I. Testudinomorpha – Turtles and Tortoises (Ch. 10)
   A. Systematics, diversity, and distribution
      1. The earliest fossils of turtles date to the late Triassic; relatively little major
         morphological change has taken place since that time
      2. Systematic relationships with other amniotes poorly understood
         a. combination of ancestral and highly derived traits makes determining
            relationships difficult
         b. two hypotheses currently being actively debated:
            (1) turtles are sister group to other reptiles (as shown on earlier cladogram)
            (2) turtles are diapsids
            (3) we’ll stick with the first (more conservative) for now, recognizing that it
                may be wrong!
      3. Modern turtles/tortoises include ~ 250 species in two lineages, one of which
         (cryptodires) includes almost 200 species
      4. Worldwide distribution and variety of habitats:
         a. turtles/tortoises can be found on all continents except Antarctica
         b. can also be found in all warm and temperate oceans
c. occupy a wide diversity of both terrestrial and aquatic habitats

B. Form and function

1. Skull is unique among modern reptiles by having a horny epidermal "beak" covering the dentary (major bone of lower jaw)

2. Most obvious characteristic = "shell"

   a. Composed of two parts:

      (1) **carapace** above

      (2) **plastron** below

      (3) two pieces connected via bony processes

   b. both plastron and carapace have same basic structure:

      (1) **dermal bone** beneath

      (2) **epidermal (protein) scales = scutes** above

   c. bones of the carapace are fused to the vertebrae and ribs, leaving the ribs outside the limb girdles (vs. inside on all other tetrapods):

        ![Diagram of turtle shell]

   d. in a number of species have hinged plastrons: front and rear lobes can be pulled upward to close openings for protection

   e. in others, plastron is reduced in size, allowing greater mobility/agility: one species (musk turtle) can even climb several feet into trees

        ![Diagram of plastron reduction]
f. variation in shell morphology is correlated with general differences in habitat and ecology (study fig 10-1 p. 270 and corresponding text):

(1) terrestrial species tend to have
   (a) high domes
   (b) broad feet
   (c) e.g., box turtles

(2) aquatic species tend to have
   (a) streamlined shells, often with reduced ossification
   (b) webbed feet for swimming
   (c) e.g., softshell turtles

(3) lots of other possibilities, even given constraints imposed by shell morphology!

3. Respiratory and circulatory systems

a. Heart is very complex:
   (1) structurally:
      (a) completely divided atria
      (b) incompletely divided 3-chambered ventricle
   (2) functionally, the arrangement permits
      (a) complete separation of oxygenated, deoxygenated blood during "normal" circulation
      (b) high pressure systemic and low pressure pulmonary circuits
      (c) but also allows shunting of blood between systemic and pulmonary circuits (during diving, e.g.)

b. Ventilation of lungs is made complex by rigid carapace: (see fig 10-6 p. 279 and associated text)
   (1) lungs are large, attached to carapace dorsally and ventrally
   (2) can’t ventilate by expanding/contracting rib cage/thoracic cavity, because it’s rigid
(3) instead, use visceral cavity:
   (a) lungs attached to visceral cavity ventrally by rigid sheet of connective tissue = **diaphragmatic sheet**
   (b) normally, weight of viscera keeps diaphragmatic sheet pulled downward
   (c) ventilation uses abdominal, pectoral girdle muscles to change the volume of the visceral cavity:
      i) increase volume of v.c. \(\rightarrow\) pull "down" on diaphragmatic sheet \(\rightarrow\) expand the lungs (and vice-versa for exhalation)
      ii) note that both inhalation and exhalation are active – both require active muscle movement
   c. aquatic species may supplement lungs by performing gas exchange with water, using specialized epithelium of the pharynx, cloaca (read p. 280)

4. Reproduction
   a. turtles are long-lived, with relatively low reproductive rates
      (1) reproductive maturity in even small species takes 7-8 years
      (2) may live 14 years or longer
   b. all are oviparous, with relatively long incubation periods and no parental care
   c. many exhibit temperature-dependent sex determination
      (1) this form of sex determination is found in many turtles, all crocodilians, and some lizards
      (2) temperature during nesting determines sex of offspring
      (3) in general, the higher temperature produces the larger sex:
         (a) so in turtles, high temperatures produce females
      (4) usually, each nest will produce predominantly individuals of one sex; multiple nests with different temperatures produces the overall sex ratio (usually 1:1).

C. Conservation status and issues
1. at least three groups of turtles are facing major conservation risks:
   a. sea turtles
   b. large land tortoises (e.g., gopher tortoises in U.S.; Galapagos and Aldabra tortoises)
   c. a whole variety of species now being exported for food and use in the exotic pet trade, with Asian species especially affected
   d. read on-line http://www.ntyts.org/proceedings/behler.htm

2. Life history traits described above place turtles at risk generally:
   a. low reproductive rates and lack of parental care mean recruitment of new individuals into populations will be slow
   b. so any time conditions create high adult mortality, populations will be in trouble

3. Specific threats include (but not limited to)
   a. habitat loss and degradation:
      (1) for terrestrial and freshwater species, this is especially problematic
      (2) for marine species, development of nesting sites is a problem (see discussion of navigation pp. 289)
   b. overexploitation for food and the pet trade
      (1) Asian economic "boom" (including opening of Chinese markets) created major market for turtle meat and other products
      (a) Asian species were/are rapidly depleted
      (b) now species are being imported to meet demand, so other species are being affected
      (c) read details p. 292
      (2) exotic pet trade has also been booming, and has had several important effects:
      (a) decline in source populations
      (b) introduction of exotics into non-native habitats as pets are released
(c) spread of disease organisms (see, e.g., box 10-1 p. 291)

  c. in the case of sea turtles, fisheries practices result in loss due to "by-catch", especially in shrimp trawlers

4. Problems with turtle conservation include

a. lack of basic natural history information for many species

  (1) means it’s hard to identify patterns in local populations
  (2) also means it’s hard to know what strategies will help (e.g., incubating and head-starting sea turtles)

b. economics: not only of major "commercial" interests (e.g., shrimpers who don’t want to use turtle-excluders in their nets) but of subsistence workers/farmers involved in turtle trade

c. international politics: good conservation measures require uniformity and cooperation among countries:

  (1) in the rules themselves
  (2) in enforcement

5. According to 1996 Red List:

a. 7 species Extinct (no reasonable doubt that the last individual has died).

b. 2 species Extinct in the Wild

c. 14 species Critically Endangered (facing an extremely high risk of extinction in the wild in the immediate future)

d. 33 species Endangered (not Critically Endangered but facing a very high risk of extinction in the wild in the near future)

e. 62 species Vulnerable (not Critically Endangered or Endangered but facing a high risk of extinction in the wild in the medium-term future)

f. 1 species is Lower Risk/Conservation Dependent (cessation of a taxon- or habitat-specific conservation program will result in the taxon qualifying for one of the threatened categories above within 5 years)

g. 47 species Lower Risk/Near Threatened (don’t qualify for conservation
dependent, but close to qualifying for vulnerable)

h. note total = 166 out of ~ 250 species = 65% of extant species currently facing documented risk!

II. Archosaurs I: dinosaurs (Ch. 14, esp. 14.5)

A. Introduction to archosaurs and their relationship to other reptiles:

1. The Diapsida radiated throughout the Mesozoic (which starts at the Triassic ~ 245 mybp)

2. derived diapsids fall into two main lineages (see cladogram):
   a. Lepidosaurs and their allies (including ichthyosaurs) = the lineage that includes modern lizards, snakes, and tuatara
   b. Archosaurs and their allies, which includes four major lineages:
      (1) crocodilians (dating from Triassic to present)
      (2) Pterosaurs = flying reptiles (note largest = *Quetzalcoatlus*, with wingspan of 13 m!)
      (3) birds
      (4) non-avian dinosaurs = two lineages: Saurischia and Ornithischia

B. The non-avian dinosaurs originated ~ 230 mybp at time when continents were still coalesced into supercontinent of Pangea

1. common ancestor was most likely similar to *Eoraptor*:
   a. small (< 1 m)
   b. bipedal
   c. carnivorous

2. for first ~15 million years, diversity was limited

3. around 215 mybp, dinosaurs radiated rapidly (although total diversity was never as great as, say, mammalian diversity)
   a. probably in conjunction with end-Triassic extinctions, which opened niches

4. "Age of dinosaurs" = subsequent 150 my (to end Cretaceous), during which
time virtually all animals >1 m in dry land habitats were dinosaurs

C. The role of hip morphology in dinosaur evolution:

1. earliest dinosaurs carried hind limbs directly beneath the body
   a. improves weight-bearing (so will permit increase in body size later)
   b. improves locomotor efficiency: using less muscle energy, can move farther, faster, by
      (1) increase stride length
      (2) increase stride frequency

2. carrying limbs beneath the body requires remodeling of hip joint
   a. to move bone through a long arc (as in a long stride), need long muscle
   b. with limbs held horizontally, relatively small pelvis still permits a long muscle to attach to the limb (at the end, e.g.)
   c. with limbs beneath the body, the relatively small pelvis doesn't offer enough distance from origin to insertion to allow for long muscle
   d. solution = remodel hip, providing anterior and posterior extensions for muscle insertion (see fig. 14.9 p. 380 & associated text)

3. this arrangement "works" for
   a. both small and large bipeds
      (1) note that bipedality represents new adaptive zone as forelimbs are freed for functions other than locomotion (e.g., food capture)
   b. very large quadrupeds
      (1) with "horizontal" posture, body size will be limited by ability to support weight with muscle during locomotion
with limbs beneath the body, bone is supporting weight – permitting much greater body size

4. the two major lineages are distinguished by the details of the hip (but functionally, both work the same)
   a. Ornithischia = "bird hipped" ("O" on diagram above)
   b. Saurischia = "lizard hipped" ("S" on diagram above)

D. Ornithischia: the "bird-hipped" dinosaurs

1. all were herbivores, with horny beaks at the fronts of the jaws and teeth specialized for slicing vegetation
2. three major groups:
   a. armored quadrupeds: ankylosaurs and stegosaurs
   b. horned quadrupeds: the ceratopsians
   c. bipedal "duck-billed" dinosaurs: hadrosaurs and their allies

E. Saurischia

1. this group includes the ancestors of birds
2. two major lineages:
   a. sauropods = large quadrupedal herbivores: e.g.
      (1) Diplodocus
      (2) Supersaurus: 40 m long
      (3) one question still unanswered = how large, long-necked forms pumped blood to head without generating such high blood pressure that the capillaries were blown out
   b. theropods = bipedal forms, including bird ancestors
      (1) three major ecological categories represented:
         (a) large predators, e.g. Tyrannosaurus
         (b) fast-moving predators specializing on small prey
(c) fast-moving predators specializing on large prey, e.g., *Velociraptor*

(2) fossil finds over last decade have "filled gaps" in dinosaur-bird evolution, to the point that we have a well-supported sequence of changes (that we'll discuss later) – for now, just compare skeletons of pigeon, *Archaeopteryx*, and small theropod (fig 15-3 p. 414):

III. Crocodilians: crocodiles, alligators, caiman, gavial = gharial (Ch. 14 pp. 373-377)

A. Brief history:
   1. true crocodilians appeared in the Triassic; haven't changed much morphologically since
   2. earliest were
      a. relatively small (cat-sized), slender
      b. probably active predators on small diapsids
   3. reached peak diversity (and max body size) during Cretaceous, when warm climates extended into what are now temperate regions
      a. *Deinosuchus* had skull 2 m long
      b. if body proportions same as modern crocs, would have been 12-15 m long (about the size of *T. rex*)!

B. Distribution and diversity
   1. Note that all are semiaquatic, limited to tropical/subtropical areas:
2. ~25 species (depending on source) in three families
   a. Alligatoridae = alligators, caiman
      (1) about 10 species (2 alligators, 8 caiman)
      (2) all fresh-HOH
      (3) New World, except for Chinese alligator
   b. Crocodylidae = crocodiles
      (1) ~15 species
      (2) cosmopolitan distribution
      (3) found in range of habitats from fresh to salt water (including brackish waters)
      (4) includes the largest modern crocodilian = Australian (saltwater) crocodile (*Crocodylus porosus*); max length = 7m
   c. Gavialidae = gavial = gharial
      (1) single species
      (2) lives in large rivers of Indian subcontinent

3. Major differences between alligators and crocodiles:

<table>
<thead>
<tr>
<th>characteristic</th>
<th>Alligators</th>
<th>Crocodiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>snout</td>
<td>relatively short, wide, u-shaped</td>
<td>relatively long, slender, pointed</td>
</tr>
<tr>
<td>teeth/jaws</td>
<td>upper jaw wider than lower; only upper teeth visible when jaws closed</td>
<td>jaws ~ same width; upper and lower teeth appear “interlocking” when jaws closed</td>
</tr>
<tr>
<td>salivary salt glands</td>
<td>present, weakly or not functional</td>
<td>present, functional</td>
</tr>
</tbody>
</table>
C. Form and Function:

1. adaptations to semiaquatic life
   a. can breathe while body underwater (only nostrils exposed)
      (1) nostrils dorsal, at tip of snout
      (2) complete **secondary palate**
         (a) = shelf of bone separating nasal passages from oral cavity
         (analogous to our hard and soft palates) –
         (b) air can move directly into trachea even if mouth full of water (note
            that can’t completely seal mouths shut)
         (c) specialized flap of tissue at base of tongue further seals off mouth
            from throat to keep water out of trachea
   b. heavy, laterally compressed tail provides propulsion during swimming (when
      swimming, limbs folded against body for streamlining)
   c. sensory pits on lower jaws detect small changes in water; probably used
      primarily in prey detection (analogous to lateral line)
   d. specialized salt glands

2. maintain general “spraddled” posture (limbs horizontal), but limbs well
   developed and capable of variety of gaits on land
   a. lateral undulation still common
   b. can also bring limbs directly under body for climbing over obstacles
   c. can gallop over short distances

3. four-chambered, completely divided heart
   a. still permits shunting of blood from pulmonary to systemic circuits via
      “passageway” = foramen of Panizza between aortic arches
   b. can alter circulation based on activity, thermoregulatory needs, and during
4. reproduction
   a. all are oviparous
   b. most build nests – mounds or cavities
   c. many exhibit extensive parental care, including (but not limited to):
      (1) helping young out of nest at hatching
      (2) carrying young to water
      (3) protecting young before, during, and after hatching (some up to 3 years)
   d. all exhibit temperature-dependent sex determination
   e. reproductive rates moderately low, although lots of variation among species
      (1) age at maturity may be as low as 4 years, or over 10 years
      (2) number of eggs per clutch averages 20-60
      (3) note that, in spite of parental care, egg mortality may be very high due to predation
      (4) incubation periods average 75-90 days

D. Conservation status (information from FMNH website)
   1. ~ 10 species considered to be at significant risk
   2. major causes include
      a. hunting for skins (this was especially problematic from 1930’s to 1960’s, and is still a problem for some species in some places)
         (1) in contrast to lepidosaurs, crocodilians retain some dermal bone (osteoderms) associated with epidermal scales
         (2) osteoderms in belly skin reduces  worth of skins – so those species without osteoderms in belly skins have historically been exploited to the greatest extent
      b. hunting for other reasons (eggs, meat, juveniles for pet trade)
      c. habitat loss/degradation
         (1) as semiaquatic species, croc’s all live in the kinds of habitats most at
risk world-wide: riparian and coastal estuarine habitats

(2) because most species tropical/subtropical, “population pressure” may be particularly high
d. indirect losses from gill net fishing, road kill, etc.

3. in places where species are particularly economically valuable, some successes from commercial farming/captive breeding (including release, protection of wild populations)

4. but remember that not all species economically valuable, so this doesn’t always work

5. note also that crocs may play very important roles in their ecosystems: American alligator, for example, is considered keystone species in Gulf Coast habitats

a. keystone species = species with disproportionately large effect on community structure/function (often because of physical effects on habitat)

b. for American alligator, effects include

(1) control of prey species populations (which, in turn, effects species diversity within the community)

(2) formation of peat through nesting habits

(3) nest use by other species

(4) habitat alteration – create “alligator holes” where water will remain even when other streams/ponds drying, creating refugia for other species