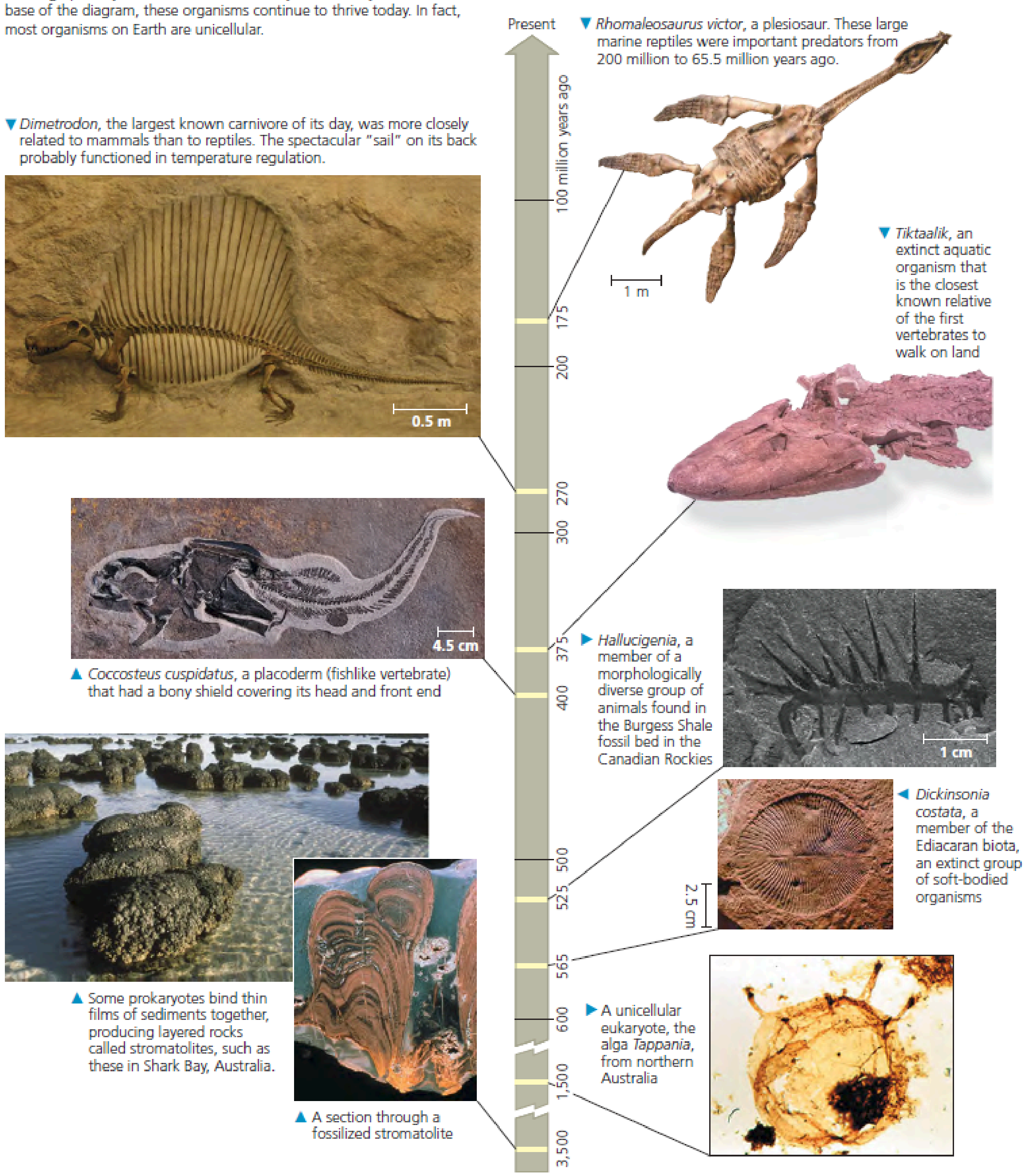
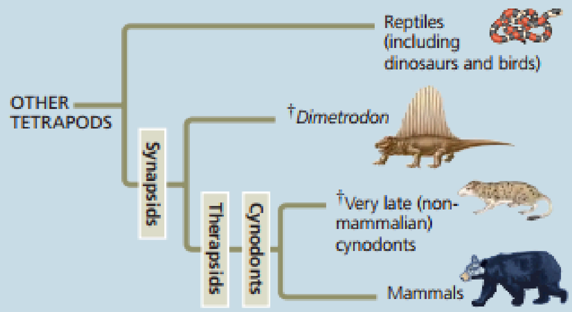
Cheat Sheet

▼ **Figure 25.4 Documenting the history of life.** These fossils illustrate representative organisms from different points in time. Although prokaryotes and unicellular eukaryotes are only shown at the base of the diagram, these organisms continue to thrive today. In fact, most organisms on Earth are unicellular.



Exploring The Origin of Mammals

Over the course of 120 million years, mammals originated gradually from a group of tetrapods called synapsids. Shown here are a few of the many fossil organisms whose morphological features represent intermediate steps between living mammals and their synapsid ancestors. The evolutionary context of the origin of mammals is shown in the tree diagram at right (the dagger symbol † indicates extinct lineages).

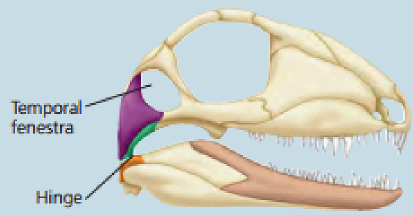


Key to skull bones

- Articular
- Dentary
- Quadrate
- Squamosal

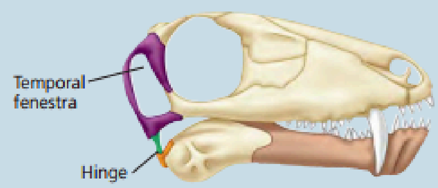
Synapsid (300 mya)

Synapsids had multiple bones in the lower jaw and single-pointed teeth. The jaw hinge was formed by the articular and quadrate bones. Synapsids also had an opening called the *temporal fenestra* behind the eye socket. Powerful cheek muscles for closing the jaws probably passed through the temporal fenestra. Over time, this opening enlarged and moved in front of the hinge between the lower and upper jaws, thereby increasing the power and precision with which the jaws could be closed (much as moving a doorknob away from the hinge makes a door easier to close).



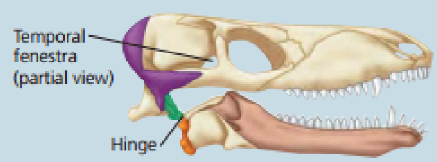
Therapsid (280 mya)

Later, a group of synapsids called therapsids appeared. Therapsids had large dentary bones, long faces, and the first examples of specialized teeth, large canines. These trends continued in a group of therapsids called cynodonts.



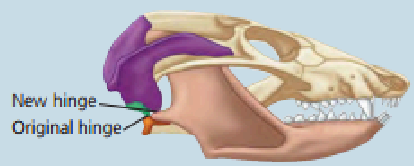
Early cynodont (260 mya)

In early cynodont therapsids, the dentary was the largest bone in the lower jaw, the temporal fenestra was large and positioned forward of the jaw hinge, and teeth with several cusps first appeared (not visible in the diagram). As in earlier synapsids, the jaw had an articular-quadrate hinge.



Later cynodont (220 mya)

Later cynodonts had teeth with complex cusp patterns and their lower and upper jaws hinged in two locations: They retained the original articular-quadrate hinge and formed a new, second hinge between the dentary and squamosal bones. (The temporal fenestra is not visible in this or the below cynodont skull at the angles shown.)



Very late cynodont (195 mya)

In some very late (non-mammalian) cynodonts and early mammals, the original articular-quadrate hinge was lost, leaving the dentary-squamosal hinge as the only hinge between the lower and upper jaws, as in living mammals. The articular and quadrate bones migrated into the ear region (not shown), where they functioned in transmitting sound. In the mammal lineage, these two bones later evolved into the familiar hammer (malleus) and anvil (incus) shown in Figure 34.31.

Relative Duration of Eons	Era	Period	Epoch	Age (Millions of Years Ago)	Some Important Events in the History of Life
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	Historical time
			Pleistocene	2.6	Ice ages; origin of genus *Homo*
		Neogene	Pliocene	5.3	Appearance of bipedal human ancestors
			Miocene	23	Continued radiation of mammals and angiosperms; earliest direct human ancestors
		Paleogene	Oligocene	33.9	Origins of many primate groups
			Eocene	55.8	Angiosperm dominance increases; continued radiation of most present-day mammalian orders
			Paleocene	65.5	Major radiation of mammals, birds, and pollinating insects
	Mesozoic	Cretaceous		145.5	Flowering plants (angiosperms) appear and diversify; many groups of organisms, including most dinosaurs, become extinct at end of period
		Jurassic		199.6	Gymnosperms continue as dominant plants; dinosaurs abundant and diverse
		Triassic		251	Cone-bearing plants (gymnosperms) dominate landscape; dinosaurs evolve and radiate; origin of mammals
	Paleozoic	Permian		299	Radiation of reptiles; origin of most present-day groups of insects; extinction of many marine and terrestrial organisms at end of period
		Carboniferous		359	Extensive forests of vascular plants form; first seed plants appear; origin of reptiles; amphibians dominant
		Devonian		416	Diversification of bony fishes; first tetrapods and insects appear
		Silurian		444	Diversification of early vascular plants
		Ordovician		488	Marine algae abundant; colonization of land by diverse fungi, plants, and animals
		Cambrian		542	Sudden increase in diversity of many animal phyla (Cambrian explosion)
Proterozoic		Ediacaran		635	Diverse algae and soft-bodied invertebrate animals appear
				2,100	Oldest fossils of eukaryotic cells appear
				2,500	
Archaean				2,700	Concentration of atmospheric oxygen begins to increase
				3,500	Oldest fossils of cells (prokaryotes) appear
				3,800	Oldest known rocks on Earth's surface
				Approx. 4,600	Origin of Earth

Chapter 25 Questions

1. **What is macroevolution?**
2. **What is *Dorudon atrox*?**
3. **What is Wadi Hitan?**
4. **What were the 4 stages by which simple cells originally arose?**
5. **What was Earth's early atmosphere mainly composed of?**
6. **What happened to the atmosphere as Earth cooled?**
7. **What are hydrothermal vents?**
8. **What are alkaline vents?**
9. **What are vesicles?**
10. **What is montmorillonite?**
11. **What was most likely the first genetic material?**
12. **What are ribozymes?**
13. **How has natural selection affected ribozymes?**
14. **Why is double stranded DNA better than RNA?**
15. **What is amber?**
16. **Describe the following: *Dimetrodon, Rhomaleosaurus victor*, *Tiktaalik*, *Coccosteus cuspidatus*, *Hallucigenia*, stromatolite, *Dickinsonia costata*, *Tappania***
17. **What is radiometric dating?**
18. **What are the half-lives of carbon-14 and uranium-238?**
19. **Up until what age can carbon-14 be used to date fossils?**
20. **What are tetrapods?**
21. **How do mammals differ from other tetrapods?**
22. **Describe the origin of mammals since 300 mya.**
23. **What is the geologic record?**
24. **What is the earliest direct evidence of life?**
25. **Where did atmospheric O_2 come from?**
26. **When did the oxygen revolution occur?**
27. **How old are the oldest widely accepted fossils of eukaryotic organisms?**
28. **How did eukaryotes originate?**
29. **What is the serial endosymbiosis hypothesis?**
30. **Which cell is thought to have engulfed the bacteria that became mitochondria?**
31. **What are the oldest known fossils of multicellular eukaryotes that can be resolved taxonomically?**
32. **What are Ediacaran biota?**
33. **What is the Cambrian explosion?**
34. **How did large animals change after the Cambrian explosion?**
35. **What is the opposite of extinct?**
36. **What is the oldest fossil assigned to an extant animal phylum?**
37. **When did large forms of life begin to colonize land?**
38. **What were plants like 420 mya?**

39. **What is mycorrhizae?**
40. **What is an arbuscule?**
41. **What were the first animals to colonize land?**
42. **How old are the earliest tetrapods and where did they come from?**
43. **When did humans originate?**
44. **How many times did the landmasses of Earth come together to form a supercontinent?**
45. **What is the theory of plate tectonics?**
46. **When/how did the himalayas form?**
47. **What was the supercontinent of 250 mya called? What two land masses did it split into?**
48. **How did antarctica form?**
49. **What is a mass extinction?**
50. **What are the two main mass extinctions?**
51. **What evidence is there that an asteroid/comet caused the Cretaceous mass extinction?**
52. **What are gastropods and bivalves?**
53. **How many mass extinctions have occurred?**
54. **What is adaptive radiations?**
55. **What is heterochrony?**
56. **What is paedomorphosis?**
57. **What are homeotic genes?**
58. **What are *Hox* genes?**
59. **What is the *Ubx* gene?**
60. **What are the simplest known eyes?**
61. **What are exaptations?**
62. **What is species selection?**

Chapter 25 Answers

1. The broad pattern of evolution above the species level
2. An ancient whale (extinct)
3. The Valley of Whales in Sahara Desert
4. 1, abiotic synthesis of small organic molecules (e.g. amino acids/nitrogenous bases)
   2, joining of small molecules into macromolecules (e.g. proteins/nucleic acids)
   3, The packaging of these molecules into protocells (droplets with membranes that maintained an internal chemistry different from that of their surroundings)
   4, The origin of self-replicating molecules that eventually made inheritance possible
5. Little oxygen, thick with water vapor and compounds released by volcanic eruptions (nitrogen and its oxides, carbon dioxide, methane, ammonia, and hydrogen)
6. Water vapor condensed into oceans and hydrogen escaped into space
7. Areas on the seafloor where heated water and minerals gush from Earth's interior into the ocean
8. Deep-sea vents that release water that has high pH (9-11) and is warm (40-90 C)
9. Fluid-filled compartments enclosed by a membrane-like structure
10. Soft mineral clay produced by weathering of volcanic ash, increases rate of vesicle self-assembly when added to solution (provides surfaces on which organic molecules can become concentrated, thought to have been common on early Earth).
11. RNA
12. RNA that serves catalytic purposes
13. single-stranded RNA molecules can have many 3D shapes, some may be able to replicate better than other sequences. RNA molecule with best replication ability will leave more descendant molecule
14. more chemically stable, can be replicated more accurately
15. Fossilized tree sap
16. See picture
17. Common technique used to determine the age of a fossil, based on the decay of radioactive isotopes. Parent isotopes decay into daughter isotopes at characteristic rate (called half-life, the time required for 50% of parent isotope to decay)
18. 5730, 4.5 billion years
19. 75,000 yrs old
20. Group of four-limbed animals (amphibians, reptiles, and mammals)
21. Lower jaw composed of one bone (dentary) and lower and upper jaws hinge between a different set of bones. Have a unique set of three bones that transmit sound in middle ear (hammer,anvil,stirrup), other tetrapods only have stirrup. Mammals have differentiated teeth (incisors for tearing, canines for piercing, premolars/molars for crushing and grinding), others don't
22. see image
23. A standard time scale that divides Earth's history into four eons and further subdivisions. First three eons (hadean, archaean, proterozoic) lasted 4 billion yrs, phanerozoic (last

half billion years) encompasses most of time with life on Earth, divided into Paleozoic, Mesozoic (age of reptiles), and Cenozoic eras, boundaries between eras represent extinction events

24. Fossilized stromatolites (layered rocks that form when certain prokaryotes bind thin sediment together) from 3.5 billion yrs ago, prokaryotes sole inhabitants for 1.5 billion years
25. Oxygen gas is mostly of biological origin. When oxygenic photosynthesis evolved, free O_2 dissolved in surrounding water until it reacts with elements to form sediments. Eventually, water became saturated, oxygen enters atmosphere (caused rusting of iron rocks about 2.7 billion yrs ago, shows that oxygen-releasing photosynthetic bacteria originated before this)
26. 2.4 billion yrs ago, oxygen levels shot up to between 1% and 10% of present level, doomed many prokaryotic groups because it attacks chemical bonds and can inhibit enzymes/damage cells
27. 1.8 billion yrs old
28. Endosymbiosis when a prokaryotic cell engulfed a small cell that would evolve into the mitochondrion
29. Mitochondria evolved before plastids through a sequence of endosymbiotic events
30. An archaean or a close relative of the archaeans
31. Small red algae that lived 1.2 billion yrs ago
32. Fossils of large, diverse multicellular eukaryotes from 600 million years ago, soft-bodied organisms (635 to 541 mya). Included algae and animals
33. 535-525 mya where many present-day animal phyla appeared suddenly
34. Before, all were soft-bodied, grazers, filter feeders, scavengers. After, predators over 1 m emerged, defensive adaptations appeared
35. extant
36. The mollusc *Kimberella* (lived 560 million years ago)
37. 500 mya
38. Small (10 cm high) with vascular system but lack of roots or leaves
39. Root fungi that form symbiotic relationships with plants, helped plants colonize land
40. Branched fungal structure
41. arthropods 450 mya
42. 365 mya, evolved from lobe finned fishes
43. 195,000 years ago
44. 3 times (1 billion, 600 million, 250 million ya)
45. Continents are part of great plates of Earth's crust that essentially float on the hot underlying portion of the mantle, movements in mantle cause plates to move (continental drift)
46. 45 mya, Indian plate crashed into Eurasian plate
47. Pangaea, Laurasia and Gondwana
48. Split from australia 40 mya
49. Large numbers of species become extinct world wide

50. Permian and Cretaceous, Permian between Paleozoic/Mesozoic eras (252 my) in less than 500000 years. Cretaceous 66 mya,killed dinosaurs
51. Iridium found in strata of that time (rare on earth, common in meteorites). Chicxulub crater off coast of Mexico was caused by an object with diameter 10 km, same age as extinction
52. Snails and relatives, clams
53. 5
54. Periods of evolutionary change in which groups of organisms form many new species whose adaptations allow them to fill different niches in their communities
55. An evolutionary change in the rate or timing of developmental events
56. Sexually mature species may retain features that were juvenile features in ancestral species, common in salamanders (e.g. axolotl)
57. Master regulatory genes that control the spatial organization of body parts
58. Genes that provide positional information in an animal embryo
59. Gene that controls leg growth
60. Patches of light-sensitive photoreceptor cells, found in small molluscs called limpets
61. Structures that evolve in one context but become co-opted for another function
62. Species that endure the longest/ generate the most new offspring species determine the direction of major evolutionary trends