Chapter 34

Vertebrates

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Half a Billion Years of Backbones

- Early in the Cambrian period, about 530 million years ago, an astonishing variety of animals inhabited Earth's oceans
- One type of animal gave rise to vertebrates, one of the most successful groups of animals

Fig. 34-1

- The animals called **vertebrates** get their name from vertebrae, the series of bones that make up the backbone
- There are about 52,000 species of vertebrates, including the largest organisms ever to live on the Earth
- Vertebrates have great *disparity*, a wide range of differences within the group

Concept 34.1: Chordates have a notochord and a dorsal, hollow nerve cord

- Vertebrates are a subphylum within the phylum Chordata
- **Chordates** are bilaterian animals that belong to the clade of animals known as Deuterostomia
- Two groups of invertebrate deuterostomes, the urochordates and cephalochordates, are more closely related to vertebrates than to other invertebrates

Fig. 34-2

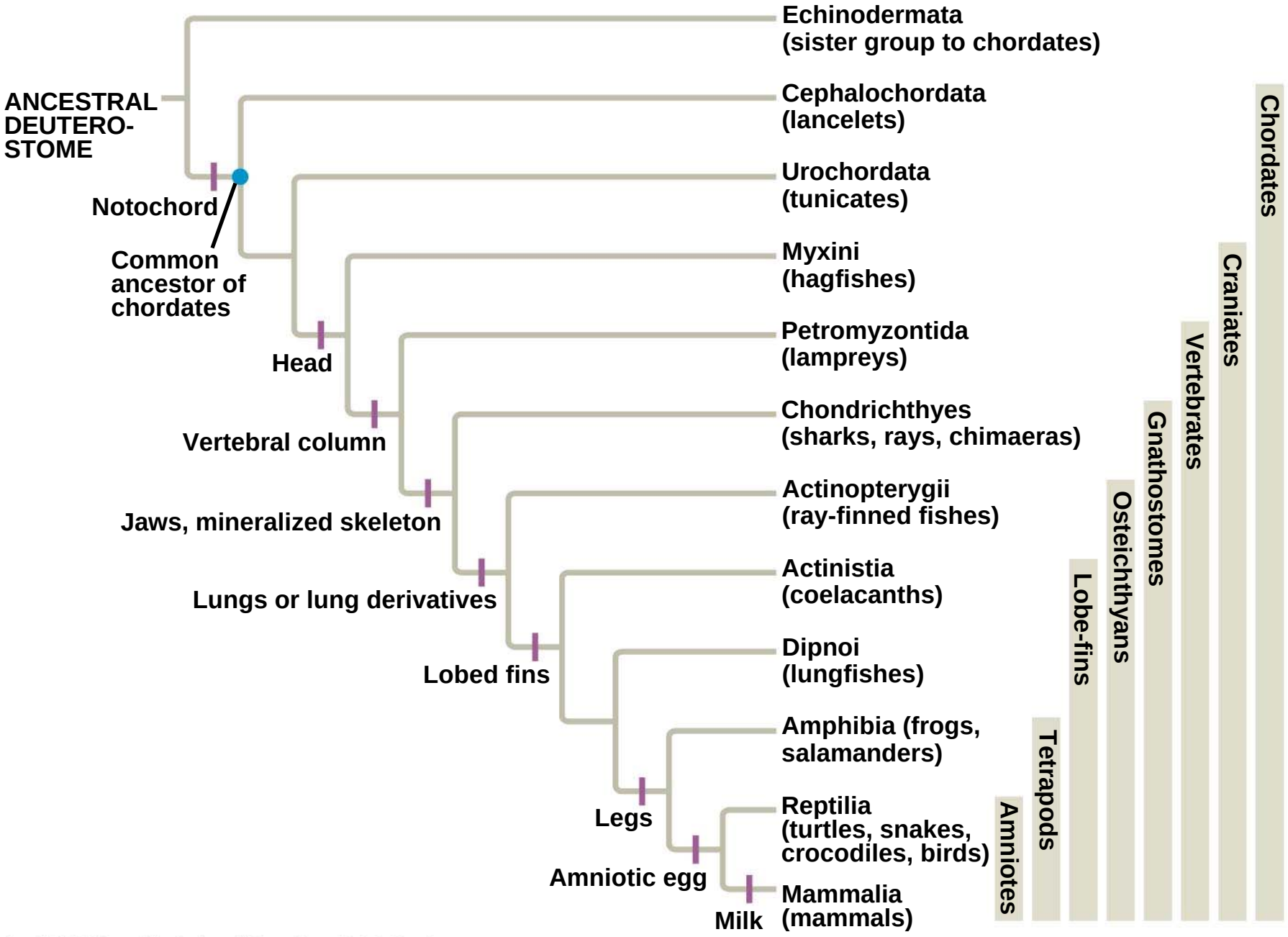


Fig. 34-2a

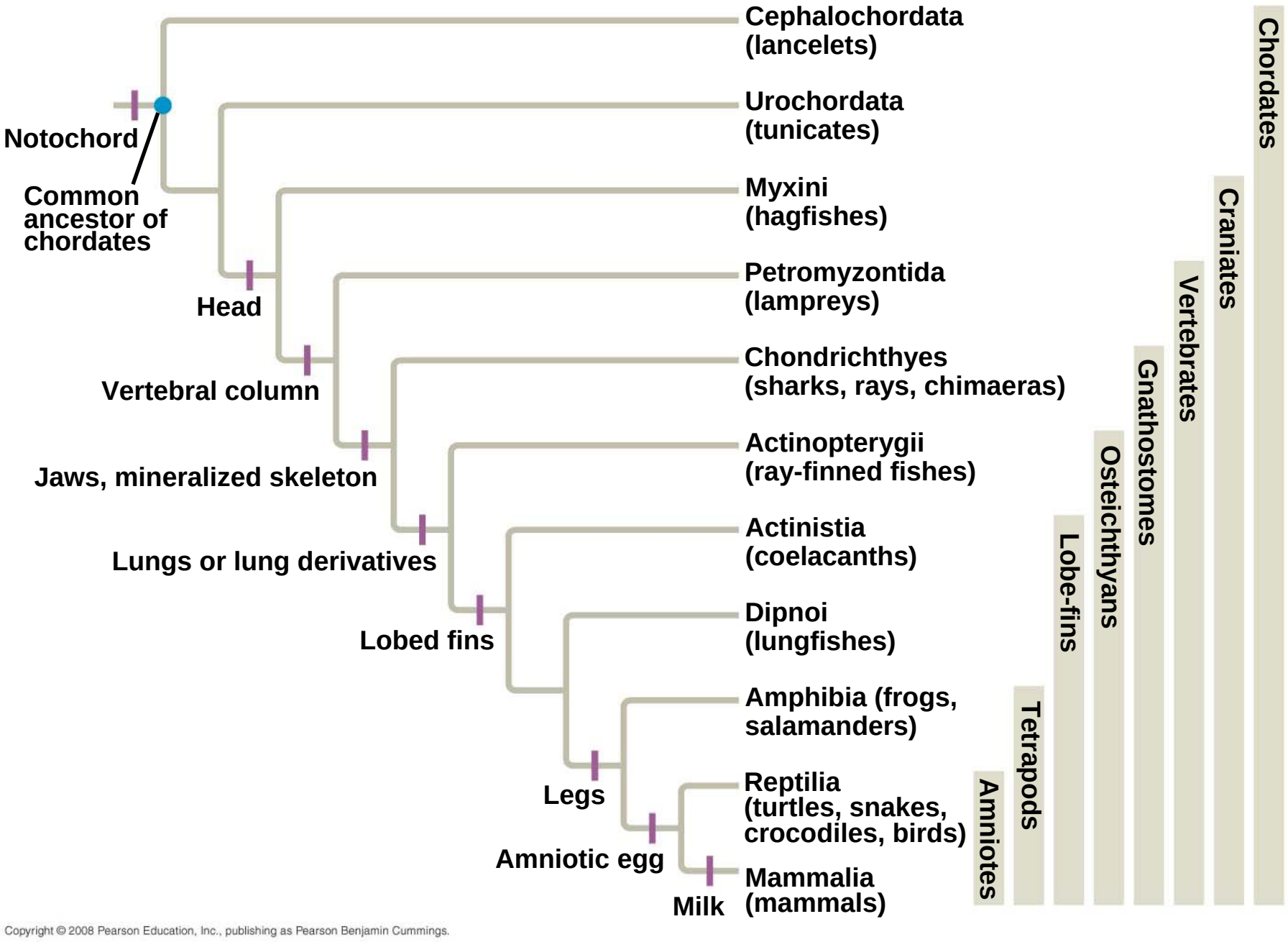


Fig. 34-2b

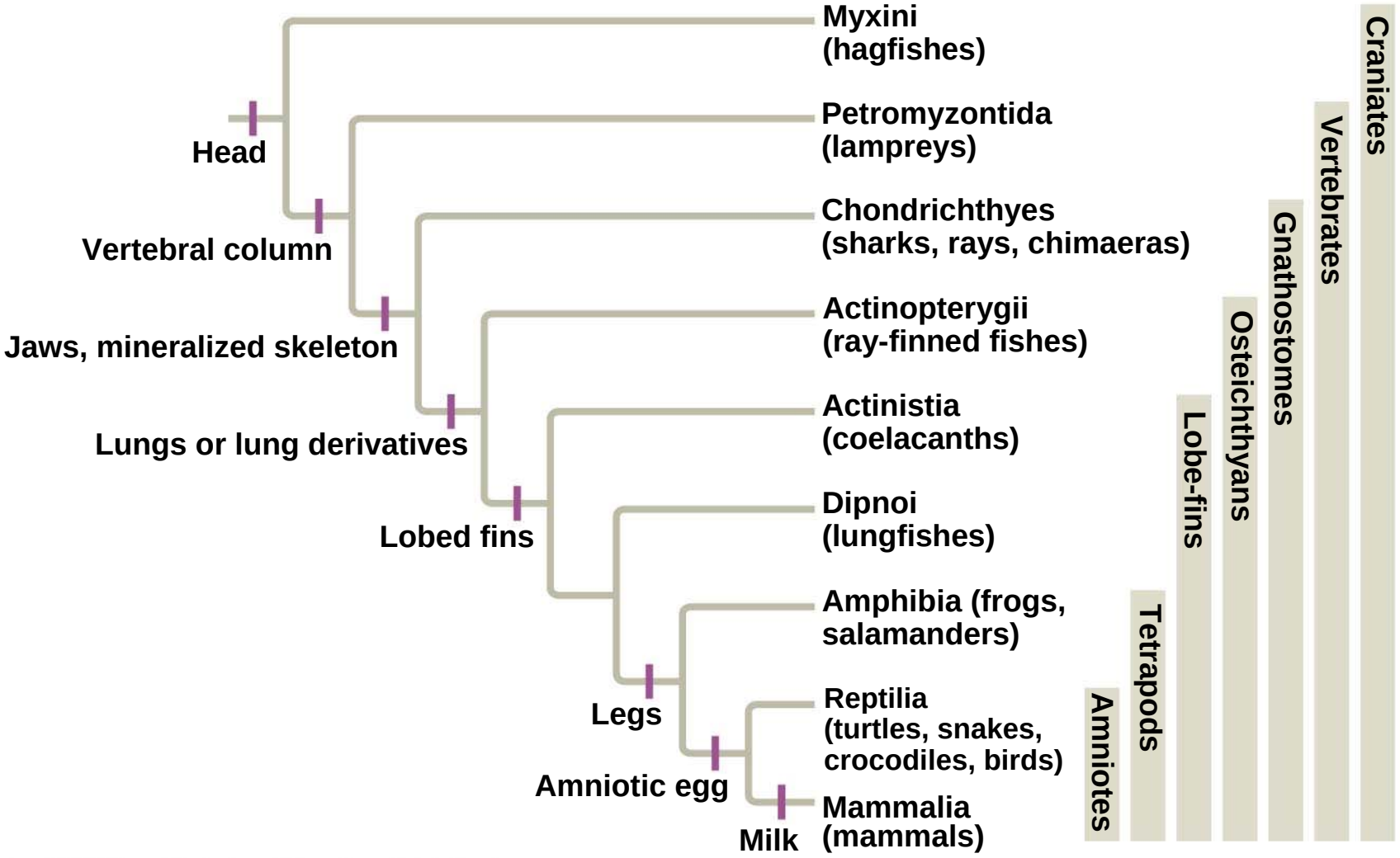


Fig. 34-2c

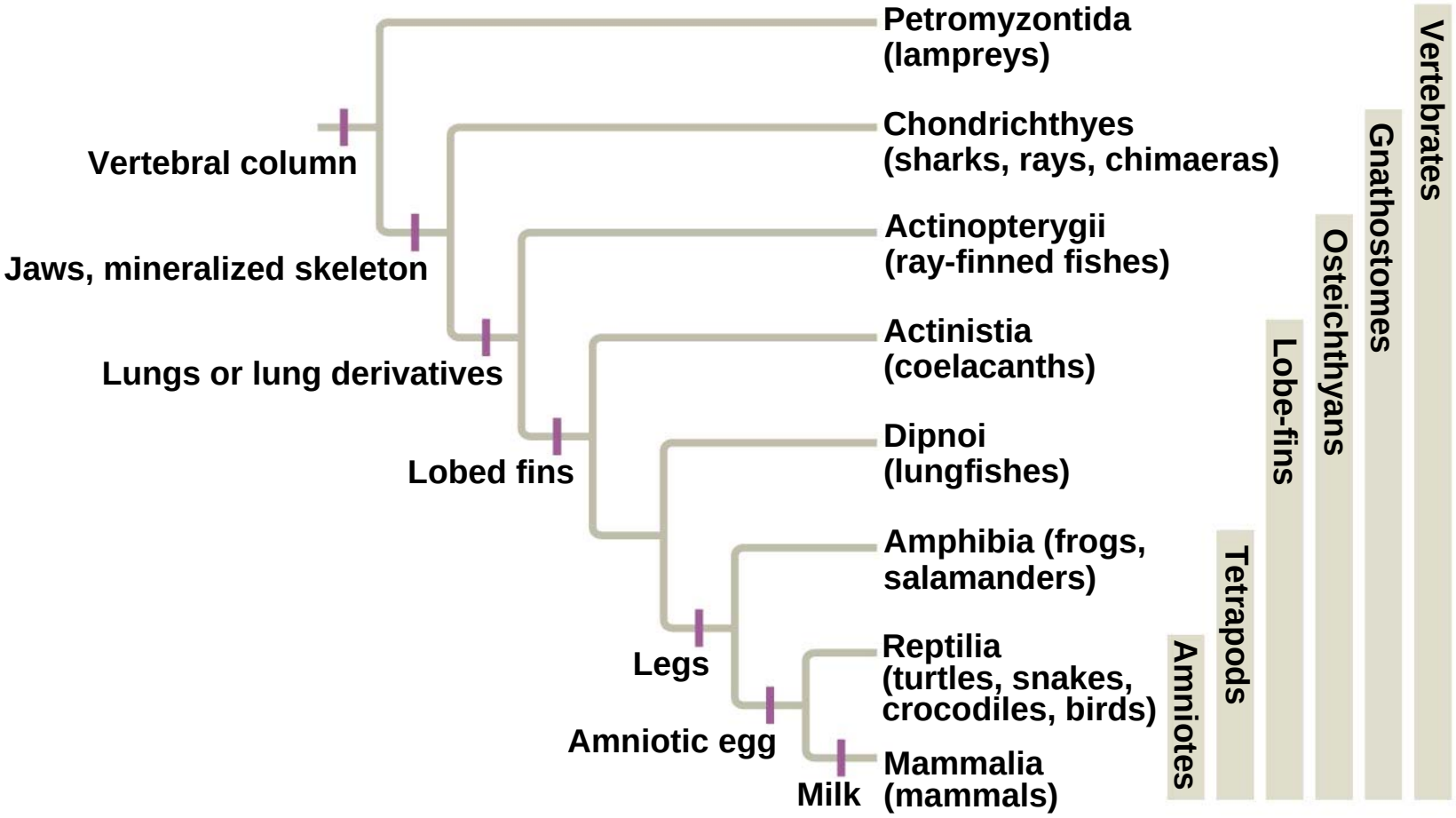


Fig. 34-2d

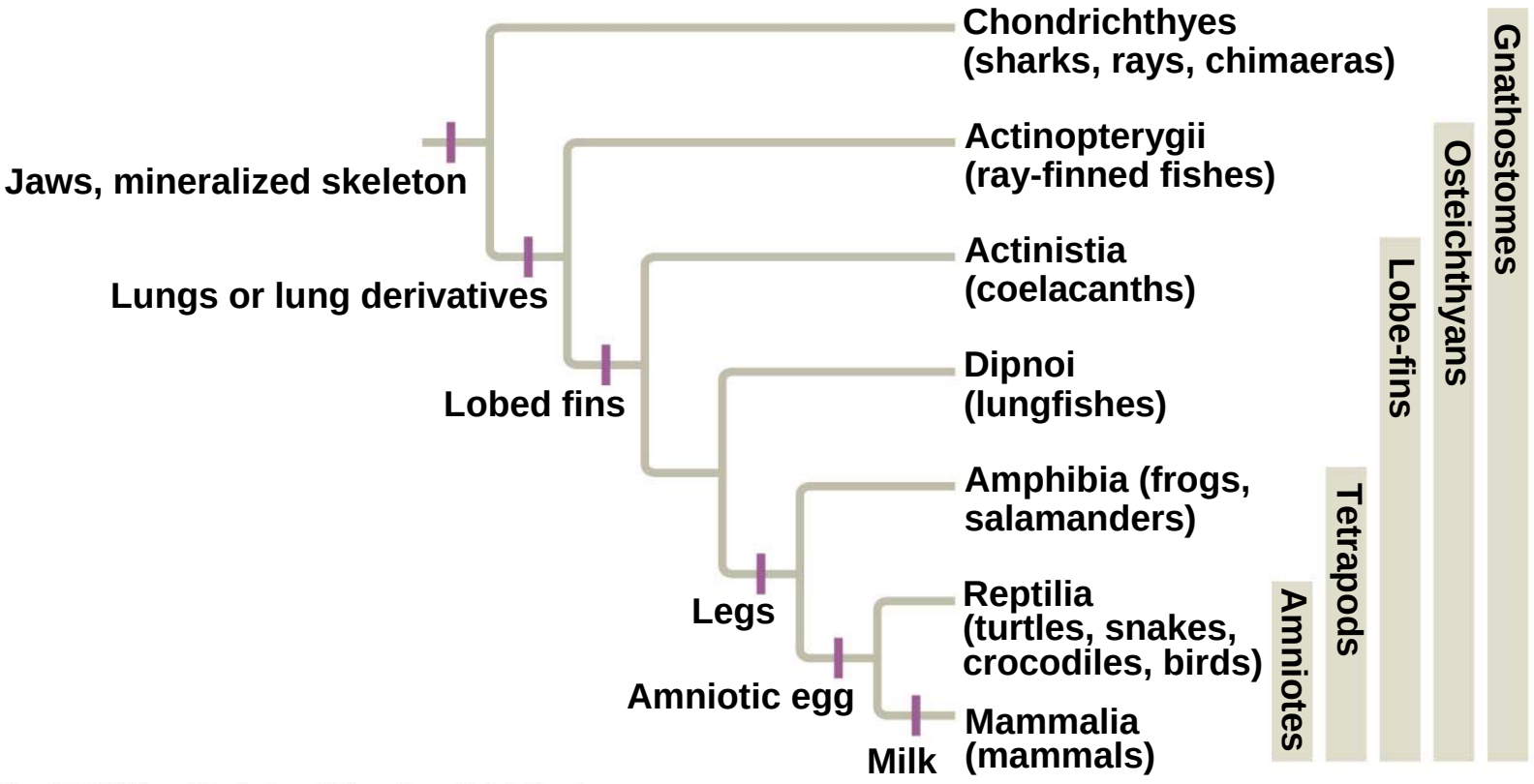


Fig. 34-2e

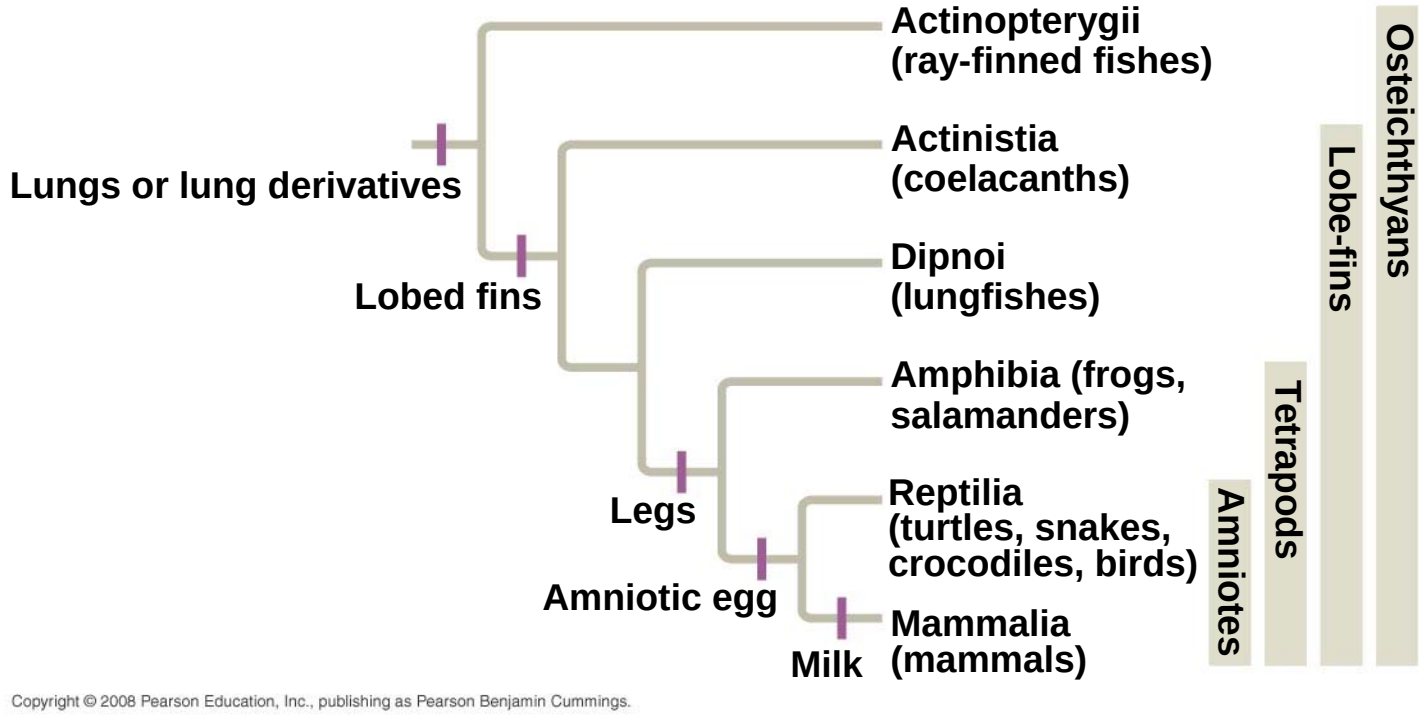


Fig. 34-2f

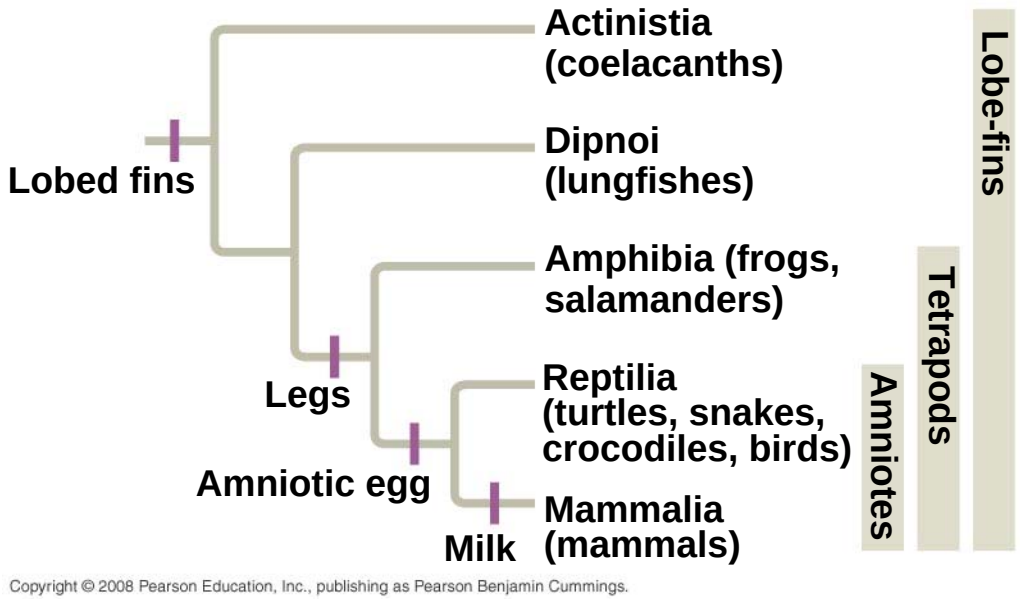


Fig. 34-2g

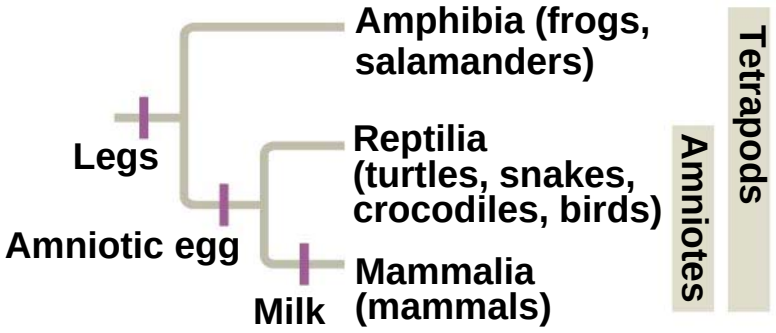
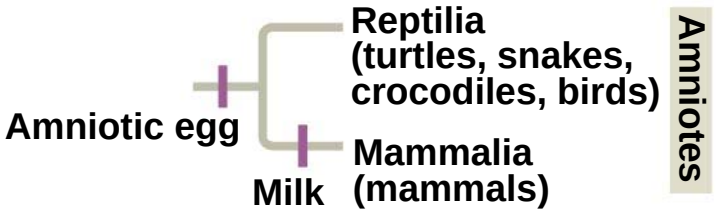


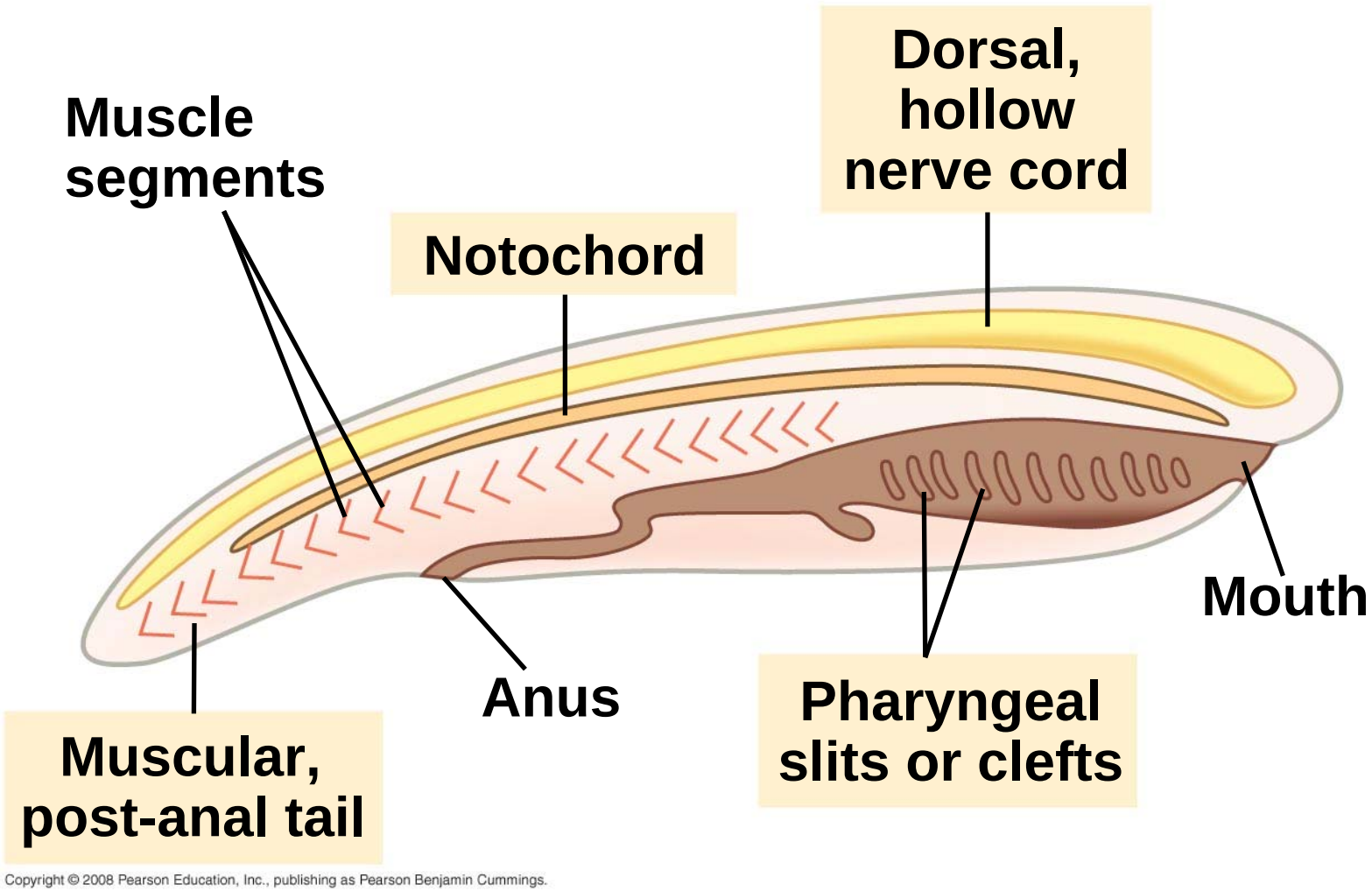
Fig. 34-2h



Derived Characters of Chordates

- All chordates share a set of derived characters
- Some species have some of these traits only during embryonic development
- Four key characters of chordates:
  - Notochord
  - Dorsal, hollow nerve cord
  - Pharyngeal slits or clefts
  - Muscular, post-anal tail

Fig. 34-3



Notochord

- The **notochord** is a longitudinal, flexible rod between the digestive tube and nerve cord
- It provides skeletal support throughout most of the length of a chordate
- In most vertebrates, a more complex, jointed skeleton develops, and the adult retains only remnants of the embryonic notochord

Dorsal, Hollow Nerve Cord

- The nerve cord of a chordate embryo develops from a plate of ectoderm that rolls into a tube dorsal to the notochord
- The nerve cord develops into the central nervous system: the brain and the spinal cord

Pharyngeal Slits or Clefts

- In most chordates, grooves in the pharynx called **pharyngeal clefts** develop into slits that open to the outside of the body
- Functions of **pharyngeal slits**:
  - Suspension-feeding structures in many invertebrate chordates
  - Gas exchange in vertebrates (except vertebrates with limbs, the tetrapods)
  - Develop into parts of the ear, head, and neck in tetrapods

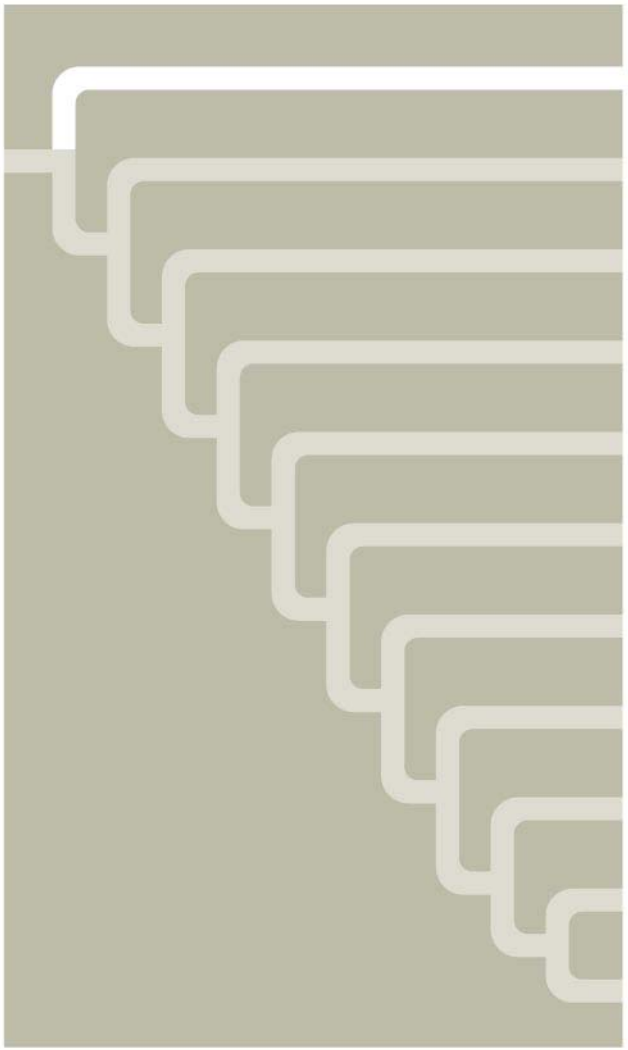
Muscular, Post-Anal Tail

- Chordates have a tail posterior to the anus
- In many species, the tail is greatly reduced during embryonic development
- The tail contains skeletal elements and muscles
- It provides propelling force in many aquatic species

Lancelets

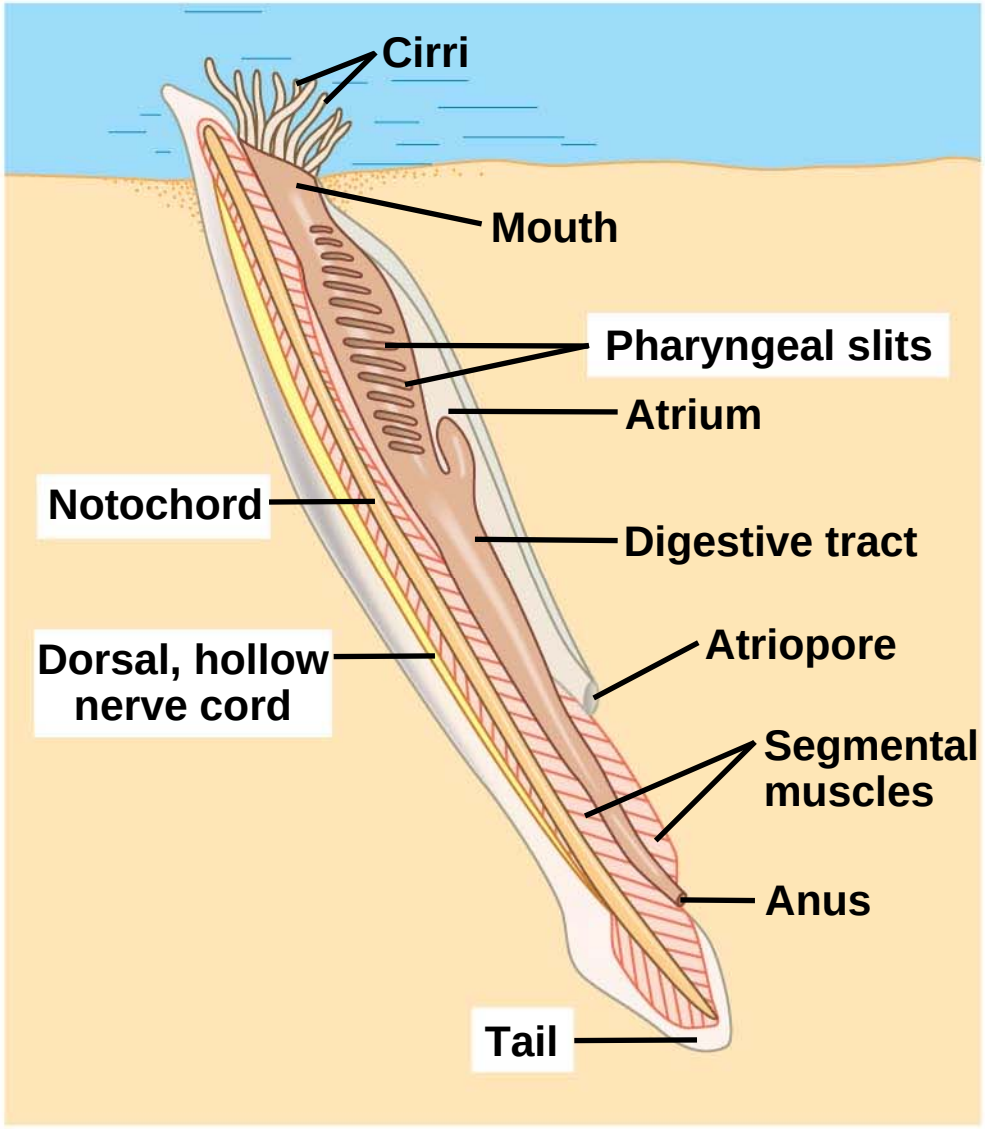
- **Lancelets** (Cephalochordata) are named for their bladelike shape
- They are marine suspension feeders that retain characteristics of the chordate body plan as adults

Fig. 34-UN1



Cephalochordata
Urochordata
Myxini
Petromyzontida
Chondrichthyes
Actinopterygii
Actinistia
Dipnoi
Amphibia
Reptilia
Mammalia

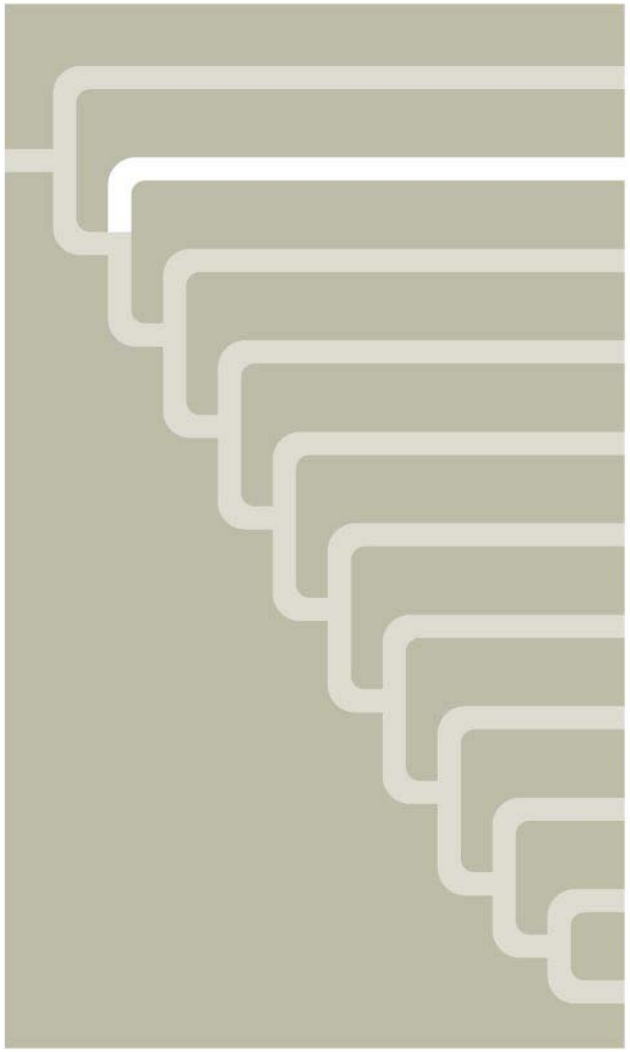
Fig. 34-4



Tunicates

- **Tunicates** (Urochordata) are more closely related to other chordates than are lancelets
- They are marine suspension feeders commonly called sea squirts
- As an adult, a tunicate draws in water through an incurrent siphon, filtering food particles

Fig. 34-UN2



Cephalochordata
Urochordata
Myxini
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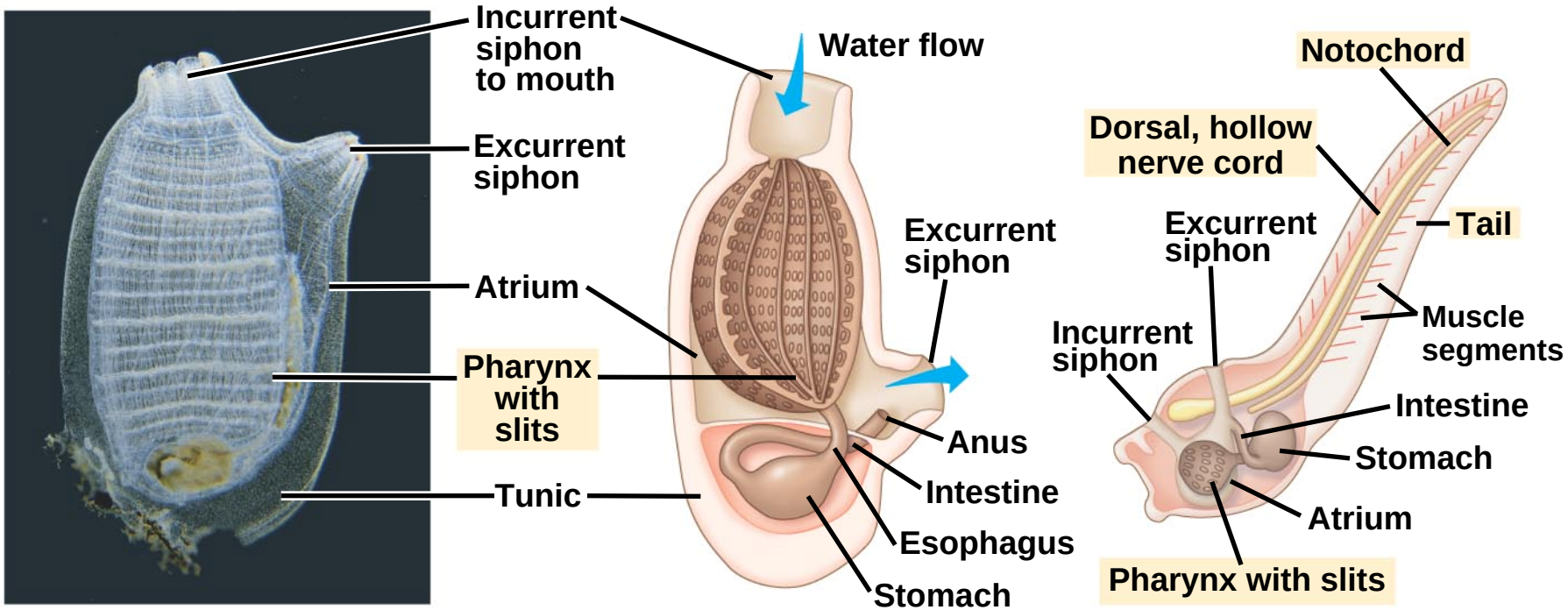
Actinopterygii
Actinistia
Dipnoi
Amphibia
Reptilia
Mammalia

Fig. 34-5



An adult tunicate

A tunicate larva

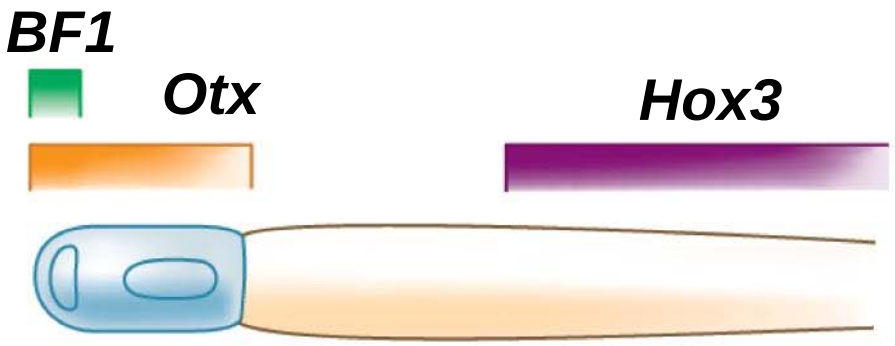
- Tunicates most resemble chordates during their larval stage, which may last only a few minutes

Early Chordate Evolution

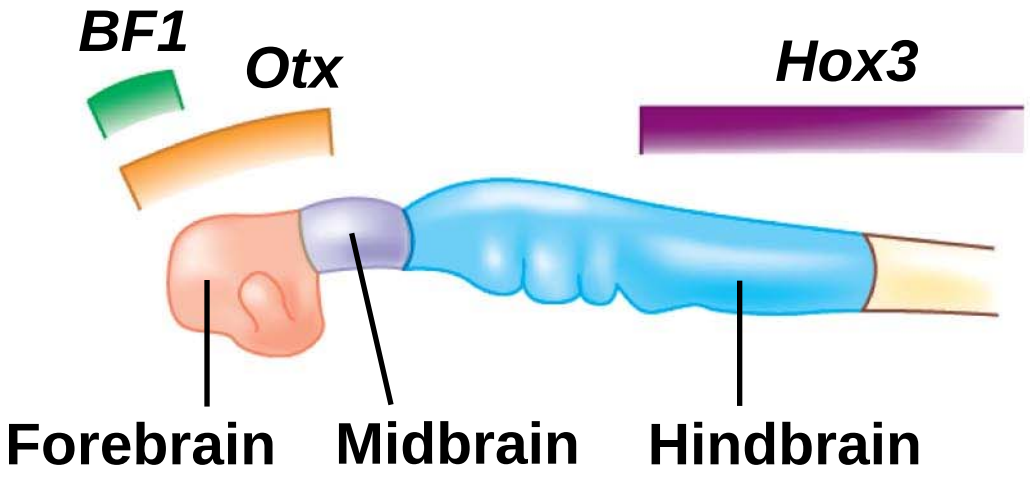
- Ancestral chordates may have resembled lancelets
- Genome sequencing of tunicates has identified genes shared by tunicates and vertebrates
- Gene expression in lancelets holds clues to the evolution of the vertebrate form

Fig. 34-6

Nerve cord of lancelet embryo



Brain of vertebrate embryo (shown straightened)



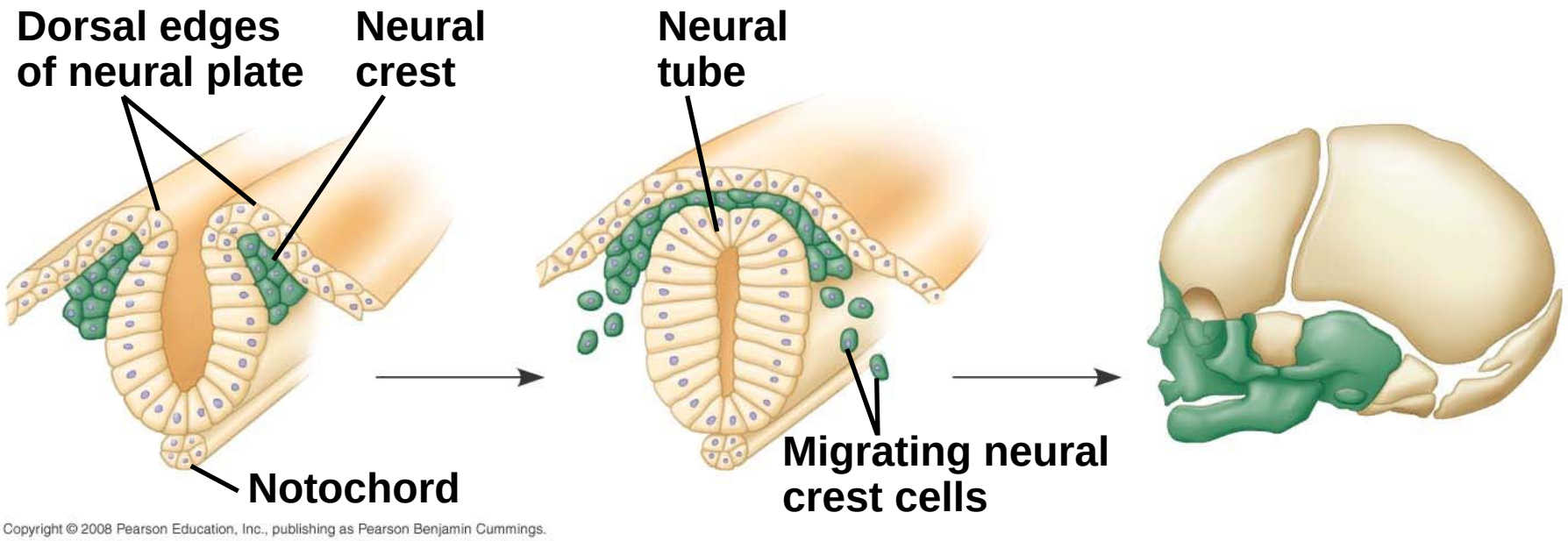
Concept 34.2: Craniates are chordates that have a head

- The origin of a head opened up a completely new way of feeding for chordates: active predation
- **Craniates** share some characteristics: a skull, brain, eyes, and other sensory organs

Derived Characters of Craniates

- Craniates have two clusters of *Hox* genes; lancelets and tunicates have only one cluster
- One feature unique to craniates is the **neural crest**, a collection of cells near the dorsal margins of the closing neural tube in an embryo
- Neural crest cells give rise to a variety of structures, including some of the bones and cartilage of the skull

Fig. 34-7



- In aquatic craniates the pharyngeal clefts evolved into gill slits
- Craniates have a higher metabolism and are more muscular than tunicates and lancelets
- Craniates have a heart with at least two chambers, red blood cells with hemoglobin, and kidneys

The Origin of Craniates

- Fossils from the Cambrian explosion 530 million years ago document the transition to craniates
- The most primitive of the fossils are those of the 3-cm-long *Haikouella*
- *Haikouella* had a well-formed brain, eyes, and muscular segments, but not a skull

Fig. 34-8

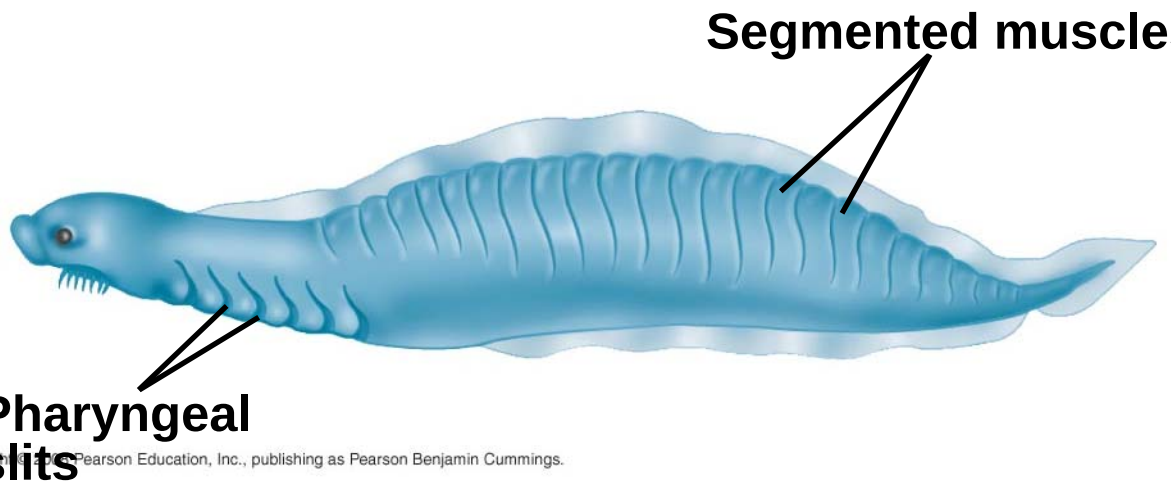
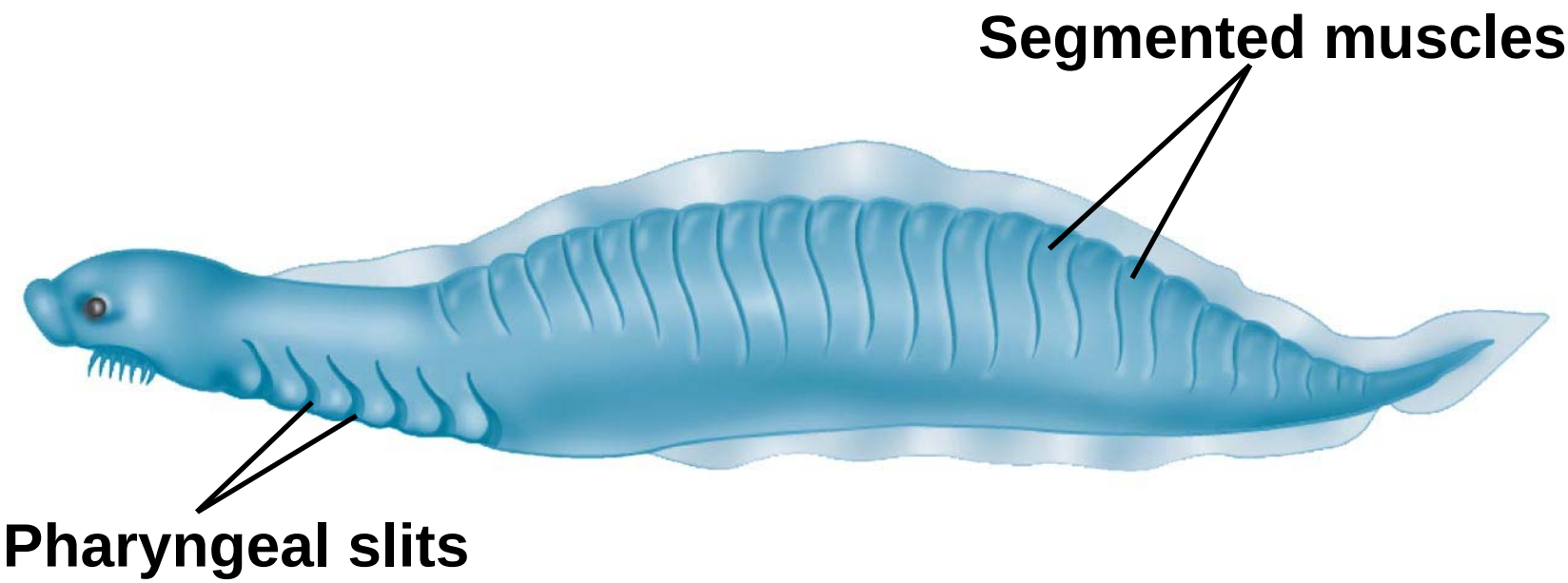


Fig. 34-8a

Fig. 34-8b

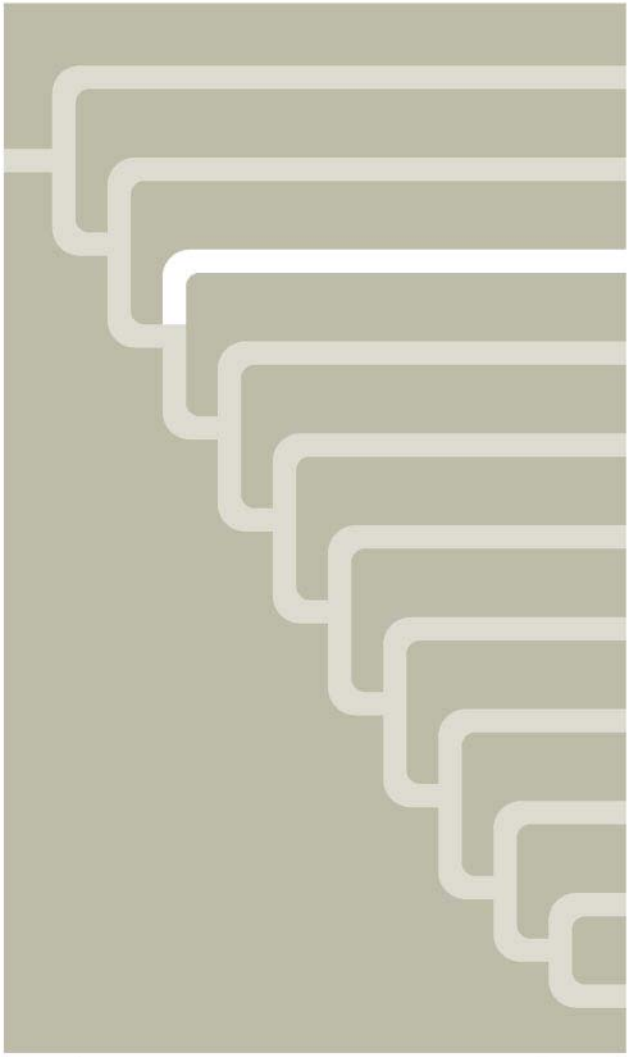


- In other Cambrian rocks, paleontologists have found fossils of even more advanced chordates, such as *Myllokunmingia*
- *Myllokunmingia* had a skull and was a true craniate

Hagfishes

- The least derived surviving craniate lineage is Myxini, the hagfishes
- Hagfishes have a cartilaginous skull and axial rod of cartilage derived from the notochord, but lack jaws and vertebrae

Fig. 34-UN3



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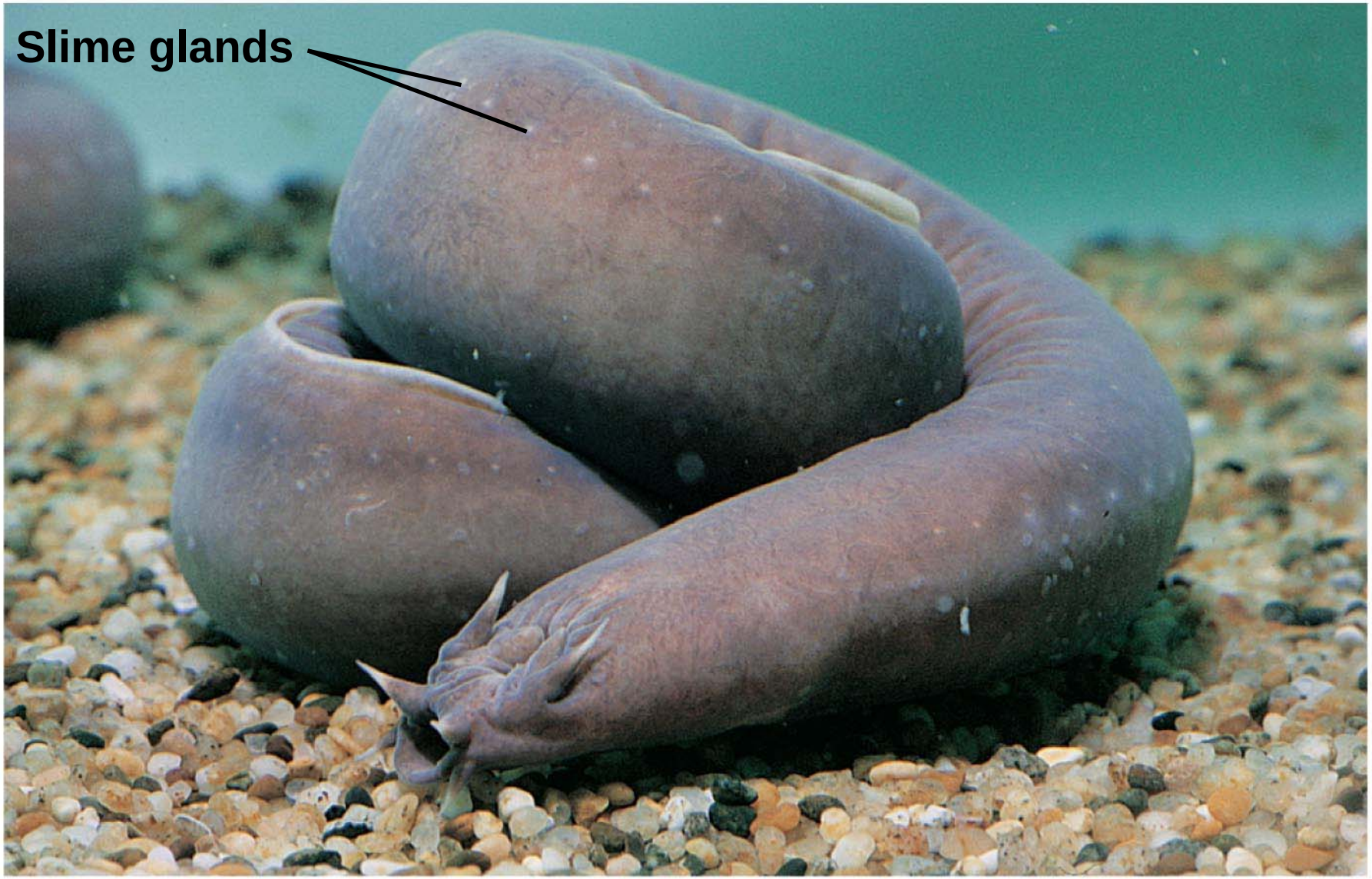
Mammalia

Fig. 34-9



Concept 34.3: Vertebrates are craniates that have a backbone

- During the Cambrian period, a lineage of craniates evolved into vertebrates
- Vertebrates became more efficient at capturing food and avoiding being eaten

Derived Characters of Vertebrates

- Vertebrates underwent a second gene duplication involving the *Dlx* family of transcription factors
- Vertebrates have the following derived characters:
  - Vertebrae enclosing a spinal cord
  - An elaborate skull
  - Fin rays, in the aquatic forms

Lampreys

- Lampreys (Petromyzontida) represent the oldest living lineage of vertebrates
- They are jawless vertebrates inhabiting various marine and freshwater habitats
- They have cartilaginous segments surrounding the notochord and arching partly over the nerve cord

Fig. 34-UN4

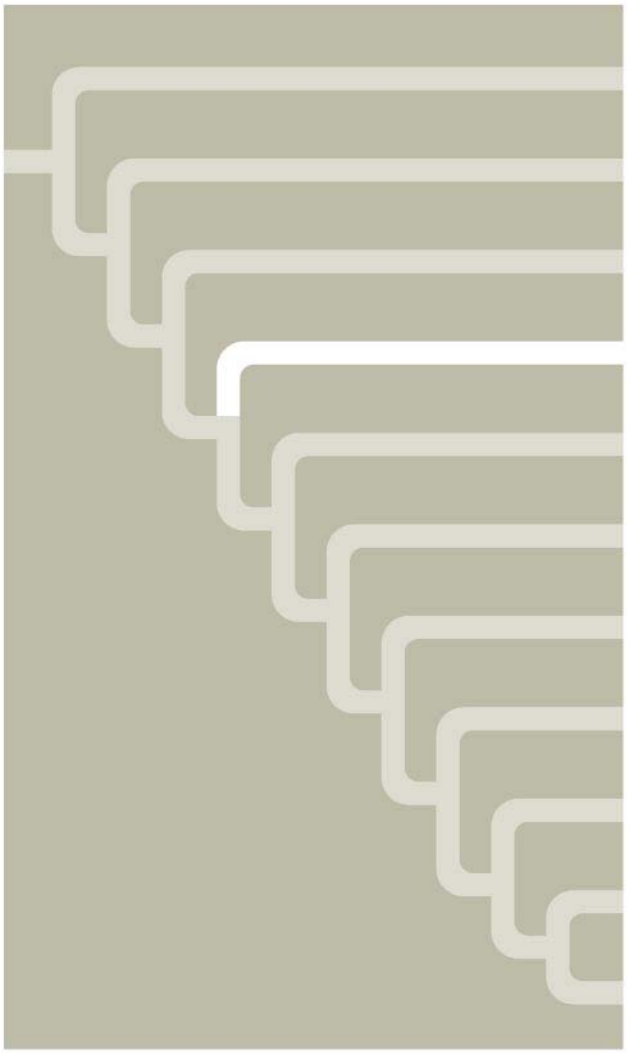


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Fig. 34-10

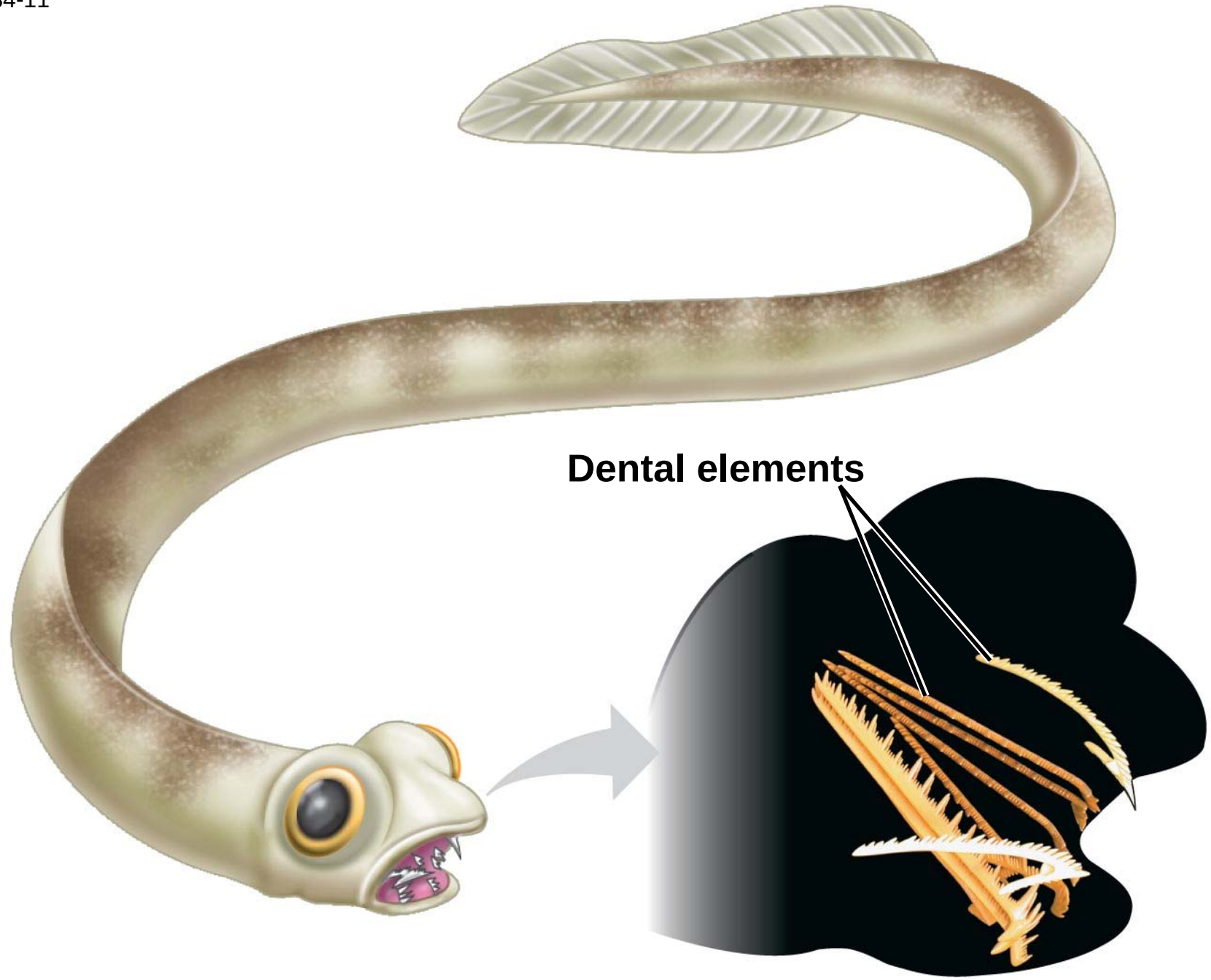
Fig. 34-10a

Fig. 34-10b

Fossils of Early Vertebrates

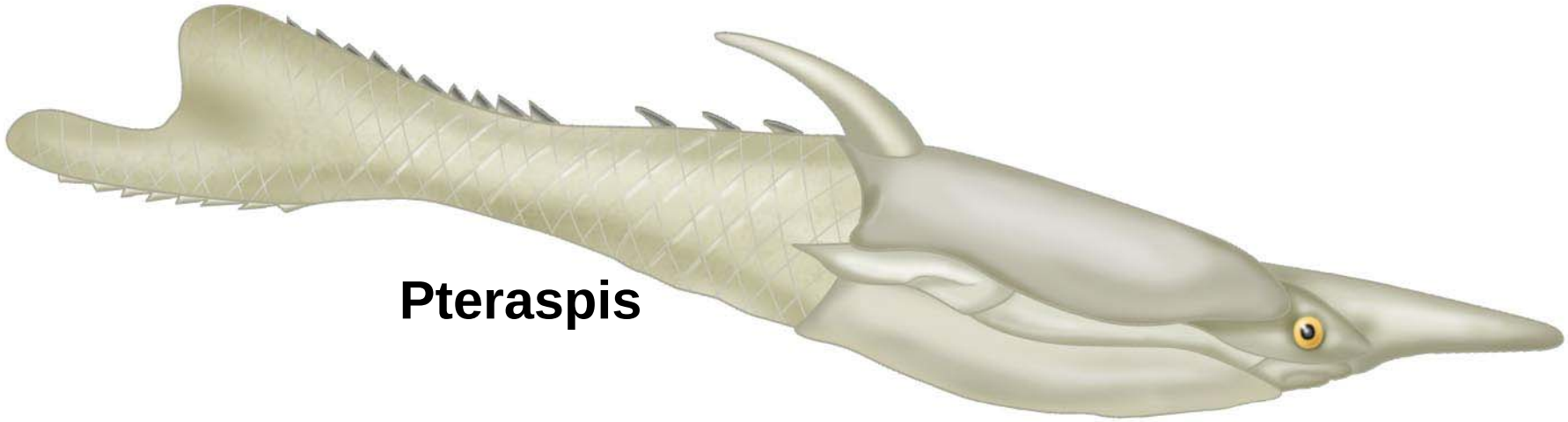
- **Conodonts** were the first vertebrates with mineralized skeletal elements in their mouth and pharynx

Fig. 34-11

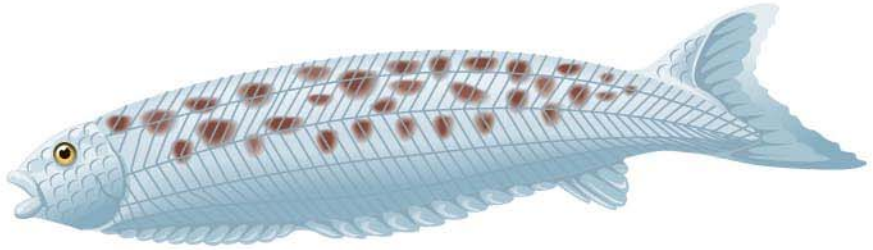


- Other armored, jawless vertebrates had defensive plates of bone on their skin

Fig. 34-12



Pteraspis



Pharyngolepis

Origins of Bone and Teeth

- Mineralization appears to have originated with vertebrate mouthparts
- The vertebrate endoskeleton became fully mineralized much later

Concept 34.4: Gnathostomes are vertebrates that have jaws

- Today, jawed vertebrates, or **gnathostomes**, outnumber jawless vertebrates

Derived Characters of Gnathostomes

- Gnathostomes have jaws that might have evolved from skeletal supports of the pharyngeal slits

Fig. 34-13-1

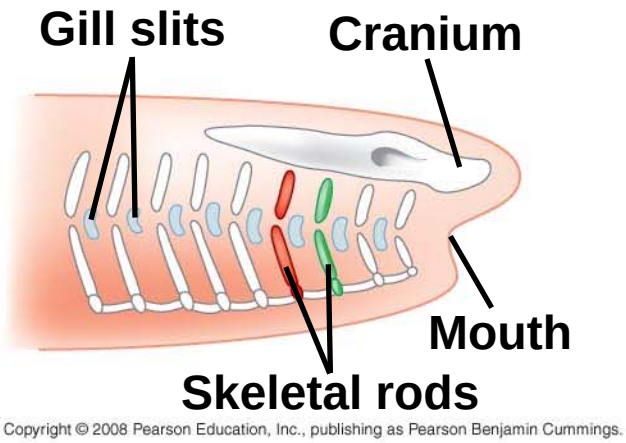


Fig. 34-13-2

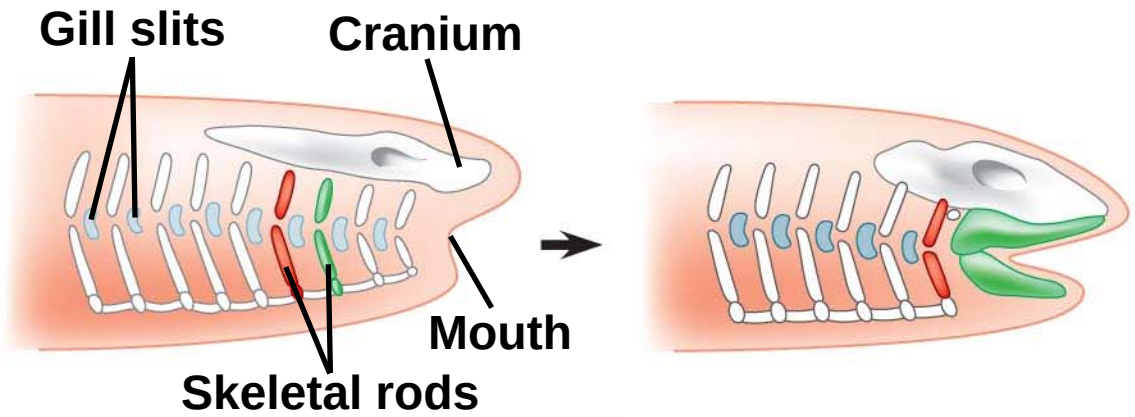
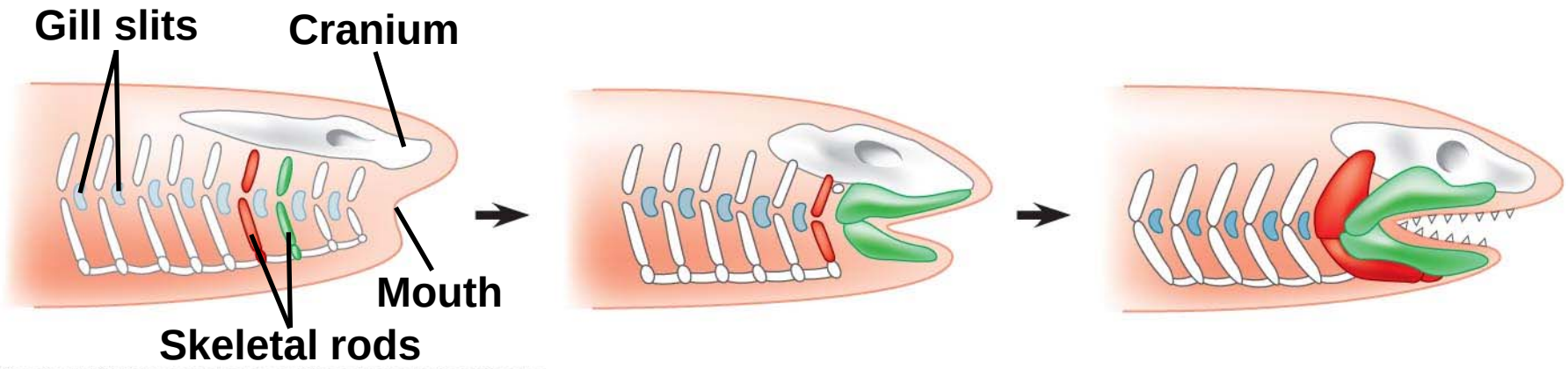


Fig. 34-13-3

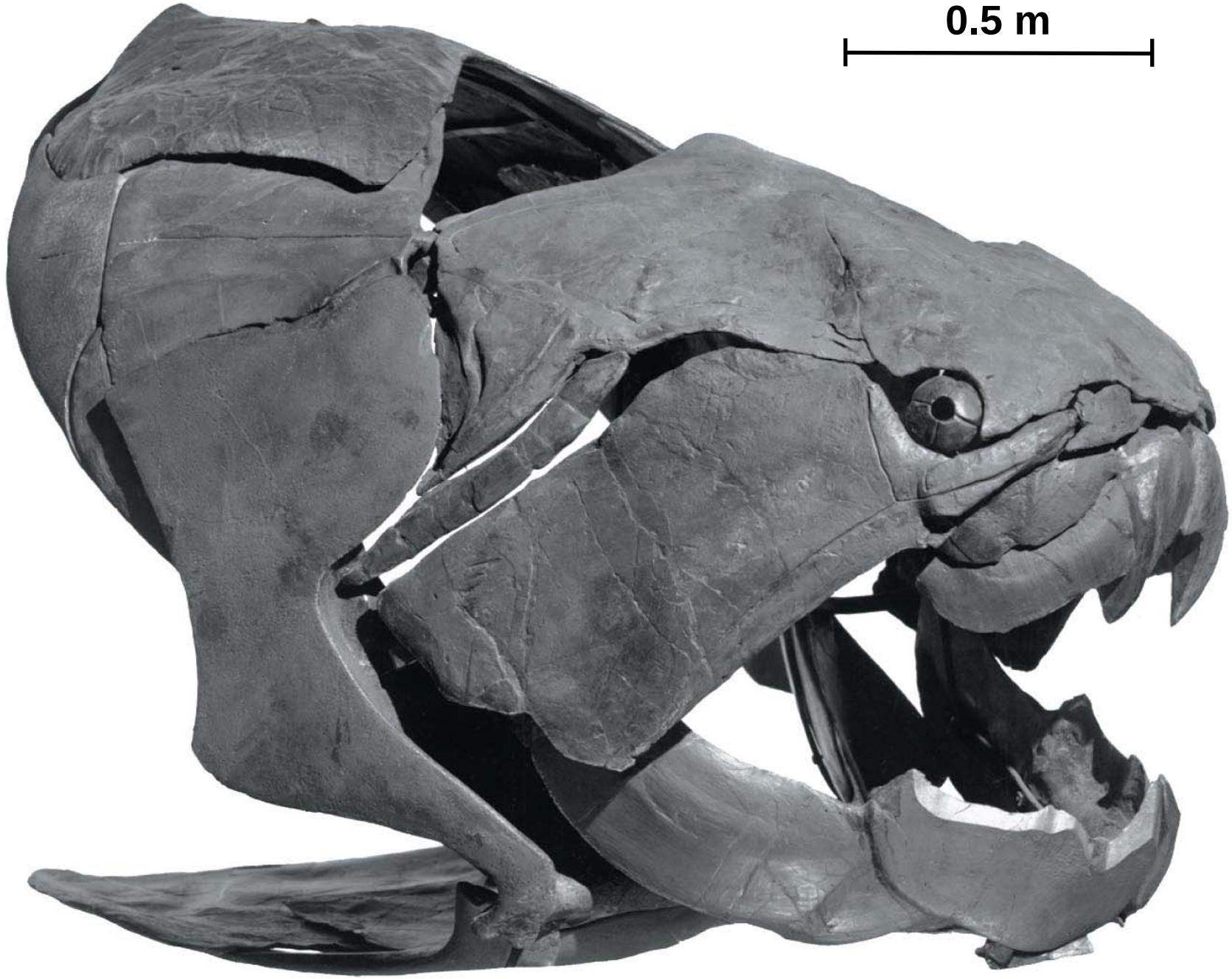


- Other characters common to gnathostomes:
  - An additional duplication of *Hox* genes
  - An enlarged forebrain associated with enhanced smell and vision
  - In aquatic gnathostomes, the **lateral line system**, which is sensitive to vibrations

Fossil Gnathostomes

- The earliest gnathostomes in the fossil record are an extinct lineage of armored vertebrates called **placoderms**

Fig. 34-14



- Another group of jawed vertebrates called acanthodians radiated during the Devonian period

Chondrichthyans (Sharks, Rays, and Their Relatives)

- **Chondrichthyans** (Chondrichthyes) have a skeleton composed primarily of cartilage
- The cartilaginous skeleton evolved secondarily from an ancestral mineralized skeleton
- The largest and most diverse group of chondrichthyans includes the sharks, rays, and skates

PLAY Video: Shark Eating Seal

PLAY Video: Manta Ray

Fig. 34-UN5

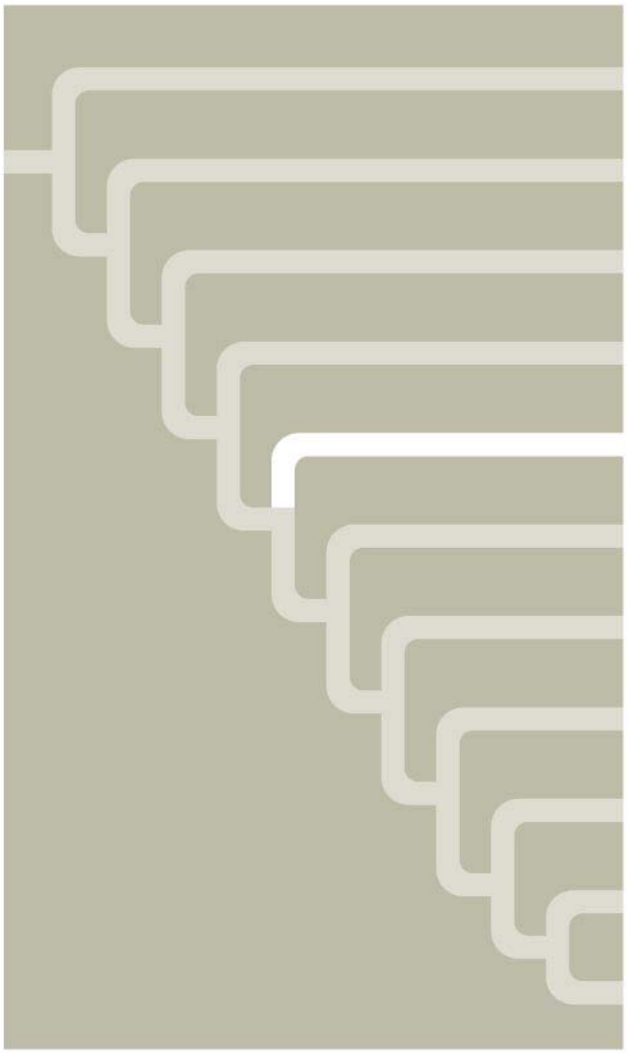


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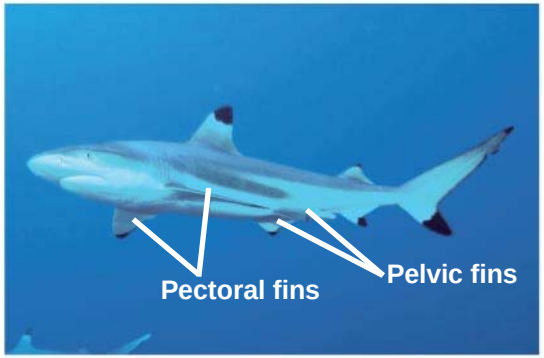
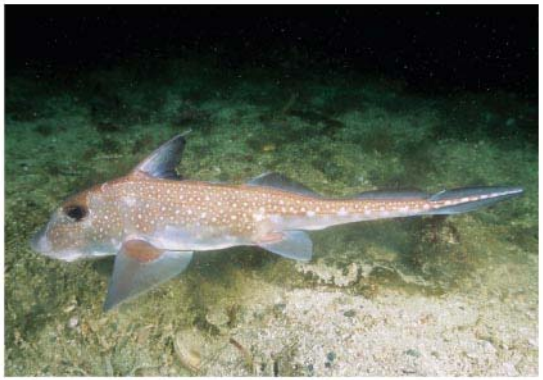
Fig. 34-15



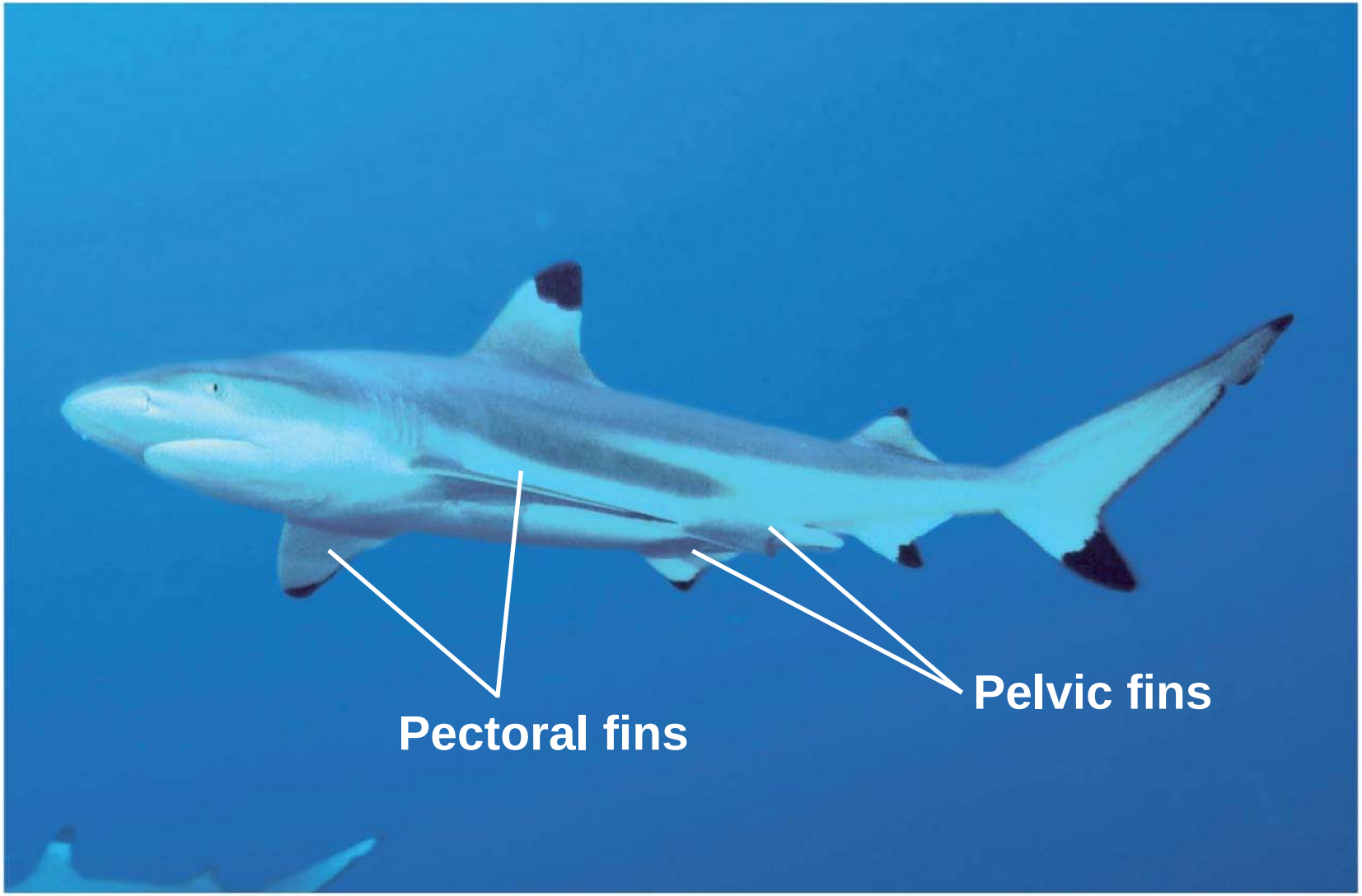
(a) Blacktip reef shark (*Carcharhinus melanopterus*)

(b) Southern stingray (*Dasyatis americana*)



(c) Spotted ratfish (*Hydrolagus colliei*)

Fig. 34-15a



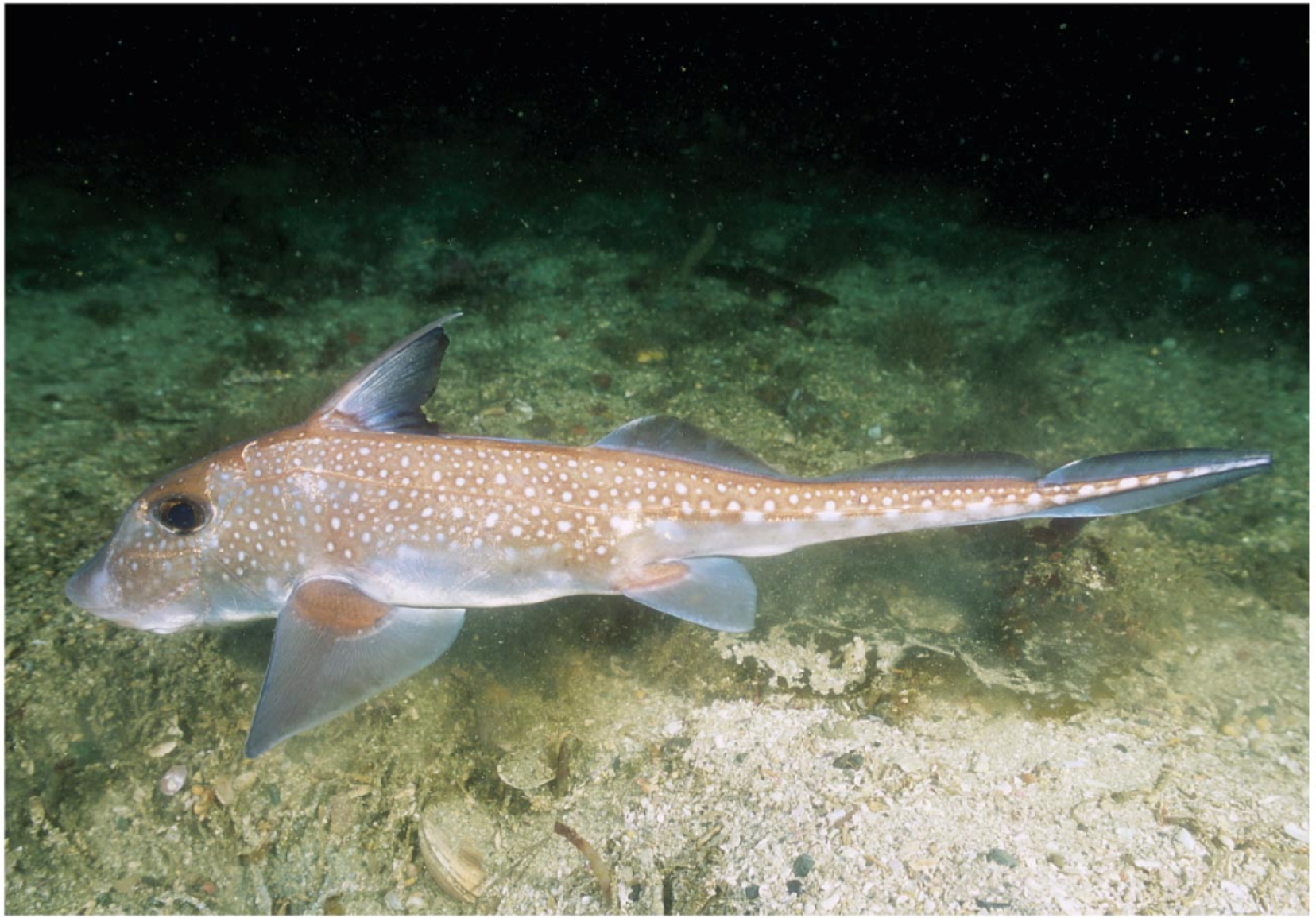
(a) Blacktip reef shark (*Carcharhinus melanopterus*)

Fig. 34-15b

(b) Southern stingray (*Dasyatis americana*)

- A second subclass is composed of a few dozen species of ratfishes

Fig. 34-15c



(c) Spotted ratfish (*Hydrolagus colliei*)

- Most sharks
  - Have a streamlined body and are swift swimmers
  - Are carnivores
  - Have a short digestive tract; a ridge called the *spiral valve* increases the digestive surface area
  - Have acute senses

- Shark eggs are fertilized internally but embryos can develop in different ways:
  - **Oviparous**: eggs hatch outside the mother's body
  - **Ovoviviparous**: the embryo develops within the uterus and is nourished by the egg yolk
  - **Viviparous**: the embryo develops within the uterus and is nourished through a yolk sac placenta from the mother's blood

- The reproductive tract, excretory system, and digestive tract empty into a common **cloaca**

Ray-Finned Fishes and Lobe-Fins

- The vast majority of vertebrates belong to a clade of gnathostomes called Osteichthyes
- Osteichthyes includes the bony fish and tetrapods

- Nearly all living **osteichthyans** have a bony endoskeleton
- Aquatic osteichthyans are the vertebrates we informally call fishes
- Most fishes breathe by drawing water over gills protected by an **operculum**
- Fishes control their buoyancy with an air sac known as a **swim bladder**

Fig. 34-UN6

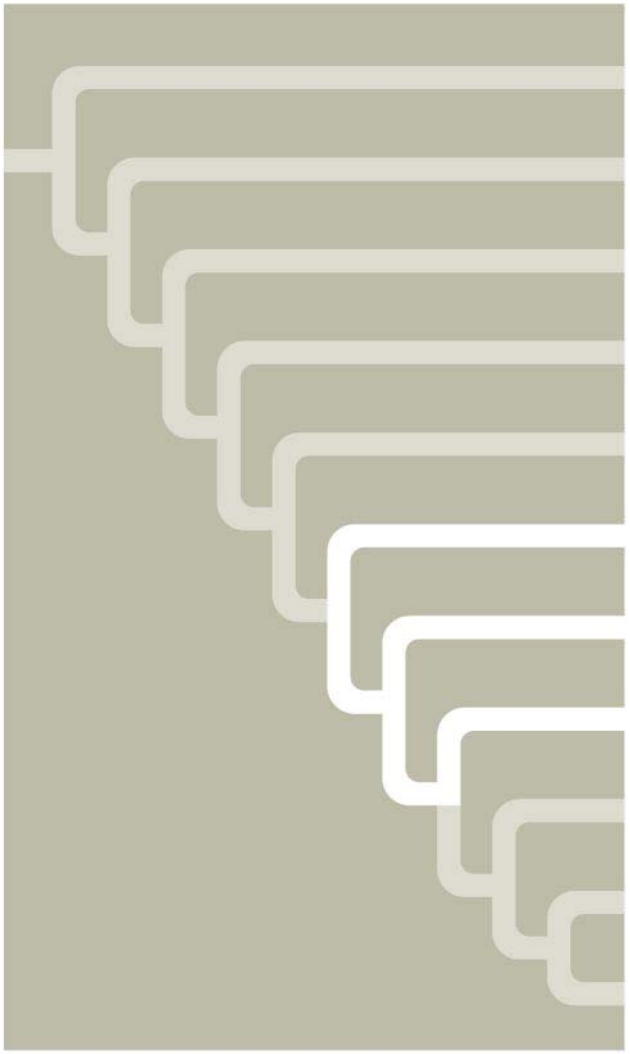


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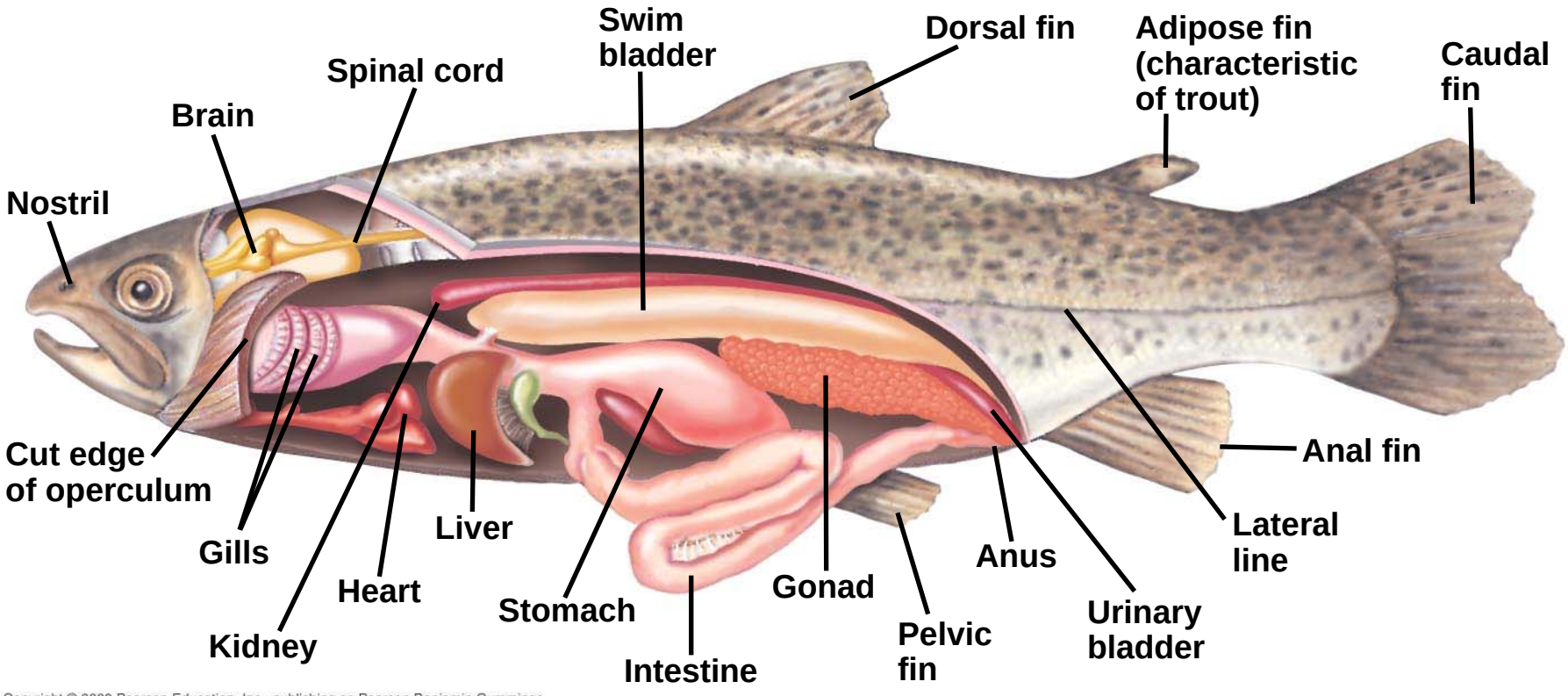
Fig. 34-16



Ray-Finned Fishes

- Class Actinopterygii, the **ray-finned fishes**, includes nearly all the familiar aquatic osteichthyans
- The fins, supported mainly by long, flexible rays, are modified for maneuvering, defense, and other functions

PLAY Video: Clownfish and Anemone

PLAY Video: Coral Reef

PLAY Video: Seahorse Camouflage

Fig. 34-17

(a) Yellowfin tuna (*Thunnus albacares*)

(b) Clownfish (*Amphiprion ocellaris*)

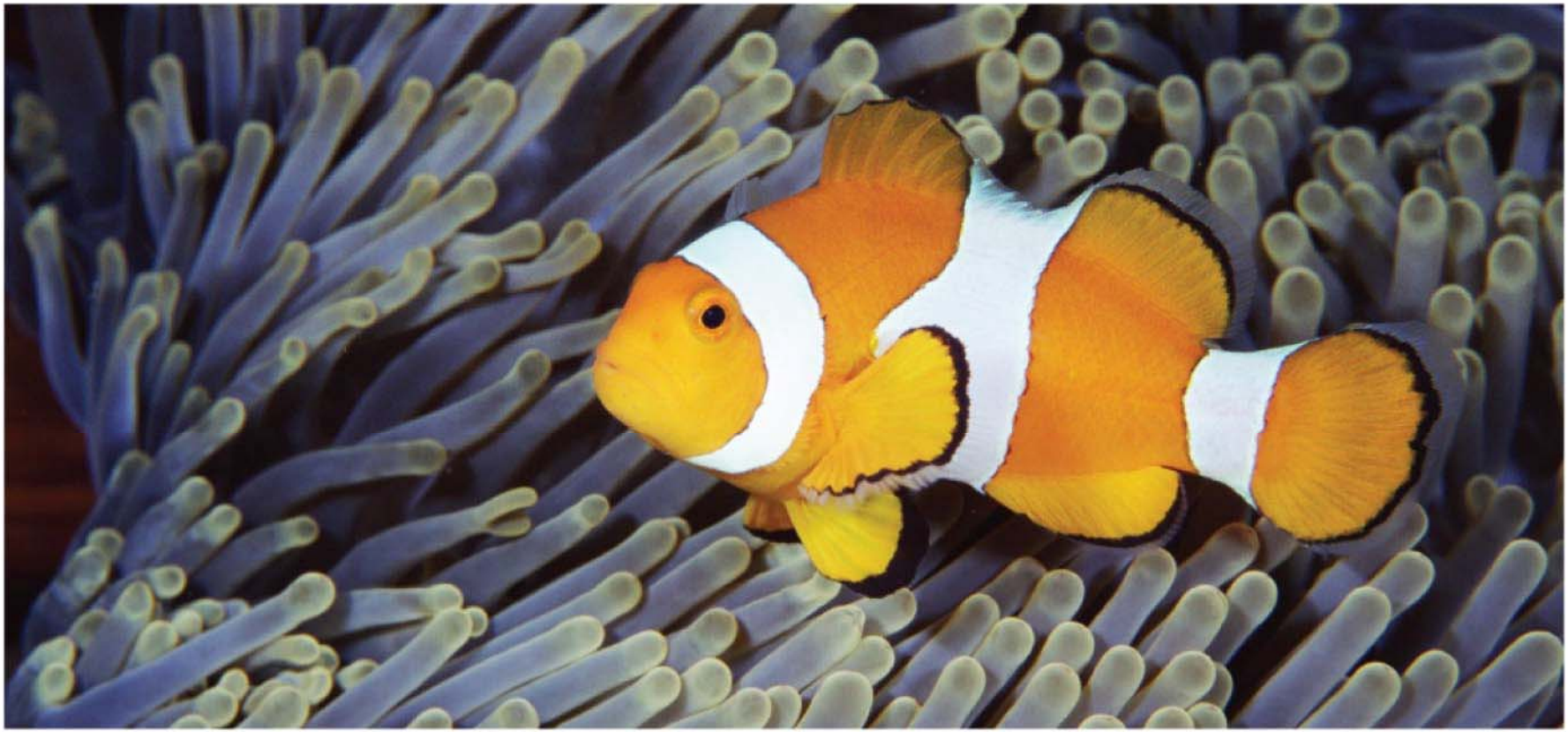
(c) Sea horse (*Hippocampus ramulosus*)

(d) Fine-spotted moray eel (*Gymnothorax dovii*)

Fig. 34-17a

(a) Yellowfin tuna (*Thunnus albacares*)

Fig. 34-17b



(b) Clownfish (*Amphiprion ocellaris*)

Fig. 34-17c

(c) Sea horse (*Hippocampus ramulosus*)

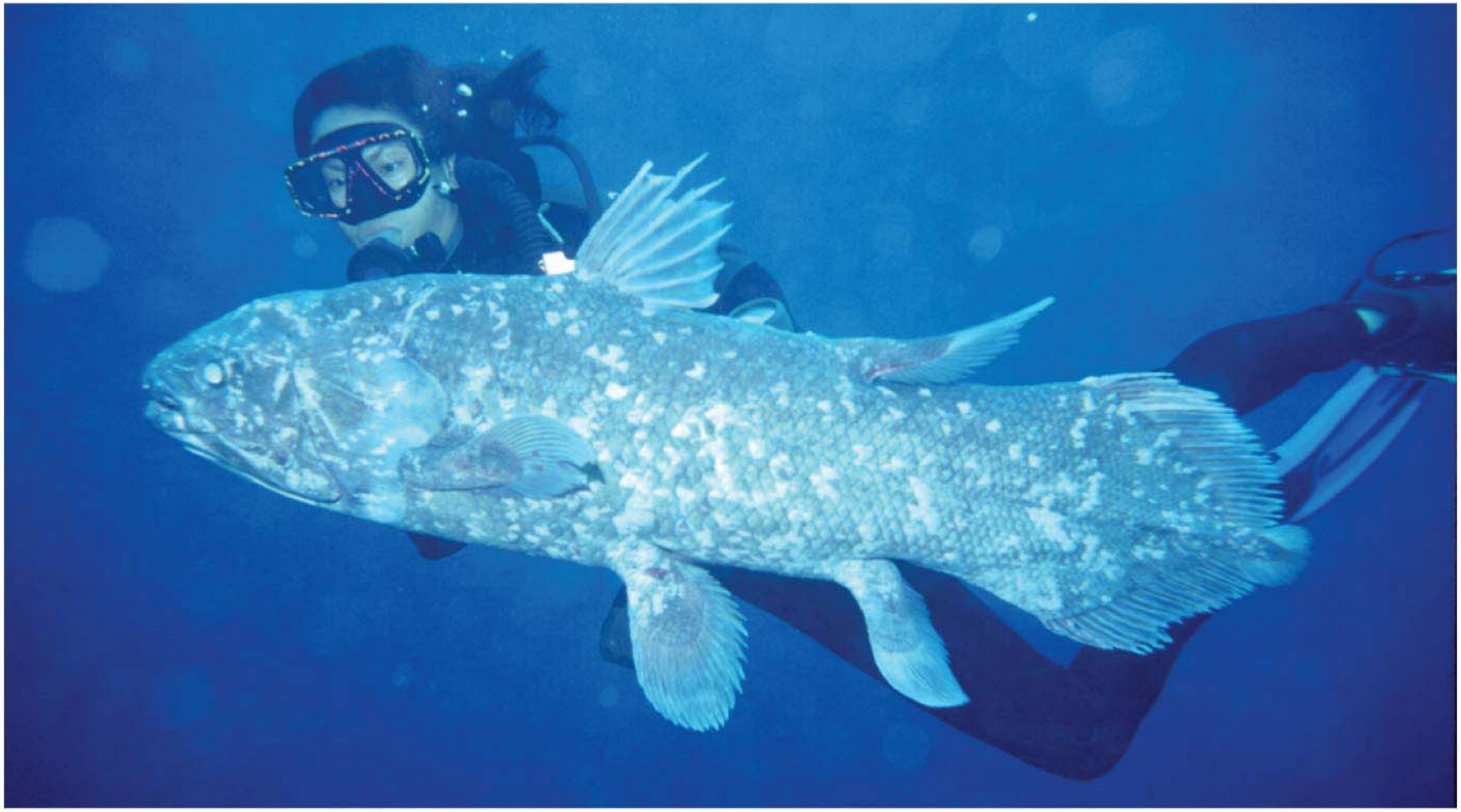
Fig. 34-17d

(d) Fine-spotted moray eel (*Gymnothorax dovii*)

Lobe-Fins

- The **lobe-fins** (Sarcopterygii) have muscular pelvic and pectoral fins
- Three lineages survive and include coelacanths, lungfishes, and tetrapods

Fig. 34-18



Concept 34.5: Tetrapods are gnathostomes that have limbs

- One of the most significant events in vertebrate history was when the fins of some lobe-fins evolved into the limbs and feet of tetrapods

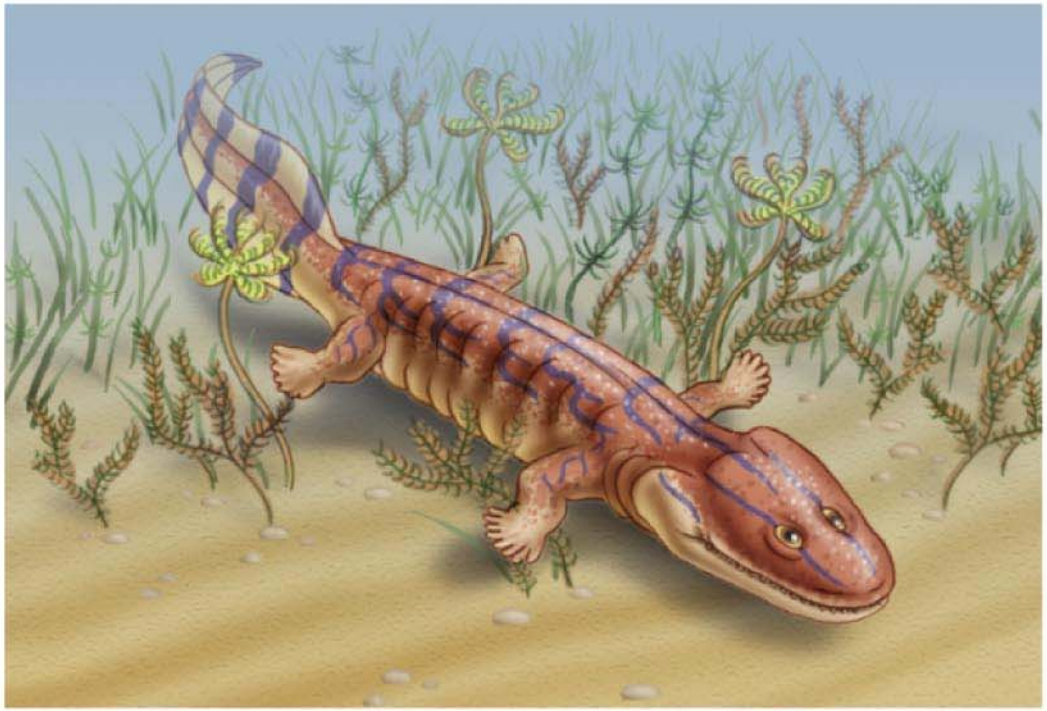
Derived Characters of Tetrapods

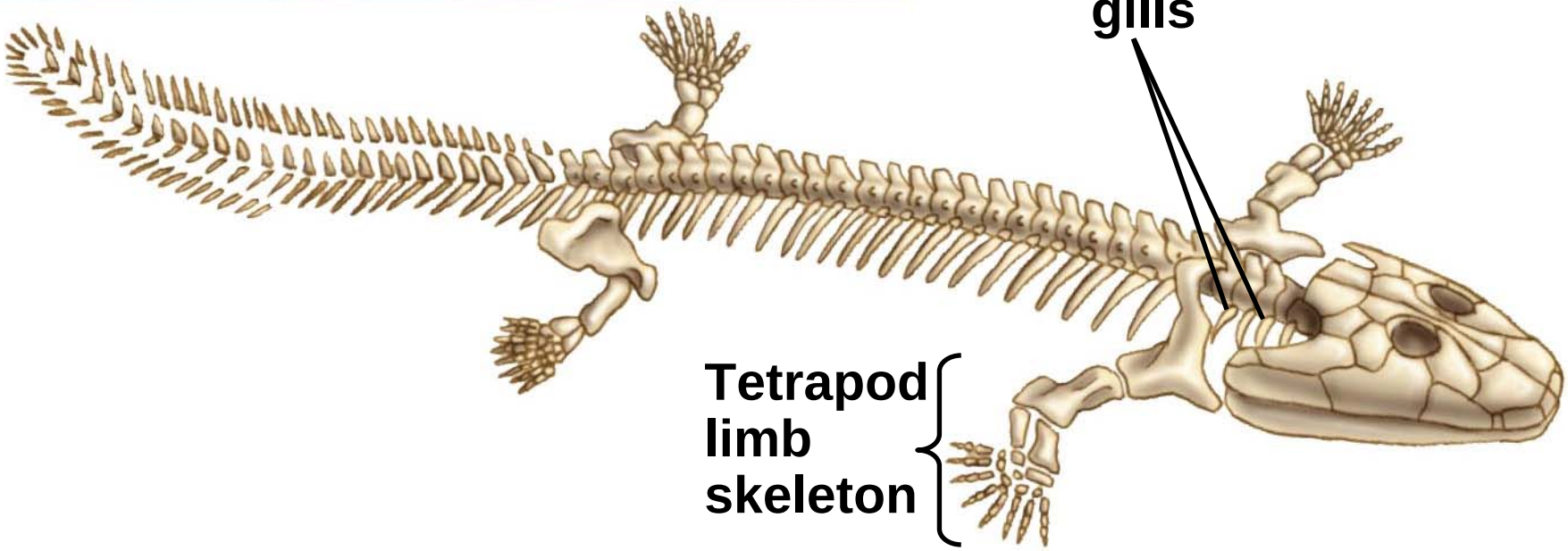
- **Tetrapods** have some specific adaptations:
  - Four limbs, and feet with digits
  - Ears for detecting airborne sounds

The Origin of Tetrapods

- In one lineage of lobe-fins, the fins became progressively more limb-like while the rest of the body retained adaptations for aquatic life
- For example, *Acanthostega* lived in Greenland 365 million years ago

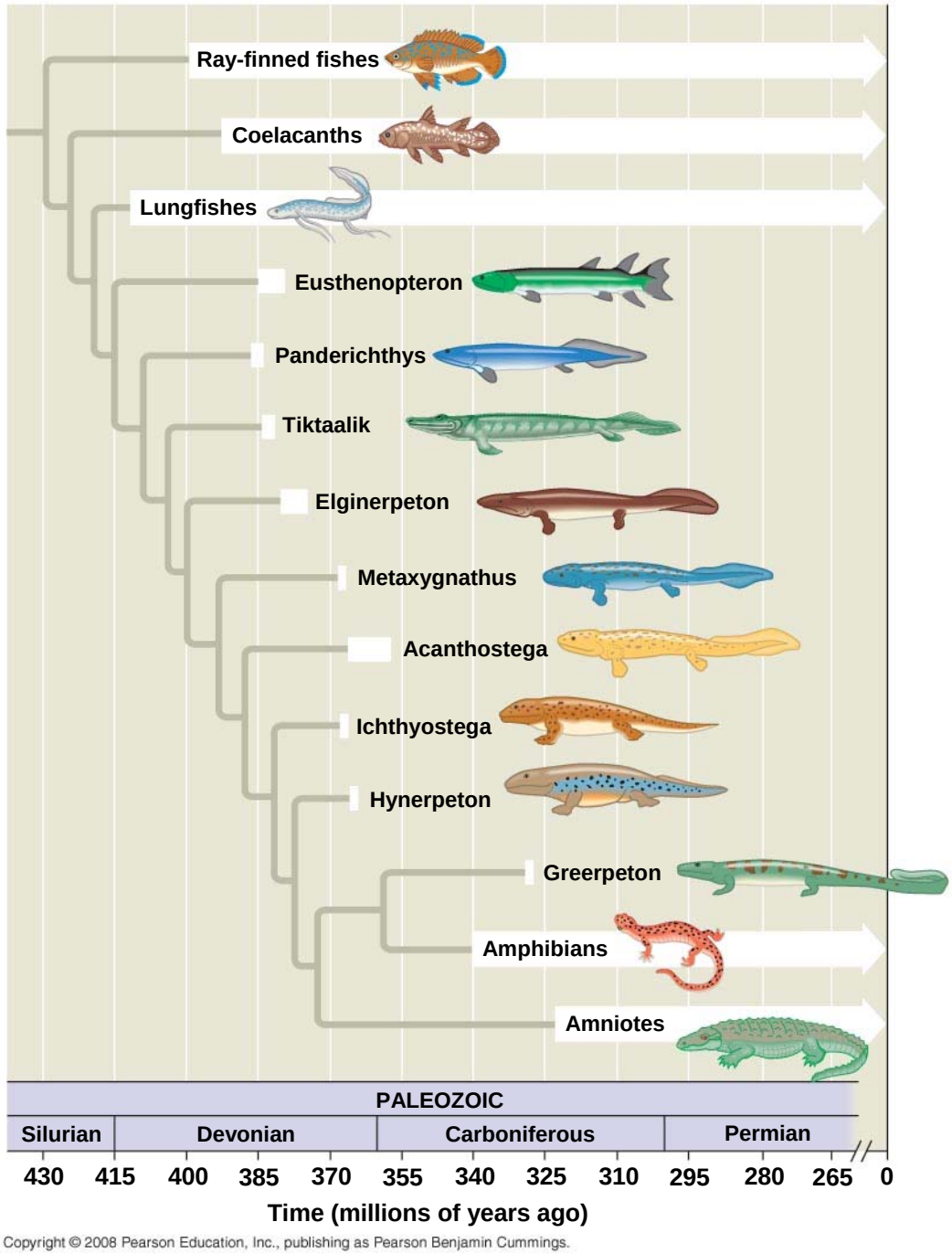
Fig. 34-19





- Extraordinary fossil discoveries over the past 20 years have allowed paleontologists to reconstruct the origin of tetrapods

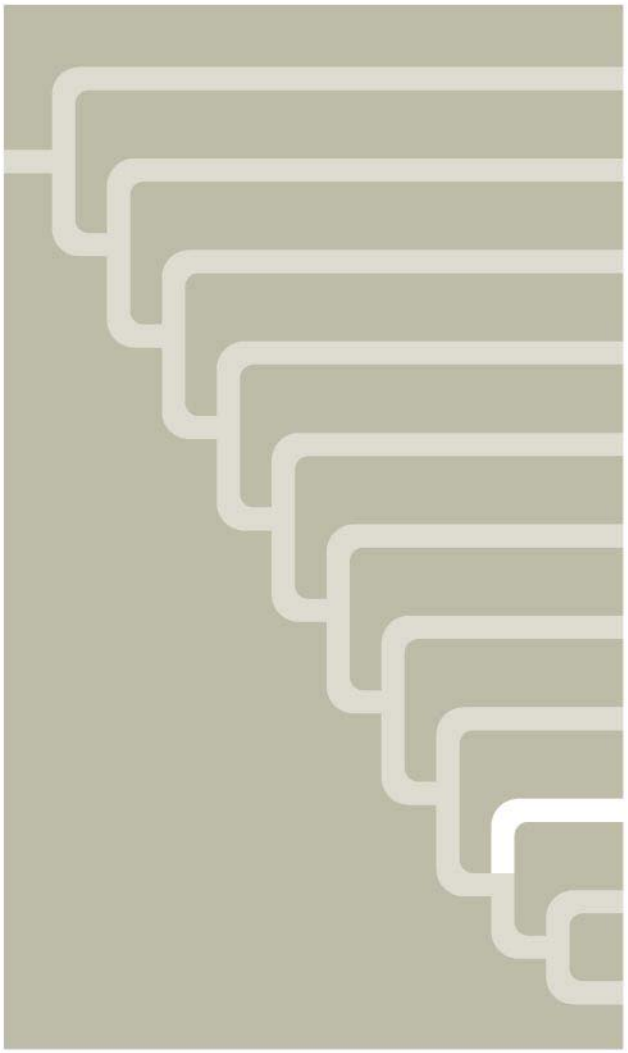
Fig. 34-20



Amphibians

- **Amphibians** (class Amphibia) are represented by about 6,150 species of organisms in three orders
- Order Urodela includes salamanders, which have tails

Fig. 34-UN7



Cephalochordata
Urochordata
Myxini
Petromyzontida
Chondrichthyes
Actinopterygii
Actinistia
Dipnoi
Amphibia
Reptilia
Mammalia

Fig. 34-21

(a) Order Urodela

(b) Order Anura

(c) Order Apoda

Fig. 34-21a

(a) Order Urodela

- Order Anura includes frogs and toads, which lack tails

Fig. 34-21b

(b) Order Anura

- Order Apoda includes caecilians, which are legless and resemble worms

Fig. 34-21c

(c) Order Apoda

- *Amphibian* means “both ways of life,” referring to the metamorphosis of an aquatic larva into a terrestrial adult
- Most amphibians have moist skin that complements the lungs in gas exchange
- Fertilization is external in most species, and the eggs require a moist environment

Fig. 34-22

(a) Tadpole

(b) During metamorphosis

(c) Mating adults

Fig. 34-22a

(a) Tadpole

Fig. 34-22b

(b) During metamorphosis

Fig. 34-22c

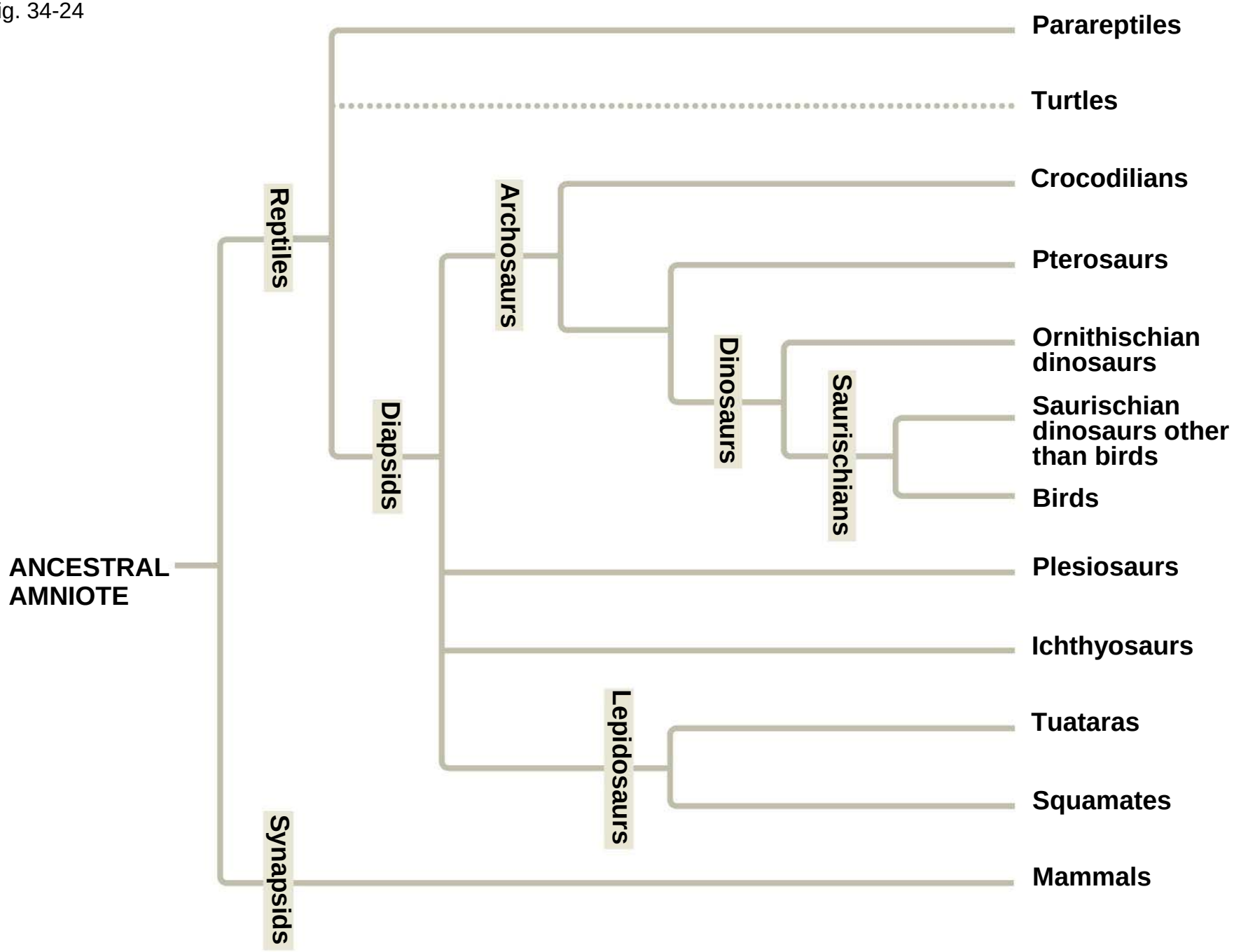
(c) Mating adults

Fig. 34-23

Concept 34.6: Amniotes are tetrapods that have a terrestrially adapted egg

- **Amniotes** are a group of tetrapods whose living members are the reptiles, including birds, and mammals

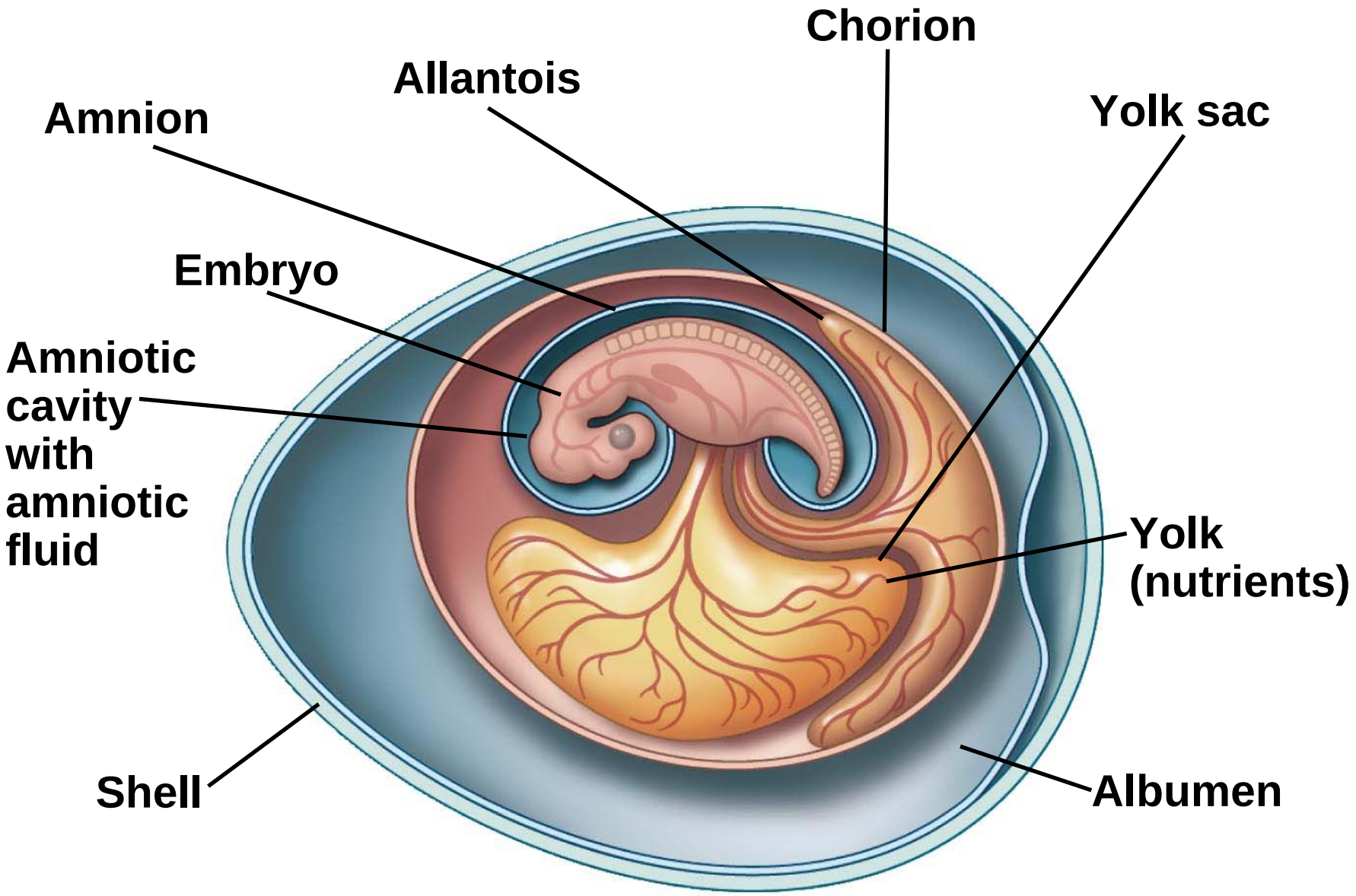
Fig. 34-24



Derived Characters of Amniotes

- Amniotes are named for the major derived character of the clade, the **amniotic egg**, which contains membranes that protect the embryo
- The *extraembryonic membranes* are the amnion, chorion, yolk sac, and allantois

Fig. 34-25



- Amniotes have other terrestrial adaptations, such as relatively impermeable skin and the ability to use the rib cage to ventilate the lungs

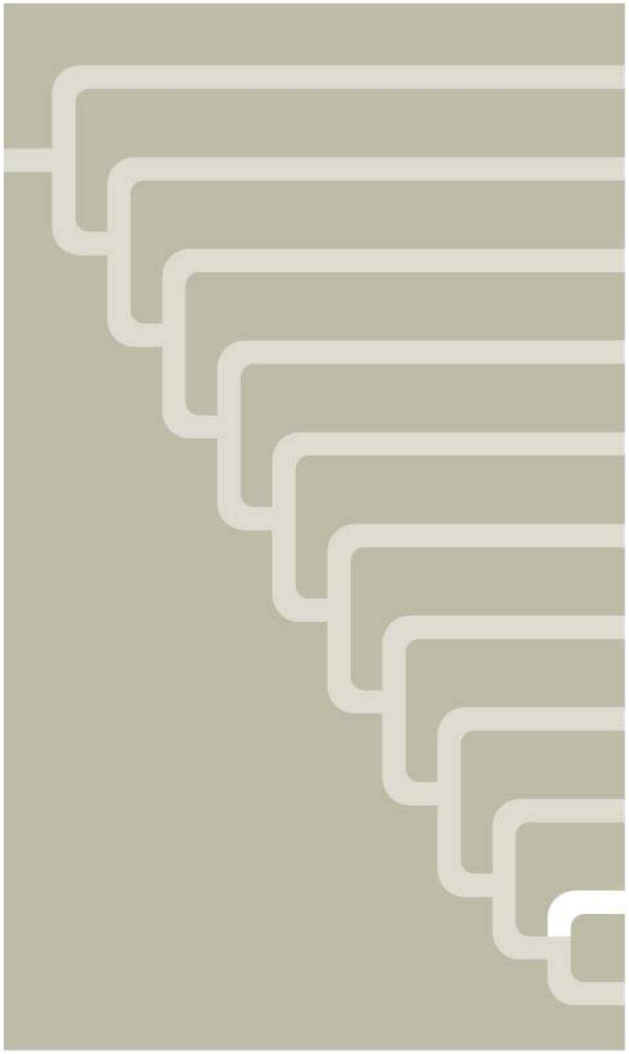
Early Amniotes

- Living amphibians and amniotes split from a common ancestor about 370 million years ago
- Early amniotes were more tolerant of dry conditions than early tetrapods

Reptiles

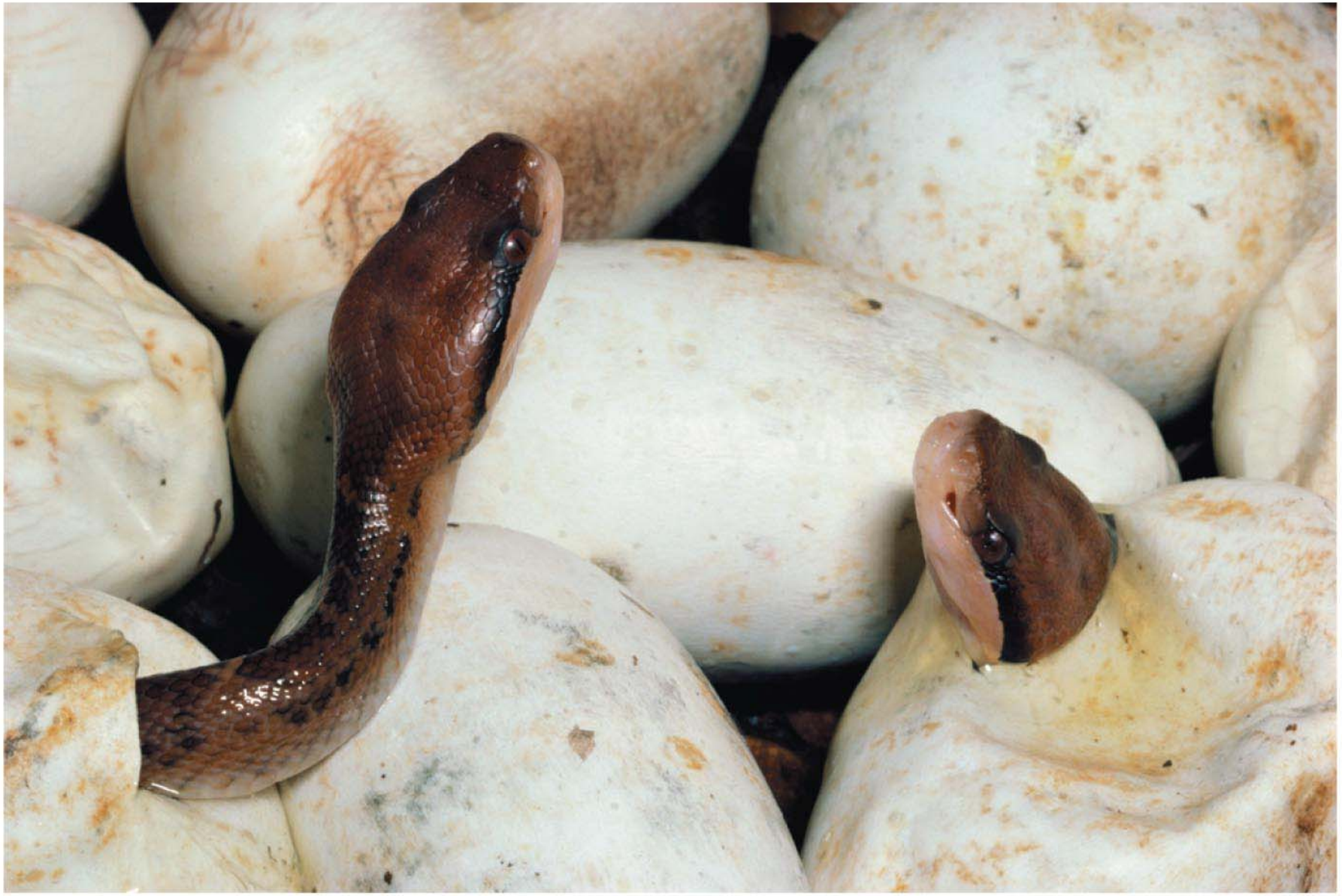
- The **reptile** clade includes the tuataras, lizards, snakes, turtles, crocodilians, birds, and the extinct dinosaurs
- Reptiles have scales that create a waterproof barrier
- They lay shelled eggs on land

Fig. 34-UN8



Cephalochordata
Urochordata
Myxini
Petromyzontida
Chondrichthyes
Actinopterygii
Actinistia
Dipnoi
Amphibia
Reptilia
Mammalia

Fig. 34-26



- Most reptiles are **ectothermic**, absorbing external heat as the main source of body heat
- Birds are **endothermic**, capable of keeping the body warm through metabolism

The Origin and Evolutionary Radiation of Reptiles

- The oldest reptilian fossils date to about 310 million years ago
- The first major group to emerge were **parareptiles**, which were mostly large, stocky herbivores

- As parareptiles were dwindling, the **diapsids** were diversifying
- The diapsids consisted of two main lineages: the lepidosaurs and the archosaurs
- The **lepidosaurs** include tuataras, lizards, and snakes
- The **archosaur** lineage produced the crocodilians, **pterosaurs**, and **dinosaurs**

- The dinosaurs diversified into a vast range of shapes and sizes
- They included bipedal carnivores called **theropods**
- Fossil discoveries and research have led to the conclusion that many dinosaurs were agile and fast moving
- Paleontologists have also discovered signs of parental care among dinosaurs

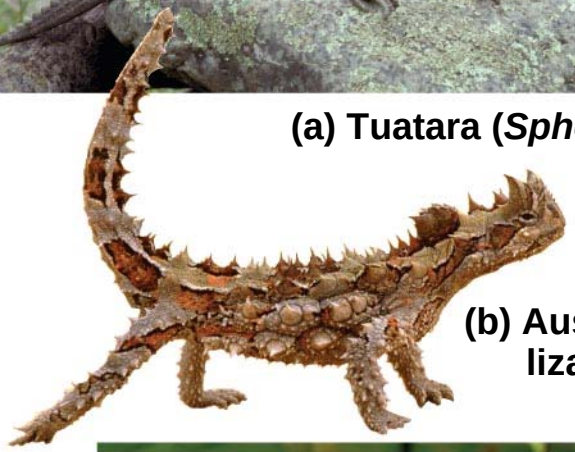
- Dinosaurs, with the exception of birds, became extinct by the end of the Cretaceous
- Their extinction may have been partly caused by an asteroid

Lepidosaurs

- One surviving lineage of lepidosaurs is represented by two species of lizard-like reptiles called tuataras

Fig. 34-27

(a) Tuatara (*Sphenodon punctatus*)



(b) Australian thorny devil lizard (*Moloch horridus*)

(c) Wagler's pit viper (*Tropidolaemus wagleri*)

(d) Eastern box turtle (*Terrapene carolina carolina*)

(e) American alligator (*Alligator mississippiensis*)

Fig. 34-27a

(a) Tuatara (*Sphenodon punctatus*)

- The other major living lineage of lepidosaurs consists of the squamates, the lizards and snakes
- Lizards are the most numerous and diverse reptiles, apart from birds

PLAY Video: Galápagos Marine Iguana

Fig. 34-27b

(b) Australian thorny devil lizard (*Moloch horridus*)

- Snakes are legless lepidosaurs that evolved from lizards

PLAY Video: Snake Ritual Wrestling

Fig. 34-27c

(c) Wagler's pit viper (*Tropidolaemus wagleri*)

Turtles

- Turtles are the most distinctive group of reptiles alive today
- All turtles have a boxlike shell made of upper and lower shields that are fused to the vertebrae, clavicles, and ribs
- Some turtles have adapted to deserts and others live entirely in ponds and rivers

PLAY Video: Galápagos Tortoise

Fig. 34-27d

(d) Eastern box turtle (*Terrapene carolina carolina*)

Alligators and Crocodiles

- Crocodilians (alligators and crocodiles) belong to an archosaur lineage that dates back to the late Triassic

Fig. 34-27e

(e) American alligator (*Alligator mississippiensis*)

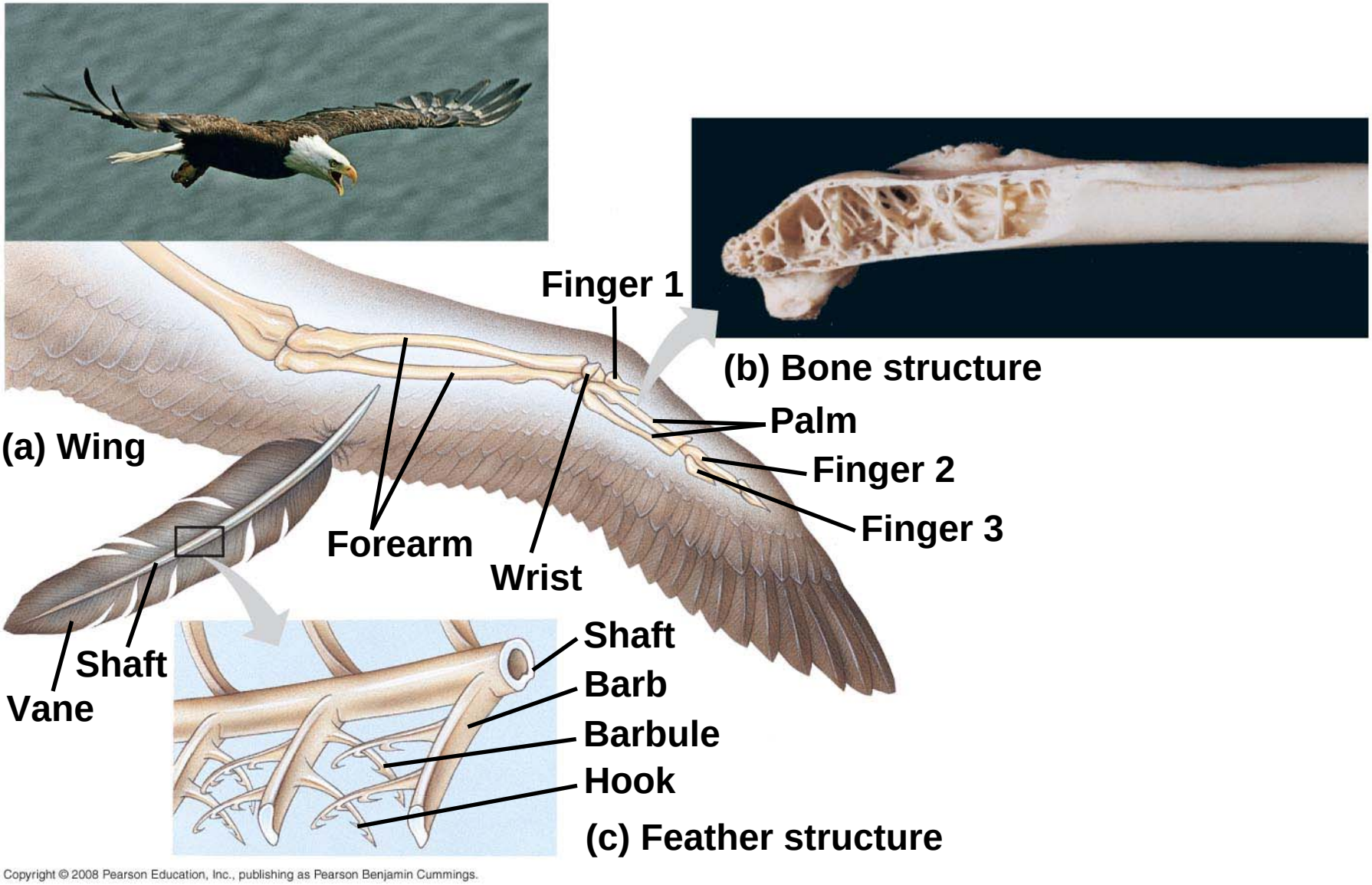
Birds

- Birds are archosaurs, but almost every feature of their reptilian anatomy has undergone modification in their adaptation to flight

Derived Characters of Birds

- Many characters of birds are adaptations that facilitate flight
- The major adaptation is wings with keratin feathers
- Other adaptations include lack of a urinary bladder, females with only one ovary, small gonads, and loss of teeth

Fig. 34-28

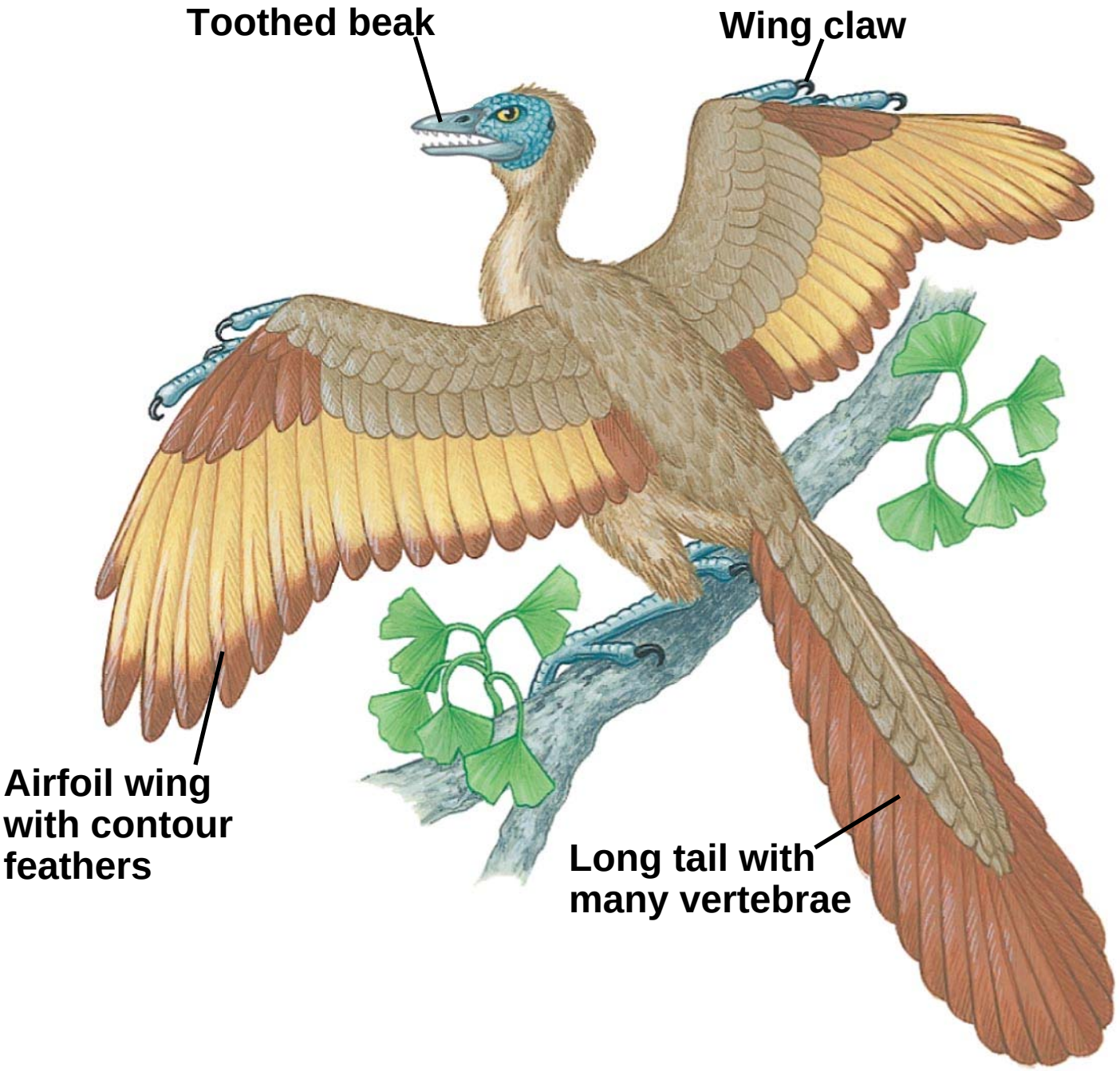


- Flight enhances hunting and scavenging, escape from terrestrial predators, and migration
- Flight requires a great expenditure of energy, acute vision, and fine muscle control

The Origin of Birds

- Birds probably descended from small theropods, a group of carnivorous dinosaurs
- By 150 million years ago, feathered theropods had evolved into birds
- *Archaeopteryx* remains the oldest bird known

Fig. 34-29



Living Birds

- Living birds belong to the clade Neornithes
- Several groups of birds are flightless
  - The **ratites**, order Struthioniformes
  - Penguins, order Sphenisciformes
  - Certain species of rails, ducks, and pigeons

- The demands of flight have rendered the general body form of many flying birds similar to one another
- Foot structure in birds shows considerable variation

Fig. 34-30

(a) Emu

(b) Mallards

(c) Laysan albatrosses

(d) Barn swallows

Fig. 34-30a

(a) Emu

Fig. 34-30b

(b) Mallards

Fig. 34-30c

(c) Laysan albatrosses

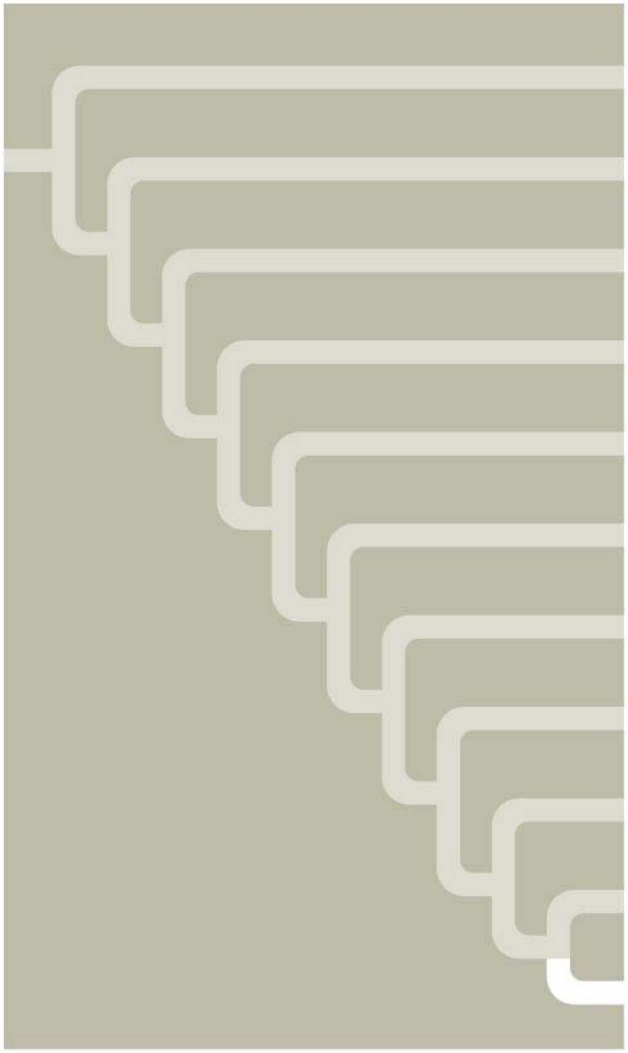
Fig. 34-30d

(d) Barn swallows

Concept 34.7: Mammals are amniotes that have hair and produce milk

- **Mammals**, class Mammalia, are represented by more than 5,300 species

Fig. 34-UN9



Cephalochordata
Urochordata
Myxini
Petromyzontida
Chondrichthyes
Actinopterygii
Actinistia
Dipnoi
Amphibia
Reptilia
Mammalia

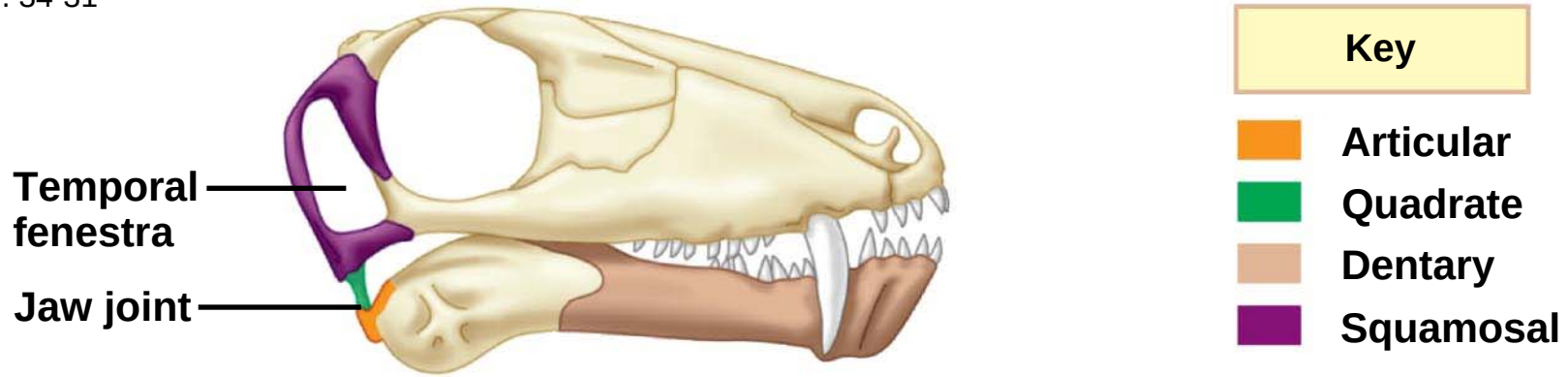
Derived Characters of Mammals

- Mammals have
  - Mammary glands, which produce milk
  - Hair
  - A larger brain than other vertebrates of equivalent size
  - Differentiated teeth

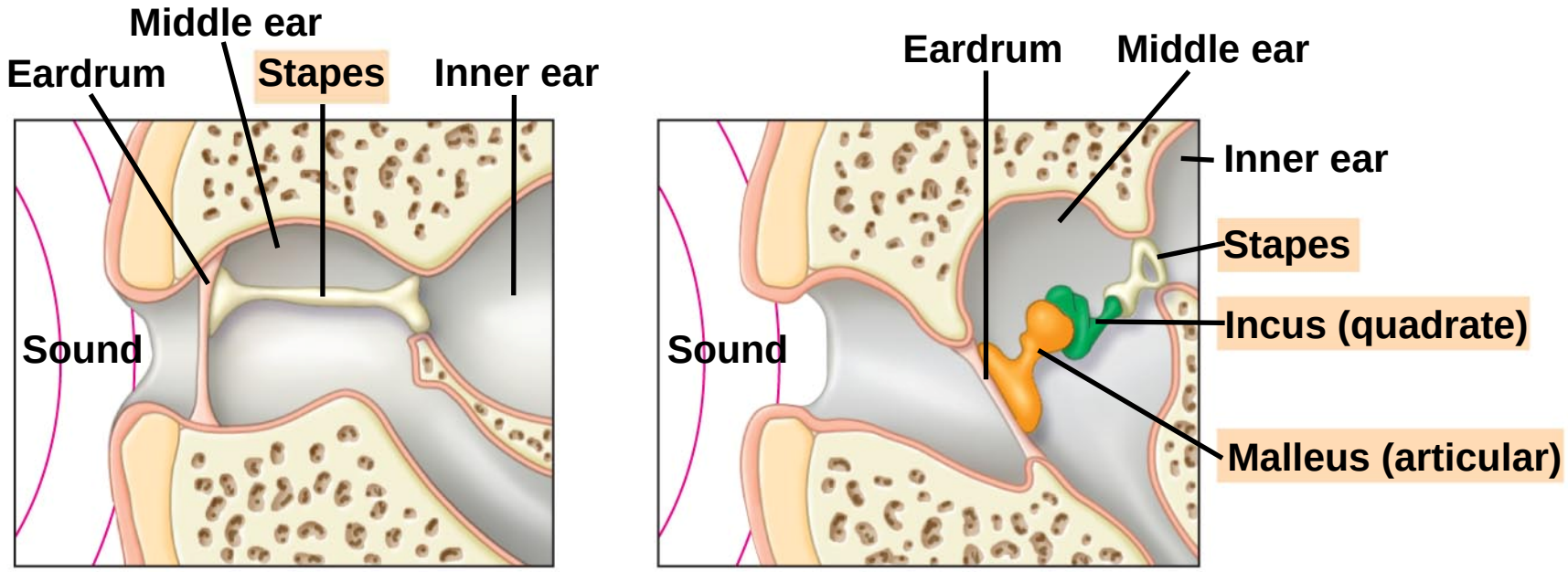
Early Evolution of Mammals

- Mammals evolved from **synapsids** in the late Triassic period
- Two bones that formerly made up the jaw joint were incorporated into the mammalian middle ear

Fig. 34-31



(a) In *Biarmosuchus,* an early synapsid, the articular and quadrate bones formed the jaw joint.



(b) In mammals, the articular and quadrate bones are incorporated into the middle ear.

- By the early Cretaceous, the three living lineages of mammals emerged: monotremes, marsupials, and eutherians
- Mammals did not undergo a significant adaptive radiation until after the Cretaceous

Monotremes

- **Monotremes** are a small group of egg-laying mammals consisting of echidnas and the platypus

Fig. 34-32

Marsupials

- **Marsupials** include opossums, kangaroos, and koalas
- The embryo develops within a **placenta** in the mother's uterus
- A marsupial is born very early in its development
- It completes its embryonic development while nursing in a maternal pouch called a marsupium

Fig. 34-33

(a) A young brushtail possum

(b) Long-nosed bandicoot

Fig. 34-33a

(a) A young brushtail possum

- In some species, such as the bandicoot, the marsupium opens to the rear of the mother's body

Fig. 34-33b

(b) Long-nosed bandicoot

- In Australia, convergent evolution has resulted in a diversity of marsupials that resemble the eutherians in other parts of the world

Fig. 34-34

Marsupial mammals	Eutherian mammals
Plantigale	Deer mouse
Marsupial mole	Mole
Sugar glider	Flying squirrel

Marsupial mammals	Eutherian mammals
Wombat	Woodchuck
Tasmanian devil	Wolverine
Kangaroo	Patagonian cavy

Eutherians (Placental Mammals)

- Compared with marsupials, **eutherians** have a longer period of pregnancy
- Young eutherians complete their embryonic development within a uterus, joined to the mother by the placenta
- Molecular and morphological data give conflicting dates on the diversification of eutherians

Fig. 34-35a

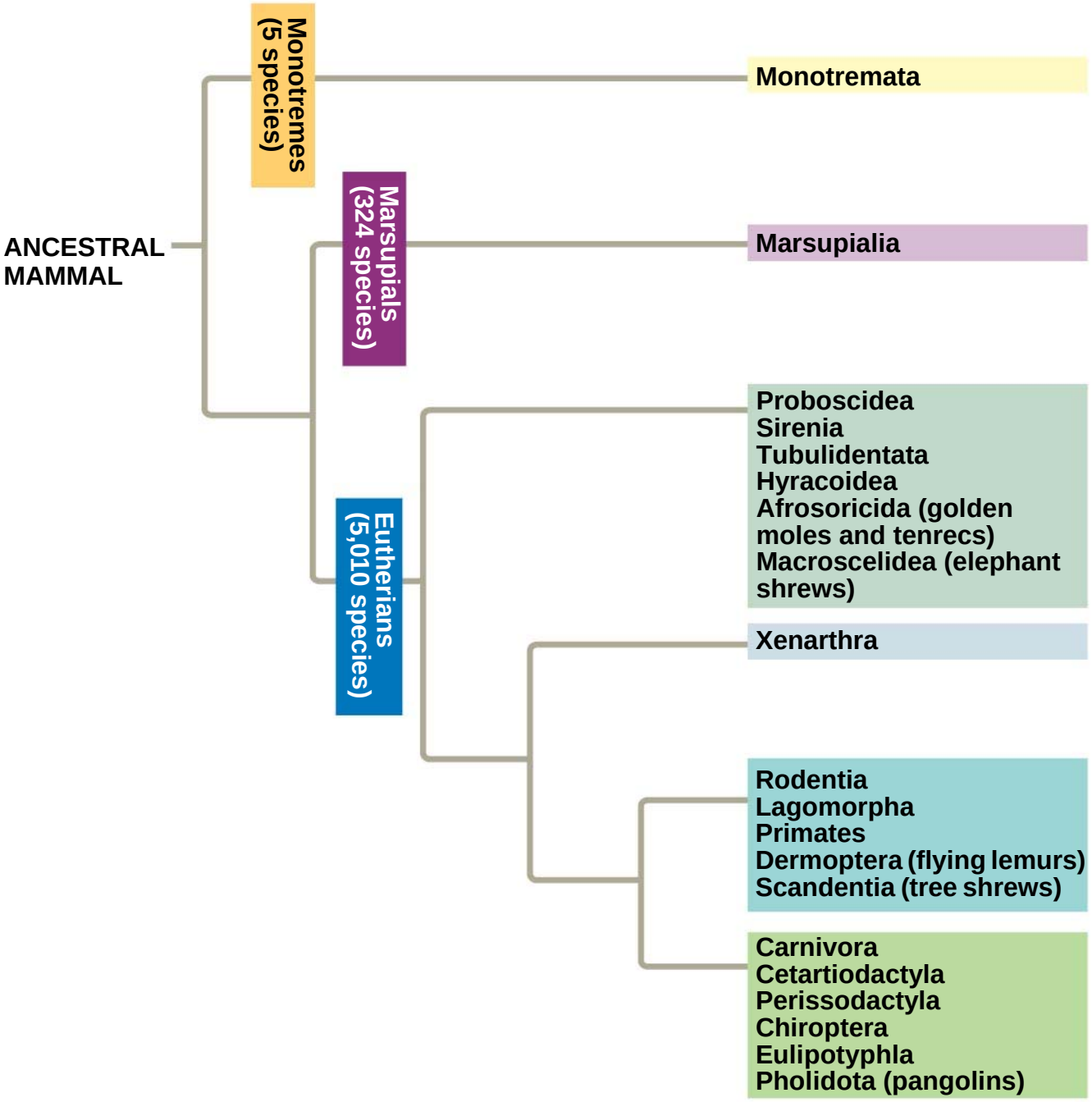


Fig. 34-35b

Orders and Examples	Main Characteristics
Monotremata Platypuses, echidnas  Echidna	Lay eggs; no nipples; young suck milk from fur of mother
Proboscidea Elephants  African elephant	Long, muscular trunk; thick, loose skin; upper incisors elongated as tusks
Sirenia Manatees, dugongs  Manatee	Aquatic; finlike forelimbs and no hind limbs; herbivorous
Xenarthra Sloths, anteaters, armadillos  Tamandua	Reduced teeth or no teeth; herbivorous (sloths) or carnivorous (anteaters, armadillos)
Lagomorpha Rabbits, hares, picas  Jackrabbit	Chisel-like incisors; hind legs longer than forelegs and adapted for running and jumping; herbivorous
Carnivora Dogs, wolves, bears, cats, weasels, otters, seals, walruses  Coyote	Sharp, pointed canine teeth and molars for shearing; carnivorous
Cetartiodactyla **Artiodactyls** Sheep, pigs, cattle, deer, giraffes  Bighorn sheep	Hooves with an even number of toes on each foot; herbivorous
Cetaceans Whales, dolphins, porpoises  Pacific white-sided porpoise	Aquatic; streamlined body; paddle-like forelimbs and no hind limbs; thick layer of insulating blubber; carnivorous

Orders and Examples	Main Characteristics
Marsupialia Kangaroos, opossums, koalas  Koala	Embryo completes development in pouch on mother
Tubulidentata Aardvarks  Aardvark	Teeth consisting of many thin tubes cemented together; eats ants and termites
Hyracoidea Hyraxes  Rock hyrax	Short legs; stumpy tail; herbivorous; complex, multichambered stomach
Rodentia Squirrels, beavers, rats, porcupines, mice  Red squirrel	Chisel-like, continuously growing incisors worn down by gnawing; herbivorous
Primates Lemurs, monkeys, chimpanzees, gorillas, humans  Golden lion tamarin	Opposable thumbs; forward-facing eyes; well-developed cerebral cortex; omnivorous
Perissodactyla Horses, zebras, tapirs, rhinoceroses  Indian rhinoceros	Hooves with an odd number of toes on each foot; herbivorous
Chiroptera Bats  Frog-eating bat	Adapted for flight; broad skinfold that extends from elongated fingers to body and legs; carnivorous or herbivorous
Eulipotyphla "Core insectivores": some moles, some shrews  Star-nosed mole	Diet consists mainly of insects and other small invertebrates

Fig. 34-35c

Orders and Examples	Main Characteristics
Monotremata Platypuses, echidnas  Echidna	Lay eggs; no nipples; young suck milk from fur of mother

Fig. 34-35d

Orders and Examples	Main Characteristics
Marsupialia Kangaroos, opossums, koalas  Koala	Embryo completes development in pouch on mother

Fig. 34-35e

Orders and Examples	Main Characteristics
Proboscidea Elephants  African elephant	Long, muscular trunk; thick, loose skin; upper incisors elongated as tusks
Sirenia Manatees, dugongs  Manatee	Aquatic; finlike forelimbs and no hind limbs; herbivorous

Orders and Examples	Main Characteristics
Tubulidentata Aardvarks  Aardvark	Teeth consisting of many thin tubes cemented together; eats ants and termites
Hyracoidea Hyraxes  Rock hyrax	Short legs; stumpy tail; herbivorous; complex, multichambered stomach

Fig. 34-35f

Orders and Examples	Main Characteristics
Xenarthra Sloths, anteaters, armadillos  Tamandua	Reduced teeth or no teeth; herbivorous (sloths) or carnivorous (anteaters, armadillos)

Fig. 34-35g

Orders and Examples	Main Characteristics
Lagomorpha Rabbits, hares, picas  Jackrabbit	Chisel-like incisors; hind legs longer than forelegs and adapted for running and jumping; herbivorous
Rodentia Squirrels, beavers, rats, porcupines, mice  Red squirrel	Chisel-like, continuously growing incisors worn down by gnawing; herbivorous
Primates Lemurs, monkeys, chimpanzees, gorillas, humans  Golden lion tamarin	Opposable thumbs; forward-facing eyes; well-developed cerebral cortex; omnivorous

Fig. 34-35h

Orders and Examples	Main Characteristics
Carnivora Dogs, wolves, bears, cats, weasels, otters, seals, walruses  Coyote	Sharp, pointed canine teeth and molars for shearing; carnivorous
Cetartiodactyla **Artiodactyls** Sheep, pigs, cattle, deer, giraffes  Bighorn sheep	Hooves with an even number of toes on each foot; herbivorous
Cetaceans Whales, dolphins, porpoises  Pacific white-sided porpoise	Aquatic; streamlined body; paddle-like forelimbs and no hind limbs; thick layer of insulating blubber; carnivorous

Orders and Examples	Main Characteristics
Perissodactyla Horses, zebras, tapirs, rhinoceroses  Indian rhinoceros	Hooves with an odd number of toes on each foot; herbivorous
Chiroptera Bats  Frog-eating bat	Adapted for flight; broad skinfold that extends from elongated fingers to body and legs; carnivorous or herbivorous
Eulipotyphla "Core insectivores": some moles, some shrews  Star-nosed mole	Diet consists mainly of insects and other small invertebrates

PLAY Video: Bat Licking Nectar

PLAY Video: Bat Pollinating Agave Plant

PLAY Video: Galápagos Sea Lion

PLAY Video: Wolf Agonistic Behavior

Primates

- The mammalian order Primates includes lemurs, tarsiers, monkeys, and apes
- Humans are members of the ape group

Derived Characters of Primates

- Most primates have hands and feet adapted for grasping

- Other derived characters of primates:
  - A large brain and short jaws
  - Forward-looking eyes close together on the face, providing depth perception
  - Complex social behavior and parental care
  - A fully **opposable thumb** (in monkeys and apes)

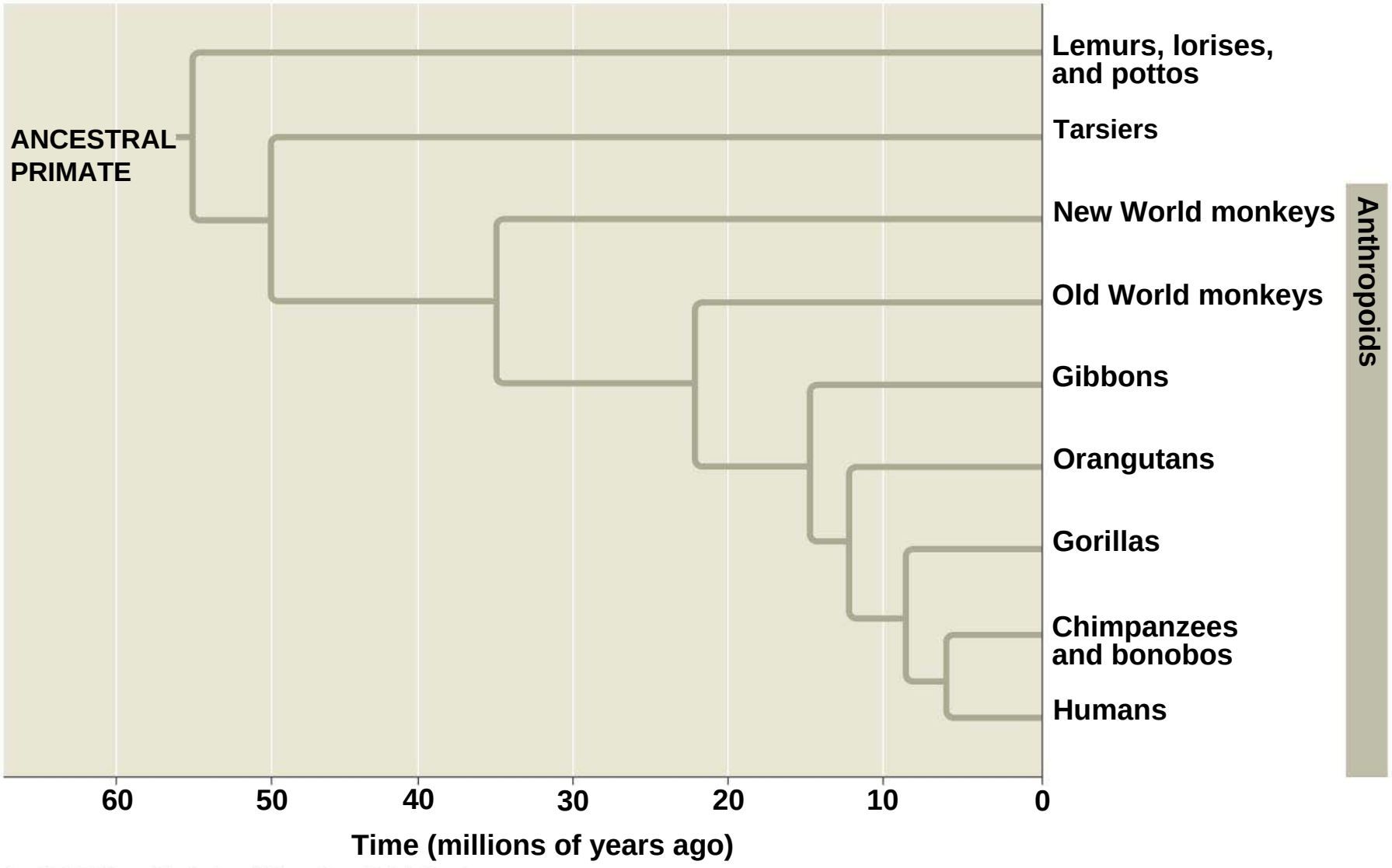
Living Primates

- There are three main groups of living primates:
  - Lemurs, lorises, and pottos
  - Tarsiers
  - **Anthropoids** (monkeys and apes)

Fig. 34-36

- The oldest known anthropoid fossils, about 45 million years old, indicate that tarsiers are more closely related to anthropoids than to lemurs

Fig. 34-37



- The first monkeys evolved in the Old World (Africa and Asia)
- In the New World (South America), monkeys first appeared roughly 25 million years ago
- New World and Old World monkeys underwent separate adaptive radiations during their many millions of years of separation

Fig. 34-38

(a) New World monkey

(b) Old World monkey

Fig. 34-38a

(a) New World monkey

Fig. 34-38b

(b) Old World monkey

- The other group of anthropoids consists of primates informally called apes
- This group includes gibbons, orangutans, gorillas, chimpanzees, bonobos, and humans
- Apes diverged from Old World monkeys about 20–25 million years ago

PLAY Video: Gibbons Brachiating

PLAY Video: Chimp Agonistic Behavior

PLAY Video: Chimp Cracking Nut

Fig. 34-39

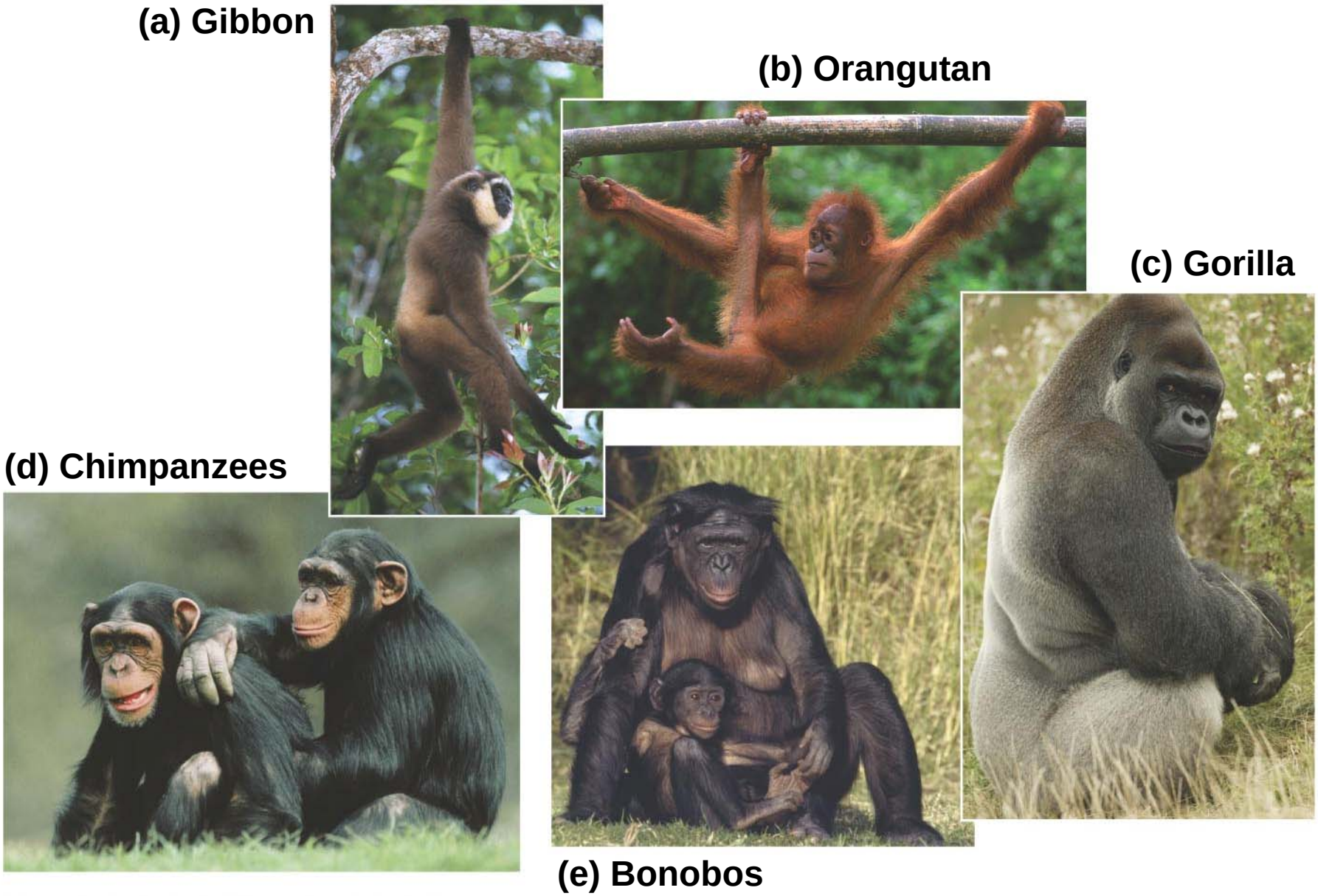


Fig. 34-39a

(a) Gibbon

Fig. 34-39b

(b) Orangutan

Fig. 34-39c

(c) Gorilla

Fig. 34-39d

(d) Chimpanzees

Fig. 34-39e

(e) Bonobos

Concept 34.8: Humans are mammals that have a large brain and bipedal locomotion

- The species *Homo sapiens* is about 200,000 years old, which is very young, considering that life has existed on Earth for at least 3.5 billion years

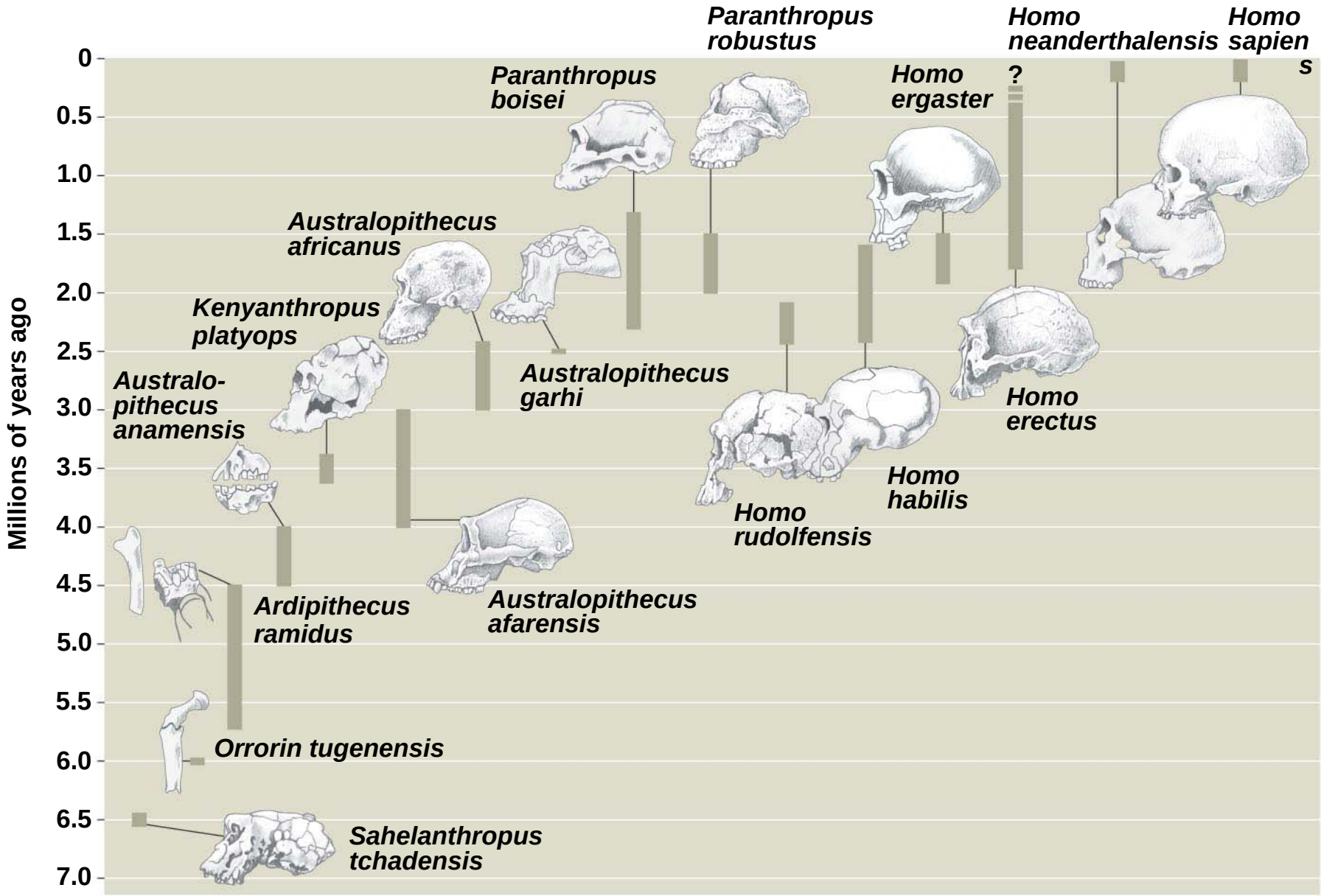
Derived Characters of Humans

- A number of characters distinguish humans from other apes:
  - Upright posture and bipedal locomotion
  - Larger brains
  - Language capabilities and symbolic thought
  - The manufacture and use of complex tools
  - Shortened jaw
  - Shorter digestive tract

The Earliest Hominins

- The study of human origins is known as **paleoanthropology**
- **Hominins** (formerly called hominids) are more closely related to humans than to chimpanzees
- Paleoanthropologists have discovered fossils of about 20 species of extinct hominins

Fig. 34-40



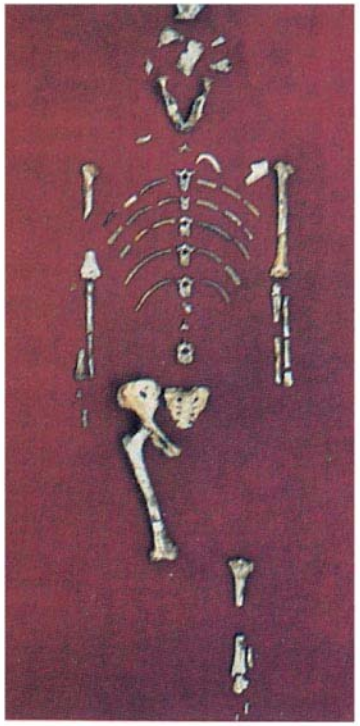
- Hominins originated in Africa about 6–7 million years ago
- Early hominins had a small brain but probably walked upright

- Two common misconceptions about early hominins:
  - Thinking of them as chimpanzees
  - Imagining human evolution as a ladder leading directly to *Homo sapiens*

Australopiths

- Australopiths are a paraphyletic assemblage of hominins living between 4 and 2 million years ago
- Some species walked fully erect
- “Robust” australopiths had sturdy skulls and powerful jaws
- “Gracile” australopiths were more slender and had lighter jaws

Fig. 34-41

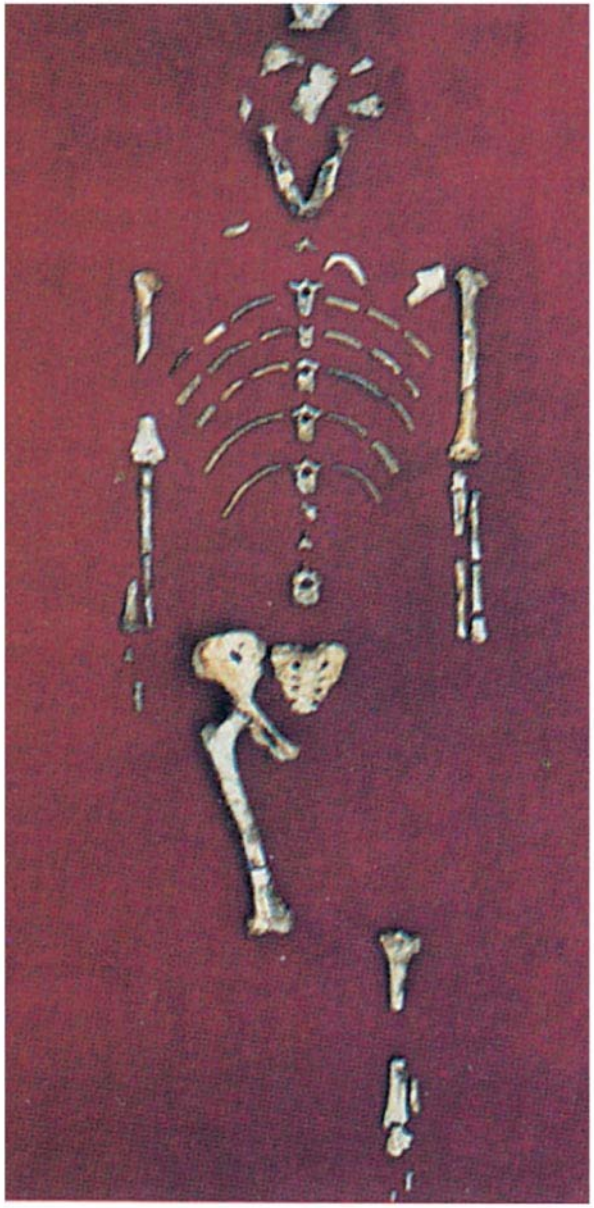


(a) *Australopithecus afarensis* skeleton

(b) The Laetoli footprints

(c) An artist's reconstruction of what *A. afarensis* may have looked like

Fig. 34-41a



(a) *Australopithecus afarensis* skeleton

Fig. 34-41b

(b) The Laetoli footprints

Fig. 34-41c

(c) An artist's reconstruction of what *A. afarensis* may have looked like

Bipedalism

- Hominins began to walk long distances on two legs about 1.9 million years ago

Tool Use

- The oldest evidence of tool use, cut marks on animal bones, is 2.5 million years old

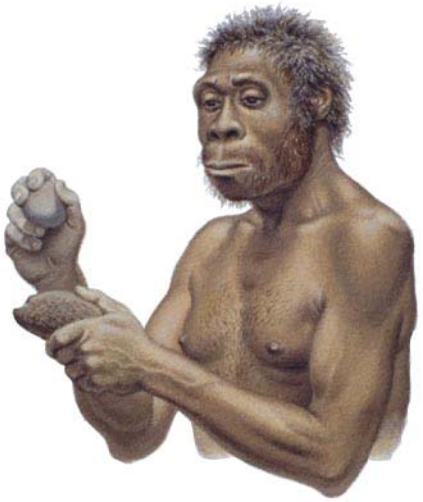
Early *Homo*

- The earliest fossils placed in our genus *Homo* are those of *Homo habilis*, ranging in age from about 2.4 to 1.6 million years
- Stone tools have been found with *H. habilis*, giving this species its name, which means “handy man”

- *Homo ergaster* was the first fully bipedal, large-brained hominid
- The species existed between 1.9 and 1.5 million years ago
- *Homo ergaster* shows a significant decrease in sexual dimorphism (a size difference between sexes) compared with its ancestors

- *Homo ergaster* fossils were previously assigned to *Homo erectus*; most paleoanthropologists now recognize these as separate species

Fig. 34-42



- *Homo erectus* originated in Africa by 1.8 million years ago
- It was the first hominin to leave Africa

Neanderthals

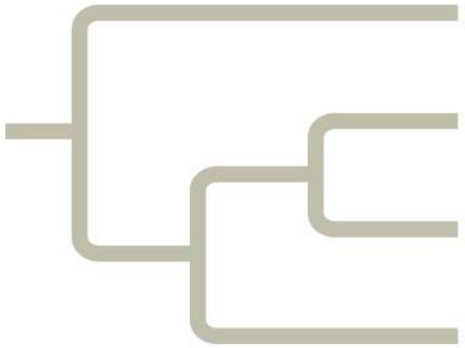
- Neanderthals, *Homo neanderthalensis,* lived in Europe and the Near East from 200,000 to 28,000 years ago
- They were thick-boned with a larger brain, they buried their dead, and they made hunting tools

Fig. 34-43

EXPERIMENT

Hypothesis: Neanderthals gave rise to European humans.

Expected phylogeny:



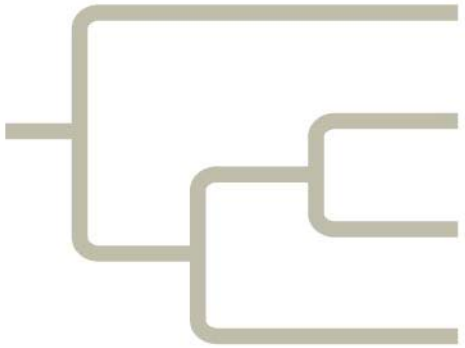
Chimpanzees

Neanderthals

Living Europeans

Other living humans

RESULTS



Chimpanzees

Neanderthal 1

Neanderthal 2

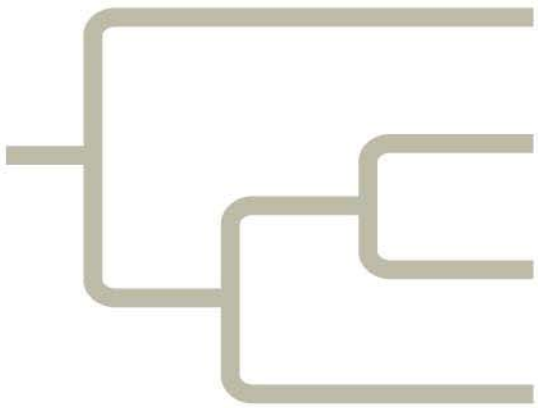
European and other living humans

Fig. 34-43a

EXPERIMENT

Hypothesis: Neanderthals gave rise to European humans.

Expected phylogeny:



Chimpanzees

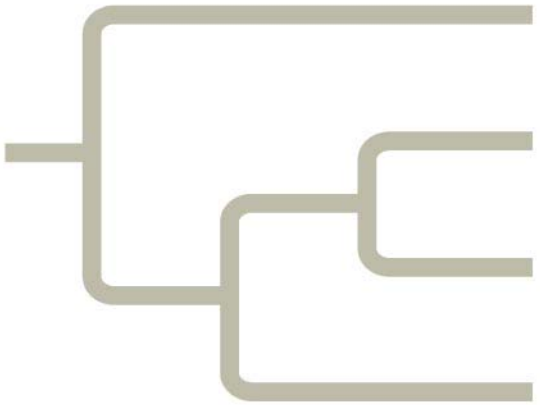
Neanderthals

Living Europeans

Other living humans

Fig. 34-43b

RESULTS



Chimpanzees

Neanderthal 1

Neanderthal 2

European and other living humans

Homo Sapiens

- *Homo sapiens* appeared in Africa by 195,000 years ago
- All living humans are descended from these African ancestors

Fig. 34-44

- The oldest fossils of *Homo sapiens* outside Africa date back about 115,000 years and are from the Middle East
- Humans first arrived in the New World sometime before 15,000 years ago
- In 2004, 18,000 year old fossils were found in Indonesia, and a new small hominin was named: *Homo floresiensis*

- Rapid expansion of our species may have been preceded by changes to the brain that made cognitive innovations possible
  - For example, the *FOXP2* gene is essential for human language, and underwent intense natural selection during the last 200,000 years
- *Homo sapiens* were the first group to show evidence of symbolic and sophisticated thought

Fig. 34-45

Fig. 34-UN10

Key Concept	Clade	Description
Concept 34.1 **Chordates** have a notochord and a dorsal, hollow nerve cord	Cephalochordata (lancelets)	Basal chordates; marine suspension feeders that exhibit four key derived characters of chordates
	Urochordata (tunicates)	Marine suspension feeders; larvae display the derived traits of chordates
Concept 34.2 **Craniates** are chordates that have a head	Myxini (hagfishes and relatives)	Jawless marine organisms; have head that includes a skull and brain, eyes, and other sensory organs
Concept 34.3 **Vertebrates** are craniates that have a backbone	Petromyzontida (lampreys)	Jawless vertebrates; typically feed by attaching to a live fish and ingesting its blood
Concept 34.4 **Gnathostomes** are vertebrates that have jaws	Chondrichthyes (sharks, rays, skates, ratfishes)	Aquatic gnathostomes; have cartilaginous skeleton secondarily evolved from an ancestral mineralized skeleton
	Actinopterygii (ray-finned fishes)	Aquatic gnathostomes; have bony skeletons and maneuverable fins supported by rays
	Actinistia (coelacanths)	Ancient lineage of aquatic lobe-fins still surviving in Indian Ocean
	Dipnoi (lungfishes)	Freshwater lobe-fins with both lungs and gills; sister group of tetrapods
Concept 34.5 **Tetrapods** are gnathostomes that have limbs	Amphibia (salamanders, frogs, caecilians)	Have four limbs descended from modified fins; most have moist skin that functions in gas exchange; many live both in water (as larvae) and on land (as adults)
Concept 34.6 **Amniotes** are tetrapods that have a terrestrially adapted egg	Reptilia (tuataras, lizards and snakes, turtles, crocodilians, birds)	One of two groups of living amniotes; have amniotic eggs and rib-cage ventilation that are key adaptations for life on land
Concept 34.7 **Mammals** are amniotes that have hair and produce milk	Mammalia (monotremes, marsupials, eutherians)	Evolved from synapsid ancestors; include egg-laying monotremes (echidnas, platypus); pouched marsupials (such as kangaroos, opossums); and eutherians (placental mammals such as rodents, primates)

Chordates
Craniates
Vertebrates
Gnathostomes
Osteichthyans
Lobe-fins
Tetrapods
Amniotes

Fig. 34-UN10a

Key Concept	Clade	Description
Concept 34.1 **Chordates** have a notochord and a dorsal, hollow nerve cord	Cephalochordata (lancelets) 	Basal chordates; marine suspension feeders that exhibit four key derived characters of chordates
	Urochordata (tunicates) 	Marine suspension feeders; larvae display the derived traits of chordates

Fig. 34-UN10b

Key Concept	Clade	Description
Concept 34.2 **Craniates** are chordates that have a head	Myxini (hagfishes and relatives) 	Jawless marine organisms; have head that includes a skull and brain, eyes, and other sensory organs

Fig. 34-UN10c

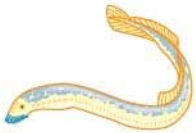
Key Concept	Clade	Description
Concept 34.3 **Vertebrates** are craniates that have a backbone	Petromyzontida (lampreys) 	Jawless vertebrates; typically feed by attaching to a live fish and ingesting its blood

Fig. 34-UN10d

Key Concept	Clade	Description
Concept 34.4 **Gnathostomes** are vertebrates that have jaws	Chondrichthyes (sharks, rays, skates, ratfishes) 	Aquatic gnathostomes; have cartilaginous skeleton secondarily evolved from an ancestral mineralized skeleton
	Actinopterygii (ray-finned fishes) 	Aquatic gnathostomes; have bony skeletons and maneuverable fins supported by rays
	Actinistia (coelacanths) 	Ancient lineage of aquatic lobe-fins still surviving in Indian Ocean
	Dipnoi (lungfishes) 	Freshwater lobe-fins with both lungs and gills; sister group of tetrapods

Fig. 34-UN10e

Key Concept	Clade	Description
Concept 34.5 **Tetrapods** are gnathostomes that have limbs	Amphibia (salamanders, frogs, caecilians) 	Have four limbs descended from modified fins; most have moist skin that functions in gas exchange; many live both in water (as larvae) and on land (as adults)

Fig. 34-UN10f

Key Concept	Clade	Description
Concept 34.6 **Amniotes** are tetrapods that have a terrestrially adapted egg	Reptilia (tuataras, lizards and snakes, turtles, crocodilians, birds)  	One of two groups of living amniotes; have amniotic eggs and rib-cage ventilation that are key adaptations for life on land

Fig. 34-UN10g

Key Concept	Clade	Description
Concept 34.7 **Mammals** are amniotes that have hair and produce milk	Mammalia (monotremes, marsupials, eutherians)  	Evolved from synapsid ancestors; include egg-laying monotremes (echidnas, platypus); pouched marsupials (such as kangaroos, opossums); and eutherians (placental mammals such as rodents, primates)

Fig. 34-T1

Deviation from Expected Brain Size	-2.4	-2.1	2.0	-1.8	-1.0	0.0	0.3	0.7	1.2	1.3	2.0	2.3	3.0	3.2
Mortality Rate	0.9	0.7	0.5	0.9	0.4	0.7	0.8	0.4	0.8	0.3	0.6	0.6	0.3	0.6

Source: D. Sol et al., Big-brained birds survive better in nature, *Proceedings of the Royal Society B* 274:763–769 (2007).

You should now be able to:

1. List the derived traits for: chordates, craniates, vertebrates, gnathostomes, tetrapods, amniotes, birds, mammals, primates, humans
2. Explain what *Haikouella* and *Myllokunmingia* tell us about craniate evolution
3. Describe the trends in mineralized structures in early vertebrates
4. Describe and distinguish between Chondrichthyes and Osteichthyes, noting the main traits of each group

5. Define and distinguish among gnathostomes, tetrapods, and amniotes
6. Describe an amniotic egg and explain its significance in the evolution of reptiles and mammals
7. Explain why the reptile clade includes birds
8. Explain the significance of *Archaeopteryx*
9. Distinguish among monotreme, marsupial, and eutherian mammals

10. Define the term hominin

11. Describe the evolution of Homo sapiens from australopith ancestors, and clarify the order in which distinctive human traits arose

12. Explain the significance of the *FOXP2* gene