# Evaluating competing hypotheses

► We challenge hypotheses with experiments and observation

# Evaluating competing hypotheses

▶ We challenge hypotheses with experiments and observation

► This is the idea that individuals change in response to their environment, and pass those changes on to their offspring

- This is the idea that individuals change in response to their environment, and pass those changes on to their offspring
  - ► Example: giraffes reaching for food

- ► This is the idea that individuals change in response to their environment, and pass those changes on to their offspring
  - ► Example: giraffes reaching for food
- ▶ It is now known that while individuals do often change in response to their environment, such changes are not (usually) passed on to offspring

- ► This is the idea that individuals change in response to their environment, and pass those changes on to their offspring
  - Example: giraffes reaching for food
- ▶ It is now known that while individuals do often change in response to their environment, such changes are not (usually) passed on to offspring

► Raise several populations of mice in the lab

- Raise several populations of mice in the lab
- ► In the acquired group, every generation stretch (or chop off) their poor little tails

- Raise several populations of mice in the lab
- ► In the acquired group, every generation stretch (or chop off) their poor little tails
- ► In the selection group, every generation, allow mice with longer (or shorter) tails more chances to breed

- ▶ Raise several populations of mice in the lab
- ► In the acquired group, every generation stretch (or chop off) their poor little tails
- ▶ In the selection group, every generation, allow mice with longer (or shorter) tails more chances to breed
- ► In the control group, do everything the same (including manipulations)

- Raise several populations of mice in the lab
- ► In the acquired group, every generation stretch (or chop off) their poor little tails
- ▶ In the selection group, every generation, allow mice with longer (or shorter) tails more chances to breed
- In the control group, do everything the same (including manipulations)
  - **\***

- ▶ Raise several populations of mice in the lab
- ► In the acquired group, every generation stretch (or chop off) their poor little tails
- ► In the selection group, every generation, allow mice with longer (or shorter) tails more chances to breed
- ► In the control group, do everything the same (including manipulations)
  - \* Except the part that is the key to treatment

- ▶ Raise several populations of mice in the lab
- ► In the acquired group, every generation stretch (or chop off) their poor little tails
- ▶ In the selection group, every generation, allow mice with longer (or shorter) tails more chances to breed
- ► In the control group, do everything the same (including manipulations)
  - \* Except the part that is the key to treatment
- ► Measure natural tail length at the beginning of the experiment, and after 100 generations.

- ▶ Raise several populations of mice in the lab
- ► In the acquired group, every generation stretch (or chop off) their poor little tails
- ▶ In the selection group, every generation, allow mice with longer (or shorter) tails more chances to breed
- In the control group, do everything the same (including manipulations)
  - \* Except the part that is the key to treatment
- ▶ Measure natural tail length at the beginning of the experiment, and after 100 generations.

► This is the idea that organisms evolve towards specific goals

- ▶ This is the idea that organisms evolve towards specific goals
  - ► Complex, multicellular organisms

- ▶ This is the idea that organisms evolve towards specific goals
  - ► Complex, multicellular organisms
  - ► Big-brained humans

- ▶ This is the idea that organisms evolve towards specific goals
  - Complex, multicellular organisms
  - ▶ Big-brained humans
- ► If the organism is moving toward a goal, it should move more or less in that direction all the time

- ▶ This is the idea that organisms evolve towards specific goals
  - Complex, multicellular organisms
  - Big-brained humans
- ▶ If the organism is moving toward a goal, it should move more or less in that direction all the time

► There is a great deal of observational evidence against goal-directed evolution:

- ► There is a great deal of observational evidence against goal-directed evolution:
  - ► Vestigial traits

- ► There is a great deal of observational evidence against goal-directed evolution:
  - Vestigial traits
  - ► Bidirectional evolution

- ► There is a great deal of observational evidence against goal-directed evolution:
  - Vestigial traits
  - Bidirectional evolution
    - ► Finch beaks get larger, then smaller

- ► There is a great deal of observational evidence against goal-directed evolution:
  - Vestigial traits
  - Bidirectional evolution
    - Finch beaks get larger, then smaller
    - ▶ Birds gain, then lose, flying ability

- ► There is a great deal of observational evidence against goal-directed evolution:
  - Vestigial traits
  - ▶ Bidirectional evolution
    - Finch beaks get larger, then smaller
    - Birds gain, then lose, flying ability
    - Things that become parasites may become much smaller and simpler

- ► There is a great deal of observational evidence against goal-directed evolution:
  - Vestigial traits
  - Bidirectional evolution
    - Finch beaks get larger, then smaller
    - Birds gain, then lose, flying ability
    - Things that become parasites may become much smaller and simpler

► Selection operates on individuals; individuals are not adapted to act for the good of the species

- ► Selection operates on individuals; individuals are not adapted to act for the good of the species
- ► The evolution of co-operation always involves tension between what is good for the group, and what is good for the individual

- Selection operates on individuals; individuals are not adapted to act for the good of the species
- ► The evolution of co-operation always involves tension between what is good for the group, and what is good for the individual
  - ► If 'cheating' strategies can evolve, they will

- Selection operates on individuals; individuals are not adapted to act for the good of the species
- ► The evolution of co-operation always involves tension between what is good for the group, and what is good for the individual
  - ▶ If 'cheating' strategies can evolve, they will
  - ► A **cheater** benefits from co-operation, but does not participate

- Selection operates on individuals; individuals are not adapted to act for the good of the species
- ► The evolution of co-operation always involves tension between what is good for the group, and what is good for the individual
  - ▶ If 'cheating' strategies can evolve, they will
  - ▶ A **cheater** benefits from co-operation, but does not participate
- Individuals are usually selected to act for themselves, sometimes for the group, and rarely or ever for the species

- Selection operates on individuals; individuals are not adapted to act for the good of the species
- ► The evolution of co-operation always involves tension between what is good for the group, and what is good for the individual
  - ▶ If 'cheating' strategies can evolve, they will
  - ▶ A **cheater** benefits from co-operation, but does not participate
- Individuals are usually selected to act for themselves, sometimes for the group, and rarely or ever for the species

# A lemming not committing suicide



# Example: calculating allele frequencies

▶ I collect 20 peppered moths from a particular place, and find that 4 have genotype  $A_1A_1$ , 8 have genotype  $A_1A_2$ , and 8 have genotype  $A_2A_2$ .

# Example: calculating allele frequencies

- ▶ I collect 20 peppered moths from a particular place, and find that 4 have genotype  $A_1A_1$ , 8 have genotype  $A_1A_2$ , and 8 have genotype  $A_2A_2$ .
- ► What is the observed frequency of each allele?

# Example: calculating allele frequencies

- ▶ I collect 20 peppered moths from a particular place, and find that 4 have genotype  $A_1A_1$ , 8 have genotype  $A_1A_2$ , and 8 have genotype  $A_2A_2$ .
- What is the observed frequency of each allele?
- ► What is the expected frequency of each genotype under the Hardy-Weinberg assumptions?

#### Example: calculating allele frequencies

- ▶ I collect 20 peppered moths from a particular place, and find that 4 have genotype  $A_1A_1$ , 8 have genotype  $A_1A_2$ , and 8 have genotype  $A_2A_2$ .
- What is the observed frequency of each allele?
- ► What is the expected frequency of each genotype under the Hardy-Weinberg assumptions?
- ► What is the observed frequency of each genotype?

#### Example: calculating allele frequencies

- ▶ I collect 20 peppered moths from a particular place, and find that 4 have genotype  $A_1A_1$ , 8 have genotype  $A_1A_2$ , and 8 have genotype  $A_2A_2$ .
- What is the observed frequency of each allele?
- ► What is the expected frequency of each genotype under the Hardy-Weinberg assumptions?
- What is the observed frequency of each genotype?

► If we flip a fair coin 100 times, what is the expected number of heads?

- If we flip a fair coin 100 times, what is the expected number of heads?
  - ► What if we flip it 25 times?

- If we flip a fair coin 100 times, what is the expected number of heads?
  - ▶ What if we flip it 25 times?
- ► We don't expect to get exactly the expected value.

- If we flip a fair coin 100 times, what is the expected number of heads?
  - ▶ What if we flip it 25 times?
- We don't expect to get exactly the expected value.
- ► The 'expected value' is an average of what is expected under our assumptions

- If we flip a fair coin 100 times, what is the expected number of heads?
  - What if we flip it 25 times?
- We don't expect to get exactly the expected value.
- The 'expected value' is an average of what is expected under our assumptions

# How do you know a coin is perfectly fair?

► You can never be sure that a coin is perfectly fair, you can only evaluate your evidence that it's more or less close to fair.

# How do you know a coin is perfectly fair?

- ➤ You can never be sure that a coin is perfectly fair, you can only evaluate your evidence that it's more or less close to fair.
- ► Similarly, we never have evidence that a population is exactly in Hardy-Weinberg equilibrium, we can only evaluate our evidence that it is not in equilibrium, or our evidence that it is close to equilibrium.

# How do you know a coin is perfectly fair?

- ➤ You can never be sure that a coin is perfectly fair, you can only evaluate your evidence that it's more or less close to fair.
- Similarly, we never have evidence that a population is exactly in Hardy-Weinberg equilibrium, we can only evaluate our evidence that it is not in equilibrium, or our evidence that it is close to equilibrium.

▶ When do we expect genotype frequencies to behave like coins?

- When do we expect genotype frequencies to behave like coins?
- ► Alleles selected at random from the previous generation:

- ▶ When do we expect genotype frequencies to behave like coins?
- ▶ Alleles selected at random from the previous generation:
  - \*

- ▶ When do we expect genotype frequencies to behave like coins?
- ▶ Alleles selected at random from the previous generation:
  - \* Random mating within a closed population

- ▶ When do we expect genotype frequencies to behave like coins?
- ▶ Alleles selected at random from the previous generation:
  - \* Random mating within a closed population
  - \*

- ▶ When do we expect genotype frequencies to behave like coins?
- ▶ Alleles selected at random from the previous generation:
  - \* Random mating within a closed population
  - \* No differences in fitness between genotypes

- When do we expect genotype frequencies to behave like coins?
- ▶ Alleles selected at random from the previous generation:
  - \* Random mating within a closed population
  - \* No differences in fitness between genotypes
- ► If these assumptions hold, we expect **Hardy-Weinberg** equilibrium

- ▶ When do we expect genotype frequencies to behave like coins?
- ▶ Alleles selected at random from the previous generation:
  - \* Random mating within a closed population
  - \* No differences in fitness between genotypes
- If these assumptions hold, we expect Hardy-Weinberg equilibrium
  - ► Hardy-Weinberg distribution, with no change in allele frequencies from generation to generation.

- When do we expect genotype frequencies to behave like coins?
- ▶ Alleles selected at random from the previous generation:
  - \* Random mating within a closed population
  - \* No differences in fitness between genotypes
- If these assumptions hold, we expect Hardy-Weinberg equilibrium
  - Hardy-Weinberg distribution, with no change in allele frequencies from generation to generation.

► If we observe large differences from the Hardy-Weinberg equilibrium, this is usually a sign that mating is not random, or that natural selection is operating

- ▶ If we observe large differences from the Hardy-Weinberg equilibrium, this is usually a sign that mating is not random, or that natural selection is operating
- ► The analysis tells us that something is going on, but not what

- ▶ If we observe large differences from the Hardy-Weinberg equilibrium, this is usually a sign that mating is not random, or that natural selection is operating
- ▶ The analysis tells us that something is going on, but not what
- Hardy-Weinberg is a null model: it tells us what to expect if complicating effects are absent

- ▶ If we observe large differences from the Hardy-Weinberg equilibrium, this is usually a sign that mating is not random, or that natural selection is operating
- ▶ The analysis tells us that something is going on, but not what
- Hardy-Weinberg is a null model: it tells us what to expect if complicating effects are absent

► What happens when isolated populations come back into contact?

- What happens when isolated populations come back into contact?
- ► Usually this happens when a geographic barrier disappears

- What happens when isolated populations come back into contact?
- ▶ Usually this happens when a geographic barrier disappears
  - ▶ a land bridge forms between an island and the continent

- What happens when isolated populations come back into contact?
- Usually this happens when a geographic barrier disappears
  - ▶ a land bridge forms between an island and the continent
  - ► a river changes course

- What happens when isolated populations come back into contact?
- Usually this happens when a geographic barrier disappears
  - ▶ a land bridge forms between an island and the continent
  - a river changes course

▶ When two isolated populations come into contact, they may fuse – go back together

- When two isolated populations come into contact, they may fuse – go back together
  - ► Adaptive differences may be small

- When two isolated populations come into contact, they may fuse – go back together
  - Adaptive differences may be small
  - ► Adaptive differences may be overwhelmed by gene flow

- When two isolated populations come into contact, they may fuse – go back together
  - Adaptive differences may be small
  - Adaptive differences may be overwhelmed by gene flow

► In some cases, hybrid offspring may have low fitness

▶ In some cases, hybrid offspring may have low fitness

**▶** 3

- ▶ In some cases, hybrid offspring may have low fitness
  - \* Incompatible alleles

- ▶ In some cases, hybrid offspring may have low fitness
  - \* Incompatible alleles
  - **\***

- ▶ In some cases, hybrid offspring may have low fitness
  - \* Incompatible alleles
  - \* Disruptive selection

- ▶ In some cases, hybrid offspring may have low fitness
  - \* Incompatible alleles
  - \* Disruptive selection
- ► In these cases we expect natural selection for traits that reinforce the distinction between the two species

- ▶ In some cases, hybrid offspring may have low fitness
  - \* Incompatible alleles
  - \* Disruptive selection
- ► In these cases we expect natural selection for traits that reinforce the distinction between the two species
  - ► They avoid mating, using coloration, timing, courtship rituals

- ▶ In some cases, hybrid offspring may have low fitness
  - \* Incompatible alleles
  - \* Disruptive selection
- ► In these cases we expect natural selection for traits that reinforce the distinction between the two species
  - ▶ They avoid mating, using coloration, timing, courtship rituals

#### Meadowlarks





► Allopatry refers to organisms living apart from each other

- ▶ Allopatry refers to organisms living apart from each other
- ► If two populations are isolated from each other, we would expect that they might diverge. Why?

- ▶ Allopatry refers to organisms living apart from each other
- If two populations are isolated from each other, we would expect that they might diverge. Why?
  - **▶** ×

- ▶ Allopatry refers to organisms living apart from each other
- If two populations are isolated from each other, we would expect that they might diverge. Why?
  - ▶ \* Genetic drift

- ▶ Allopatry refers to organisms living apart from each other
- If two populations are isolated from each other, we would expect that they might diverge. Why?
  - ▶ \* Genetic drift
  - \*

- Allopatry refers to organisms living apart from each other
- If two populations are isolated from each other, we would expect that they might diverge. Why?
  - ▶ \* Genetic drift
  - \* Natural selection

- ▶ Allopatry refers to organisms living apart from each other
- If two populations are isolated from each other, we would expect that they might diverge. Why?
  - ▶ \* Genetic drift
  - \* Natural selection
    - **\***

- Allopatry refers to organisms living apart from each other
- ▶ If two populations are isolated from each other, we would expect that they might diverge. Why?
  - ▶ \* Genetic drift.
  - \* Natural selection
    - ▶ \* Different environments, or different adaptive mutations

- Allopatry refers to organisms living apart from each other
- ▶ If two populations are isolated from each other, we would expect that they might diverge. Why?
  - ▶ \* Genetic drift.
  - \* Natural selection
    - ▶ \* Different environments, or different adaptive mutations

#### Mechanisms of isolation

► Isolated populations of the same species can develop if some individuals **disperse** (move) to a new area and **colonize** it (establish a new population).

#### Mechanisms of isolation

- Isolated populations of the same species can develop if some individuals disperse (move) to a new area and colonize it (establish a new population).
- ► Isolated populations of the same species can develop by vicariance — when a population is split by a geographical or ecological barrier

#### Mechanisms of isolation

- Isolated populations of the same species can develop if some individuals disperse (move) to a new area and colonize it (establish a new population).
- Isolated populations of the same species can develop by vicariance – when a population is split by a geographical or ecological barrier

#### Example: ratites



TRIASSIC 200 million years ago

► The ancestors of today's ostriches, emus, etc. were isolated when the super-continent of Gondwanaland drifted apart starting about 140 million years ago

# Example: ratites



TRIASSIC 200 million years ago

► The ancestors of today's ostriches, emus, etc. were isolated when the super-continent of Gondwanaland drifted apart starting about 140 million years ago

► **Sympatry** refers to organisms living in the same geographic area

- Sympatry refers to organisms living in the same geographic area
- ► In general, it should be hard for populations of the same species living in sympatry to diverge.

- Sympatry refers to organisms living in the same geographic area
- ▶ In general, it should be hard for populations of the same species living in sympatry to diverge.
  - **▶** ≯

- Sympatry refers to organisms living in the same geographic area
- ▶ In general, it should be hard for populations of the same species living in sympatry to diverge.
  - ▶ \* Gene flow

- Sympatry refers to organisms living in the same geographic area
- ▶ In general, it should be hard for populations of the same species living in sympatry to diverge.
  - ▶ \* Gene flow
- ► Divergence by partitioning habitats

- Sympatry refers to organisms living in the same geographic area
- ▶ In general, it should be hard for populations of the same species living in sympatry to diverge.
  - ▶ \* Gene flow
- Divergence by partitioning habitats
  - ► In some cases, gene flow will prevent divergence

- Sympatry refers to organisms living in the same geographic area
- ▶ In general, it should be hard for populations of the same species living in sympatry to diverge.
  - ▶ \* Gene flow
- ▶ Divergence by partitioning habitats
  - ▶ In some cases, gene flow will prevent divergence
- ► Divergence by genetic incompatibility

- Sympatry refers to organisms living in the same geographic area
- In general, it should be hard for populations of the same species living in sympatry to diverge.
  - ▶ \* Gene flow
- Divergence by partitioning habitats
  - ▶ In some cases, gene flow will prevent divergence
- Divergence by genetic incompatibility
  - ▶ In some cases, one will drive the other extinct via competition

- Sympatry refers to organisms living in the same geographic area
- In general, it should be hard for populations of the same species living in sympatry to diverge.
  - ▶ \* Gene flow
- Divergence by partitioning habitats
  - ▶ In some cases, gene flow will prevent divergence
- Divergence by genetic incompatibility
  - ▶ In some cases, one will drive the other extinct via competition

► A **monophyletic group** is a group *defined by* a single common ancestor

- A monophyletic group is a group defined by a single common ancestor
  - ► All descendants of the ancestor must be in the group

- A monophyletic group is a group defined by a single common ancestor
  - ▶ All descendants of the ancestor must be in the group
- ► Monophyletic groups can also be called **clades** or **taxa**.

- A monophyletic group is a group defined by a single common ancestor
  - ▶ All descendants of the ancestor must be in the group
- ▶ Monophyletic groups can also be called **clades** or **taxa**.
- ► As biologists, we should try to think in terms of clades

- A monophyletic group is a group defined by a single common ancestor
  - ▶ All descendants of the ancestor must be in the group
- ▶ Monophyletic groups can also be called **clades** or **taxa**.
- As biologists, we should try to think in terms of clades
  - ► Are flying vertebrates a clade?

- ► A monophyletic group is a group *defined by* a single common ancestor
  - ▶ All descendants of the ancestor must be in the group
- ▶ Monophyletic groups can also be called **clades** or **taxa**.
- As biologists, we should try to think in terms of clades
  - Are flying vertebrates a clade?
  - What are some prominent groups that are not clades?

- ► A monophyletic group is a group *defined by* a single common ancestor
  - All descendants of the ancestor must be in the group
- ▶ Monophyletic groups can also be called **clades** or **taxa**.
- As biologists, we should try to think in terms of clades
  - Are flying vertebrates a clade?
  - What are some prominent groups that are not clades?

- ► A monophyletic group is a group *defined by* a single common ancestor
  - All descendants of the ancestor must be in the group
- ▶ Monophyletic groups can also be called **clades** or **taxa**.
- As biologists, we should try to think in terms of clades
  - Are flying vertebrates a clade?
  - What are some prominent groups that are not clades?
    - \* apes, reptiles, dinosaurs

# Monophyletic group

- A monophyletic group is a group defined by a single common ancestor
  - All descendants of the ancestor must be in the group
- ▶ Monophyletic groups can also be called **clades** or **taxa**.
- As biologists, we should try to think in terms of clades
  - Are flying vertebrates a clade?
  - ▶ What are some prominent groups that are not clades?
    - \* apes, reptiles, dinosaurs

► Sister taxa can be a useful way of thinking about trees

- Sister taxa can be a useful way of thinking about trees
  - two taxa that share a common node

- ▶ Sister taxa can be a useful way of thinking about trees
  - two taxa that share a common node
  - ▶ You need to take the whole taxon, when appropriate

- Sister taxa can be a useful way of thinking about trees
  - two taxa that share a common node
  - ▶ You need to take the whole taxon, when appropriate
- ► E.g., sisters of: *Homo sapiens*; *Homo erectus*; humans?

- Sister taxa can be a useful way of thinking about trees
  - two taxa that share a common node
  - ▶ You need to take the whole taxon, when appropriate
- ► E.g., sisters of: *Homo sapiens*; *Homo erectus*; humans?
  - ,

- Sister taxa can be a useful way of thinking about trees
  - two taxa that share a common node
  - ▶ You need to take the whole taxon, when appropriate
- ▶ E.g., sisters of: *Homo sapiens*; *Homo erectus*; humans?
  - ▶ \* Homo neanderthalensis; Hn and Hs; Paranthropus

- Sister taxa can be a useful way of thinking about trees
  - two taxa that share a common node
  - ▶ You need to take the whole taxon, when appropriate
- ▶ E.g., sisters of: *Homo sapiens*; *Homo erectus*; humans?
  - ▶ \* Homo neanderthalensis; Hn and Hs; Paranthropus

► The tree indicates the pattern of branching of **lineages** (evolving lines)

- ► The tree indicates the pattern of branching of **lineages** (evolving lines)
- ► Tips are assumed by the model to be monophyletic

- ► The tree indicates the pattern of branching of **lineages** (evolving lines)
- ▶ Tips are assumed by the model to be monophyletic
- ► A tree is a model of how evolution occurred

- ► The tree indicates the pattern of branching of **lineages** (evolving lines)
- ▶ Tips are assumed by the model to be monophyletic
- A tree is a model of how evolution occurred

► A new adaptive mutation can open up further possibilities for adaptation

- A new adaptive mutation can open up further possibilities for adaptation
  - ► Hox gene mutations allowed early animals to develop complex body plans

- ► A new adaptive mutation can open up further possibilities for adaptation
  - Hox gene mutations allowed early animals to develop complex body plans
  - ► The arthropod body plan

- ► A new adaptive mutation can open up further possibilities for adaptation
  - Hox gene mutations allowed early animals to develop complex body plans
  - ▶ The arthropod body plan
    - insects, arachnids, crustaceans . . .

- A new adaptive mutation can open up further possibilities for adaptation
  - Hox gene mutations allowed early animals to develop complex body plans
  - ▶ The arthropod body plan
    - ▶ insects, arachnids, crustaceans . . .
  - ► The tetrapod body plan

- ► A new adaptive mutation can open up further possibilities for adaptation
  - Hox gene mutations allowed early animals to develop complex body plans
  - ▶ The arthropod body plan
    - ▶ insects, arachnids, crustaceans . . .
  - ▶ The tetrapod body plan
    - ► reptiles, mammals . . .

- ► A new adaptive mutation can open up further possibilities for adaptation
  - Hox gene mutations allowed early animals to develop complex body plans
  - ▶ The arthropod body plan
    - ▶ insects, arachnids, crustaceans . . .
  - The tetrapod body plan
    - reptiles, mammals . . .

► Hox genes are involved in determining the identity of different body parts

- Hox genes are involved in determining the identity of different body parts
- ► Taxa with simpler body structures tend to have fewer hox genes

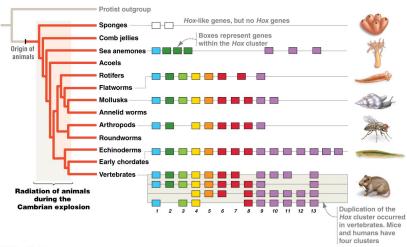
- Hox genes are involved in determining the identity of different body parts
- ► Taxa with simpler body structures tend to have fewer hox genes
  - ► Phylogenetic comparisons provide important evidence that hox genes were involved in evolution of complex body plans

- Hox genes are involved in determining the identity of different body parts
- ► Taxa with simpler body structures tend to have fewer hox genes
  - Phylogenetic comparisons provide important evidence that hox genes were involved in evolution of complex body plans
- Evidence that new hox genes were largely created by gene duplication events

- Hox genes are involved in determining the identity of different body parts
- ► Taxa with simpler body structures tend to have fewer hox genes
  - Phylogenetic comparisons provide important evidence that hox genes were involved in evolution of complex body plans
- Evidence that new hox genes were largely created by gene duplication events
  - ► A kind of mutation; random change

- Hox genes are involved in determining the identity of different body parts
- ► Taxa with simpler body structures tend to have fewer hox genes
  - Phylogenetic comparisons provide important evidence that hox genes were involved in evolution of complex body plans
- Evidence that new hox genes were largely created by gene duplication events
  - A kind of mutation; random change
  - ► If it persists, it was selected for

- Hox genes are involved in determining the identity of different body parts
- ► Taxa with simpler body structures tend to have fewer hox genes
  - Phylogenetic comparisons provide important evidence that hox genes were involved in evolution of complex body plans
- Evidence that new hox genes were largely created by gene duplication events
  - A kind of mutation; random change
  - If it persists, it was selected for



© 2014 Pearson Education, Inc.