals with better copper tolerance will survive whereas some individuals without/lower copper tolerance will not survive.

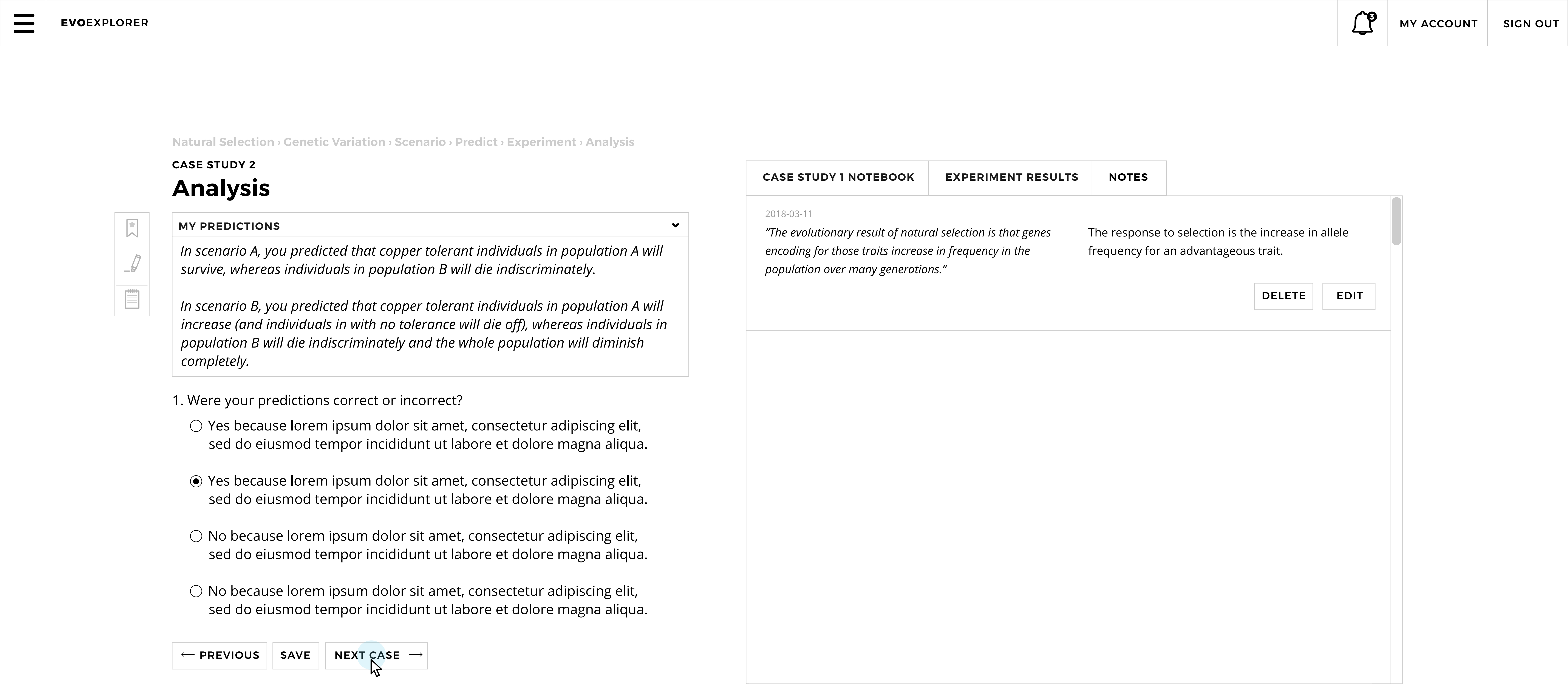
Grass population B has lower genetic variation, therefore, no genetic trait for copper-tolerance is present. When placed in high copper pollution, some individuals die indiscriminately.

Experiment B Observations

☑ LOW GENETIC VARIATION

After a couple generations, population A will consist of 90% individuals with copper tolerance

In contrast, after a couple generations, population B gets wiped out



EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Genetic Variation › Scenario › Predict › Experiment › Analysis

CASE STUDY 2

Analysis

MY PREDICTIONS

In scenario A, you predicted that copper tolerant individuals in population A will survive, whereas individuals in population B will die indiscriminately.

In scenario B, you predicted that copper tolerant individuals in population A will increase (and individuals in with no tolerance will die off), whereas individuals in population B will die indiscriminately and the whole population will diminish completely.

1. Were your predictions correct or incorrect?

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● Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

⟵ PREVIOUS | SAVE | NEXT CASE ⟶

CASE STUDY 1 NOTEBOOK | EXPERIMENT RESULTS | NOTES

2018-03-11

“The evolutionary result of natural selection is that genes encoding for those traits increase in frequency in the population over many generations.”

The response to selection is the increase in allele frequency for an advantageous trait.

DELETE | EDIT

Natural Selection › Generation Time

How generation time affects adaptation

Climate change has led to temperature increases, earlier springtime, and rising sea levels in certain areas. This has huge impacts on many animals and plants. The generation time (the average time between two consecutive generations in the lineages of a population) of these species play a role in how fast they can adapt to the rapidly changing climate.

During meiosis, **recombination** results in new combinations of alleles on chromosomes and **independent assortment** results in gametes with different combinations of maternal and paternal alleles. This produces great potential genetic variation. Therefore, sexual species with shorter generation times generally have faster rates of molecular evolution compared to species with longer generation times, because they undergo these events of recombination and assortment more often per year, resulting in greater genetic variation being present in the population and greater potential for adaptive traits to be selected for.

BEGIN CASE STUDY 3 ⟶

Natural Selection › Generation Time

How generation time affects adaptation

Climate change has led to temperature increases, earlier springtime, and rising sea levels in certain areas. This has huge impacts on many animals and plants. The generation time (the average time between two consecutive generations in the lineages of a population) of these species play a role in how fast they can adapt to the rapidly changing climate.

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combinations of maternal and pa
genetic variation. Therefore, sexu
generally have faster rates of mo
longer generation times, because
and assortment more often per y
present in the population and gr
selected for.

TERM

Genetic recombination: in meiosis, it is a process that involves the exchange of genetic material either between multiple chromosomes or between different regions of the same chromosome.

BEGIN CASE STUDY 3 ⟶

Natural Selection › Generation Time › Scenario

CASE STUDY 3

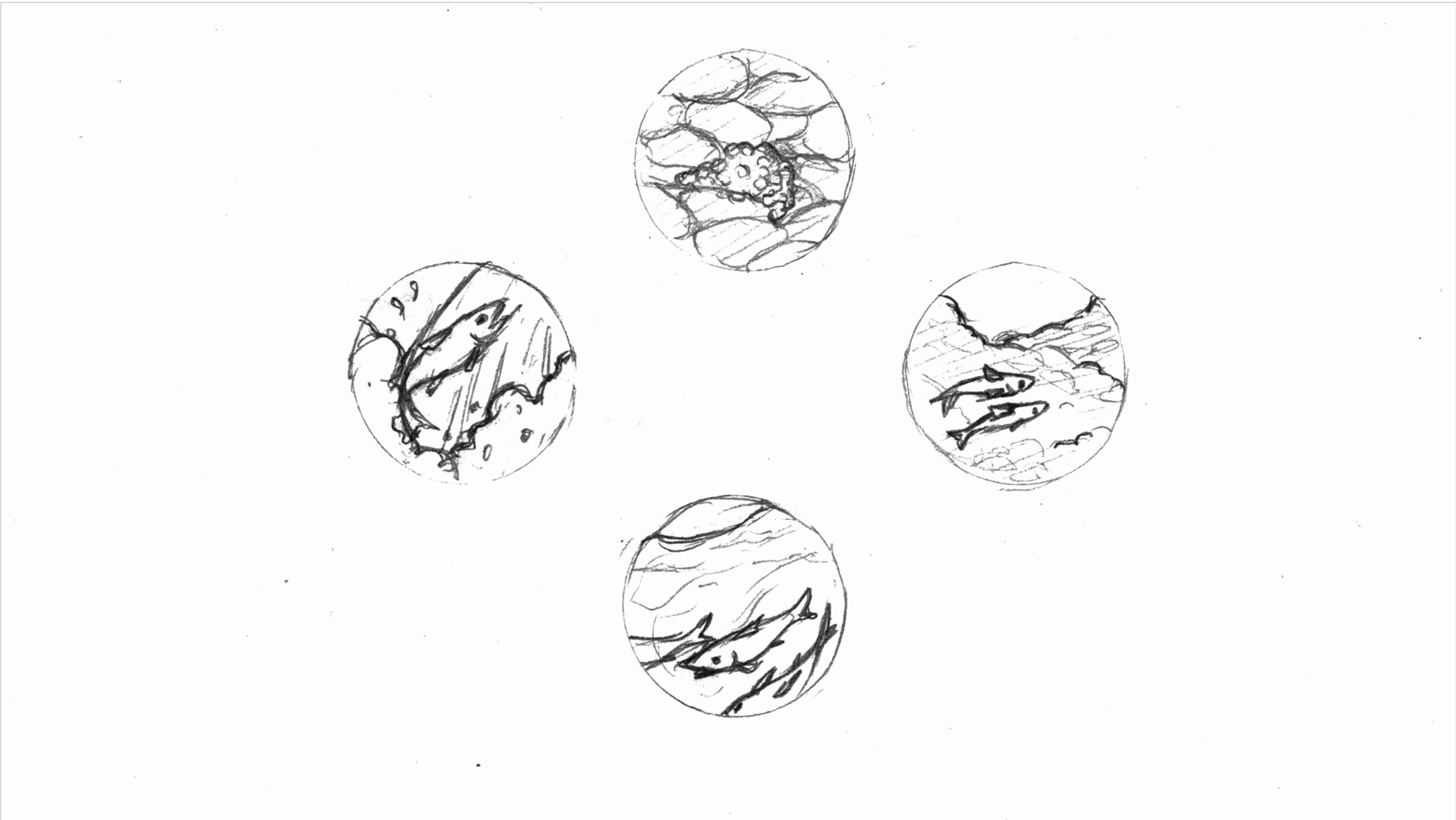
Pink Salmon

The timing of events in the salmon life cycle is often adapted to local thermal conditions in freshwater rivers, streams and lakes, and the ocean. In particular, the growth of juvenile salmon requires cold, oxygenated water.

In the spring, the eggs hatch, and tiny pink salmon (called alevins at this stage) rely on the yolk sac of the egg attached to their bellies. After a few months, they will have consumed all the yolk sac and grown in size. The fish at this stage are called fry and pink fry will immediately travel to the ocean and stay there for 18 months.

Once a female pink salmon reaches about two years old, they migrate back to their home stream to spawn, usually sometime between July to October. This means that pink salmon have a generation time (the time between consecutive generations of a lineage) of 2 years.

⟵ PREVIOUS NEXT ⟶



EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Generation Time › Scenario

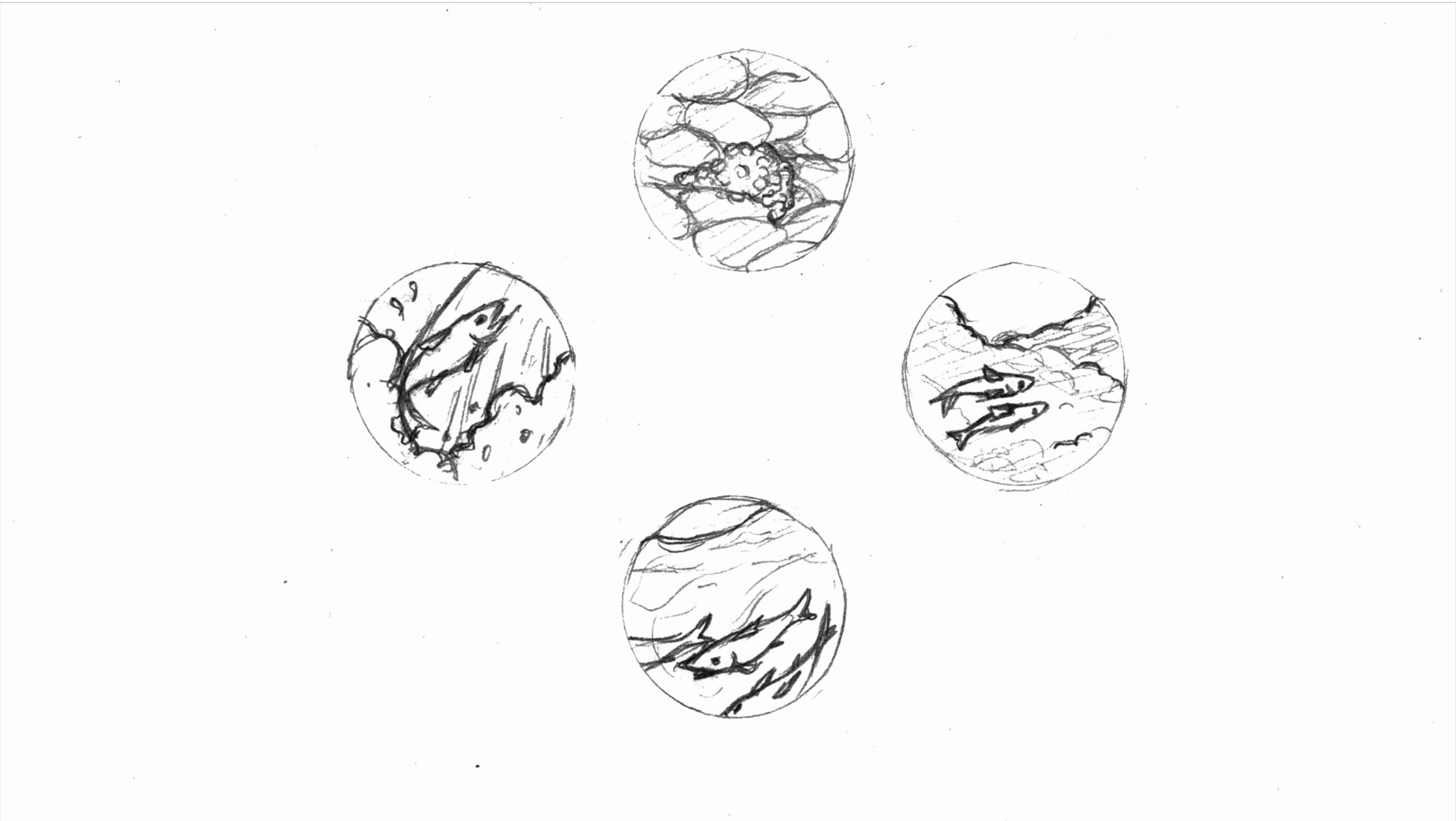
CASE STUDY 3

Pink Salmon

With climate change, spring occurs earlier and waters become warmer each year, which means that populations of pink salmon that migrate later to spawn may be laying eggs in less-than-optimal thermal conditions.

← PREVIOUS

NEXT →



Natural Selection › Generation Time › Scenario

CASE STUDY 3

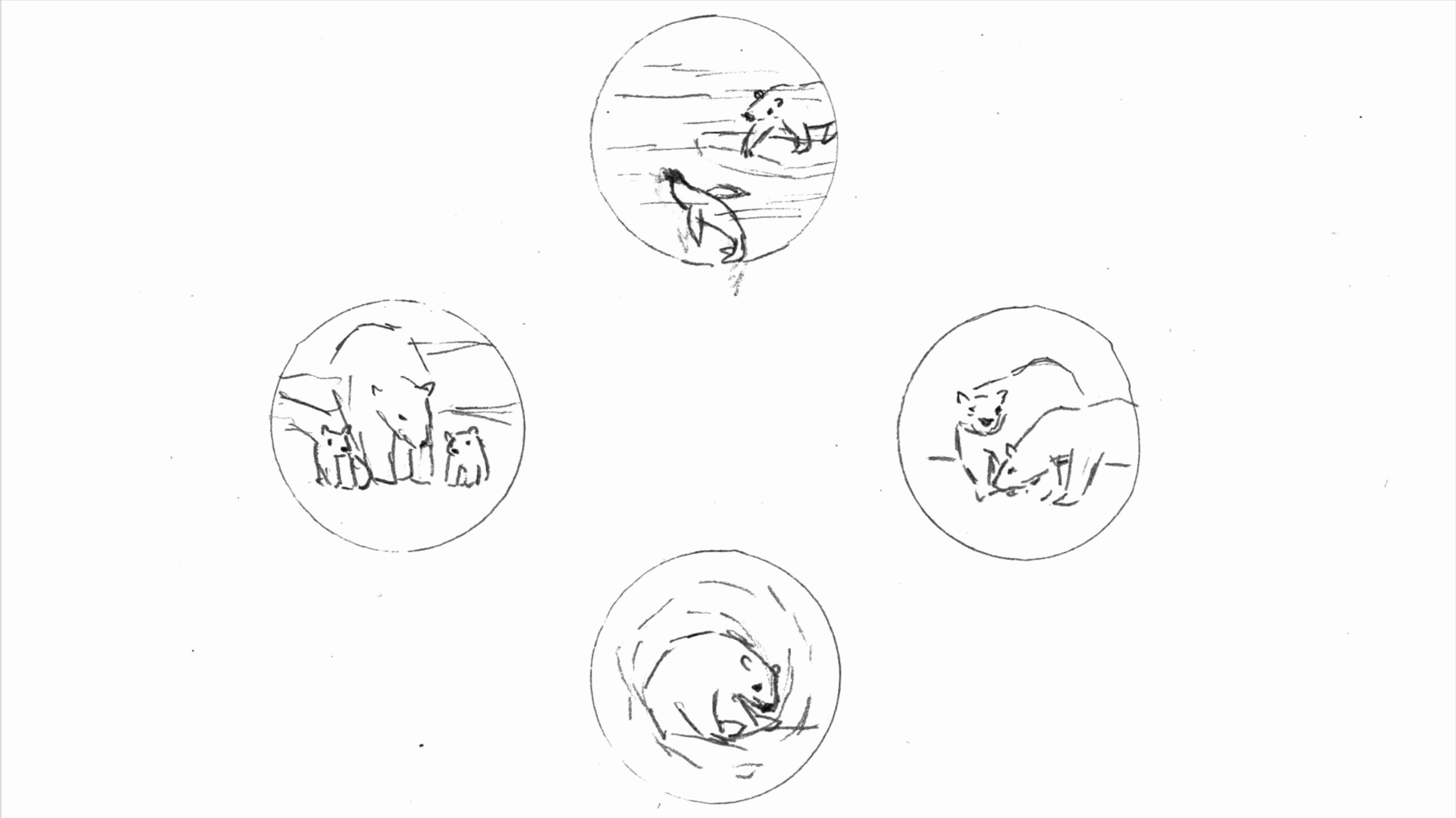
Polar Bear

The native range of the polar bear lies largely within the Arctic Circle. While polar bears can sometimes be found on the tundra, they usually live near water and travel on floating sheets of sea ice to hunt their favourite food, harp seals.

While polar bears begin mating in April and May, fertile eggs remain in a suspended state (i.e., do not implant) until August or September, and only if the mother has enough fat to sustain herself and her cubs during the denning season. Polar bears have an average generation length of 11.5 years.

⟵ PREVIOUS

NEXT ⟶



EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Generation Time › Scenario

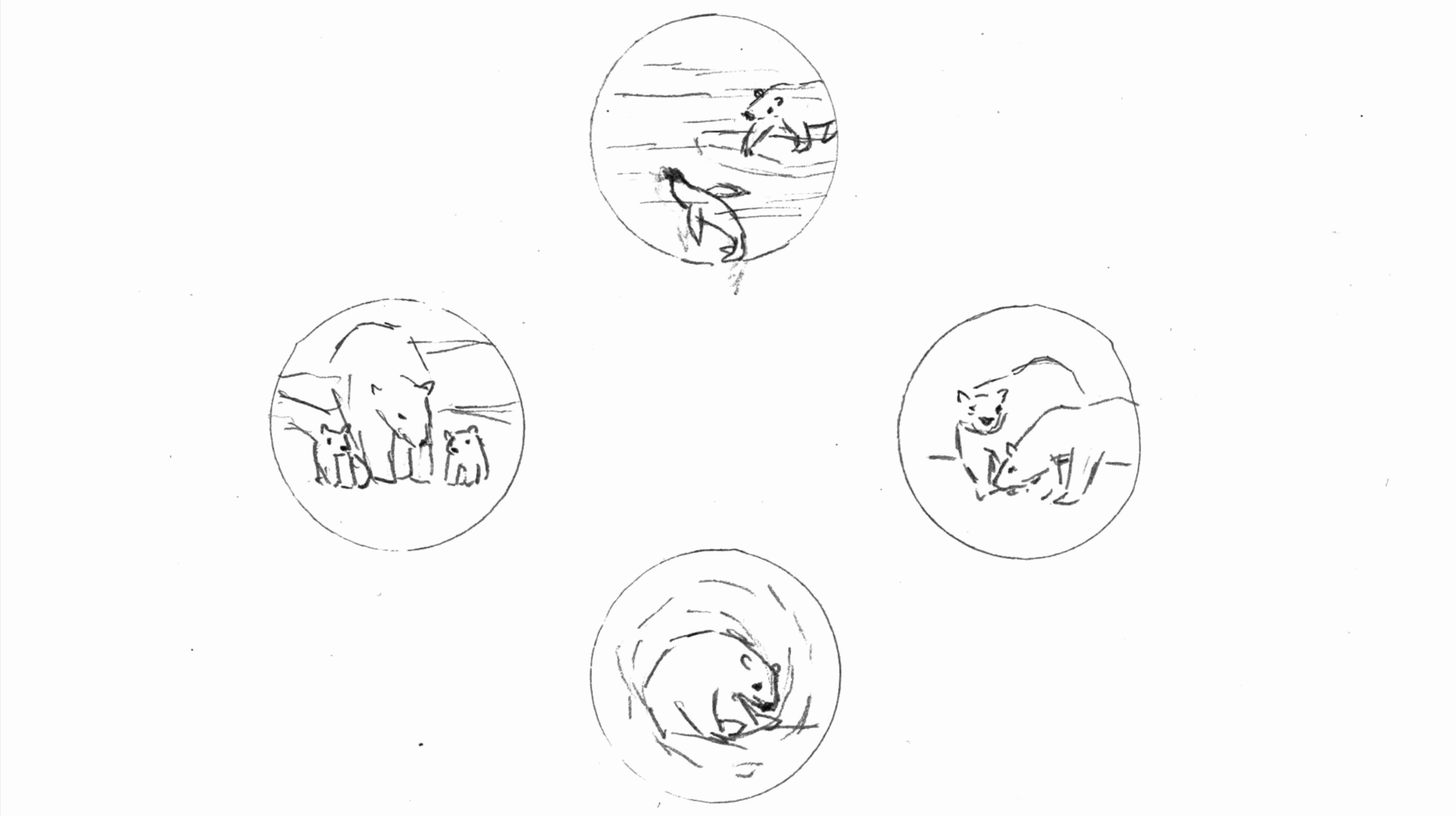
CASE STUDY 3

Polar Bear

With rising temperatures, sea ice melts earlier each year, which makes it difficult for polar bears to hunt and limits them to the shore before they have built enough fat reserves to survive the period of scarce food in late summer and early fall. Insufficient nourishment leads to lower reproductive rates in adult females and lower survival rates in cubs and young bears.

⟵ PREVIOUS

NEXT ⟶



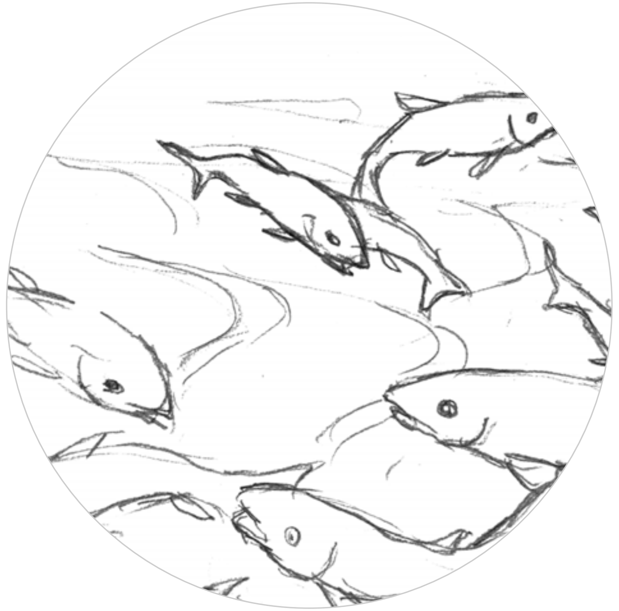
Natural Selection › Generation Time › Scenario › Predict

CASE STUDY 3

Predict

Now as a scientist, you are curious about how generation time can potentially affect how quickly populations can adapt. First, calculate how many generations the pink salmon and polar bears would have gone through in the past 34 years of increasing temperatures, earlier springtime and rising sea levels.

⟵ PREVIOUS NEXT ⟶



Pink salmon have a generation time of **2 years**

Polar bears have a generation time of **11.5 years**

Natural Selection › Generation Time › Scenario › Predict

CASE STUDY 3

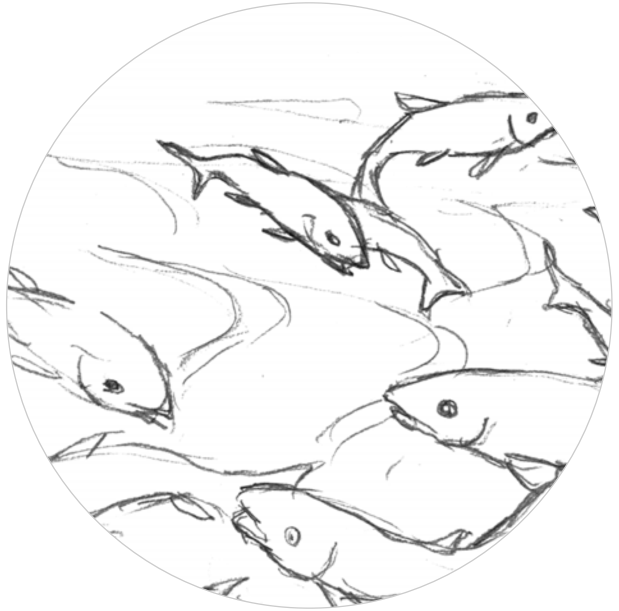
Predict

You've discovered a small percentage of the pink salmon population migrate earlier while most migrate later. You suspect that earlier migration may allow the pink salmon to avoid the warmer temperatures of earlier spring and contribute to overall reproductive success. In addition, you are pleased to find that migration timing has a genetic basis.

As for the polar bear population, let's say you hypothetically discovered that a small percentage of the population possess a trait (trait X) that allows them to have greater reproductive success in warmer climates.

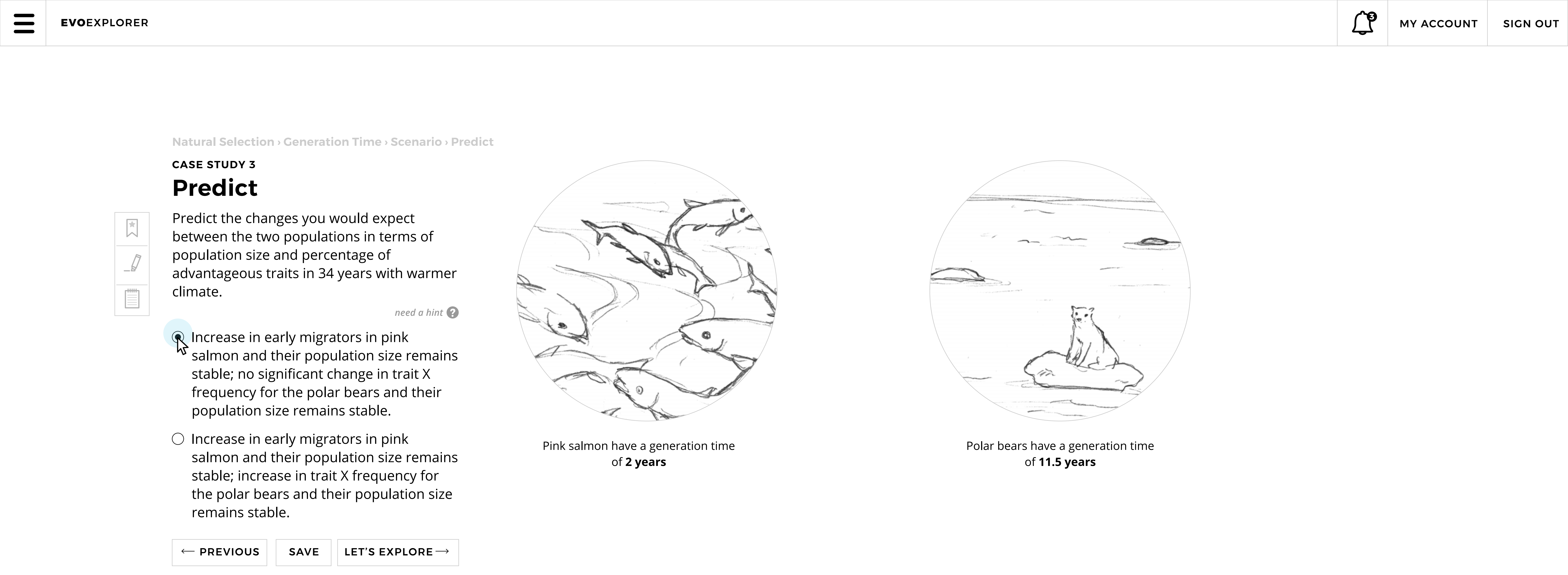
← PREVIOUS

PREDICT →



Pink salmon have a generation time of **2 years**

Polar bears have a generation time of **11.5 years**



Natural Selection › Generation Time › Scenario › Predict

CASE STUDY 3

Predict

Predict the changes you would expect between the two populations in terms of population size and percentage of advantageous traits in 34 years with warmer climate.

- ● Increase in early migrators in pink salmon and their population size remains stable; no significant change in trait X frequency for the polar bears and their population size remains stable.
- ○ Increase in early migrators in pink salmon and their population size remains stable; increase in trait X frequency for the polar bears and their population size remains stable.

Pink salmon have a generation time of **2 years**

Polar bears have a generation time of **11.5 years**

Natural Selection › Generation Time › Scenario › Predict › Experiment

CASE STUDY 3

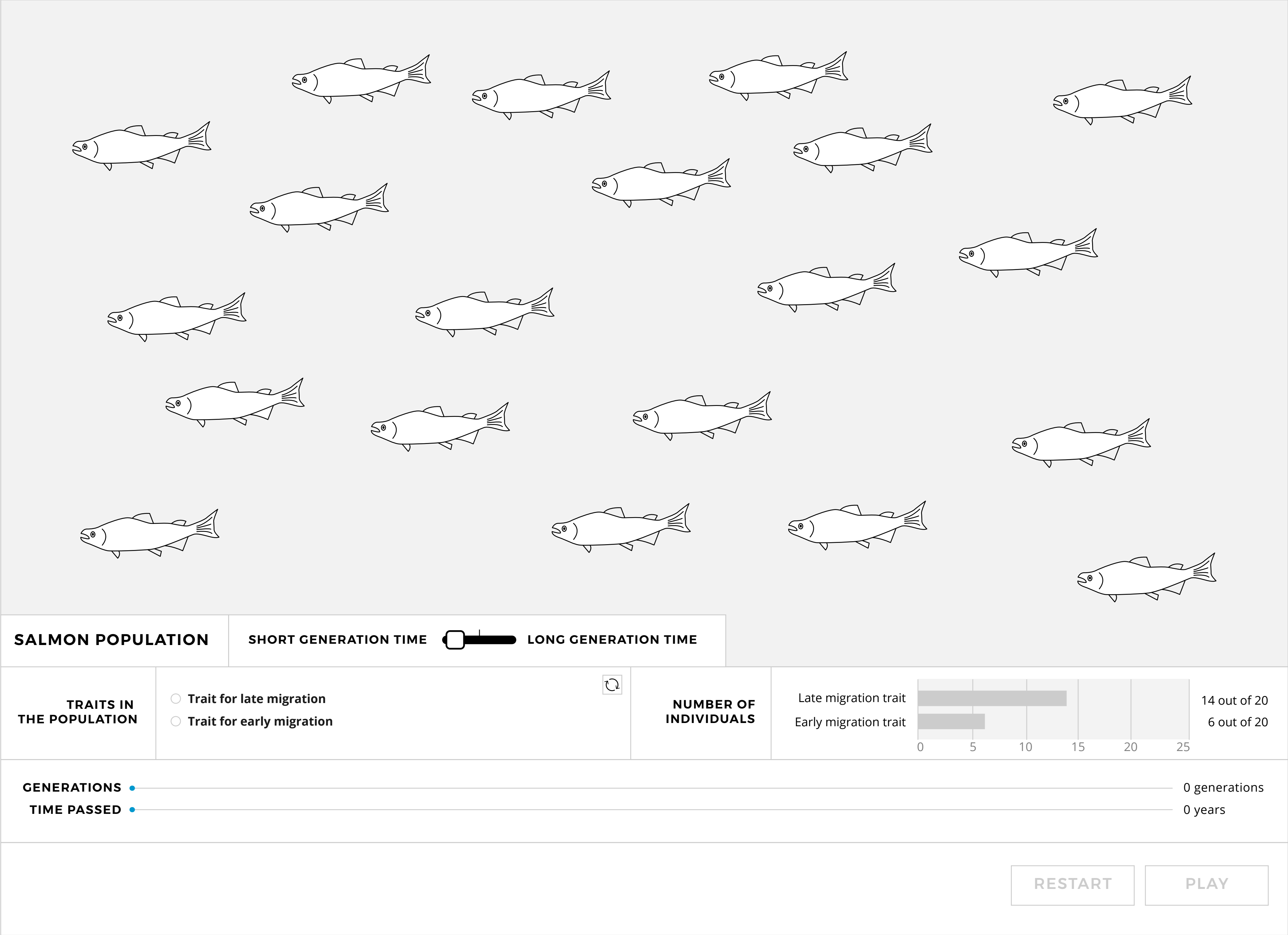
Experiment A

In 34 years, pink salmon population will have gone through 17 generations whereas the polar bears will have gone through approximately 3 generations.

Knowing that a small percentage of the pink salmon population possess traits that leads to earlier migration which may help them avoid the warm temperatures of earlier spring, you predicted that there will be *an increase in early migrators in pink salmon and that the population size will remain stable.*

Toggle towards “short generation time” to observe changes in the salmon population over time.

← PREVIOUS   NEXT →



Late migration trait 14 out of 20
Early migration trait 6 out of 20

GENERATIONS 0 generations
TIME PASSED 0 years

Natural Selection › Generation Time › Scenario › Predict › Experiment

CASE STUDY 3

Experiment A

To observe the overall trend, you decide to collect data on the salmon population for 34 years.

Record how many individuals in the population have or don’t have an advantageous trait for warmer climate in the starting population (generation 0). Click “play” and pause every 2 years to continue collecting data.

CASE STUDY 3 NOTEBOOK | DATA LOG

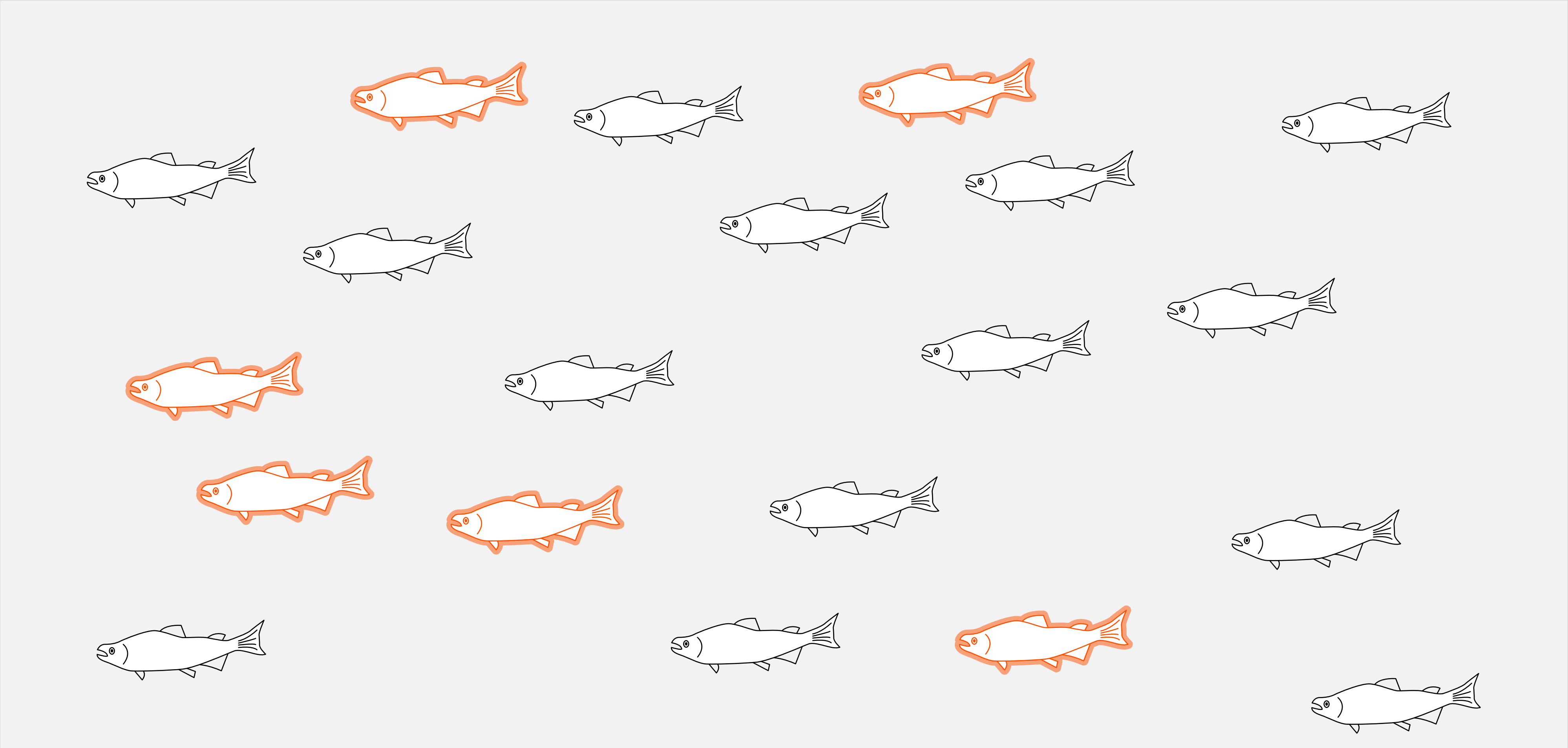
Salmon Population Data

Generation #: 0

Number of individuals	**Trait**
14	Late migration − +
6	Early migration − +

ADD NEW DATA | SAVE

← PREVIOUS | PART B →



SALMON POPULATION

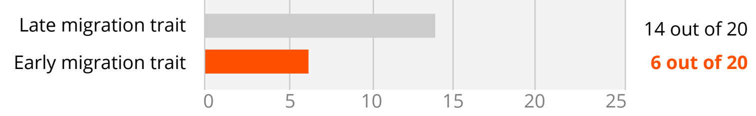
SHORT GENERATION TIME — LONG GENERATION TIME

TRAITS IN THE POPULATION

○ Trait for late migration

● Trait for early migration

NUMBER OF INDIVIDUALS



GENERATIONS 0 generations

TIME PASSED 0 years

RESTART | PLAY

Natural Selection › Generation Time › Scenario › Predict › Experiment

CASE STUDY 3

Experiment A

To observe the overall trend, you decide to collect data on the salmon population for 34 years.

Record how many individuals in the population have or don’t have an advantageous trait for warmer climate in the starting population (generation 0). Click “play” and pause every 2 years to continue collecting data.

CASE STUDY 3 NOTEBOOK | DATA LOG

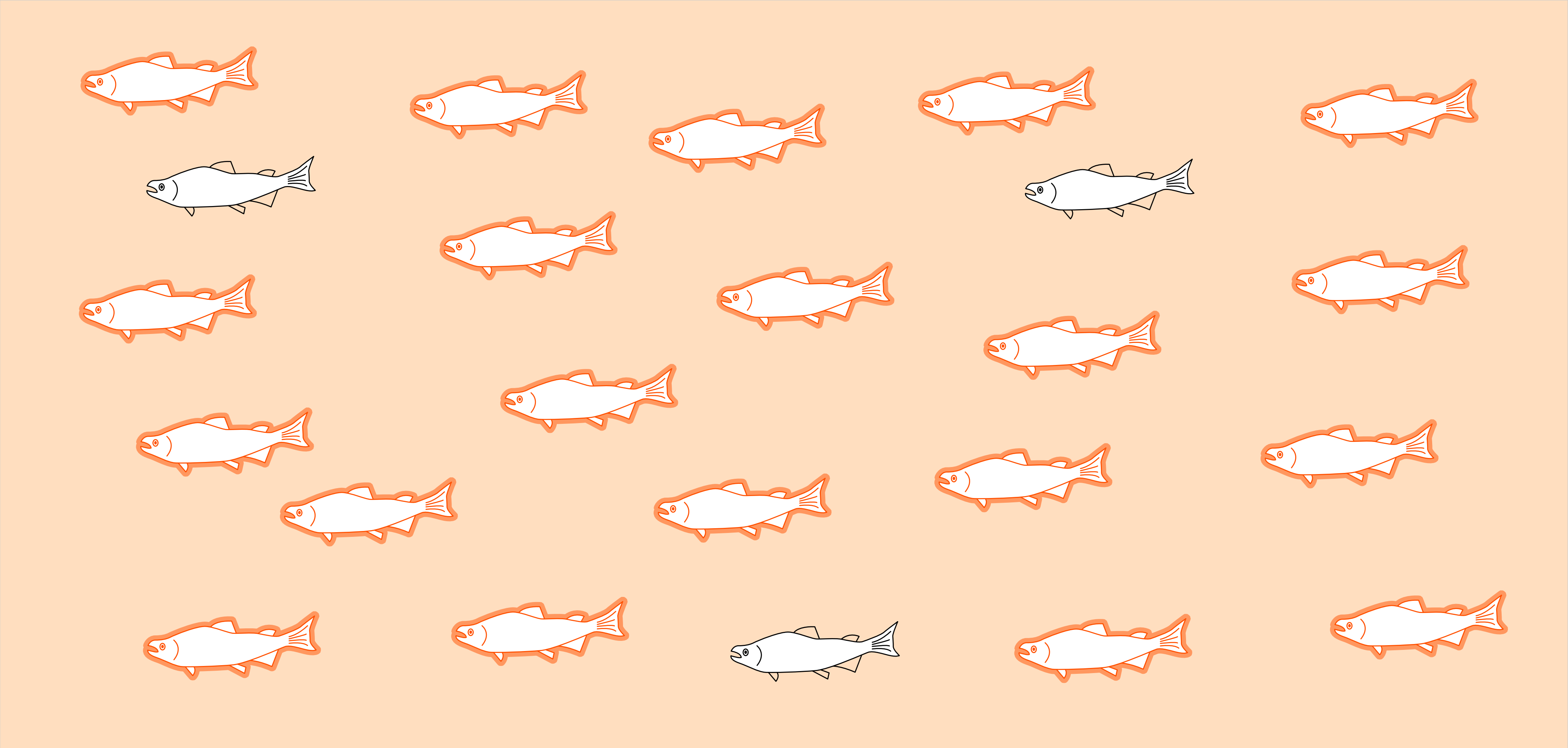
Salmon Population Data

Generation #: 17

Number of individuals	**Trait**
3	Late migration
20	Early migration

ADD NEW DATA | SAVE

← PREVIOUS | PART B →



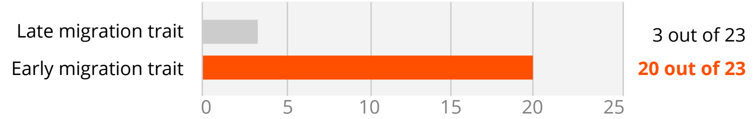
SALMON POPULATION

SHORT GENERATION TIME — LONG GENERATION TIME

TRAITS IN THE POPULATION

○ Trait for late migration
● Trait for early migration

NUMBER OF INDIVIDUALS



3 out of 23
20 out of 23

GENERATIONS 17 generations
TIME PASSED 34 years

RESTART
PLAY

EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Generation Time › Scenario › Predict › Experiment

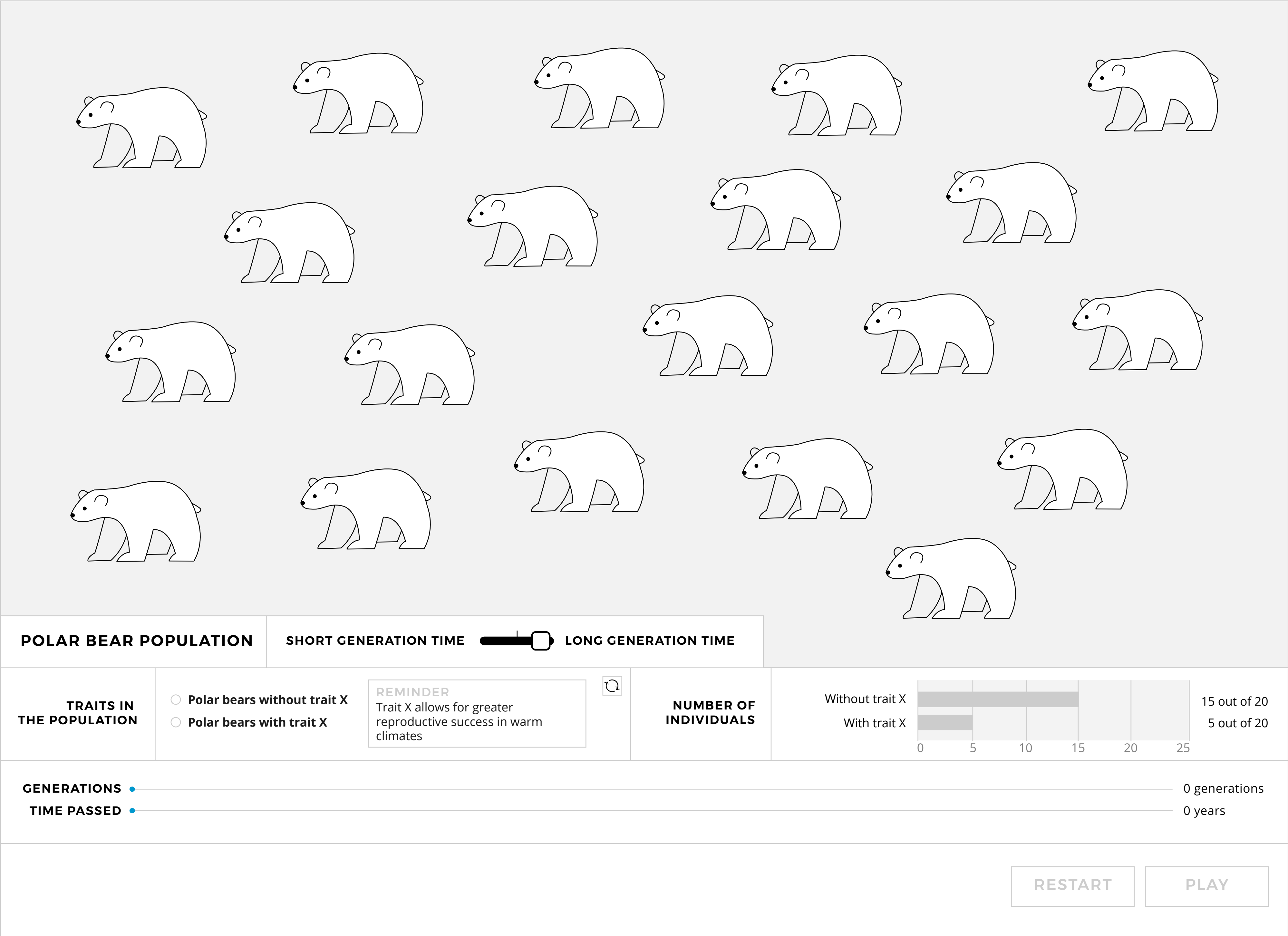
CASE STUDY 3

Experiment B

Next, you plan to observe the polar bears. You have hypothetically discovered trait X that leads to greater chances of survival and reproductive success for the polar bear in a warmer climate. Therefore, you predicted that with a longer generation time, there will be *no significant selection of trait X and the population size of polar bears remains stable.*

Toggle towards “long generation time” to observe the changes in the polar bear population over time.

← PREVIOUS NEXT →



○ Polar bears without trait X

○ Polar bears with trait X

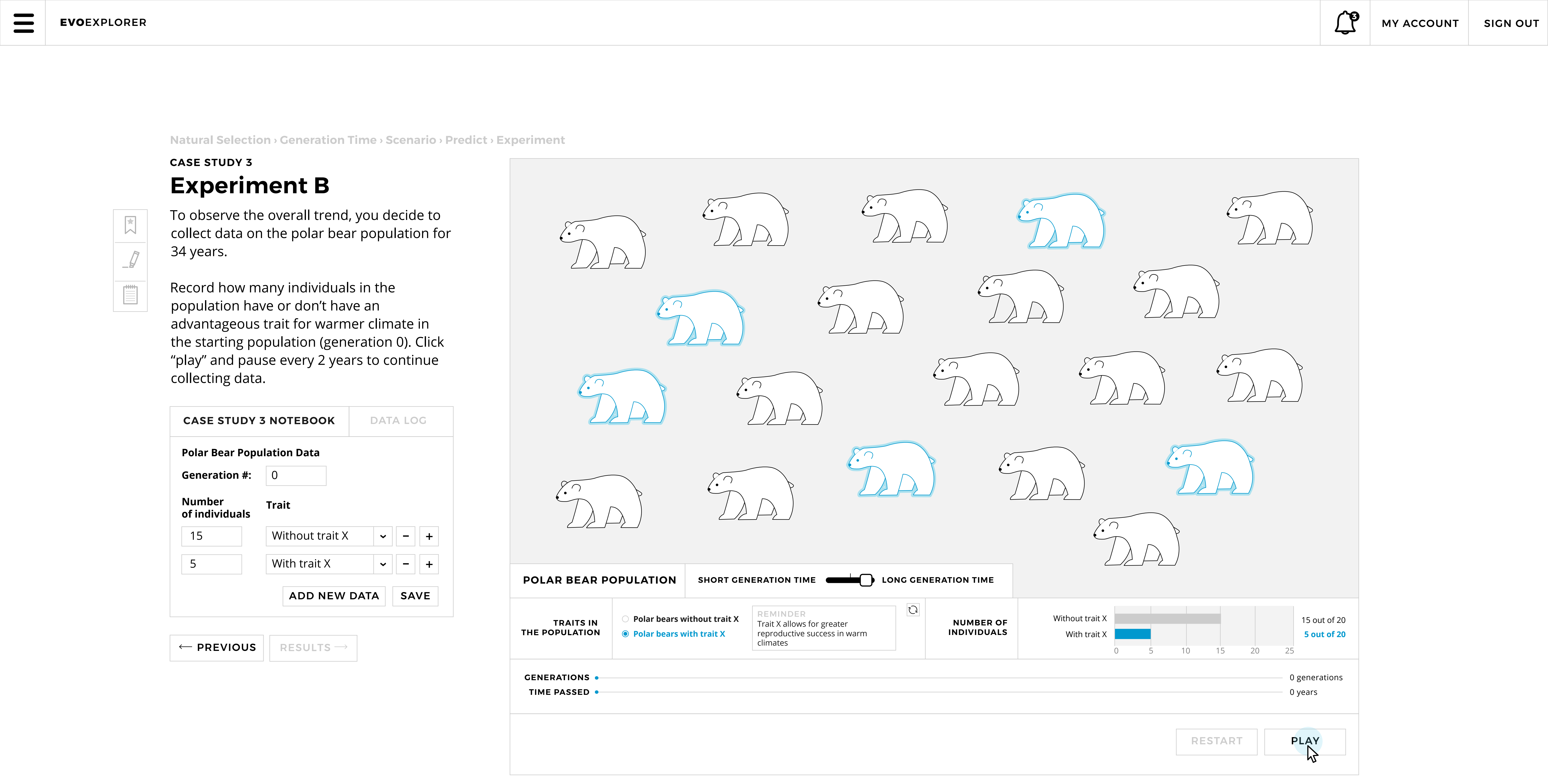
REMINDER
Trait X allows for greater reproductive success in warm climates

Without trait X: 15 out of 20

With trait X: 5 out of 20

GENERATIONS: 0 generations

TIME PASSED: 0 years



Natural Selection › Generation Time › Scenario › Predict › Experiment

CASE STUDY 3

Experiment B

To observe the overall trend, you decide to collect data on the polar bear population for 34 years.

Record how many individuals in the population have or don’t have an advantageous trait for warmer climate in the starting population (generation 0). Click “play” and pause every 2 years to continue collecting data.

Polar Bear Population Data

Generation #: 0

Number of individuals	Trait
15	Without trait X
5	With trait X

○ Polar bears without trait X
● Polar bears with trait X

REMINDER
Trait X allows for greater reproductive success in warm climates

Without trait X: 15 out of 20
With trait X: 5 out of 20

GENERATIONS: 0 generations
TIME PASSED: 0 years

Natural Selection › Generation Time › Scenario › Predict › Experiment

CASE STUDY 3

Experiment B

To observe the overall trend, you decide to collect data on the polar bear population for 34 years.

Record how many individuals in the population have or don't have an advantageous trait for warmer climate in the starting population (generation 0). Click "play" and pause every 2 years to continue collecting data.

CASE STUDY 3 NOTEBOOK | DATA LOG

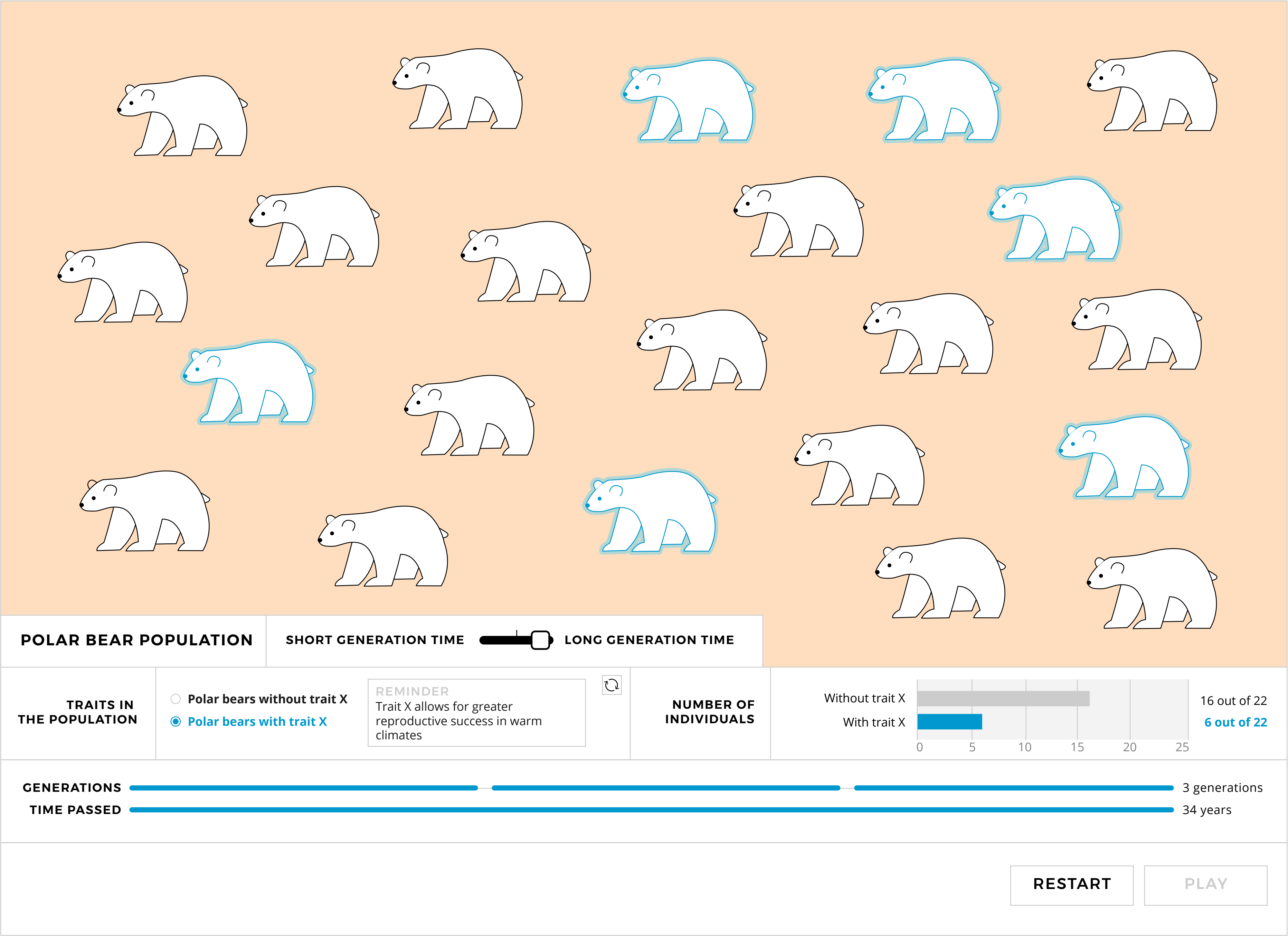
Polar Bear Population Data

Generation #: 3

Number of individuals	**Trait**
16	Without trait X
6	With trait X

ADD NEW DATA SAVE

← PREVIOUS RESULTS →



Natural Selection › Generation Time › Scenario › Predict › Experiment

CASE STUDY 3

Results

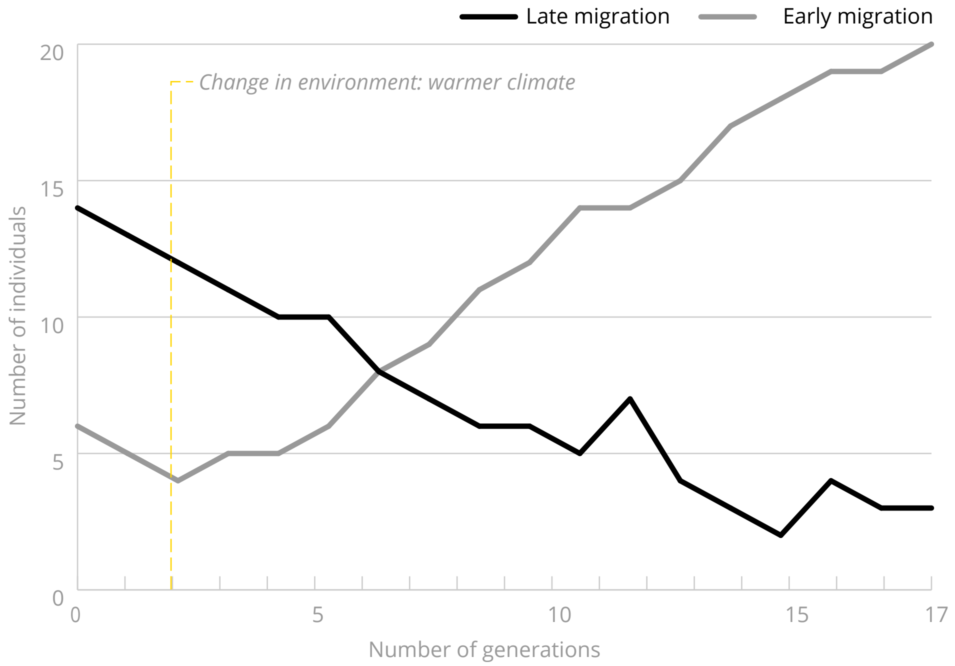
You've hired a statistician to help you plot the data. Your assistant helped with collecting data as well so you have data from every generation. Take a look at your plotted data to observe the trends. Note the changes between the two populations.

Now that you have your data, it's time to analyze them!

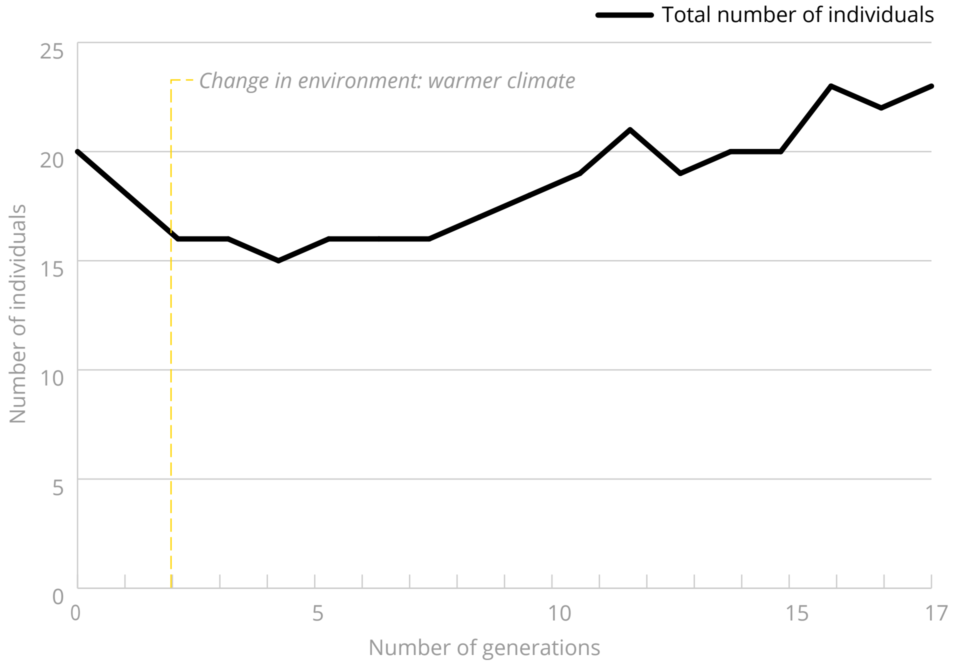
← PREVIOUS ANALYZE →

GRASS POPULATION A ☑ SHORT GENERATION TIME

Number of individuals with a specific trait



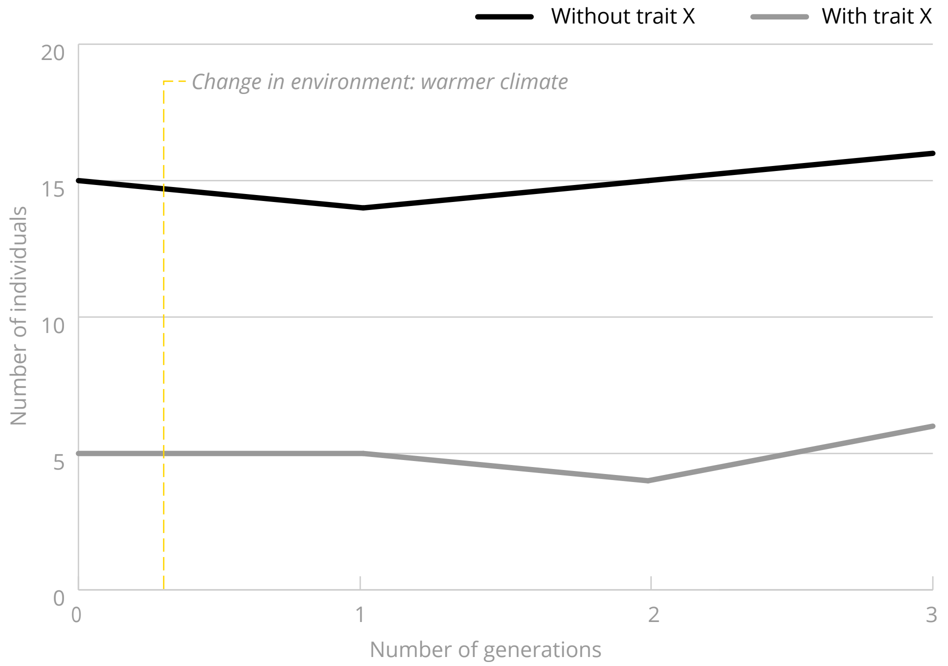
Size of population over generations



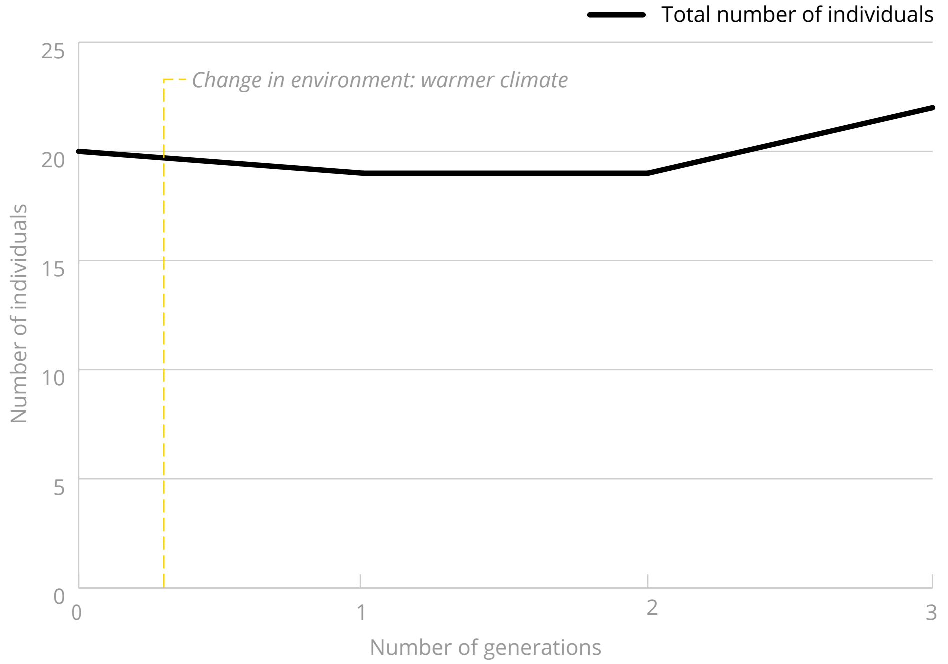
Add notes

GRASS POPULATION B ☑ LONG GENERATION TIME

Number of individuals with a specific trait



Size of population over generations



Add notes

Natural Selection › Genetic Variation › Scenario › Predict › Experiment › Analysis

CASE STUDY 2

Analysis

MY PREDICTIONS

You predicted that there would be an increase in early migrators in pink salmon and their population size remains stable.

You predicted that there would be no significant change in trait X frequency for the polar bears and their population size remains stable.

1. Were your predictions correct or incorrect?

○ Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

● Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

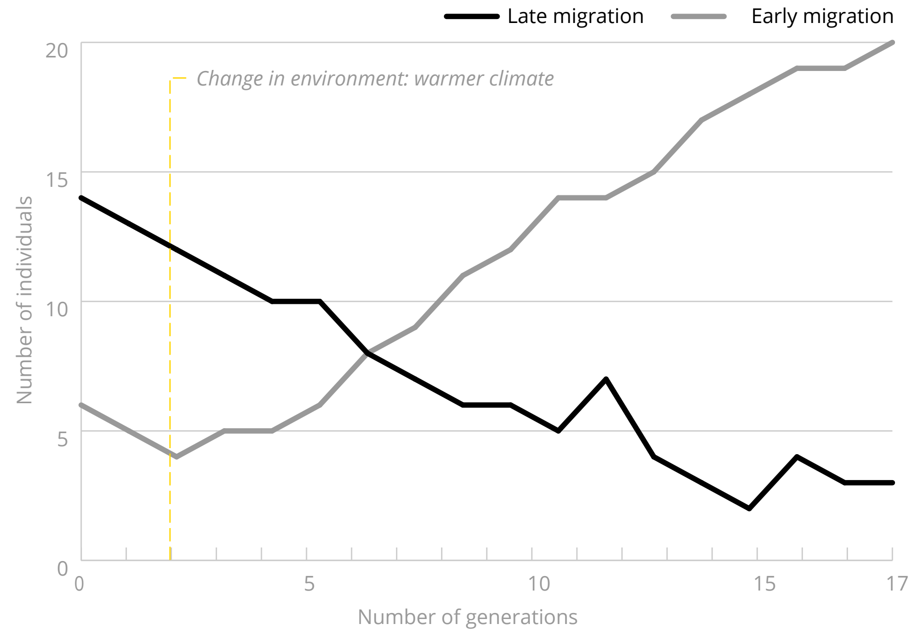
○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

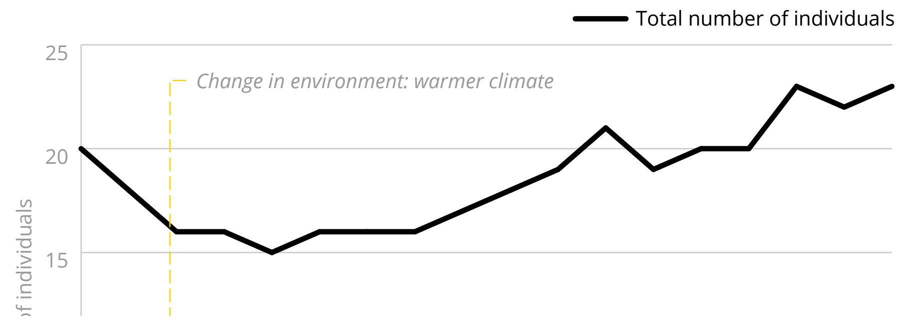
← PREVIOUS SAVE NEXT CASE →

CASE STUDY 3 NOTEBOOK | **EXPERIMENT RESULTS** | NOTES

Number of individuals with a specific trait



Size of population over generations



Experiment A Observations

☑ SHORT GENERATION TIME

A shorter generation time potentially allows for many more cycles of selection to act on advantageous genetic variation.

Changes in migration timing would allow salmon populations to persist under climate warming. With a generation length of two years, this allowed for faster selection of pink salmon that were able to survive and reproduce successfully despite the earlier spring and warming waters. In fact, there was a significant decrease in the frequency of a genetic marker for late-migration timing in the population, indicating that pink salmon has evolved to migrate earlier corresponding with the earlier spring.

EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Bringing it all together

Bringing it all together

Let’s explore how a combination of factors can potentially affect how quickly adaptation by natural selection can occur.

BEGIN CASE STUDY 4 ⟶

EVOEXPLORER

MY ACCOUNT

SIGN OUT

Natural Selection › Bringing it all together › Scenario

CASE STUDY 4

Insecticide Resistance

Insects spread disease and destroy millions of tonnes of crops each year. Farmers often deal with this problem by applying insecticide to their crops. However, the continual use of insecticide has resulted in increased resistance in the insect population to insecticides that were previously effective at controlling the pest. Let’s explore how the three factors we’ve previously investigated (heritability, genetic variation, and generation time) interact to affect how slowly or quickly insecticide resistance may arise.

⟵ PREVIOUS

NEXT ⟶

Natural Selection › Bringing it all together › Scenario › Predict

CASE STUDY 4

Predict

With continuous application of insecticide to a crop that is frequented by a certain population of insects, what combination of factors should the insects possess that would potentially allow the population to rapidly evolve by natural selection?

The insect population should have the following:

○ No factors will make a difference because evolution can only occur slowly

Trait for the upregulation of a gene that codes for a protective enzyme that breaks the pesticide into less toxic chemicals:

● Heritable ○ Non-heritable

Genetic variation:

○ Low ● High

Generation time:

● 10 days ○ 40 days

⟵ PREVIOUS SAVE LET'S EXPLORE ⟶

Natural Selection › Bringing it all together › Scenario › Predict › Experiment

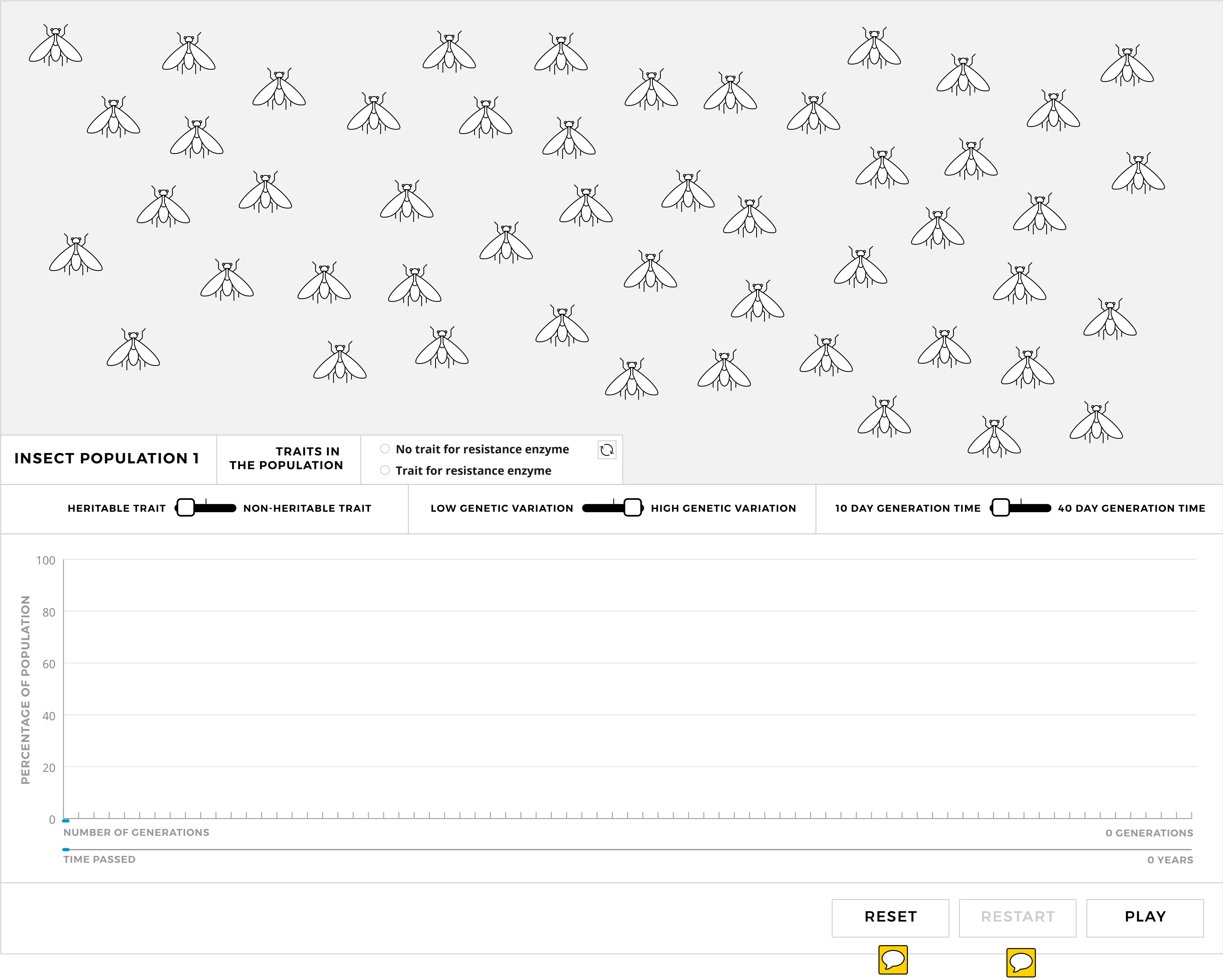
CASE STUDY 4

Experiment

With continuous application of insecticide to the insect population's preferred crop, you predicted that if the population had *a heritable trait for enzyme that breaks down pesticide, high genetic variation and 10 day generation time*, they would potentially be able to rapidly evolve insecticide resistance by natural selection.

Adjust the three toggles according to your prediction.

← PREVIOUS NEXT →



INSECT POPULATION 1

TRAITS IN THE POPULATION

○ No trait for resistance enzyme

○ Trait for resistance enzyme

HERITABLE TRAIT ● NON-HERITABLE TRAIT

LOW GENETIC VARIATION ● HIGH GENETIC VARIATION

10 DAY GENERATION TIME ● 40 DAY GENERATION TIME

Natural Selection › Bringing it all together › Scenario › Predict › Experiment

CASE STUDY 4

Experiment

Observe what happens within 2 years. Record in your Notebook whether insecticide resistance occurs, differences you notice in the percentage of population with the trait for the protective enzyme and when the population is 90% resistant.

Click “save trial” to save your data and the population graph on the left for this combination of factors.

Try at least 4 more combinations of factors by clicking “reset” to see if there are other ways rapid evolution can occur. Remember to save your trials so that you can consult them later in your analysis.

CASE STUDY 4 NOTEBOOK | DATA LOG

Trial variables:

☑ Heritable trait ☑ High genetic variation

☑ 10 days generation time

Does insecticide resistance occur?

○ Yes ○ No ○ Maybe

Percentage of population with...

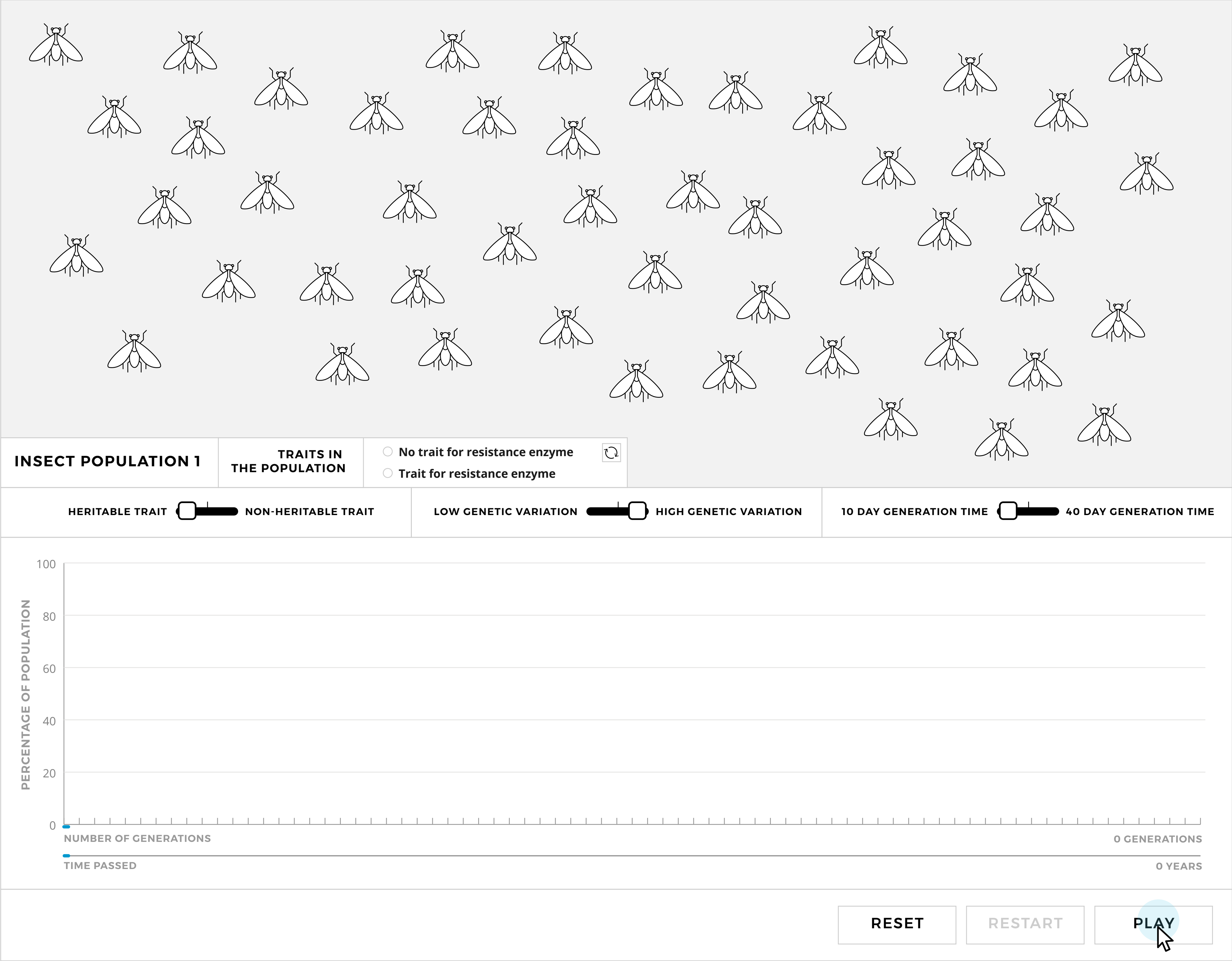
No trait for enzyme *Select an option*

Trait for enzyme *Select an option*

Population is 90% resistant in ____ **years**

SAVE TRIAL

⟵ PREVIOUS RESULTS ⟶



Natural Selection › Bringing it all together › Scenario › Predict › Experiment

CASE STUDY 4

Experiment

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Try at least 4 more combinations of factors by clicking “reset” to see if there are other ways rapid evolution can occur. Remember to save your trials so that you can consult them later in your analysis.

CASE STUDY 4 NOTEBOOK | **DATA LOG**

Trial variables:

- ☑ Heritable trait
- ☑ High genetic variation
- ☑ 10 days generation time

Does insecticide resistance occur?

● Yes ○ No ○ Maybe

Percentage of population with...

No trait for enzyme: decreases

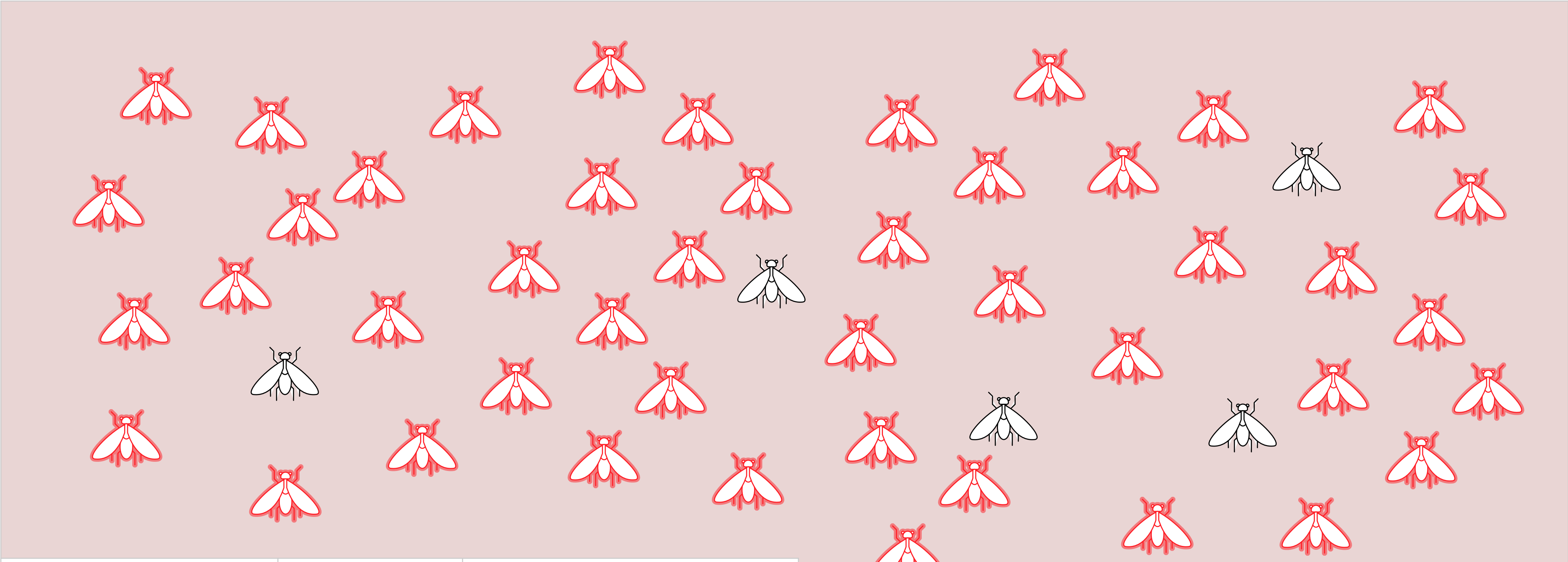
Trait for enzyme: increases

Population is 90% resistant in 2 **years**

SAVED

← PREVIOUS

RESULTS →



INSECT POPULATION 1

TRAITS IN THE POPULATION

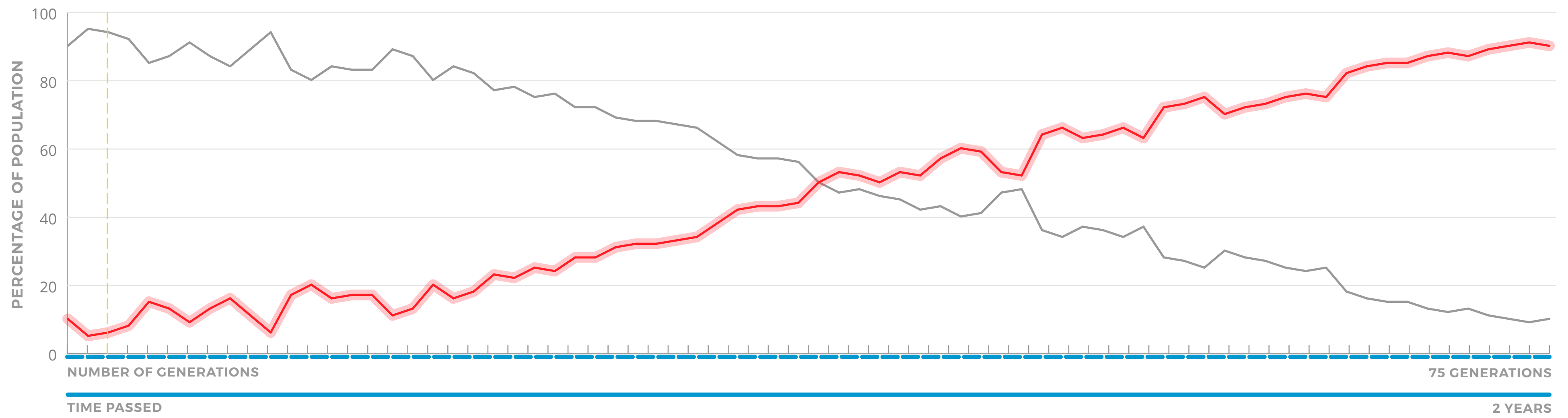
○ No trait for resistance enzyme

● Trait for resistance enzyme

HERITABLE TRAIT / NON-HERITABLE TRAIT

LOW GENETIC VARIATION / HIGH GENETIC VARIATION

10 DAY GENERATION TIME / 40 DAY GENERATION TIME



Natural Selection › Bringing it all together › Scenario › Predict › Experiment

CASE STUDY 4

Experiment

Observe what happens within 2 years. Record in your Notebook whether insecticide resistance occurs, differences you notice in the percentage of population with the trait for the protective enzyme and when the population is 90% resistant.

Click “save trial” to save your data and the population graph on the left for this combination of factors.

Try at least 4 more combinations of factors by clicking “reset” to see if there are other ways rapid evolution can occur. Remember to save your trials so that you can consult them later in your analysis.

CASE STUDY 4 NOTEBOOK | **DATA LOG**

Trial variables:

☑ Heritable trait ☑ High genetic variation

☑ 40 day generation time

Does insecticide resistance occur?

○ Yes ○ No ○ Maybe

Percentage of population with...

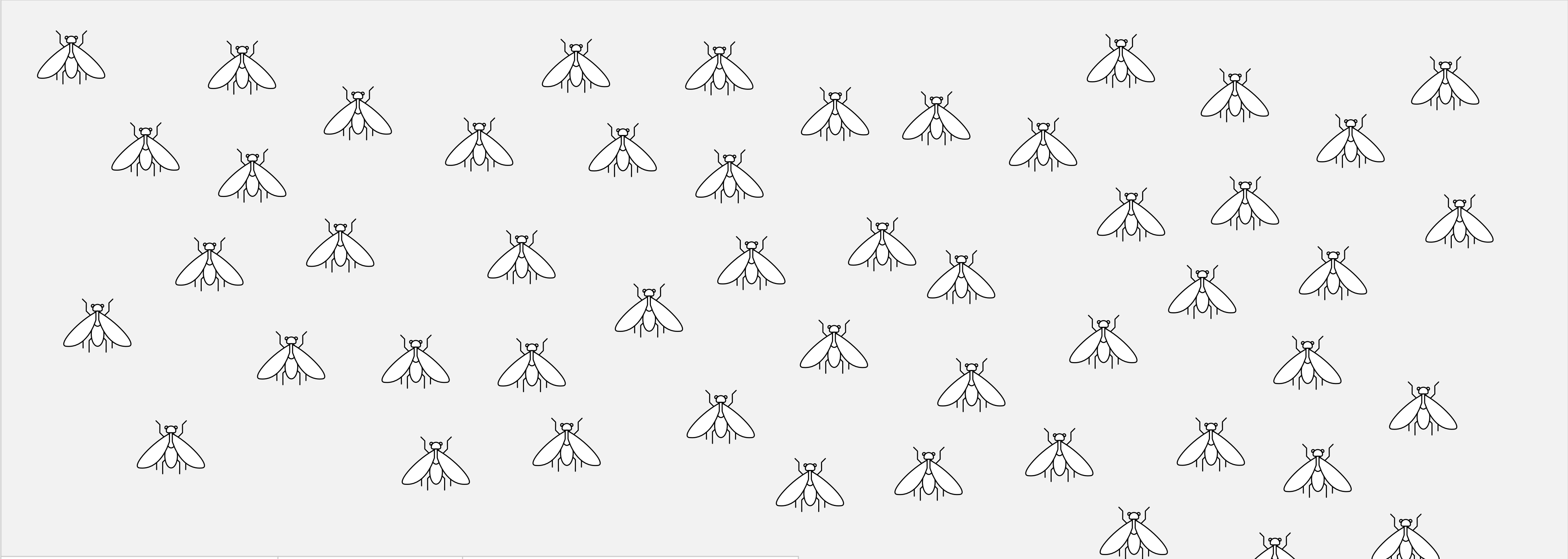
No trait for enzyme: Select an option

Trait for enzyme: Select an option

Population is 90% resistant in ______ years

SAVE TRIAL

← PREVIOUS RESULTS →



INSECT POPULATION 4

TRAITS IN THE POPULATION

○ No trait for resistance enzyme

○ Trait for resistance enzyme

HERITABLE TRAIT — NON-HERITABLE TRAIT

LOW GENETIC VARIATION — HIGH GENETIC VARIATION

10 DAY GENERATION TIME — 40 DAY GENERATION TIME

RESET RESTART PLAY

Natural Selection › Bringing it all together › Scenario › Predict › Experiment

CASE STUDY 4

Experiment

Observe what happens within 2 years. Record in your Notebook whether insecticide resistance occurs, differences you notice in the percentage of population with the trait for the protective enzyme and when the population is 90% resistant.

Click “save trial” to save your data and the population graph on the left for this combination of factors.

Try at least 4 more combinations of factors by clicking “reset” to see if there are other ways rapid evolution can occur. Remember to save your trials so that you can consult them later in your analysis.

CASE STUDY 4 NOTEBOOK | **DATA LOG**

Trial variables:

☑ Heritable trait ☑ High genetic variation

☑ 40 days generation time

Does insecticide resistance occur?

○ Yes ○ No ● Maybe

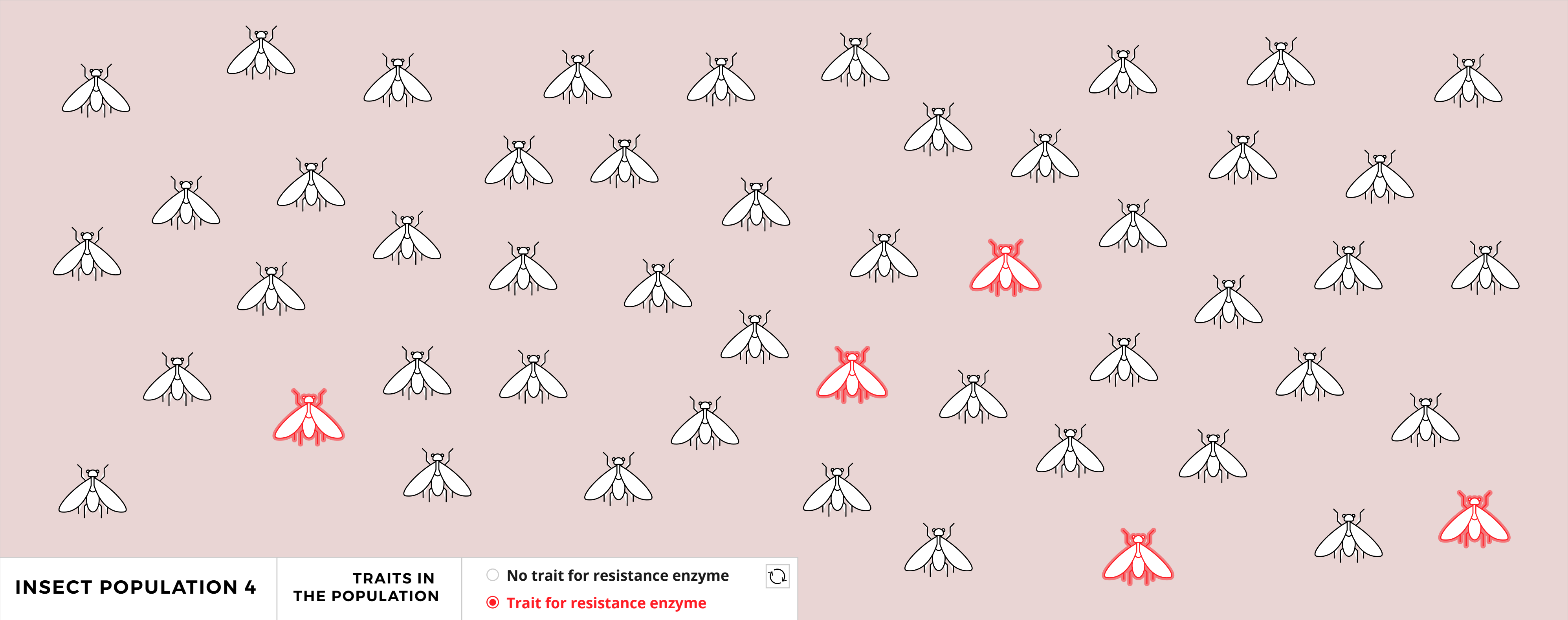
Percentage of population with...

No trait for enzyme: no change

Trait for enzyme: no change

Population is 90% resistant in unknown **years**

SAVE TRIAL



INSECT POPULATION 4

TRAITS IN THE POPULATION

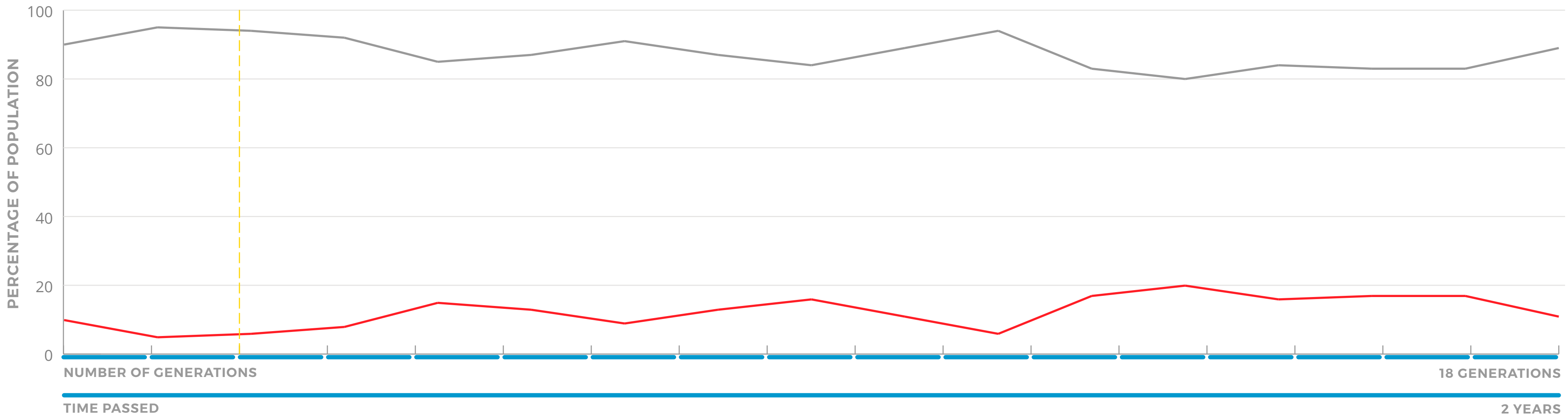
○ No trait for resistance enzyme

● Trait for resistance enzyme

HERITABLE TRAIT / NON-HERITABLE TRAIT

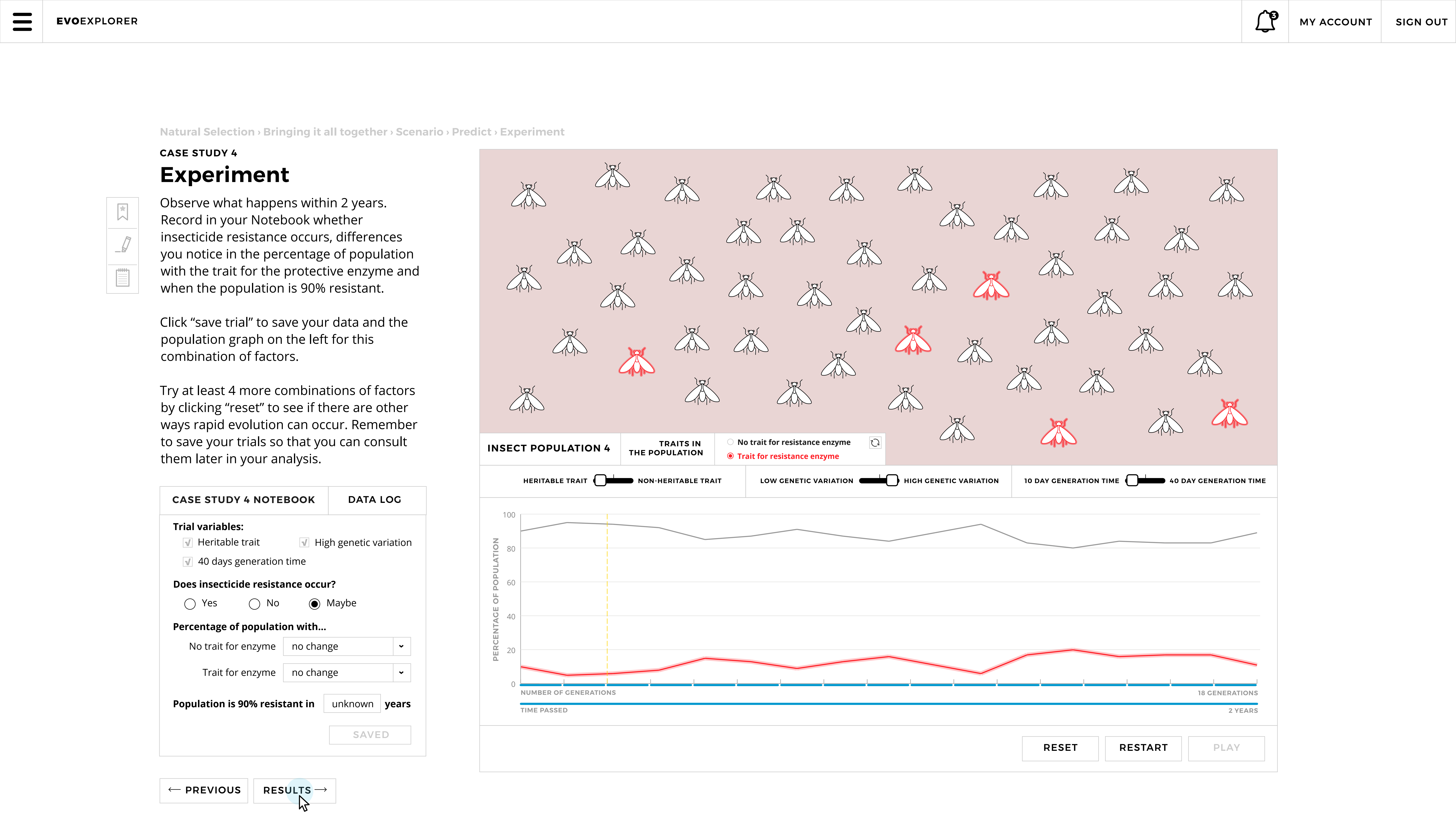
LOW GENETIC VARIATION / HIGH GENETIC VARIATION

10 DAY GENERATION TIME / 40 DAY GENERATION TIME



RESET RESTART PLAY

← PREVIOUS RESULTS →



Natural Selection › Bringing it all together › Scenario › Predict › Experiment

CASE STUDY 4

Experiment

Observe what happens within 2 years. Record in your Notebook whether insecticide resistance occurs, differences you notice in the percentage of population with the trait for the protective enzyme and when the population is 90% resistant.

Click "save trial" to save your data and the population graph on the left for this combination of factors.

Try at least 4 more combinations of factors by clicking "reset" to see if there are other ways rapid evolution can occur. Remember to save your trials so that you can consult them later in your analysis.

CASE STUDY 4 NOTEBOOK | **DATA LOG**

Trial variables:

☑ Heritable trait ☑ High genetic variation

☑ 40 days generation time

Does insecticide resistance occur?

○ Yes ○ No ● Maybe

Percentage of population with...

No trait for enzyme: no change

Trait for enzyme: no change

Population is 90% resistant in unknown **years**

CASE STUDY 4

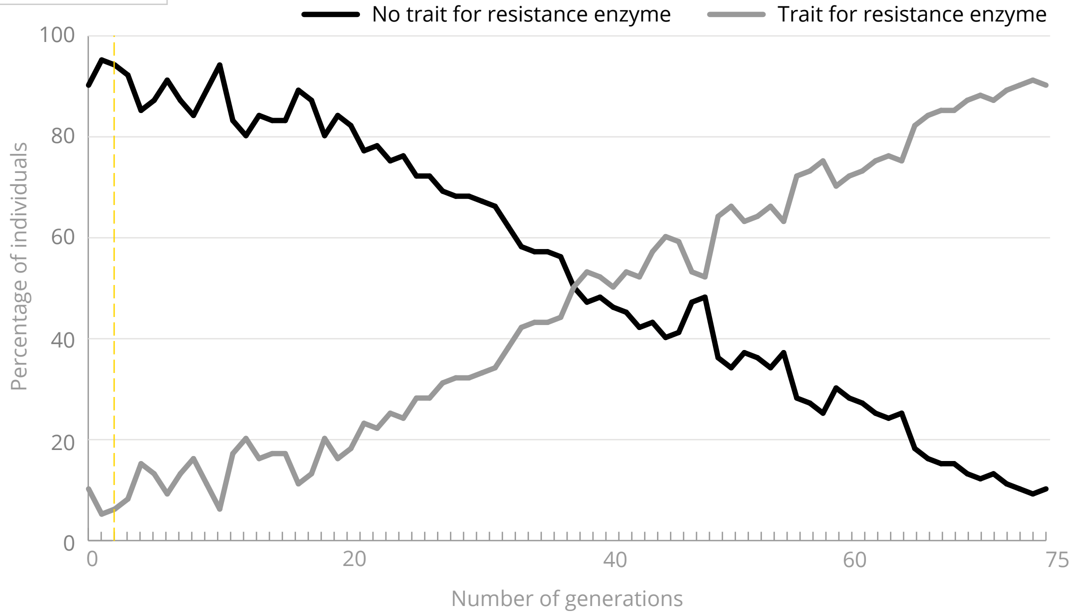
Results

You've hired a statistician to help you plot the data. Your assistant helped with collecting data as well so you have data from every generation. Take a look at your plotted data to observe the trends. Note the changes between the two populations.

Now that you have your data, it's time to analyze them!

← PREVIOUS ANALYZE →

TRIAL 1



☑ HERITABLE TRAIT
☑ HIGH GENETIC VARIATION
☑ SHORT GENERATION TIME

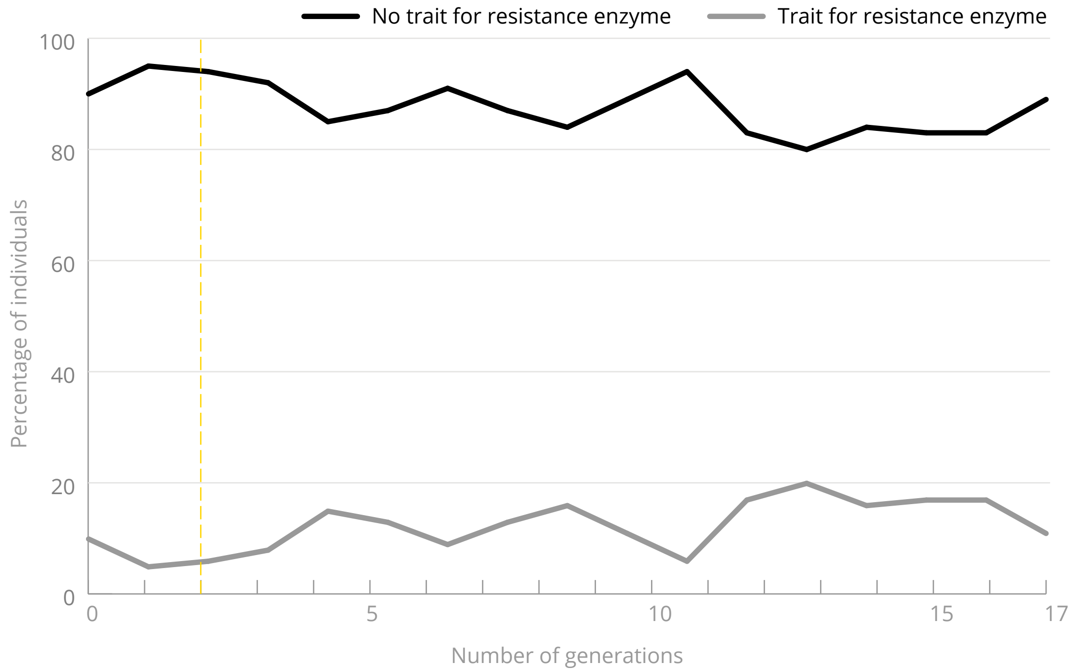
Insecticide resistance does occur.
Percentage of population with
- › no trait for enzyme decreases.
- › trait for enzyme increases.

Population is 90% resistant in 2 years.

Add notes

SAVE NOTES

TRIAL 2



☑ HERITABLE TRAIT
☑ HIGH GENETIC VARIATION
☑ LONG GENERATION TIME

Insecticide resistance may occur.
Percentage of population with
- › no trait for enzyme: no significant change.
- › trait for enzyme: no significant change.

Population is 90% resistant in unknown years.

Add notes

SAVE NOTES

EVOEXPLORER

3 MY ACCOUNT SIGN OUT

Natural Selection › Bringing it all together › Scenario › Predict › Experiment › Analysis

CASE STUDY 4

Analysis

MY PREDICTIONS

You predicted that with continuous application of insecticide to the insect population's preferred crop, you predicted that if the population had a heritable trait for enzyme that breaks down pesticide, high genetic variation and 10 day generation time, they would potentially be able to rapidly evolve insecticide resistance by natural selection.

1. Were your predictions correct or incorrect?

○ Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

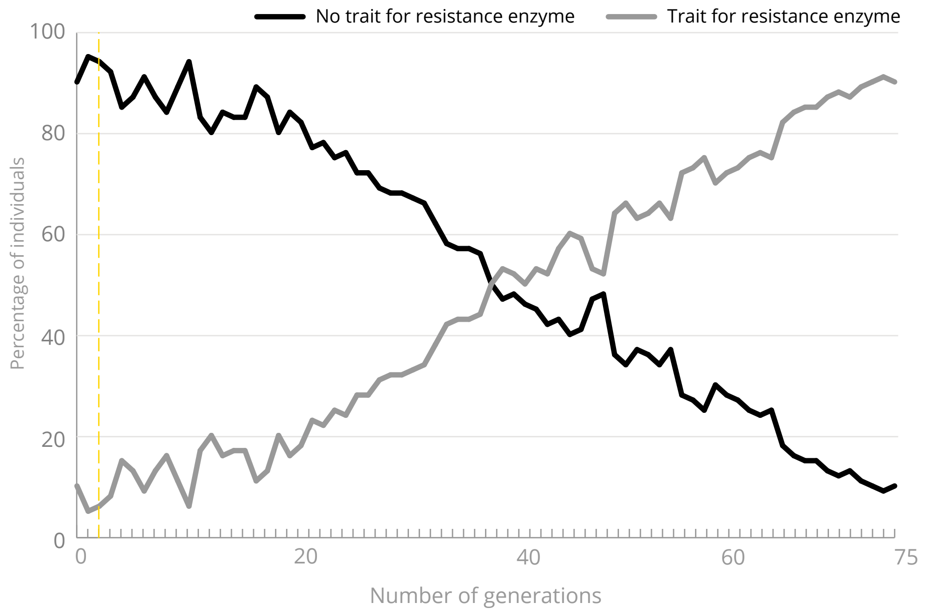
● Yes because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

○ No because lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.

← PREVIOUS SAVE CLOSING STATEMENT →

CASE STUDY 4 NOTEBOOK | EXPERIMENT RESULTS | NOTES

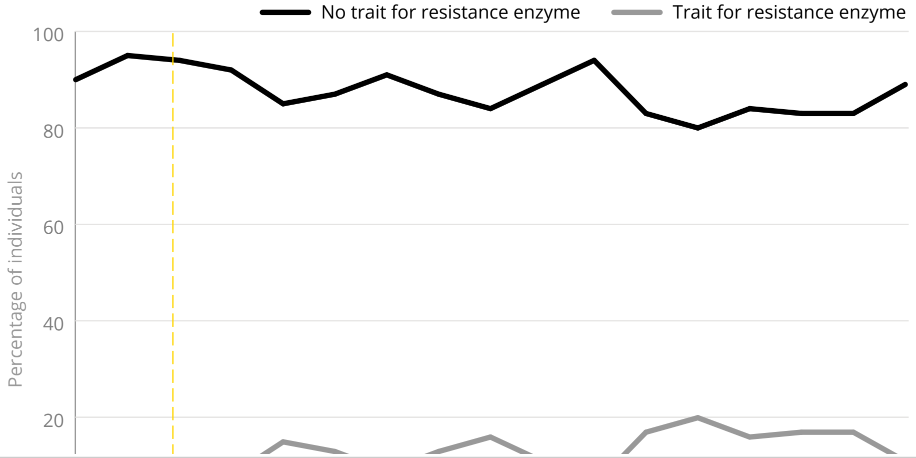


Trial 1 Observations

☑ HERITABLE TRAIT
☑ HIGH GENETIC VARIATION
☑ SHORT GENERATION TIME

Insecticide resistance does occur.
Percentage of population with
- no trait for enzyme decreases.
- trait for enzyme increases.

Population is 90% resistant in 2 years.



Trial 2 Observations

☑ HERITABLE TRAIT
☑ HIGH GENETIC VARIATION
☑ LONG GENERATION TIME

Insecticide resistance may occur.
Percentage of population with
- no trait for enzyme: no significant change.
- trait for enzyme: no significant change.

Population is 90% resistant in unknown years.

Natural Selection › Closing Statement

Selection, not perfection: limitations to natural selection

In summary, natural selection is a process that requires heritability, phenotypic variation, and differential reproductive success in response to a selection pressure. It might be tempting to think of adaptation as a drive towards perfection, but that's not true! The new population likely is better adapted to new environmental conditions but it may come at a cost or may be disadvantageous if the environment changes. Natural selection acts on all variable traits that contribute to the survival and reproduction of a species, and often, selected traits may not be ideal or “perfectly” designed for their lifestyle. What matters is relative and not ultimate fitness or reproductive success.

NEXT →

Natural Selection › Closing Statement

Selection, not perfection: limitations to natural selection

Adaptations can be less-than-perfect because there are limitations to natural selection:

The presence of heritable phenotypic variation limits the response to selection: Natural selection can only select phenotypic variants currently present in the population. If there is a lack of the necessary heritable phenotypic variation, selection pressure itself cannot create an advantageous phenotype – selection can only act on existing heritable phenotypic variations.

PREVIOUS

NEXT →

Natural Selection › Closing Statement

Selection, not perfection: limitations to natural selection

Adaptations can be less-than-perfect because there are limitations to natural selection:

Species may retain non-adaptive features or be unable to evolve adaptive traits due to their phylogenetic histories (phenotypic and genetic variation). Remember, evolution is “modification with descent”, meaning that it operates on traits that are present in a population, primarily those that were passed down from ancestral forms.

For example, birds with long necks, such as swans, have more neck vertebrae than birds with shorter necks. However, almost all mammals have seven neck vertebrae including giraffes and whales despite the extreme differences in the lengths of their necks. The number of vertebrae is a trait established in the first mammals and thus has become a phylogenetic (historical) constraint that has not been optimized by natural selection during the evolution of long necks in certain mammals such as giraffes.

PREVIOUS NEXT →

Natural Selection › Closing Statement

Selection, not perfection: limitations to natural selection

Adaptations can be less-than-perfect because there are limitations to natural selection:

There are often trade-offs to adaptations; changes to one trait that increases reproductive success can be linked to changes in other traits that decrease reproductive success.

For example, cheetahs have longer and more slender leg bones, which allow them to run with great speed, but long and slender bones are weaker and is susceptible to break.

PREVIOUS TEST YOUR KNOWLEDGE! ⟶

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Natural Selection › Post-Quiz

POST-QUIZ

Test your knowledge!

Review your answers from the pre-quiz and see if you would like to make any changes.

(A) Natural selection occurs because the organism needs to adapt

○ True ○ False ● I don’t know

(B) Natural selection will result in an organism being a perfect match to the environment

○ True ● False ○ I don’t know

(C) Individuals cannot adapt

● True ○ False ○ I don’t know

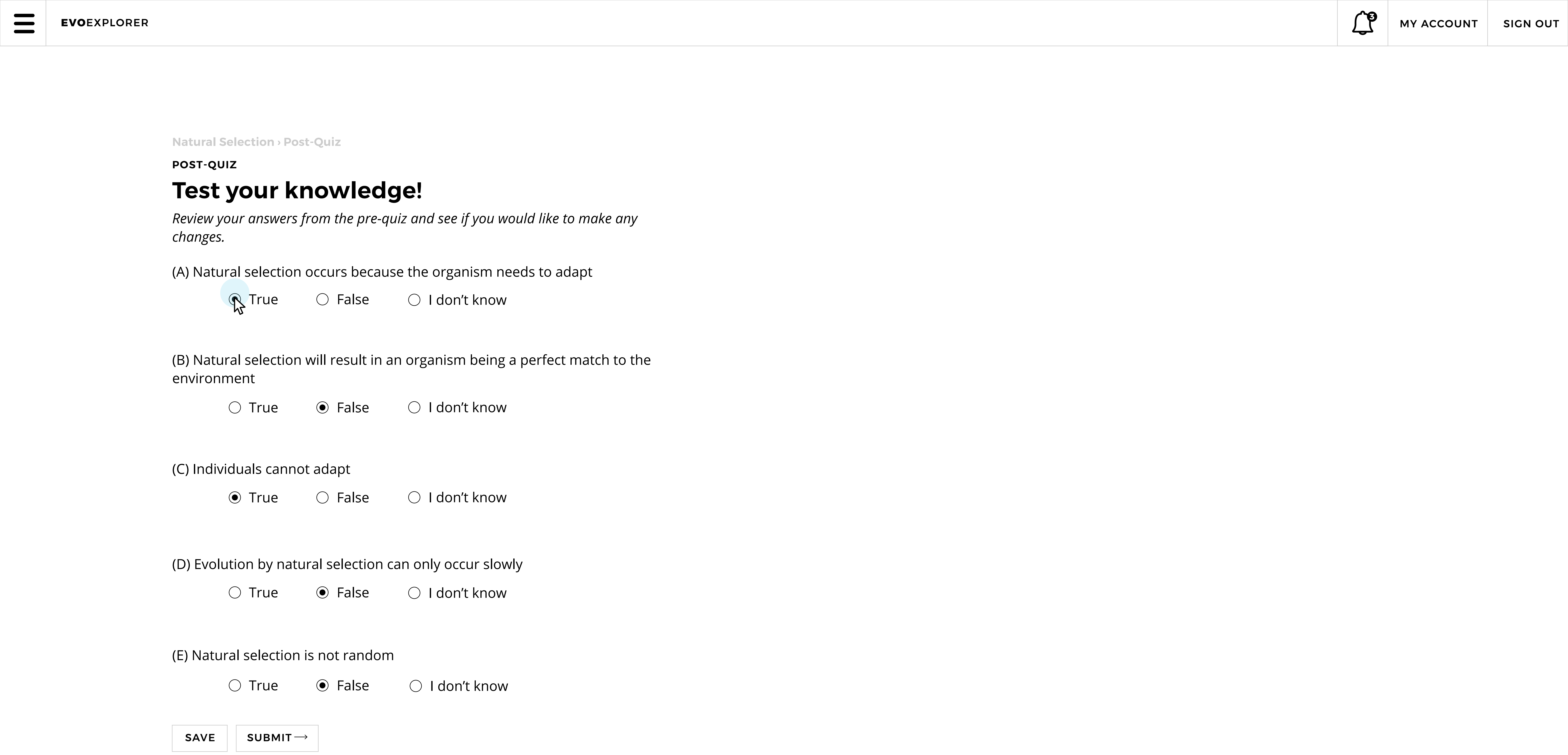
(D) Evolution by natural selection can only occur slowly

○ True ● False ○ I don’t know

(E) Natural selection is not random

○ True ● False ○ I don’t know

SAVE SUBMIT ⟶



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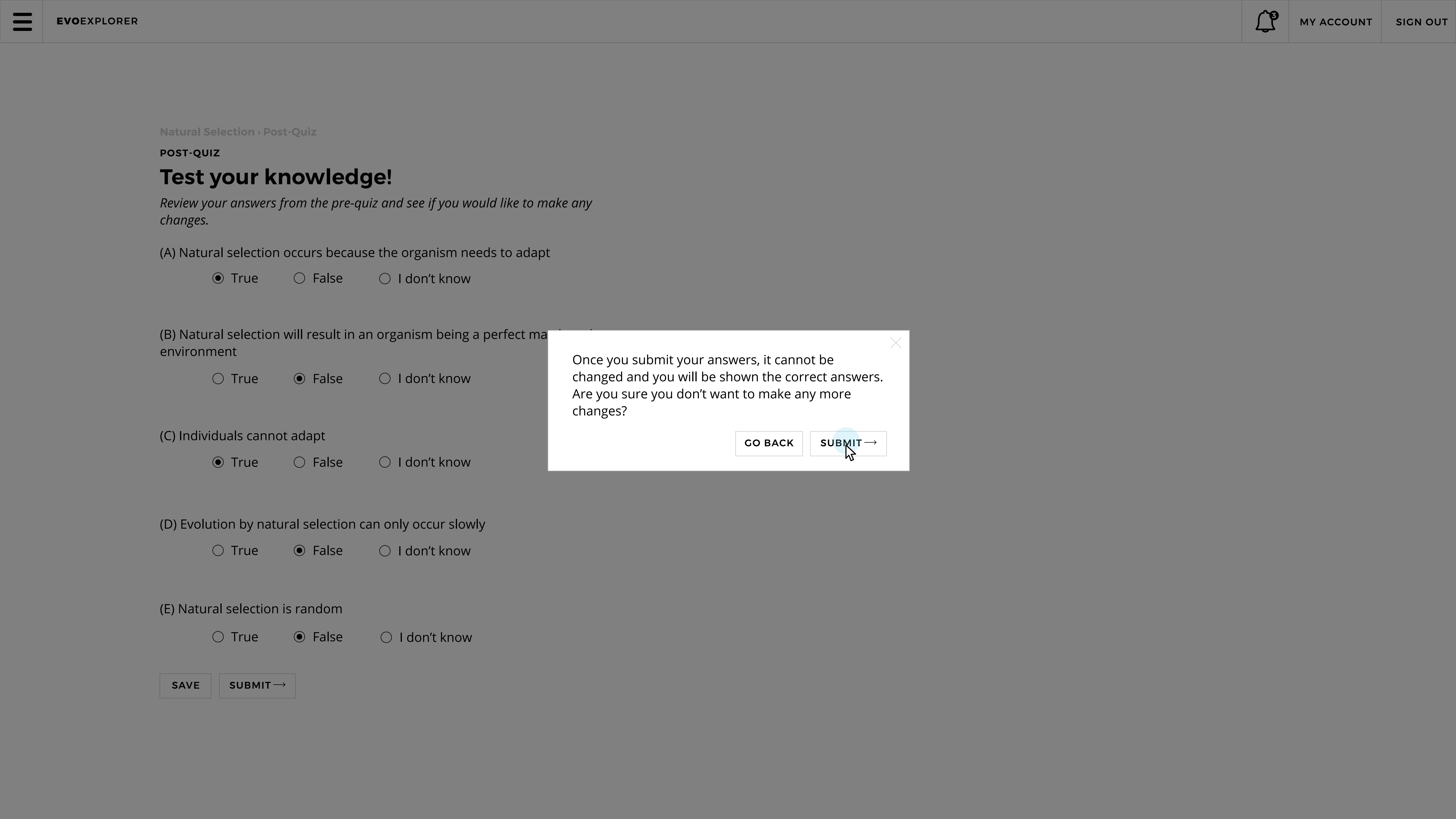

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Once you submit your answers, it cannot be changed and you will be shown the correct answers. Are you sure you don’t want to make any more changes?

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Natural Selection › Post-Quiz

POST-QUIZ

Test your knowledge!

The following are the answers to the quiz.

(A) Natural selection occurs because the organism needs to adapt

● True ✗　○ False

Answer: Your answer is incorrect. The answer is false. There is no goal or aim to adaptation by natural selection, i.e., organisms can't adapt because they desire or "need" to, they adapt if there is a heritable genetic trait that confers an advantage in which they are better able to survive and reproduce.

Review:
Bookmarks ›
Notebooks ›
Heritability ›
Genetic Variation ›

(B) Natural selection will result in an organism being a perfect match to the environment

○ True　● False ✓

Answer: You are correct. The answer is false. Often, adaptations may result in trade-offs in which adaptive traits comes with disadvantages that make it harder for an organism to survive and/or reproduce in the same or a different environment.

(C) Individuals cannot adapt

● True ✓　○ False

Answer: You are correct. The answer is true. Adaptation is a product of evolution by natural selection. Natural selection is a process that involves changes in the genetic makeup of populations over time, therefore, populations can evolve, and species can adapt, but individuals cannot evolve or adapt in their lifespan.

(D) Evolution by natural selection can only occur slowly

○ True　● False ✓