1. Myxinoïdès (hagfish) are sister to what monophyletic group?

   a) Vertébrata
   b) Gnathostomata
   c) Urochordata
   d) Cephaloïdachordata

2. Which is NOT a characteristic of chordata?

   a) Pharyngeal pouches
   b) Notochord
   c) Exoskeleton
   d) Myomeres
3. Which is an example of a paraphyletic group?

a) Gnathostomata  
b) Agnatha  
c) Vertebrata  
d) Chondrichthyes

4. What was the name of the supercontinent that consisted of present day Africa, South America, Australia, and Antarctica?

a) Laurentia  
b) Gondwana  
c) Pangaea  
d) Baltica
Osteichthyes Systematics and characteristics
Figure 1-4  Phylogenetic relationships of extant vertebrates. This diagram shows the probable relationships among the major groups of extant vertebrates. Note that the cladistic groupings are nested progressively; that is, all placental mammals are therians, all therians are synapsids, all synapsids are amniotes, all amniotes are tetrapods, and so on.
Traditional classification

• Class Osteichthys
  – About 27,000 species of Bony Fishes
• Chondrichthyes - cartilaginous fish
  – Osteichthys - bony fish
  – Chondrostei - fish with bone and cartilage
  – Holostei - entirely bony fish
  – Teleostei - final bony fish
• This series of names implies a gradual increase in bone during evolution -- we now know this was not the case.
Phylogenetic placement of bony fishes

- Osteichthyes is monophyletic group (node 4 on figure)
- Actinopterygii is sister to Sarcopterygii
- Sarcopterygii contains Actinistia + Dipnoi + Tetrapoda

Figure 1-4: Phylogenetic relationships of extant vertebrates. This diagram shows the probable relationships among the major groups of extant vertebrates. Note that the cladistic groupings are nested progressively; that is, all placental mammals are therians, all therians are synapsids, all synapsids are amniotes, all amniotes are tetrapods, and so on.
Table 6.1: Classification and geographic distribution of osteichthyans, the bony fishes.

Major groups are shown in boldface. Only the evolutionarily or numerically most important groups are listed. The subdivision of the Neopterygii varies greatly from author to author. Groups in quotation marks are not monophyletic, but relationships are not yet understood. Names in square brackets are alternative names for the groups; common names are in parentheses.

**Sarcopterygii (fleshy-finned fishes and tetrapods)**
- Actinistia [Coelacanthiformes] (coelacanths); Western Indian Ocean and central Indonesia, deep-water marine.
- Dipnoi (lungfishes)—Southern Hemisphere, freshwater.
- Tetrapods—Worldwide

**Actinopterygii (ray-finned fishes)**
- Polypteriformes [Cladistia] (bichirs)—Africa, freshwater.
- Acipenseriformes [Chondrostei] (sturgeons and paddlefishes)—Northern Hemisphere, coastal and freshwater.

**Neopterygii**
- Lepisosteiformes [Ginglymodi] (gars)—North and Central America, fresh and brackish water.
- Amiiformes (bowfins)—North America, freshwater.

**Teleostei**
- Osteoglossomorpha (bony tongues)—Worldwide, mostly tropical freshwater.
- Elopomorphi (tarpons and eels)—Worldwide, mostly marine.
- Clupeomorphi (herrings and anchovies)—Worldwide, especially marine.

**Euteleostei**
- Ostariophysi (catfish and minnows)—Worldwide, mostly freshwater.
  - Protacanthopterygii (trouts, salmon, and relatives)—Temperate Northern and Southern Hemisphere, freshwater.
  - Stem Neoteleostei (lanternfishes and relatives)—Worldwide, mostly mesopelagic or bathypelagic marine.
- Paracanthopterygii (cods and anglerfishes)—Northern Hemisphere, marine and freshwater.
- Acanthopterygii (spiny-rayed fishes)—Atherinomorpha (silversides, killifishes, and relatives) worldwide, surface-dwelling, freshwater and marine; Perciformes (perches and relatives), worldwide, primarily marine; and other smaller groups.

**Figure 1-4** Phylogenetic relationships of extant vertebrates. This diagram shows the probable relationships among the major groups of extant vertebrates. Note that the cladistic groupings are nested progressively; that is, all placental mammals are therians, all therians are synapsids, all synapsids are amniotes, all amniotes are tetrapods, and so on.
Bony fishes experienced 3 major radiations

- **Mainly Paleozoic;**
  - Bichirs and reedfishes are extant;

- **Mesozoic**
  - Gars and bowfin are extant.
  - The primitive sharks appeared in Mesozoic, but no cartilaginous fish survive from the Mesozoic radiation.

- **Cenozoic**
  - The extant sharks and rays
  - Sturgeons and paddlefishes
  - Teleosts (~27,000 species today)
Bony fish

Characteristics of bony fish:
- Few characters because of diversity of group

1) All have some true bone
   - Skulls have sutures (sharks have a single block of cartilage)
   - Teeth fused to mandibles
   - Swim bladder or lungs usually present

5) Bony operculum present
• Actinopterygii Ray-finned fishes
• Exist from late Silurian
• Characteristics:
  – 1) Scales ganoid, cycloid, ctenoid or no scales.
  – 2) Membranous fins supported by fine bony rays.
  – 3) Caudal fins highly variable.
• Actinopterygii Contains Polypteriformes (extant bichirs and reedfishes)
  ● *Polypterus* – bichir or African rope-fish
    – Have lungs, lobed fins, found in Africa, ganoid scales cover body
      • 1) Spiracle present.
      • 2) Heterocercal tail in some.
      • 3) Ganoid scales.
• Actinopterygii Contains Acipenseriformes
  – Sturgeons and paddlefish
    • Ganoid Scales on tail, dermal bony plates on back.
• *Accipenser* - sturgeons Important economically for meat and Caviar.

• *Huso huso* - beluga Largest of the sturgeon group, from Caspian Sea, Up to 3,300 lbs. The finest black caviar in the world comes from this species ($5 per gram).
Essay Question

• Describe the major structures in fish gills and explain how gills efficiently obtain oxygen from the water.
Scales

- Placoid – found in sharks, they are modified on the anterior to form teeth, they are composed of a vascular inner core of pulp, a middle layer of dentine and a hard enamel-like outer layer of vitrodentine
- Ganoid – found in gars, bichirs and reedfish, are rhomboid in shape and have a bony basal layer of dentine and outer layer of ganoine, they do not overlap
- Cycloid – found in bowfin, they consist of a surface bony layer and a deeper fibrous layer composed mainly of collagen
- Ctenoid – found in most teleosts, are similar to cycloid scales but they have a spiny posterior margin, both cycloid and ctenoid scales grow with the fish so they lay down concentric growth rings and can be used to determine age and growth rates of fish.
Scales

- **Placoid Scale**
- **Ganoid Scale**
- **Cycloid Scale**
- **Ctenoid Scale**
Tails

- Heterocercal
- Hypocercal
- Homocercal
Actinopterygii

- **Polydon** - paddlefish
  - Includes two species, one in the US (including Texas) and one in China. Weighs up to 200 lbs.
• Neopterygii
  – Lepisosteiformes (gars)
    • Body covered with Ganoid scales.
    • Swim bladder aids in respiration.
    • Long snout with many teeth, voracious predators on small fish.
    • Restricted to North America.
    • No marine forms (no sea-gars)
Neopterygii

– Amiiformes (bowfin) *Amia*
  • Cycloid scales cover body.
  • Predator on smaller fish.
  • Also use swim bladder for respiration.
  • The one living species (*Amia calva*) is restricted to the Mississippi drainage of North America but fossils are known from Europe.
4 important characteristics of gars and bowfin

1) They are extant members of lineages that are older than Teleost fishes.
2) Modified heterocercal tail.
3) Scales ganoid (gars) or Cycloid (bowfin).
4) Swim bladder connected to pharynx aids in respiration.
Fig 6-8. Nonteleostean actinopterygian fishes and primitive neopterygians

- Actinopterygians:
  - Bichir
  - Sturgeon
  - Paddlefish

- Primitive Neopterygians:
  - Gar
  - Bowfin
Teleosti

• There are at least 24 Orders of teleost fishes, comprising ~27,000 species.

• 1) Tails homocercal in most species.
• 2) Scales cycloid or ctenoid, NOT ganoid.
• 3) Swim bladder present in most species.
Osteoglossomorpha

- Worldwide, mostly tropical freshwater
- Include one of the largest bony fish
  - *Arapaima gigas*, up to 200kg and 450cm
Elopomorpha

- Tarpons and Eels
- Worldwide, mostly marine
- The Atlantic tarpon is an important game fish
- American Freshwater Eel
  *Anguilla rostrata*  
  - Catadromous
Clupeomorpha

- Herrings and Anchovies
- Worldwide, especially marine
Euteleostei

- Largest clade of teleosts
  Ostariophysi (catfish and minnows)
  dominant fishes of freshwater; 25-30 percent of fish and 80 percent of freshwater
  two characters
  Weberian apparatus – small bones that connect the swim bladder to the inner ear
  Presence of fright or alarm substance in the skin (phermones)
Ostariophysi

• [http://www.youtube.com/watch?v=fxw1EFcm3vw](http://www.youtube.com/watch?v=fxw1EFcm3vw)
Euteleosti

• Protacanthopterygii (Salmonids and relatives)
  – This includes the anadromous salmon
• Paracanthopterygii (cods and anglerfish)
  – About 1200 species
Acanthopterygii

- True spiny-rayed fishes
  - Largest group of extant fish
  - Most species are in the order Perciformes with well over 9300 species