Microevolution: Modes of speciation
Core course: ZOOL3014
B.Sc. (Hons'): VIth Semester

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Modes of Speciation

The key to speciation is the evolution of genetic differences between the incipient species

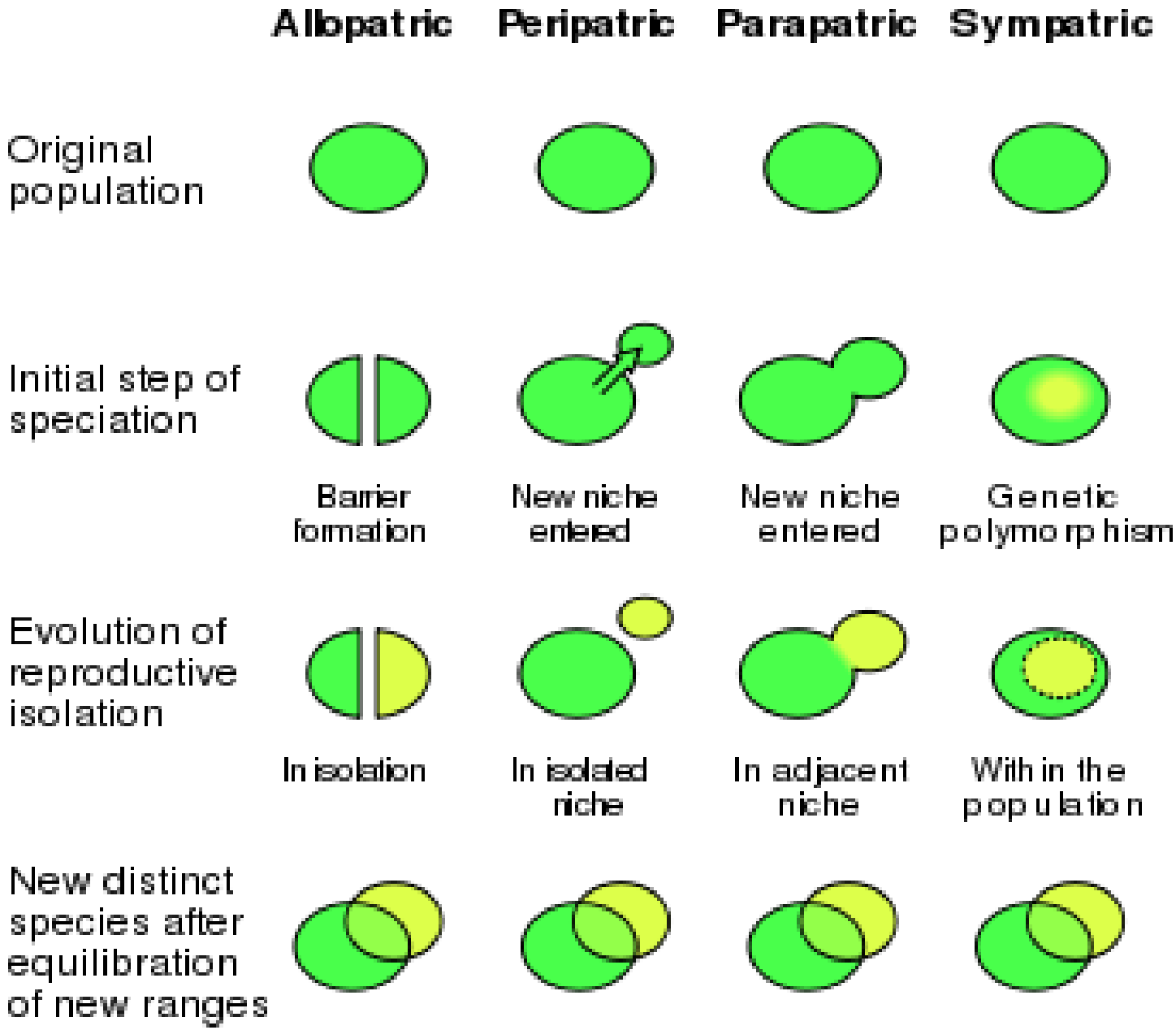
For a lineage to split once and for all, the two incipient species must have genetic differences that are expressed in some way that cause matings between them to either not happen or to be unsuccessful

These need not be huge genetic differences A small change in the timing, location, or rituals of mating could be enough. But still, some difference is necessary

This change might evolve by natural selection or genetic drift

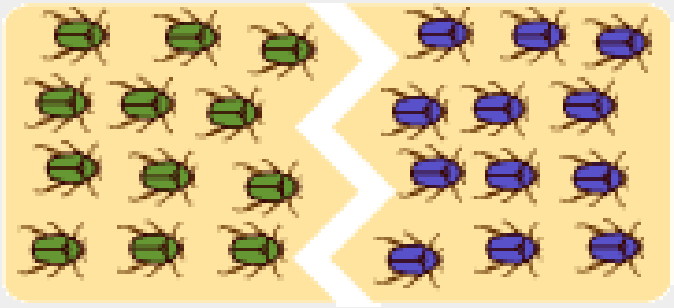
Reduced gene flow probably plays a critical role in speciation

Modes of speciation are often classified according to how much the geographic separation of incipient species can contribute to reduced gene flow


Allopatric
Peripatric
Parapatric
Sympatric
Original population
Initial step of speciation
Barrier formation
New niche entered
New niche entered
Genetic polymorphism
Evolution of reproductive isolation
In isolation
In isolated niche
In adjacent niche
Within the population
New distinct species after equilibration of new ranges

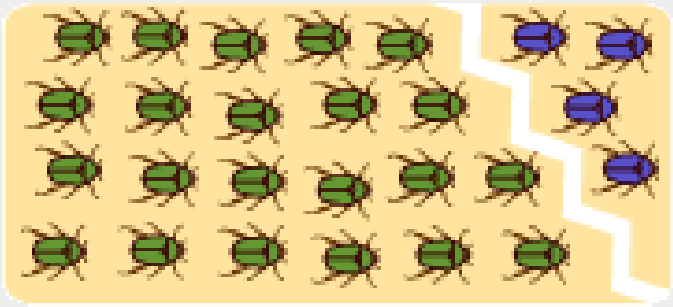
Allopatric
(allo = other, patric = place)

geographically isolated populations



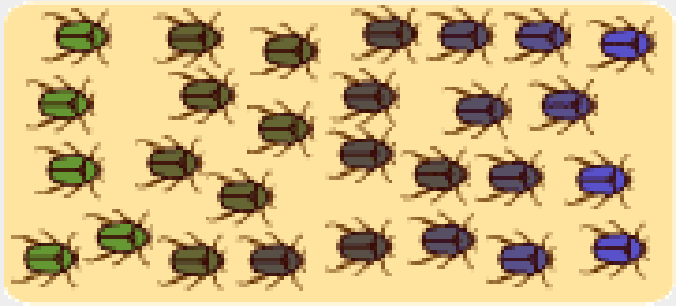
Peripatric
(peri = near, patric = place)

a small population isolated at the edge of a larger population



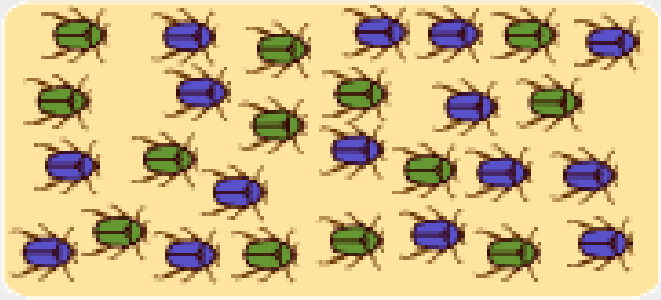
Parapatric
(para = beside, patric = place)

a continuously distributed population

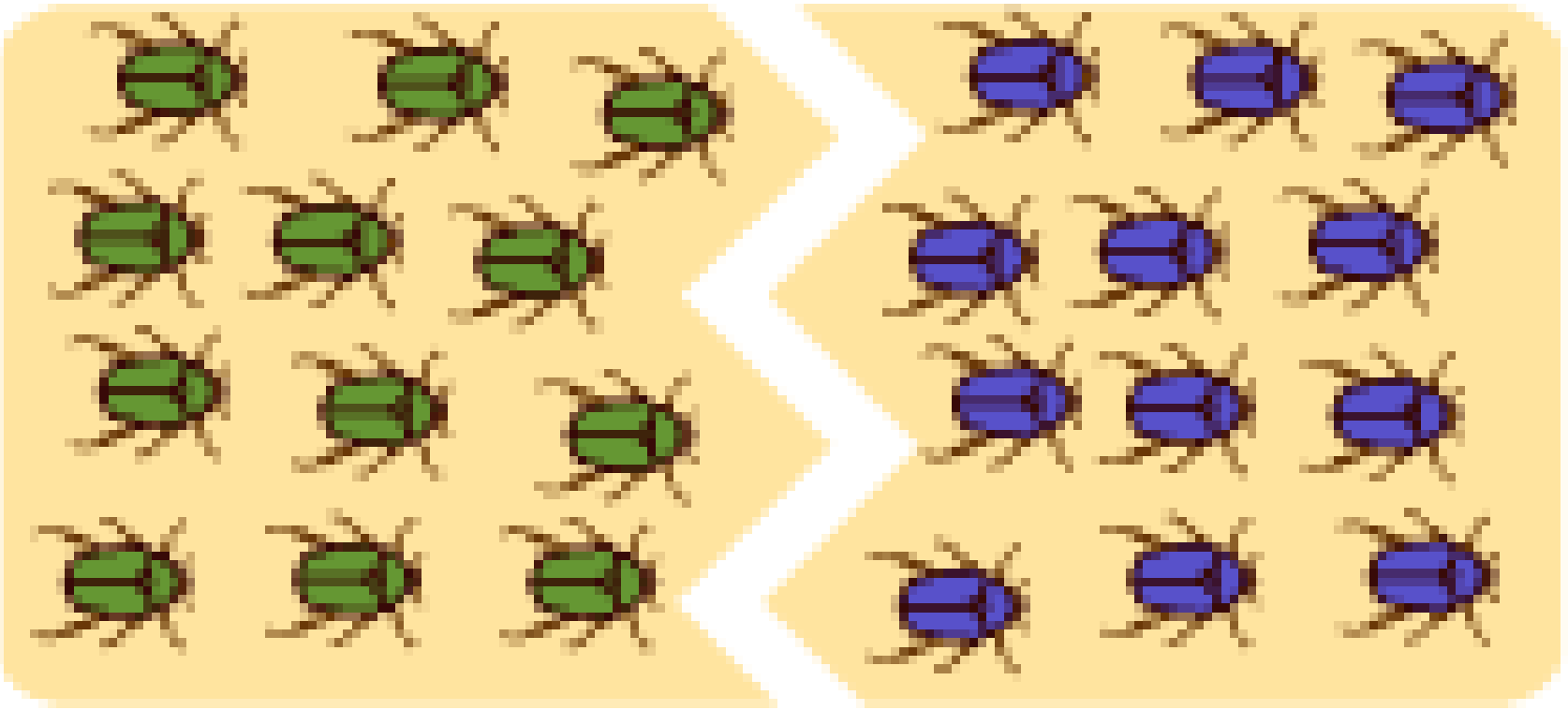


Sympatric
(sym = same, patric = place)

within the range of the ancestral population



Allopatric Speciation: The Great Divide



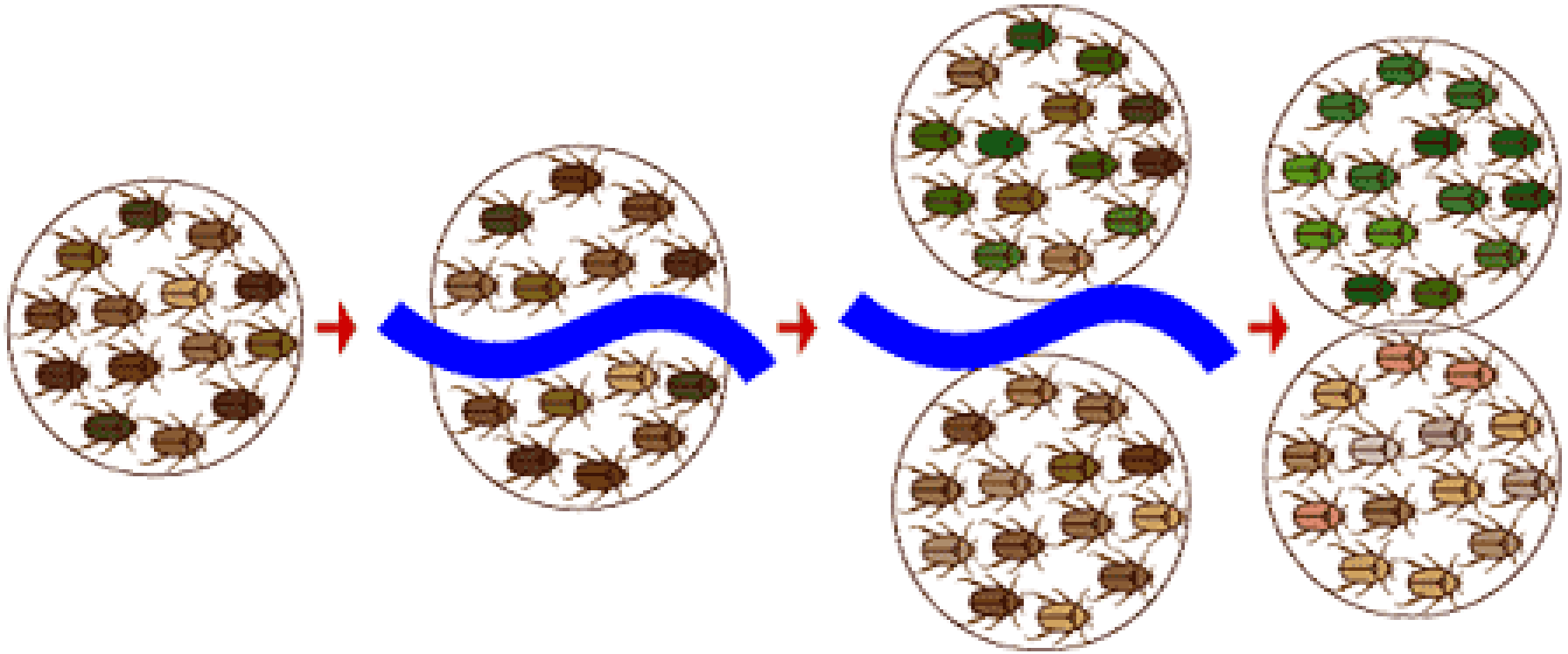
Allopatric speciation is just a fancy name for speciation by geographic isolation

In this mode of speciation, something extrinsic to the organisms prevents two or more groups from mating with each other regularly, eventually causing that lineage to speciate

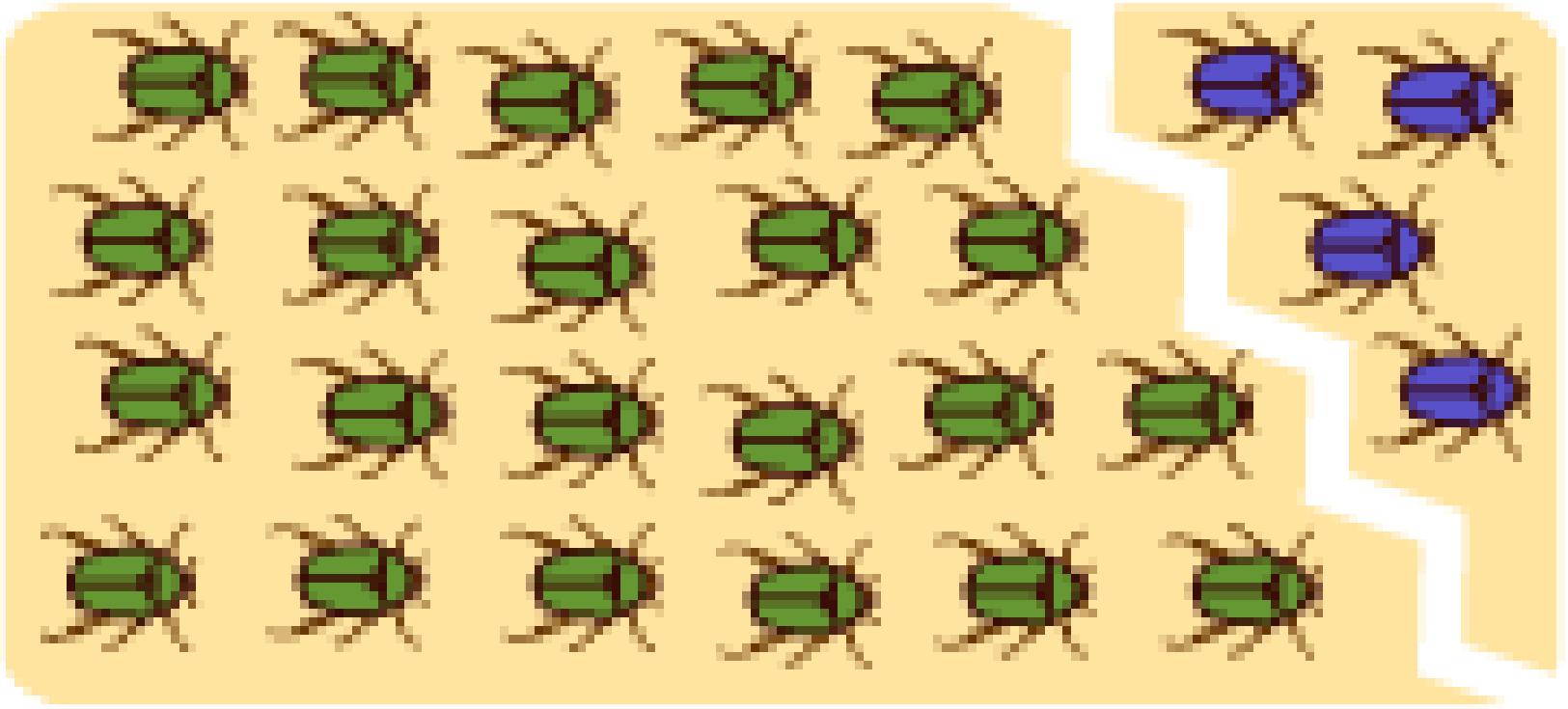
Isolation might occur because of great distance or a physical barrier, such as a desert or river, as shown below

Allopatric speciation can occur even if the barrier is a little "porous," that is, even if a few individuals can cross the barrier to mate with members of the other group

In order for a speciation even to be considered "allopatric," gene flow between the soon-to-be species must be greatly reduced—but it doesn't have to be reduced completely to zero



Peripatric speciation



Peripatric speciation is a special version of the allopatric speciation mode and happens when one of the isolated populations has very few individuals

Here's a very hypothetical example of how the peripatric speciation mode works, returning to our intrepid fruit flies venturing off the mainland on a bunch of rotting bananas

In peripatric speciation, small population size would make full-blown speciation a more likely result of the geographic isolation because genetic drift acts more quickly in small populations

Genetic drift, and perhaps strong selective pressures, would cause rapid genetic change in the small population. This genetic change could lead to speciation

The essential characteristic of this mode is that genetic drift plays a role in speciation

There are likely many cases where a population is split into two unequally-sized populations and they become separate species

However, it is very difficult for us to tell after the fact what role genetic drift played in the divergence of the two populations — so gathering evidence to support or refute this mode is challenging

We pick up their story as their banana bunch is washed up on an island:

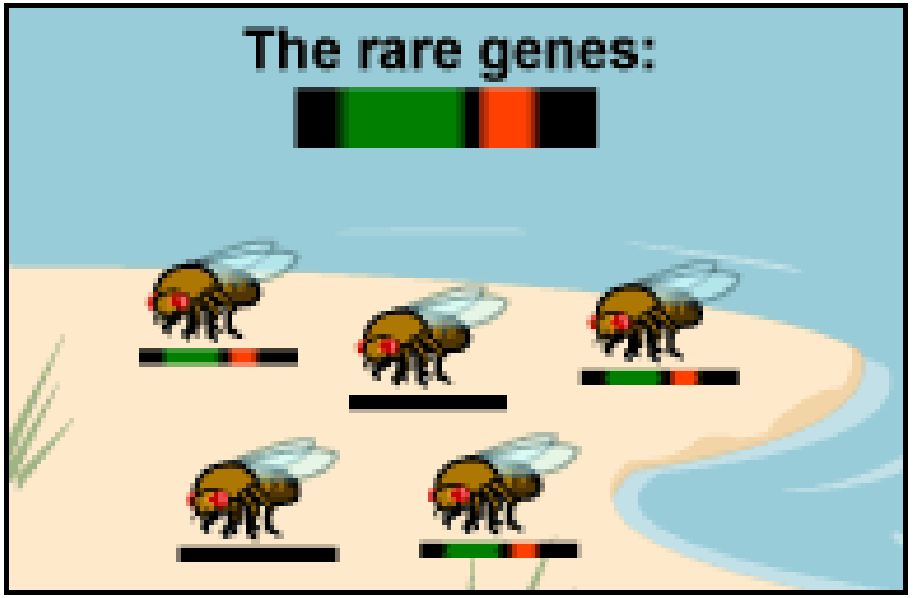
1. Double disaster: Not only are the island fruit flies now geographically isolated from their mainland relatives, but only a few larvae have survived the harrowing journey to end up colonizing the island

2. Rare genes survive: **These few survivors just by chance carry some genes that are rare in the mainland population**

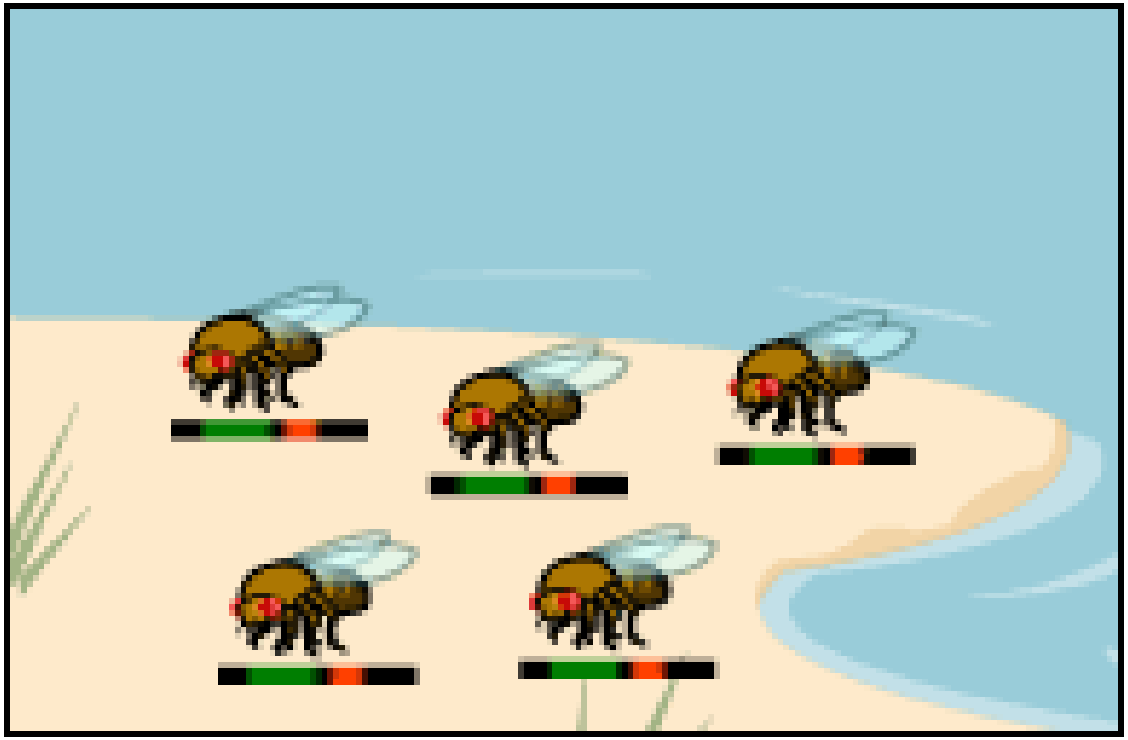
One of these rare genes happens to cause a slight variation in the mating dance

Another causes a slight difference in the shape of male genitalia

This is an example of the founder effect



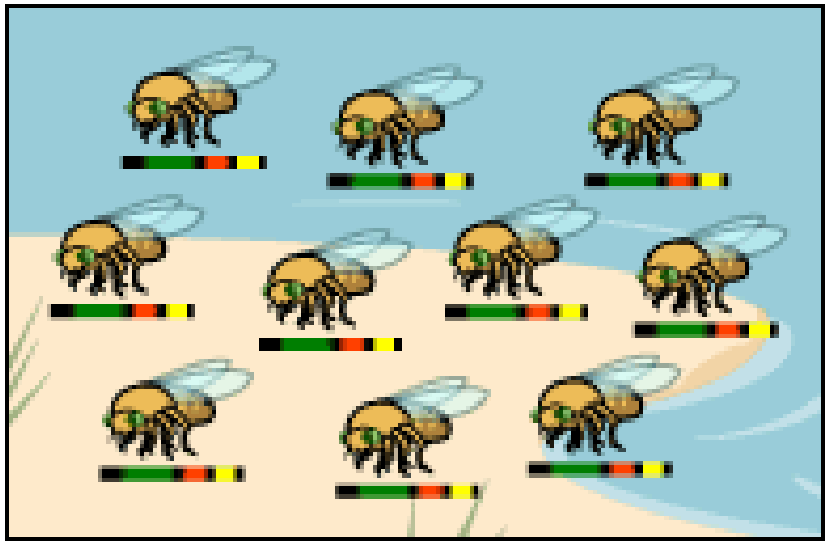
3. Gene frequencies drift: **These small differences, which are rare on the mainland, drift to fixation in the small population on the island over the course of a few generations (i.e., the entire island population ends up having these genes)**



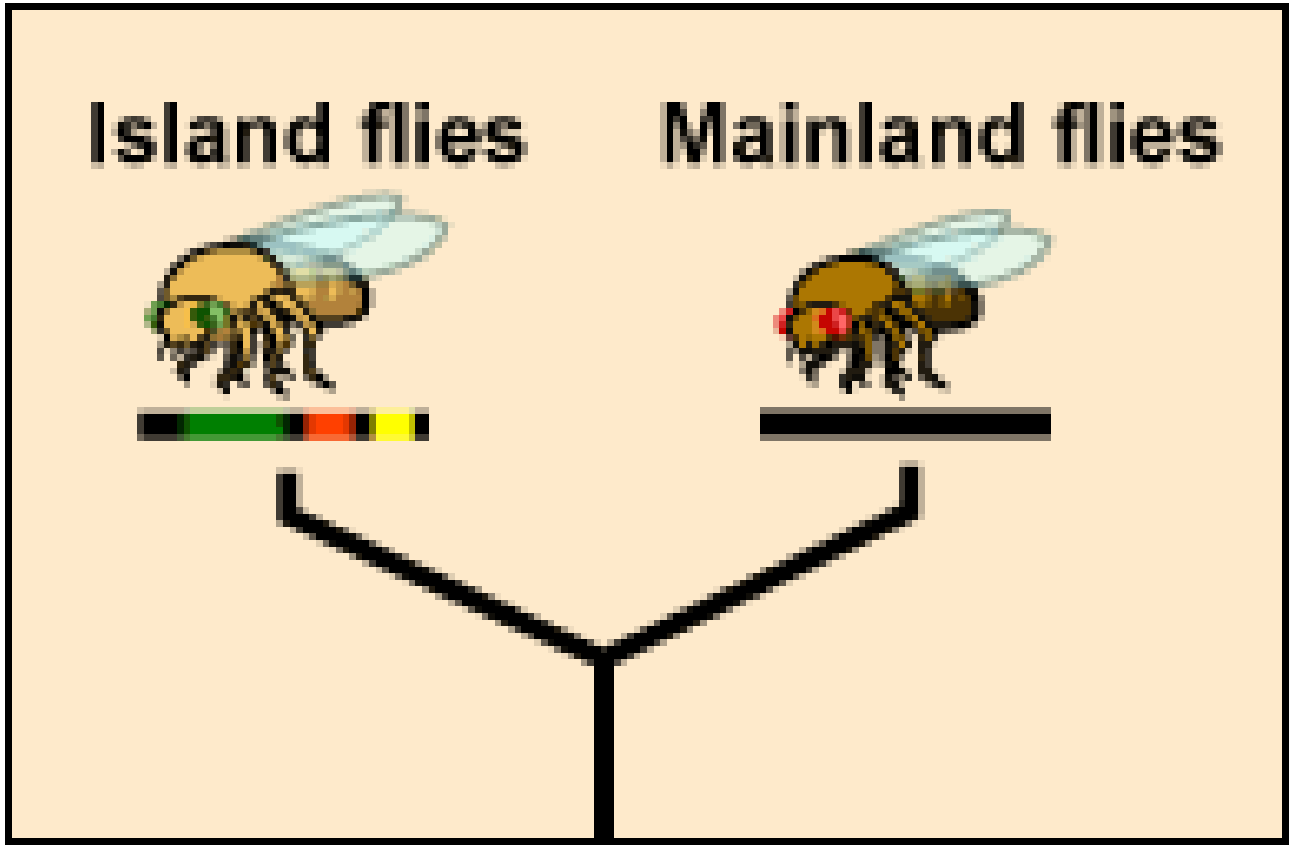
4. More changes: As the island population grows, the unique reproductive features on the island result in a cascade of changes caused by sexual selection

These changes optimize, or at least improve, the fit of male and female genitalia to one another and female sensitivity to nuances of the mating ritual

Flies also experience natural selection that favors individuals better suited to the climate and food of the island



5. Speciation: **After some generations, the island flies become reproductively isolated from the mainland flies. Peripatric speciation has occurred**



Great example of peripatric speciation is the London Underground mosquitoes

The London Underground mosquito (*Culex pipiens f. Molestus)* due to its edacious biting) is a form of mosquito found in the London

This mosquito, was first discovered in the London Underground system, and can be found in various underground systems around the world

From being a local above-ground *Culex pipiens*, it gradually adapted to human-made underground systems

Recent evidence suggests it is a southern mosquito variety related to *C. pipiens* that has adapted to the warm underground spaces of northern cities

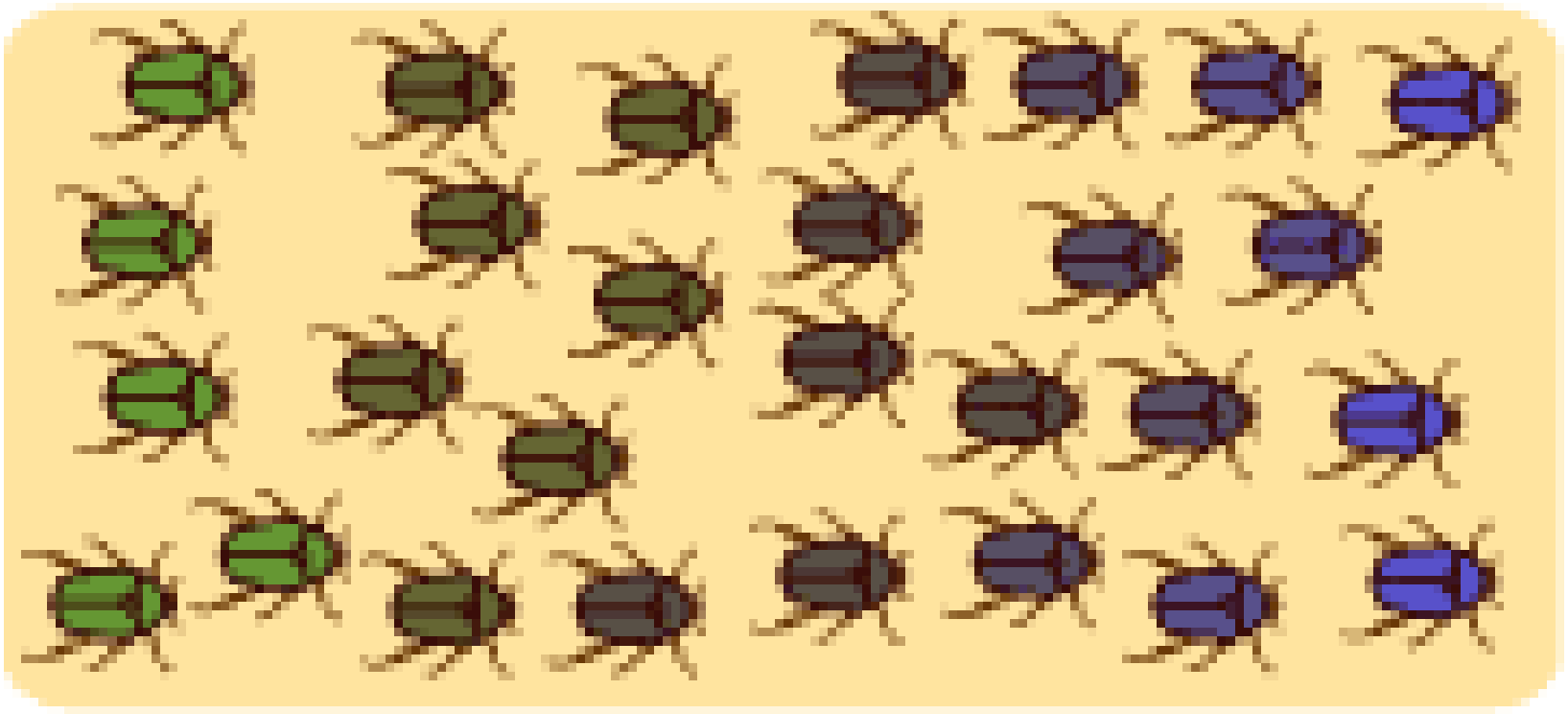
The evidence for this particular mosquito being a completely different species from *C. pipiens* comes from research done by Kate Byrne and Richard Nichols

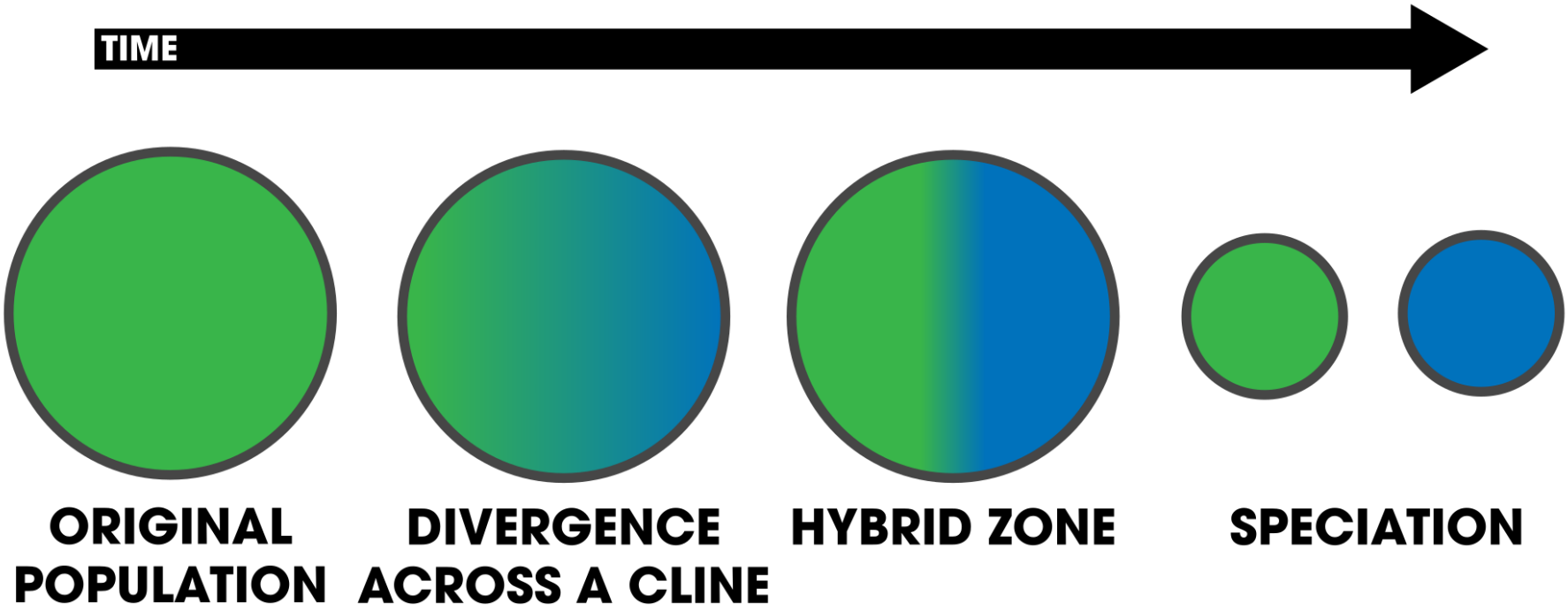
The species have very different behaviours and are exceedingly difficult to mate. More specifically, the *C. p. f. molestus*, can breed all-year round, is cold intolerant and bites rats, mice, and humans

The above-ground species is also cold tolerant but hibernates in the winter and bites only birds

When these two varieties were cross-bred, the eggs were infertile, suggesting reproductive isolation

Parapatric speciation





A diagram representing population subject to a selective gradient of phenotypic or genotypic frequencies (a cline). Each end of the gradient experiences different selective conditions (divergent selection). Reproductive isolation occurs upon the formation of a hybrid zone. In most cases, the hybrid zone may become eliminated due to a selective disadvantage. This effectively completes the speciation process

In parapatric speciation, a species is spread out over a large geographic area

Although it is possible for any member of the species to mate with another member, individuals only mate with those in their own geographic region

Like allopatric and peripatric speciation, different habitats influence the development of different species in parapatric speciation

Instead of being separated by a physical barrier, the species are separated by differences in the same environment

Parapatric speciation sometimes happens when part of an environment has been polluted

Mining activities leave waste with high amounts of metals like lead and zinc. These metals are absorbed into the soil, preventing most plants from growing

Some grasses, such as buffalo grass, can tolerate the metals

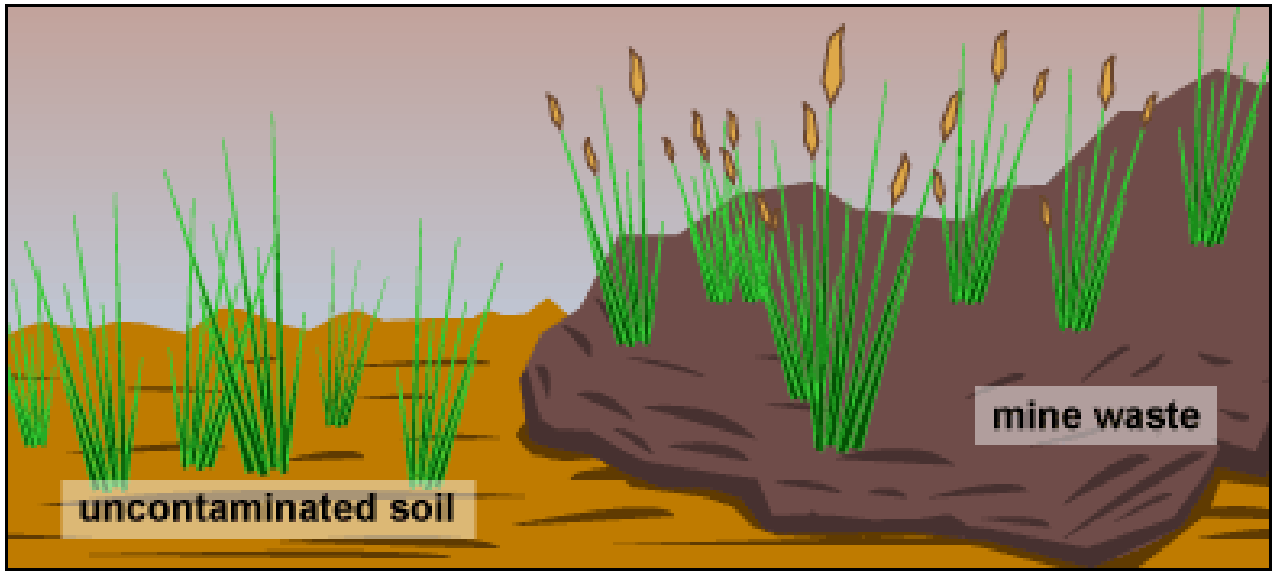
Buffalo grass, also known as vanilla grass, is native to Europe and Asia, but is now found throughout North and South America, too

Buffalo grass has become a unique species from the grasses that grow in areas not polluted by metals

Long distances can make it impractical to travel to reproduce with other members of the species

Buffalo grass seeds pass on the characteristics of the members in that region to offspring

Sometimes a species that is formed by parapatric speciation is especially suited to survive in a different kind of environment than the original species



Parapatric speciation in the grass species *Anthoxanthum odoratum*

In parapatric speciation there is no specific extrinsic barrier to gene flow

The population is continuous, but nonetheless, the population does not mate randomly

Individuals are more likely to mate with their geographic neighbors than with individuals in a different part of the population's range

In this mode, divergence may happen because of reduced gene flow within the population and varying selection pressures across the population's range

Some of these plants live near mines where the soil has become contaminated with heavy metals

The plants around the mines have experienced natural selection for genotypes that are tolerant of heavy metals

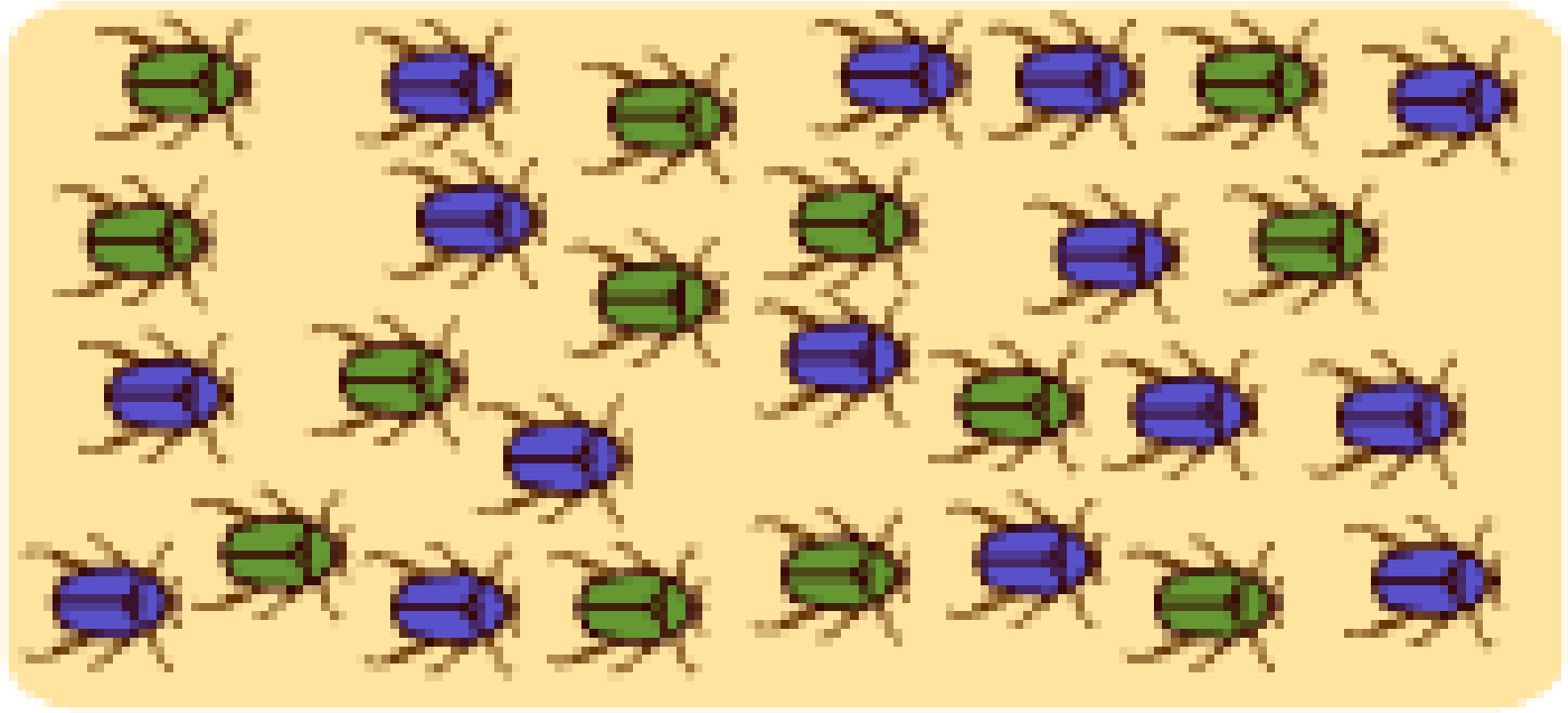
Meanwhile, neighboring plants that don't live in polluted soil have not undergone selection for this trait

The two types of plants are close enough that tolerant and non-tolerant individuals could potentially fertilize each other — so they seem to meet the first requirement of parapatric speciation, that of a continuous population

However, the two types of plants have evolved different flowering times

This change could be the first step in cutting off gene flow entirely between the two groups

Sympatric Speciation



Unlike the previous modes, sympatric speciation does not require large-scale geographic distance to reduce gene flow between parts of a population

How could a randomly mating population reduce gene flow and speciate?

Merely exploiting a new niche may automatically reduce gene flow with individuals exploiting the other niche

This may occasionally happen when, for example, herbivorous insects try out a new host plant

Apple maggot flies & Hawthorns: A case of sympatric speciation

Ancestors of apple maggot flies laid their eggs only on hawthorns

Today, these flies lay eggs on hawthorns (which are native to America) and domestic apples (which were introduced to America by immigrants and bred)

Females generally choose to lay their eggs on the type of fruit they grew up in, and males tend to look for mates on the type of fruit they grew up in

So hawthorn flies generally end up mating with other hawthorn flies and apple flies generally end up mating with other apple flies

This means that gene flow between parts of the population that mate on different types of fruit is reduced

This host shift from hawthorns to apples may be the first step toward sympatric speciation—in fewer than 200 years, some genetic differences between these two groups of flies have evolved

Apple maggot flies

Apples

Hawthorns

Gene flow has been reduced between flies that feed on different food varieties, even though they both live in the same geographic area

However, biologists question whether this type of speciation happens very often

In general, selection for specialization would have to be extremely strong in order to cause the population to diverge

This is because the gene flow operating in a randomly-mating population would tend to break down differences between the incipient species