FLAPPERS

How do animals fly?

Glide/Parachute  -  continuously lose altitude, slow descent with membrane
Soar  -  use rising atmospheric energy to generate lift
Flap  -  use body energy to generate lift

First Flying Vertebrates

Lizards (Diapsids)  -  Permian lizards: all gliders or parachuters, lept from trees

Pterosaurs  -  First abundant and diverse flying vertebrates
Arose in Triassic, extinct in end Cretaceous
Dinosaurs nearest relatives - advanced ankle structure.
Last common ancestor with dinos was a small, agile, bipedal, carnivore.

Pterosauria
Basic modifications for flight present in early pterosaurs

Early forms: late Triassic - late Jurassic
short bodies, reduced fused hip bones
5 long toes, including a divergent 5th toe (membrane support?)
long neck and large heads
long 4th finger to support wing
pterooid - forward pointing wrist bone to support membrane
certainly had front and side membranes, probably had back membranes
retain long tail, often with a vane
small bodies (down to sparrow-sized)

Pterodactyloids  -  late Jurassic - late Cretaceous
very large with big head crests for steering
reduced tails
fused bones (ribs, sacrum, sternum)
pneumatic foramen (air-filled bones)
Keeled sternum: Muscle attachment
Supracoracoideus through pulley (like in birds)
High metabolic rate - high stamina/activity - hair

Bats or Birds

Bat  -  wings attach to legs, 4-foot & clumsy on ground vs
Roadrunner  -  wing attach to waist, legs free, biped & fast
Trackways, 3-D hip analysis, and body balance issues all suggest bipedality is out.

Flight
Lift = constant x wing area \* velocity^2
To fly, body weight must be balanced by lift
Weight = constant x wing area \* velocity^2
Rearrange to get minimum velocity needed to maintain body aloft
\[ V_{\text{min}} = (1.1 \times \text{weight/wing area})^{0.5} \]
Wing loading = weight/wing area
Pterosaurs have exceptionally low wing loadings (very light body, very big wings)
So \( V_{\text{min}} \) is tiny (6 - 8 m/s) even for big animals
Brains
Bird-like attributes - expanded cerebrum and cerebellum
Enlarged optic lobes
Reduced olfactory regions
Big semi-circular canals (balance)
Huge flocculus: integrates neck, eyes, and balance organs: gaze stabilization
  Does it integrate information from wing membranes?
Smaller brains than birds, larger than other archosaurs
Can deduce head orientation from semi-circular canal orientation

Babies
Lay eggs
Tooth wear on baby's teeth suggest parental care

Head Gear Variations
Most were fish eaters, some ate insects & small vertebrates, filter-feeders too
May have bias in record - all from fine-grained marine deposits

FLIPPERS
Major groups
Sauropterygians (basal diapsids)
  Placodonts
  Nothosaurs
  Pleisiosaurs and Pliosaurs
Ichthyosaurs (another basal diapsid)
Mosasaurus
Turtles (despite lack of temporal fenestrae, apparently also basal diapsids!)
Crocodiles

Placodonts
  mid to late Triassic
  several continents
  shallow coastal environments
  small forms (1-3 ft long)
  turtle-like shape, long tail
  boxy skull
  tooth comb and crushing teeth
  strain mollusks?

Nothosaurs
  mid Triassic of Eurasia
  coastal environments?
  up to 12 ft long
  long neck, streamlined body
  paddlelike forelimbs, hindlimbs reduced
  small pointy teeth - piscivores?
Plesiosaurs
- Early Jurassic to late Cretaceous
- Several continents
- Fully marine and deep water habitats
- Front and hind limbs modified to flippers
- Stiff trunk, strong pectoral and pelvic girdles
- Short, boxy body with massive ventral ribs

“Regular” plesiosaurs: long necks, short tails, small head, sharp teeth, piscivores?
Pliosaurs: short neck, large head, generalized carnivores

Ichthyosaurs (basal diapsid): Early Triassic to late Cretaceous (worldwide)
- Most “fish-like” marine reptile
- Triassic forms - longer bodies; Cretaceous forms - more dolphin-like
- Forelimbs modified into flippers; reduced hindlimbs and pelvic girdle
- Hyperdactyly and hyperphalangy
- Uneven tail, tipped ventrally and dorsal fin
- Large eyes and beak-like snout, lots of small, pointy teeth
- Specialized pursuit predators?

Mosasaurs (lepidosaur diapsids): Cretaceous
- Shallow water - nearshore
- Related to Monitor lizards
- 5 to 45 ft long, long and slender
- Hands and feed not as modified as in other marine vertebrates
- Blunt snouts - ram prey
- Large eyes and stout teeth
- Ate everything!

Turtles and Crocodiles: Both develop aquatic forms at this time

Marine Reptile Paleobiology
- Reproduction - preserved evidence of live birth in ichthyosaurs and mosasaurs
  - Did the others come ashore to lay eggs?
  - No pelvic/vertebral contact in plesiosaurs, so this seems unlikely
- Metabolism - highly active - endothermic but perhaps not high metabolic rate
- Senses - no evidence for echolocation; big eyes with sclerotic rings

Marine Reptile Locomotion
- Axial: fish-like, fins for steering not propulsion
  - Best example: post-Triassic ichthyosaur, mosasaurs
- Paraxial (limbs):
  - Paddling, rowing
  - Best example: placodonts?
  - Underwater "flying"
    - Best example: plesiosaurs