

SPECIATION

SPECIATION

“There is probably no more original, more complex, and bolder concept in the history of ideas than Darwin's mechanistic explanation of adaptation.”

Ernst Mayr (1982)

SPECIATION

- ▶ Have you ever thought about what makes a species?
- ▶ A fundamental question of evolutionary biology.
 - ▶ What is a species?
 - ▶ How do new species arise?
 - ▶ What accounts for the bewildering diversity of species?

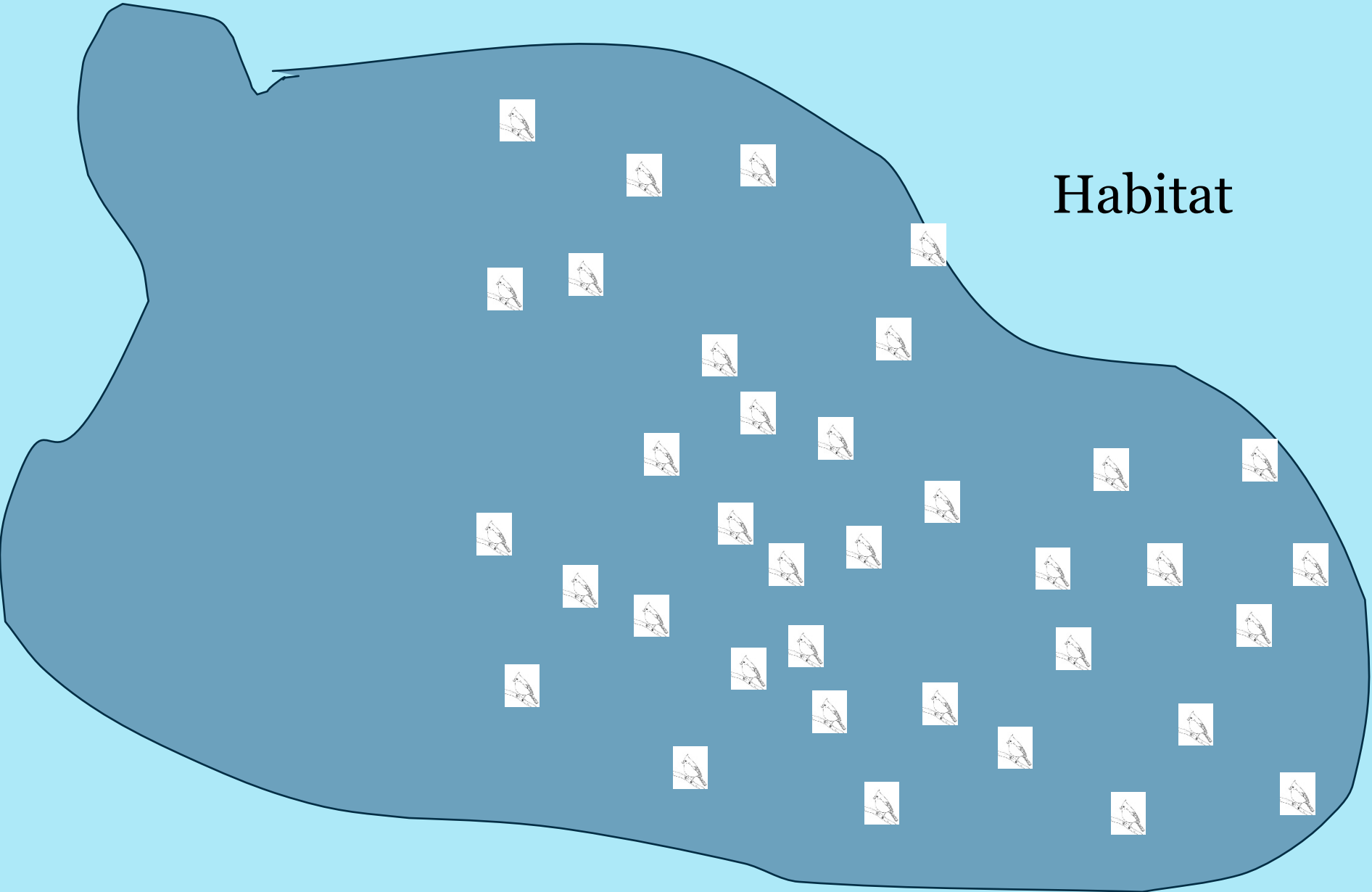
SPECIATION

- ▶ **Species** – basic unit of classification & taxonomy
- ▶ Total number of **species** ~ 8 to 8.7 million
- ▶ Only ~ 14% described by 2011
- ▶ **Speciation** – formation of new species through genetic differentiation & eventual reproductive isolation
- ▶ **Selection** (with or without **dispersal**)

SPECIATION

Dispersal

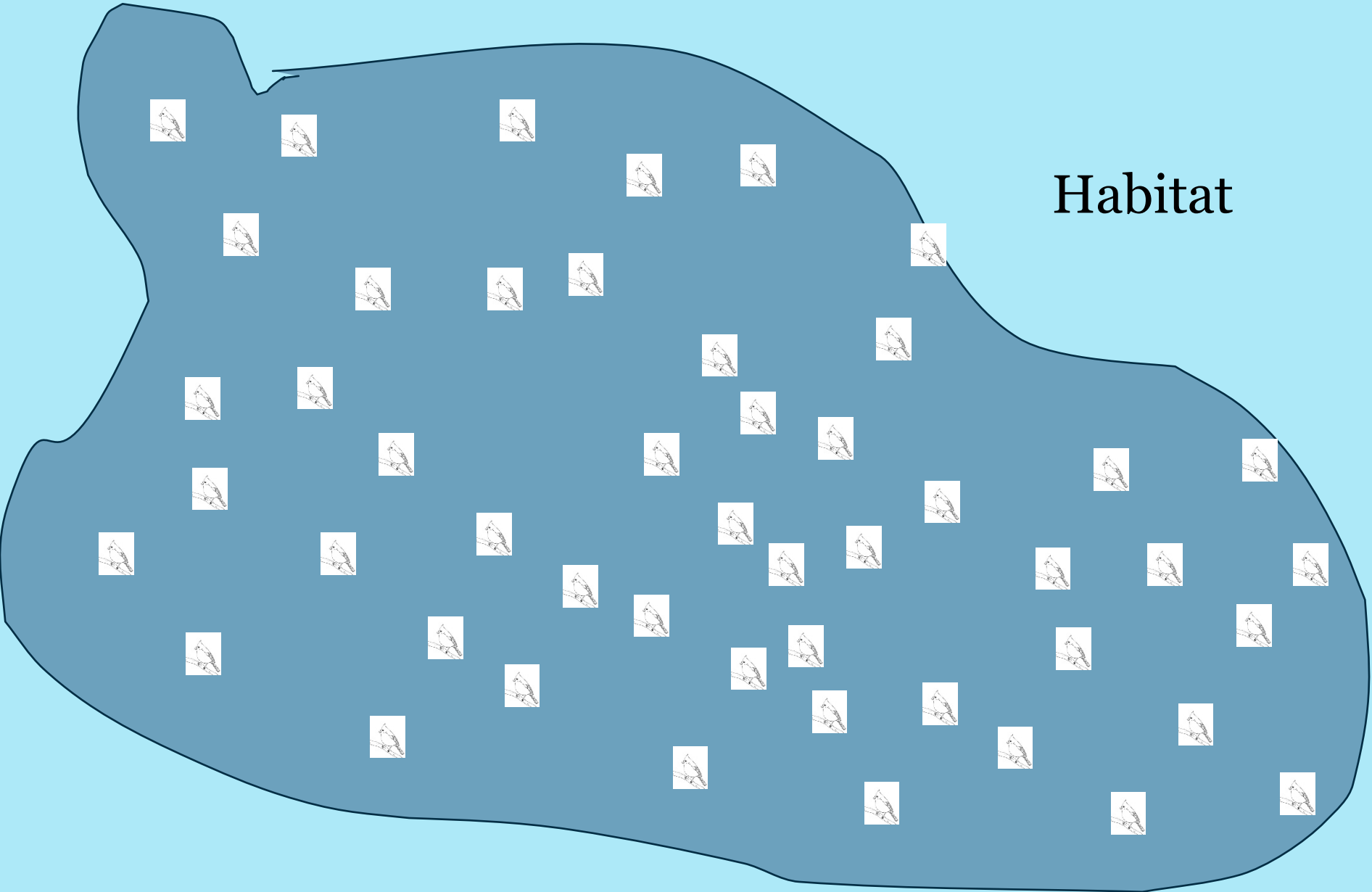
Habitat



SPECIATION

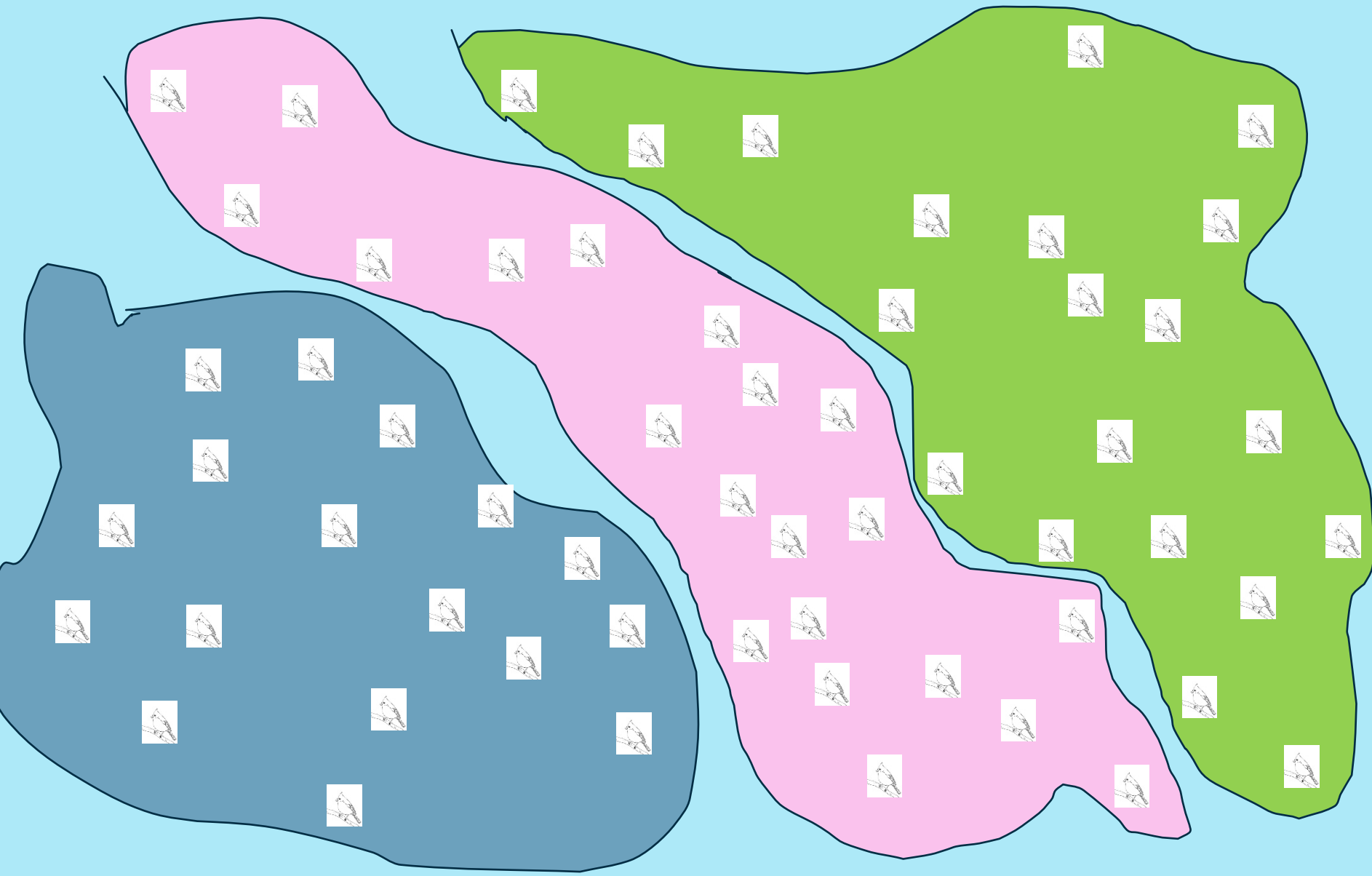
Dispersal

Habitat



HABITATS MAY CHANGE OVER TIME OR BECOME ISOLATED

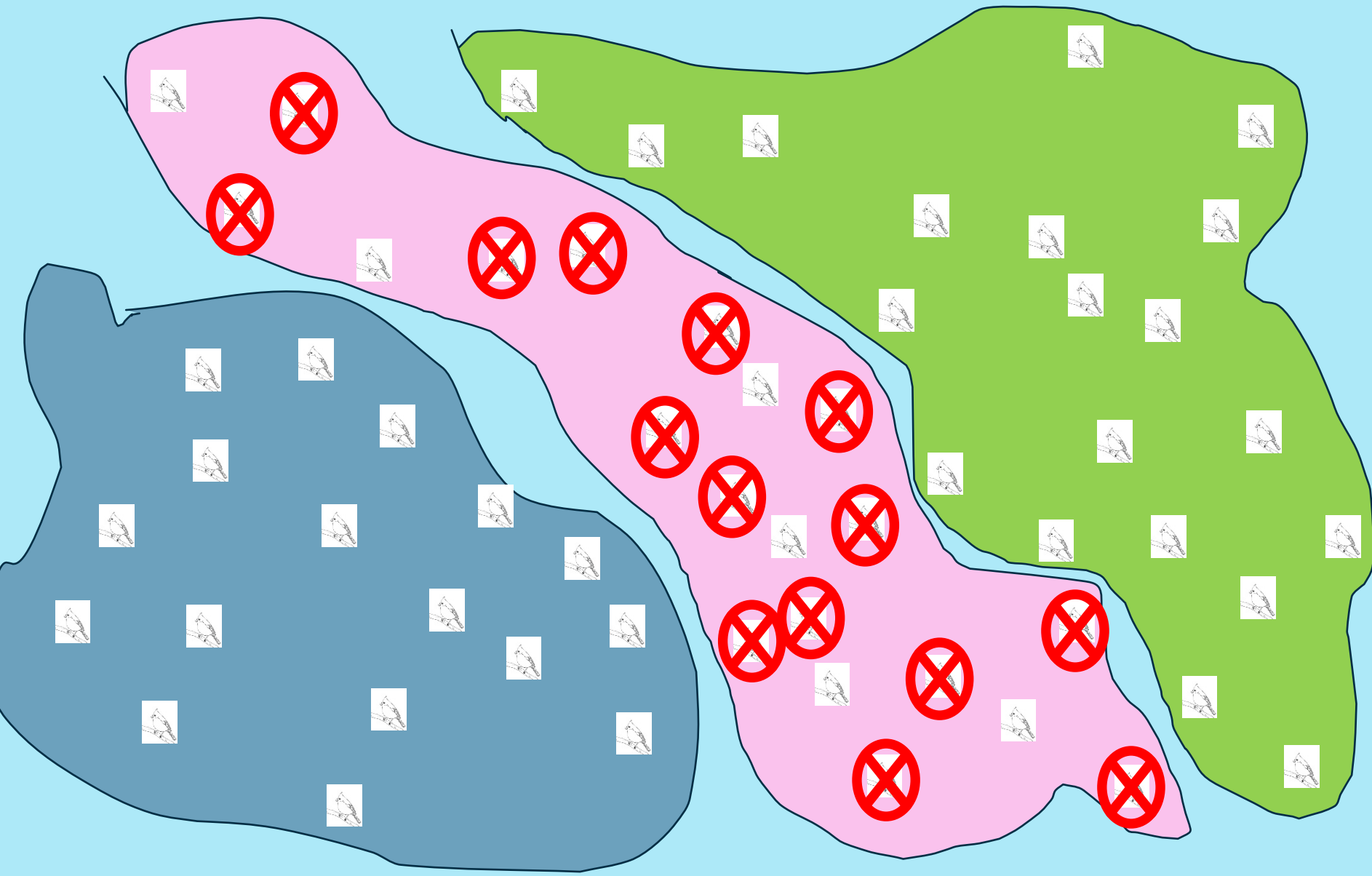
Dispersal



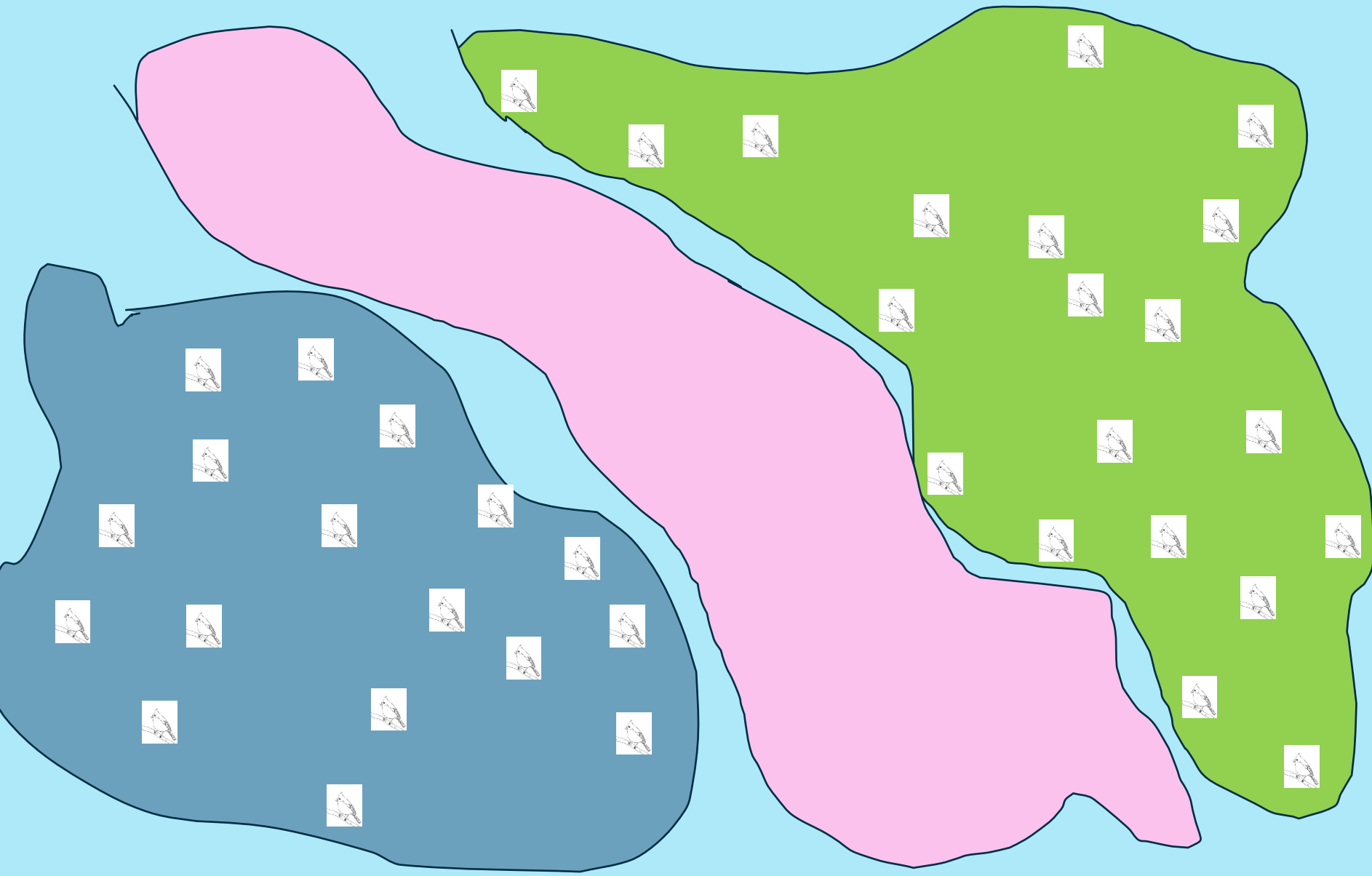
LESS FIT IN CHANGED HABITAT

Selection

Dispersal

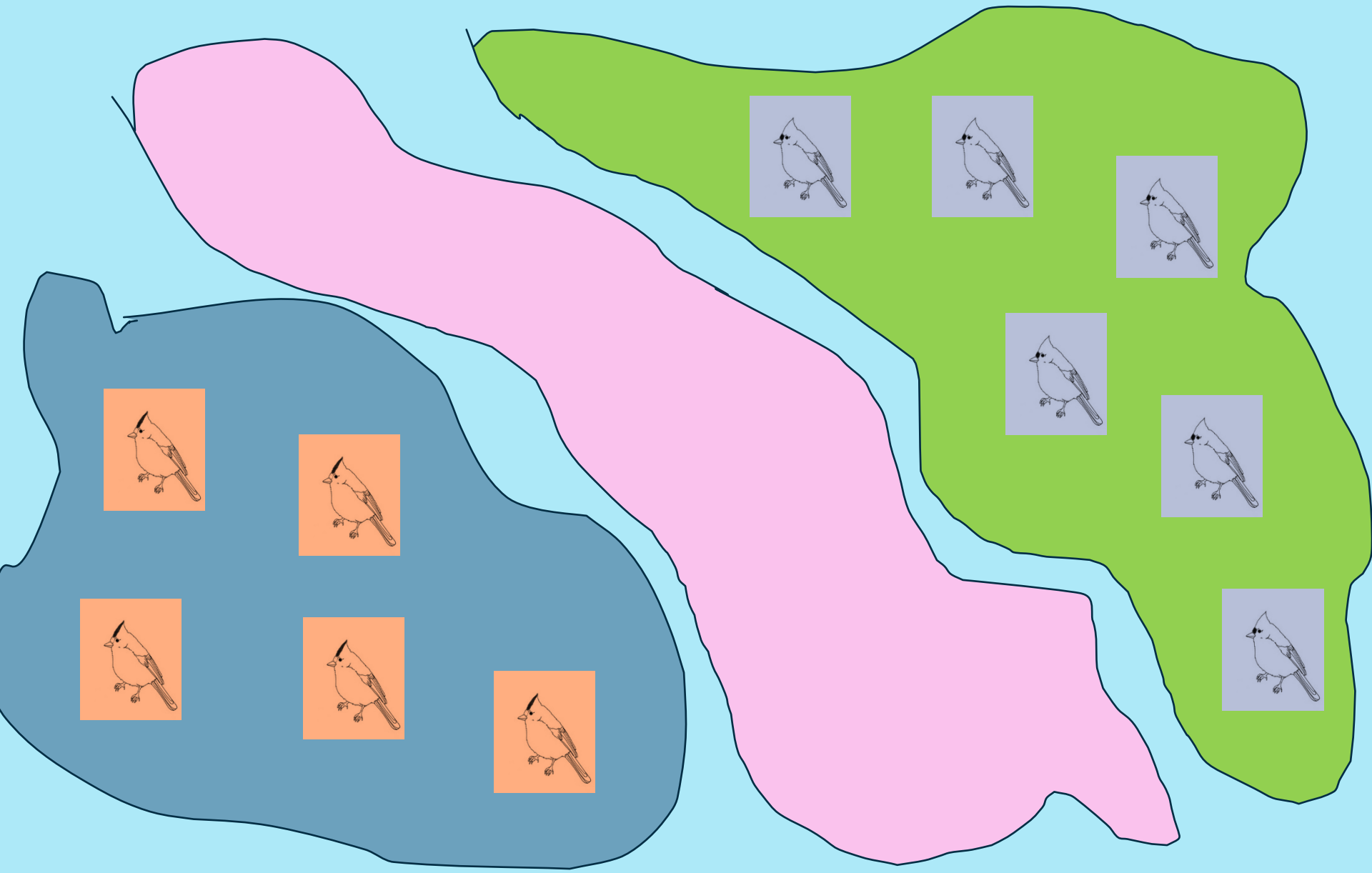


GEOGRAPHIC SEPARATION



CHANGE OVER TIME

Separate species develop



THE SPECIES CONCEPT

CONCEPT OF SPECIES

- ▶ **Aristotle** – (384-322BC) coined the terms “genus” and “species”
- ▶ Generally, from Aristotle to Darwin – species were “immutable”
 - ▶ Unchanging
 - ▶ Created by God
- ▶ Organisms were separated by whimsical means
 - ▶ Color – yellow plants, red plants, green plants...
 - ▶ Behavior – snakes, scorpions, biting ants...
 - ▶ Etc...
- ▶ **Ray** (1627-1705) – first to attempt a biological definition of species
- ▶ **Linnaeus** (1707-1778) – modern taxonomy
- ▶ **Lamarck** (1744-1829) – change over time

DARWIN

▶ Darwin's 1859 book *On the Origin of Species*

▶ “*I am fully convinced that species are not immutable...*”

Charles Darwin

▶ Continually arise & change through evolutionary processes

A UNIFYING THEORY FOR BIOLOGY

- ▶ Mid-1800s – no unifying theory for biology
- ▶ **Charles Darwin (1809–1882)**
 - ▶ *On the Origin of Species* (1859) – provided that unifying theory !!!!!
- ▶ **Alfred Russell Wallace (1823–1913)**
 - ▶ Independently conceived theory of evolution through natural selection
 - ▶ Jointly published some papers with **Darwin** (1858)
 - ▶ Prompted **Darwin** to publish *On the Origin of Species*
 - ▶ Proponent of natural selection throughout his life
 - ▶ **Out-lived Darwin by 31 years**
 - ▶ **Preeminent evolutionary biologist for decades**



THE SPECIES CONCEPT

- ▶ **Species concept** – attempt to define what a species is
- ▶ > **26** recognized species concepts, including:
 - ▶ DNA sequence
 - ▶ Morphology
 - ▶ Behavior
 - ▶ Ecological niche
 - ▶ Chronospecies (paleontology) – fossil reproduction cannot be examine

THE BIOLOGICAL SPECIES CONCEPT

▶ **Biological species concept –**

"species are groups of interbreeding natural populations that are reproductively isolated from other such groups."

Ernst Mayr 1942

▶ **Philosophy– AOU North American Classification Committee:**

“Although the committee recognizes the controversy over species concepts in ornithology, it generally adheres to the principles of the Biological Species Concept”.

PROBLEM WITH SPECIES CONCEPT

- ▶ Any such definition is problematic
- ▶ Might work well for sexually reproducing organisms (birds)
- ▶ Not for asexually reproducing organisms (bacteria)
- ▶ First recognized by Darwin
- ▶ None are perfect
- ▶ Incredibly useful tools

NATURAL SELECTION

NATURAL SELECTION

- ▶ **Natural selection** – the process whereby organisms better adapted to their environment tend to survive and produce more offspring.
- ▶ Aka “**selection**”
- ▶ **Natural selection** = reproductive success.
 - ▶ **NOT the competition to survive.**
 - ▶ **Not “survival of the fittest.”**
 - ▶ **It is the competition to pass on genes.**

SELECTION

Selection – better adapted tend to survive & reproduce more

Continual !!!!

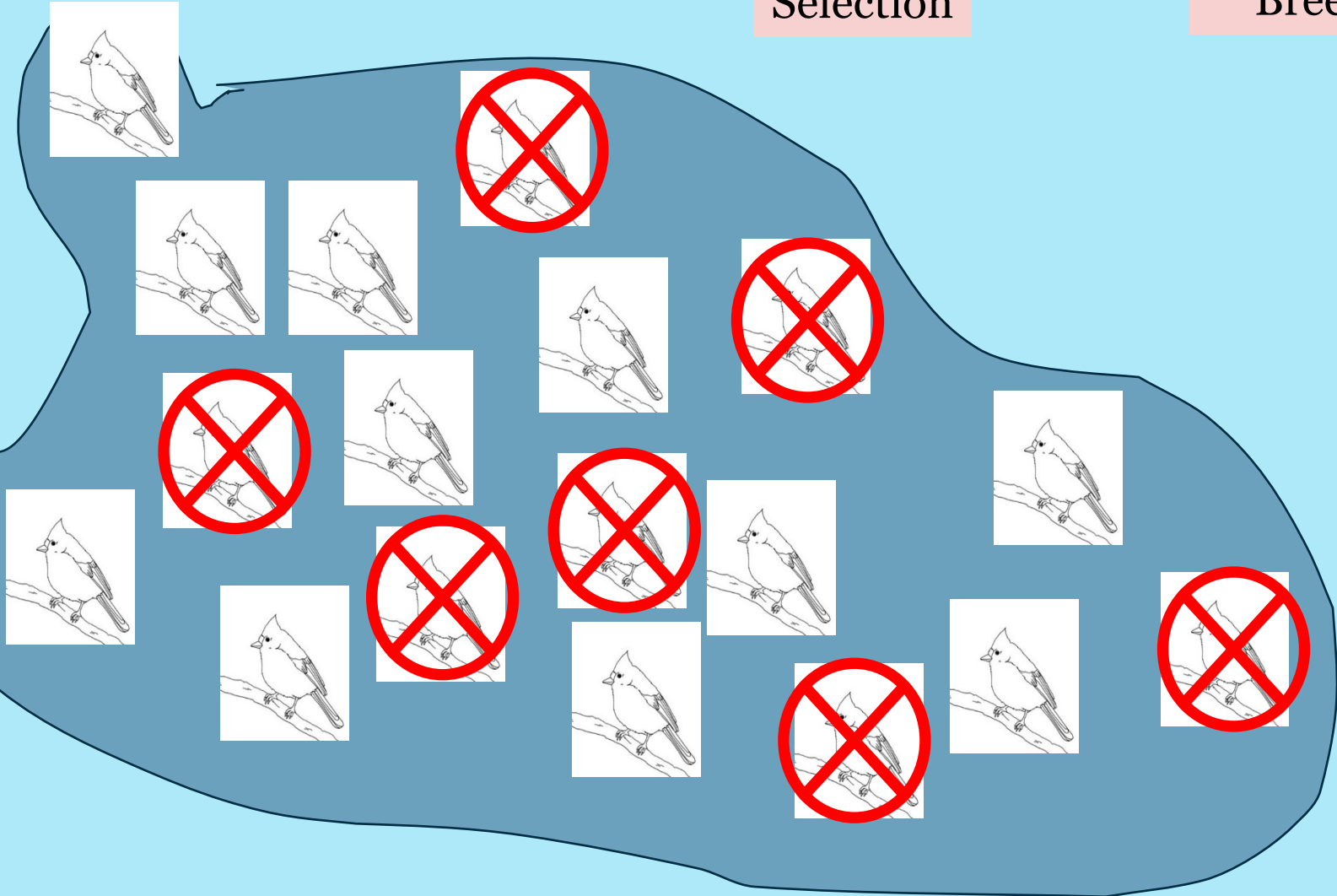


SELECTION

Selection

Natural Selection

Selective Breeding



SPECIES LESS FIT IN NEW HABITAT

Selection – better adapted tend to survive & reproduce more



THE TERM “*SURVIVAL OF THE FITTEST*”



- ▶ **Herbert Spencer**, biologist
 - ▶ Coined the phrase “*survival of the fittest*”
 - ▶ After reading **Darwin**

- ▶ **Darwin**
 - ▶ In later writings Darwin adopted the phrase
 - ▶ At **Wallace’s** urging

THE TERM “*SURVIVAL OF THE FITTEST*”



▶ **Wallace**

- ▶ Out-lived **Darwin** by 31 years
- ▶ Preeminent evolutionary biologist for decades
- ▶ Wallace construed “*survival of the fittest*” to be synonymous with “*natural selection*”
 - ▶ “*Natural selection*” = “*Survival of the fittest*”

“*NATURAL SELECTION THROUGH SURVIVAL OF THE FITTEST*”

- ▶ “*Survival of the fittest*” became synonymous with “*natural selection*”
- ▶ *Natural selection* became understood as
 - ▶ the **fight** to survive
 - ▶ the **fight** to procreate


ANOTHER
MECHANISM OF EVOLUTION

ONLY ONE OF THE MECHANISMS OF EVOLUTION

- ▶ *“Natural selection” ≠ “Survival of the fittest”*
- ▶ **“Natural selection” = reproductive success**

ANOTHER MECHANISM OF EVOLUTION

I think he meant
“survival of the
fittest”



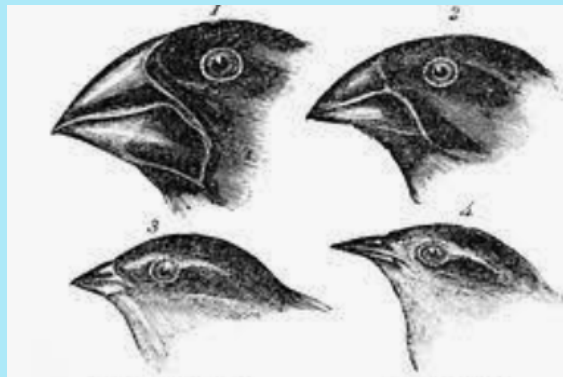
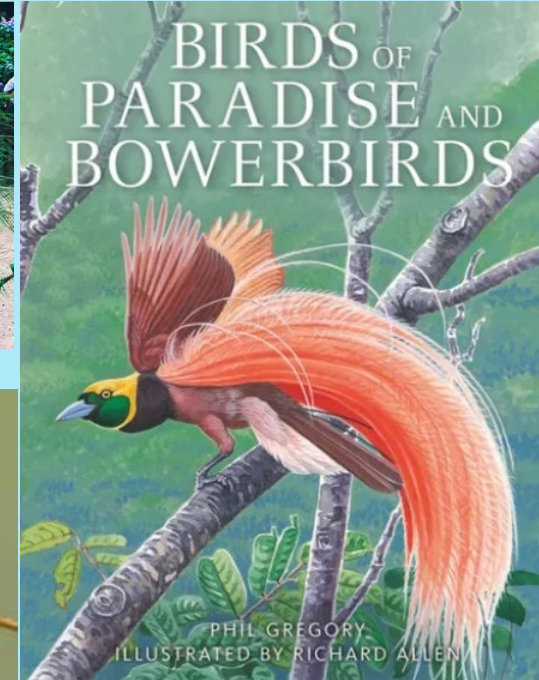
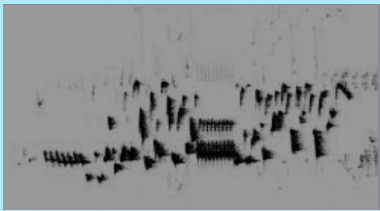
- ▶ Many evolutionary processes cannot be explained by “*survival of the fittest*” alone
- ▶ “..., *I am convinced that natural selection has been the most important, but not the exclusive, means of modification*”

Charles Darwin

ORNAMENTS & DISPLAYS

- ▶ Tail of peacock
- ▶ Gorget of hummer
- ▶ Elaborate birdsong
- ▶ Incredibly Birds-of-Paradise
- ▶ Crazy displays by Bower Birds
- ▶ Different functions

- ▶ Evolved under very different evolutionary pressures:
 - ▶ Beak shape
 - ▶ Running speed
 - ▶ strength
 - ▶ Etc....



ORNAMENTS & DISPLAYS

- ▶ Evolution can even be “decadent”
 - ▶ Ornaments don't signal mate quality
 - ▶ Actually lower survival & reproductive success
 - ▶ Less likely to survive & pass on genes
 - ▶ Peacocks tail,.... Etc.



“HONEST INDICATORS”



According to
who?

- ▶ Peacock's tail = fitness of the peacock
- ▶ More elaborate, beguiling, **beautiful** tail = more fit male
- ▶ Fitness = prowess, strength, hardiness, skill, virility...
- ▶ *“the only way in which we can account for the observed facts is by supposing that color and ornament are strictly correlated with health and fitness to survive”*

Russel Alfred Wallace

“HONEST INDICATORS”

- ▶ Most evolutionary biologists
 - ▶ Ornaments evolve because:
 - ▶ Beauty provides “honest indicator” of quality
 - ▶ Beauty of tail = fitness of the male
- ▶ The argument goes:
 - ▶ *“he’s so fit he can afford to expend enormous resources to produce that tail”*
- ▶ Female chooses fittest male
- ▶ As indicated by “honest indicators” – the peacock’s tail

ACCEPTED IN POPULAR CULTURE

► **Beauty** = practical information about adaptive qualities

“Remember that physical beauty is evolution's way of showing us that the other person doesn't have too many intestinal parasites”.

Ben S. Barnanke

Former Chairman of Federal Reserve
Commencement speech at Princeton

WHAT DARWIN SAID

▶ Darwin's 2 most important books:

▶ *On the Origin of Species* (1859)

▶ *The Descent of Man* (1871)

That word
again



▶ Full title:

▶ *The Descent of Man, and Selection in Relation to Sex*

And THAT word



WHAT DARWIN SAID

SEXUAL SELECTION

- ▶ *Survival of the fittest* can't be only mechanism of evolution
- ▶ Doesn't fully account for diversity of ornaments

- ▶ **Darwin** proposed:
 - ▶ *Aesthetic Theory of Evolution by Mate Choice*
 - ▶ (aka: *Sexual Selection*)

SEXUAL SELECTION

- ▶ **Explicitly aesthetic !!!!!!!**
- ▶ **Darwin** repeatedly wrote
 - ▶ Mating preferences are:
 - ▶ “...*aesthetic faculty*...”
 - ▶ “...*a taste for the beautiful*...”

FEMALE CHOICE

ANOTHER RADICAL IDEA BY DARWIN !!!

- ▶ *Survival of the fittest* occurs **on the organism**
 - ▶ Competition
 - ▶ Predation
 - ▶ Climate
 - ▶ Geography, etc.
- ▶ **Sexual selection** directed **by the organism**
 - ▶ Female chooses beautiful tail
 - ▶ Female chooses beguiling singer
- ▶ Animals are active agents in their own (species) evolution
 - ▶ **Especially females !!!!!**
- ▶ Females choose mates based on **their judgment** of beauty
- ▶ **Female choice is responsible for speciation!!!** (in part)

RECEPTION

- *Survival of the fittest*
 - ▶ Male/male competition
 - ▶ Fight for survival

Almost universally
accepted

- ▶ Sexual Selection
- ▶ Female choice

- ▶ ABSURD !!!!!
 - ▶ Animals lack:
 - ▶ Sensory powers
 - ▶ Cognitive capacity
 - ▶ Free will
 - ▶ Females too fickle:
 - ▶ Never produce peacock's tail !!!!!

**How do you think
that
went down in
Victorian Age?**

A “DISHONEST INDICATOR” ??

- ▶ Trait originally preferred for adaptive reasons (“honest”)
- ▶ No longer strictly correlated with fitness
- ▶ **But it’s still attractive !!!!!**
- ▶ Continues to evolve & elaborate merely because it’s preferred
- ▶ **Ornaments/displays** + **standards of beauty**
 - ▶ Co-evolve
 - ▶ Mutually influencing & reinforcing

SEXUAL SELECTION

- ▶ **Darwin** promoted
- ▶ Later suppressed, misunderstood, redefined, forgotten
- ▶ Largely under influence of **who?**
- ▶ **Wallace** so successful
 - ▶ Almost completely marginalized & forgotten
 - ▶ Even within evolutionary biology
 - ▶ Until 1970s
 - ▶ Many scientists still oppose today

THE WORD “*BEAUTY*”

- ▶ “*Beauty*” – captures what is involved in biological attraction
- ▶ Animals are making social & sexual choices
- ▶ Based on their judgement of aesthetic standards

“Beauty & desire for animals can be irrational, unpredictable, and dynamic just like humans experiences of them”.

Richard O. Prum

EXAMPLE: GREAT ARGUS PHEASANT

- Polka dots
- Stripes and
- Swirling op-art waves
- 300 pale yellow spots radiating outward
- Spots increase in size up wing
- **Forced perspective illusion** to the hen
- Dots all appear same size,
- Delicate color gradients
- Shaded bottom curve & highlighted top
- **Illusion of 3-dimensional spheres**
- **Bright glowing golden orbs floating in forest**



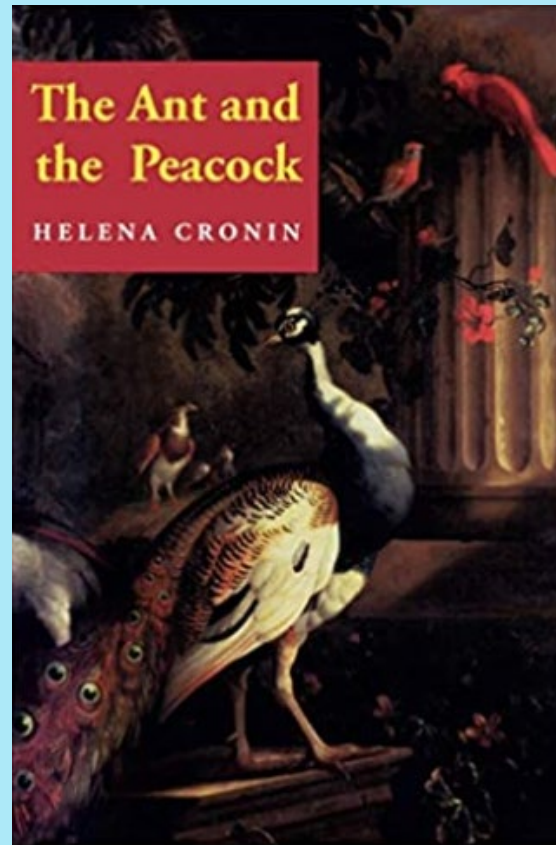
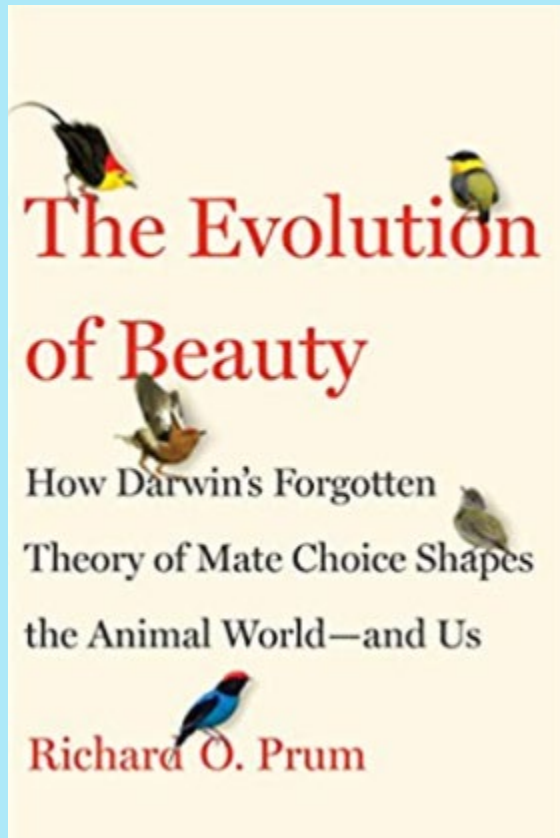
RECOMMENDED READING

Aesthetic Evolution by Mate Choice: Darwin's Really Dangerous Idea

Richard O. Prum

Wings of Desire: How birds Became Beautiful And Art Got Weird

<https://www.growbyginkgo.com/2020/10/26/wings-of-desire/>



BACK TO SPECIATION

SPECIATION

- ▶ A 2-stage process:
 - ▶ Populations isolated (must be genetically, may also be physically)
 - ▶ Traits change over time

MECHANISMS WHICH MAY RESULT IN **SPECIATION**

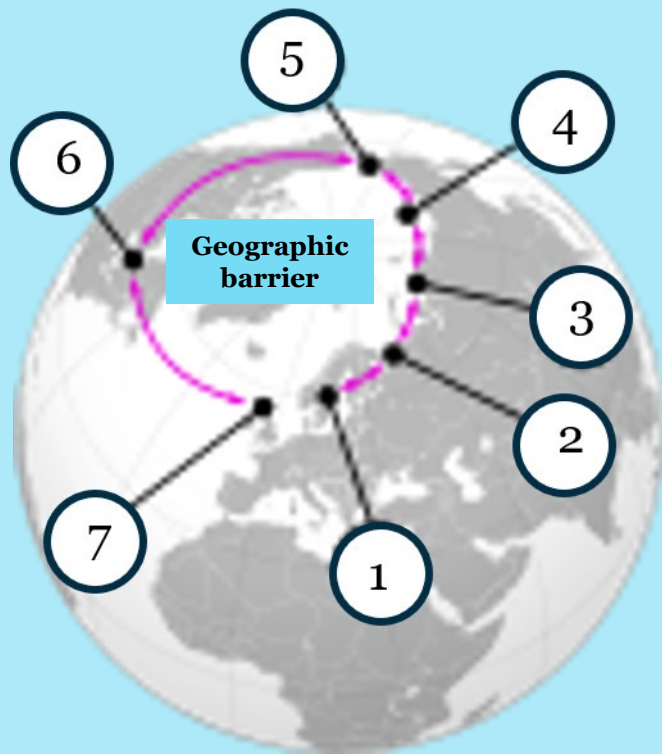
1. Natural selection (survival of the fittest)
2. Sexual selection
3. Genetic drift
4. Chromosomal mutation & recombination
5. Mass extinctions – open ecological niches
6. Geographic isolation
 - Migration
 - Continental drift
 - Island formation
 - Land bridges
7. Glacier expansion & retreat
8. Fragmentation & expansion of habitat
9. Climate changes

GENERAL FACTORS IN SPECIATION

- ▶ Climactic changes – (Oligocene)
 - ▶ Glaciation
 - ▶ Reduced temperature
 - ▶ First permanent Antarctic ice sheets
 - ▶ Global decline of broad leaf forests
- ▶ Ecological changes(Miocene)
 - ▶ Expansion of grasslands
 - ▶ Fragmentation of forest
 - ▶ New edge habitats
- ▶ Oscines proliferation
 - ▶ Exploit different foods
 - ▶ Exploit different habitat
 - ▶ Adapted to cold temperatures
 - ▶ Adaptation to more carbohydrate-rich diet

HYBRIDS IN SPECIATION

EXAMPLE: RING SPECIES (LARUS)



- 1) *L. fuscus*,
- 2) Siberian population of *L. fuscus*
- 3) *L. heuglini*,
- 4) *L. vegae birulai*
- 5) *L. vegae*,
- 6) *L. smithsonianus*
- 7) *L. argentatus*

Speciated only recently
Insufficient time for
reproductive isolation

- ▶ The *Larus* gulls breed in a ring around the arctic
- ▶ Near-by neighbors interbreed
- ▶ End populations too distantly related
- ▶ Don't interbreed

▶ Mayr (1942)

HYBRIDIZATION AND THE SPECIES CONCEPT

- ▶ Shows weaknesses of **biological species concept**
- ▶ Boundaries between species blurred
- ▶ Not so much discrete entities
- ▶ “Species” = a continuum

