I. CERATOPSIAN LIFESTYLES

A. PRESERVATION
   Excellent
   Bone beds

B. LIFESTYLES
   1. HABITAT
      Arid (protoceratopids) & well watered plains (ceratopsids)
      Gregarious?
   2. MOVEMENT
      Slow (4 km/ph) up to 30 kmph
      Trackways suggest upright posture
      Skeletal structure more like sprawling lizard than upright mammal
      Trackways suggest 30-35 km/hr running, -4 km/hr walking
      Powerful, but not built for sustained speed
   3. FEEDING
      Herbivores
      Possessed dental batteries (dense clusters of cheek teeth)
      Fleshy cheeks (Genasauria)
      Chewed well (first group!)
      Upper and lower teeth occluded at an angle
      No > 2m high browsers
      Co-evolved with flowering plants??
      Gastroliths in Psittacosaurus (which lacked dental battery)
   4. BRAININESS
      Moderate EQ
   5. PARENTAL CARE
      Eggs and nests known
   6. HORNS
      Defense early hypothesis
      Now thought used for within species combat more than for defense
      Puncture wounds in at least five specimens suggest they were used for aggression
      Species distinctions - appear early in ontogeny in some forms
      Probably had horny sheaths
   7. FRILLS
      Functions:
      - Jaw muscle attachment
      - Protection
      - Species recognition
      - Sexual dimorphism
      Frill development happens when individuals close to full body size
      Thermoregulation of body or brain temperature
      Frills have highly vascular bone
8. **SOCIAL BEHAVIOR**
   many bone beds suggest sociability (known for 9 sp.)
   >100 in each bed
   brain size moderate
   nesting common

II. **ORNITHOPODA**
A large, diverse clade that is misnamed. Ornithopod means ‘bird-footed’, but ornithopods have feet more like mammals (‘beasts’ or ‘thero’) while theropod dinosaurs have feet more like birds.

Systematics is unstable; it contains more than 100 species and includes bipeds and facultative quadrupeds; in this clade crests and spikes take the place of the osteoderms, horns and frills of other ornithischians.

One of the longest lived dinosaur groups (Early Jurassic to latest Cretaceous)

One of the best-preserved dinosaurian clades; we know a LOT about hadrosaurs.

A. **WHO - THE MAIN GROUPS**

**Ornithopoda**: Shared derived characters: ventrally offset premaxilla, low jaw joint

**Heterodontosauridae**: 
Shared derived characters: high crowned teeth with denticles, dental battery, caniform tooth, kinetic lower jaw, fusion of lower leg bones (tibia, fibula, tarsals) for added stability for fast running
General traits of Heterodontisaurids: bipedal, short necks, long tails
1-1.5 m long
used tusks for defense, display, rooting?
some lacked tusks – were they females?
plant eaters
Lower Jurassic, Africa

**Euornithopoda**: 
Shared derived characters: kinetic skulls, beak, fully occluding molars for grinding, strongly indented tooth rows (cheeks)
General traits of Euornithopoda: small to medium sized bipeds (2-4 m)
skulls resemble heterodontosaurus, but no tusks
Very well known from complete skeletons and nests with eggs
Basal forms persist from Middle Jurassic to Late Cretaceous
1st ornithopods with worldwide distribution
**Hypsilophodon**, common basal euornithopod (also **Orodromeus** and **Thescelosaurus**)

**Iguanodontia**: bushiest of all ornithopod clades: 
Shared derived characters: Everted premaxillae, no premaxillary teeth, broad predentary, broad horse-like snout overall, enlargement of external nares, reduction of digit 4 in hand, thumb-spike, extensive networks of ossified tendons, broad feet with hooves, heavily built (massive fore and hind limbs) and large, facultative quadrupeds
Basal: **Tenontosaurus**, **Camptosaurus**; More advanced **Iguanodon**, **Ouranosaurus**
Upper Jurassic to Late Cretaceous
**Hadrosauridae:** the duck-billed dinosaurs
Shared derived characters 3+ teeth per tooth position (up to 1200 teeth per mouth), large coronoid process, no thumb (mitten-like hands, reflecting a trend in ornithpods of loss of hand mobility in more derived groups), thick bumpy skin, 7-17m (large); best known dinosaur group, strange antorbital fenestrae, large number of sacral vertebrae, enlargement of external nares, hoof-like toes on feet

**Hadrosaurinae:**
Shared derived characters: very wide snouts, no cranial crests
*Hadrosaurus, Edmontosaurus, Maiasaura, Anatosaurus, Gryposaurus, Rhabodon, Telmatosaurus,* etc.

**Lambeosaurinae:**
Shared derived characters: hollow crests on head
*Lambosaurus, Parasaurolophus, Saurolophus, Tsintaosaurus, Corythosaurus,* etc.

**B. WHEN?**
- Heterodontosaurs: Early Jurassic
- Basal euornithopods (e.g. *Hypsilophodon*): Late Jurassic to end Cretaceous
- Iguanodontids: Late Jurassic to end Cretaceous
- Hadrosaurids: Late Cretaceous

**C. WHERE?**
- Heterodontosaurs: South Africa and North America
- Basal euornithopods (e.g. *Hypsilophodon*): worldwide
- Iguanodontids: global, excepting India and South America (for now)
- Hadrosaurids: northern hemisphere and South America

**D. PRESERVATION:**
Outstanding. More than 10,000 specimens known, including many bone beds.

**E. LIFESTYLES**

**1. HABITAT**
- Highly varied, ornithpods lived in many different habitats
- Hadrosaurs may have spent some time in shallow water (especially for defensive purposes), but their hands were padded, not webbed, so they were not well-adapted to swimming; they lived in varied habitats, including inland floodplains, coastal swamps, jungles, and at very high latitudes
- Hadrosaurs (along with ankylosaurs) are commonly found in shallow marine sediments (in California and the mid continent)

**2. EATING**
- All ornithpods had fleshy cheeks (Genasauria)
- Some hadrosaurs have been found with remains of conifer needles, twigs and seeds in their rib cages, but may also have eaten herbs and other angiosperms
- Hadrosaurs processed food very efficiently in their mouths; none are found with gastroliths
- Heterodontosaurs and hypsilophodonts had narrow beaks for selective cropping of vegetation; More derived ornithpods had broader snouts, less selective.
Heterodontosaurs moved teeth up and down but also moved their kinetic lower jaws front and back and in and out for grinding
Euornithopods used kinetic skulls when chewing (upper jaws rotated outwards upon occlusion): evidence = scratch marks on teeth
Large guts of iguanodontineans suggests gut fermentation

3. MOVEMENT
Small, bipedal ornithopods were faster than the larger facultative quadrupeds (the former could move up to 60 km/hr; the latter 15-20 km/hr??)
Long, muscular tails strengthened by ossified tendons used for balance and maneuvering
Hands were used for digging or grabbing foliage (or in the case of iguanodontians, perhaps for self defense?)
Large ornitopods were probably quadrupedal walkers, bipedal runners
One hadrosaurid trail in NE Arizona seems to show a tail drag mark, but this is a unique phenomena in hadrosaurid tracks and is probably something else

4. MAKING NOISE
Lambeosaurusine hadrosaurids probably used their hollow crests as resonating tubes and noise makers. Parasaurolophus crests were up to 5 feet long, and show evidence of sexual dimorphism
Hadrosaurusine hadrosaurids may have inflated bags of skin on their broad noses and make bagpipe-like noises
Preserved middle and inner ear structures in some individuals suggest that lambeosaurine could hear across a wide range of frequencies

5. SOCIAL BEHAVIOR
Trackways, preserved nesting sites and bone beds suggest that many ornithopods engaged in complex social behaviors; ornate head structures also hint at sophisticated social behavior
Lambeosaurusine crests tend to be more distinctive where more different types of hadrosaurids were living in the same vicinity
Bonebed and trackway evidence suggest that many ornithpod species lived in herds Some nested in large colonies (e.g. Maiasaura)

6. BABY SITTING
Some hadrosaurids adopted a K-reproductive strategy (as many babies as the environment can handle), producing relative few (altricial) offspring that were tended by adults after hatching
The basal euornithopod Orodromeus used an r-strategy (maximize output of young, figuring that most won’t survive), producing many eggs and precocial young which were left to fend for themselves after hatching

7. DEFENSE
The best defenses of ornithopods were probably sheer number and flight (running away)
Wide hips gave ornithopods more stability and a smaller turning radius than theropods

8. BRAINS
Hi EQ
9. **EVOLUTION**

The appearance of hadrosaurs marked a decline in the abundance of other types of ornithischians – they were good at what they did!

Other evolutionary trends in ornithopods: a) toward facultative quadrupedalism (reduction in # of hand digits and in hand flexibility, increasing number of sacral vertebrae) and b) increasing number of cheek teeth with thicker enamel and more complex occlusion.