

HETEROCHRONY

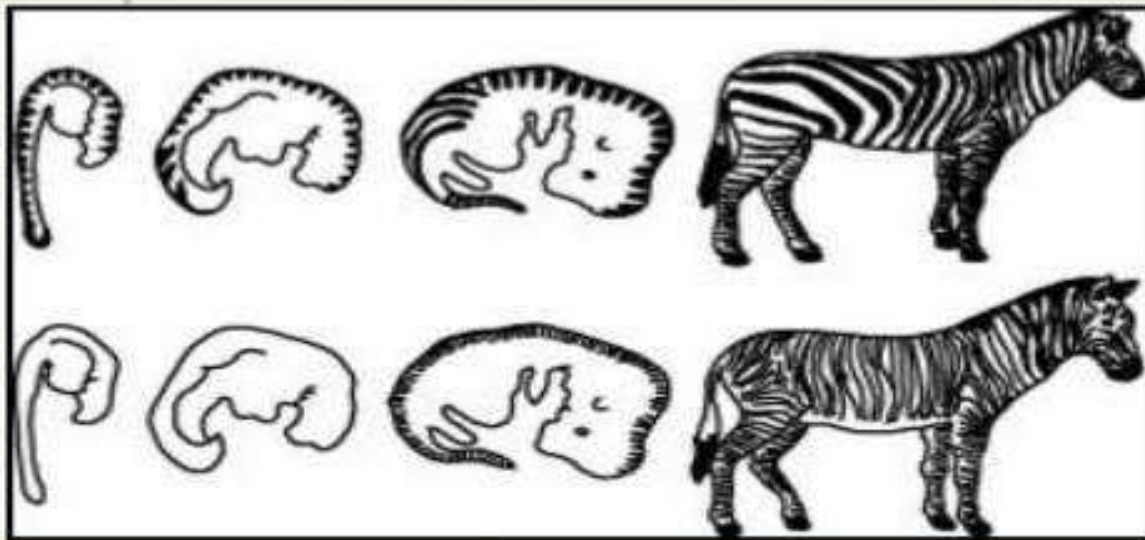
- ▶ All Vertebrates pass from embryo through a larval change and/or juvenile stage on their way to the adult stage.
- ▶ Evolutionary modification of adults often begin here first, in the early stages of ontogeny, by relative changes in timing of developmental events.
- ▶ The term heterochrony describes such a phyletic change, wherein there is an ontogenetic shift in the onset or timing of the feature's appearance in a descendant species compared to the ancestors.

DEFINITION OF HETEROCHRONY

- ▶ In developmental biology , heterochrony is a developmental change in the timing or rate of events leading to changes in size, shape of organs and features over evolutionary time scale.
- ▶ **EXAMPLE:**
- ▶ The oral disk of lampreys enlarges early in their larval ontogeny. However in a few parasitic forms, it remains small until later at sexual maturity , when it enlarges.

HETEROCHRONY INVOLVES A SHIFT IN THE TIMING OF DEVELOPMENTAL PROCESSES SO THAT AN EVENT OCCURS EARLIER, LATER OR AT A DIFFERENT RATE IN A TAXON COMPARED TO THE ADULT

- Today's definition of heterochrony 'the mechanism that produces a parallel between ontogeny and phylogeny'.
- Heterochrony involves a shift in the timing of developmental processes so an event occurs earlier, later, or at a different rate in a taxon compared to its ancestor.



(Leonard & James, 1993)

Embryonic development and stripe patterns of the zebras *Equus burchelli* (top) and *grevyi* (bottom). Illustration drawn by Carole B.

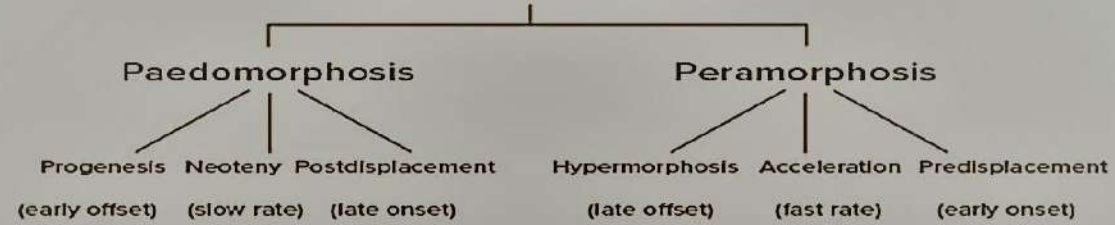
TYPES OF HETEROCHRONY

- ▶ Heterochrony includes several ontogenetic processes that affect the rate of growth of a part, the onset of its debut during embryology, or the offset of its growing period.
- ▶ Depending on the rate, onset and offset during ontogeny, the consequence is to produce two major phylogenetic results:
 - A. PAEDOMORPHOSIS** (meaning “child” and “form”)- Embryonic or juvenile characteristics of ancestors appear in the adults of descendants.
 - B. PERAMORPHOSIS** (meaning “beyond” and “form”)- The adult characters of ancestors are exaggerated and extended in shape and appear in adults of descendants.

ILLUSTRATION WITH EXAMPLE

IN HUMANS , OUR FLAT FACE , RATHER THAN A MUZZLE, SEEMS TO BE A PAEDOMORPHIC FEATURE, THE RETENTION OF THE JUVENILE CHARACTERISTIC OF YOUNG PRIMATES. HOWEVER , OUR RELATIVELY LONG LIMBS, COMPARED TO THOSE OF PRIMATES, SEEM TO BE A PERAMORPHIC FEATURE , THE RESULT OF PROLONGED GROWTH IN HINDLIMB LENGTH AFTER SEXUAL MATURITY

HETEROCHRONY



Ancestor



Newborn



Juvenile



Sub adult



Adult

Paedomorphosis

Peramorphosis

Progenesis



Hypermorphosis



Neoteny



Acceleration

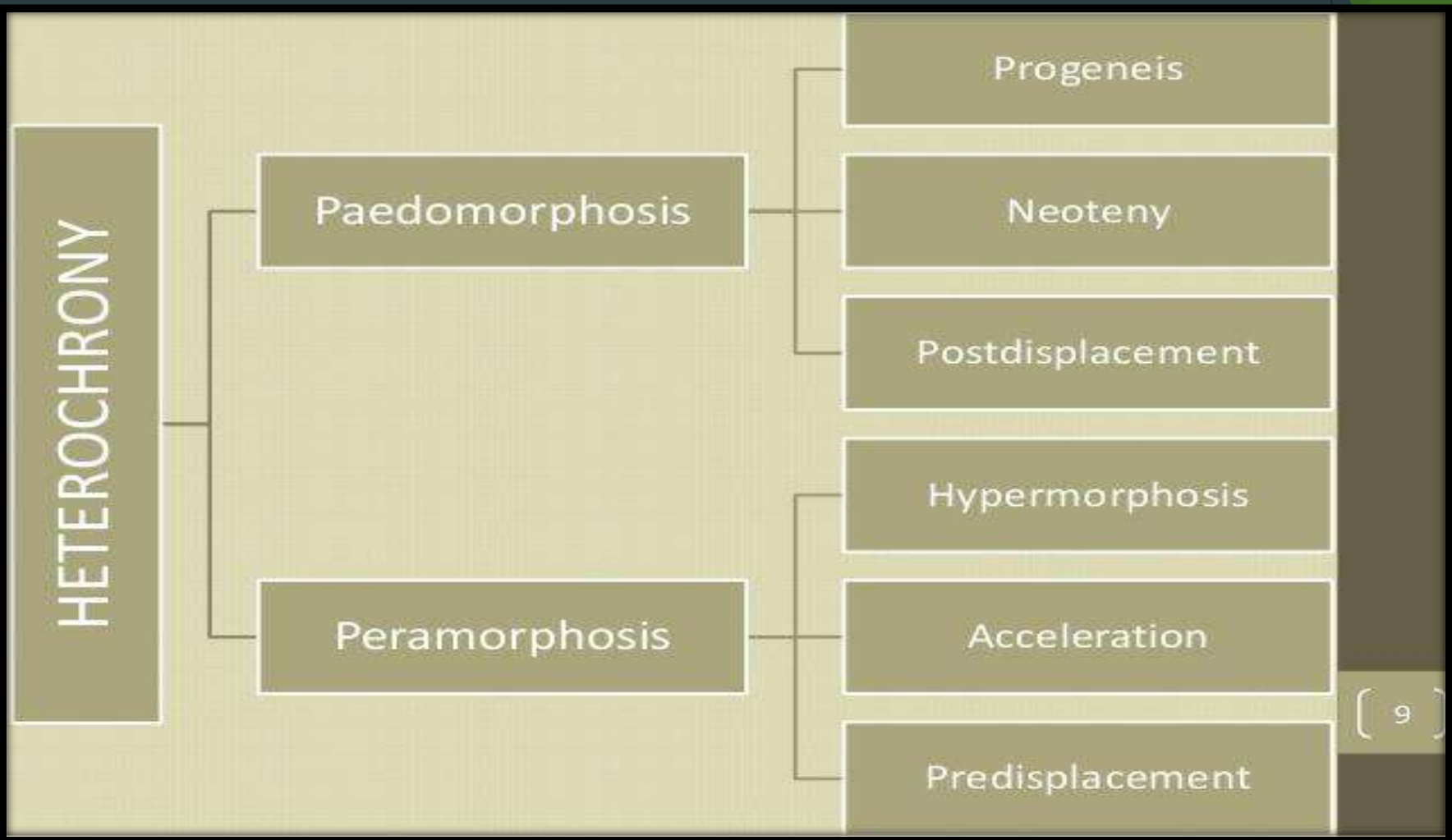


Postdisplacement



Predisplacement

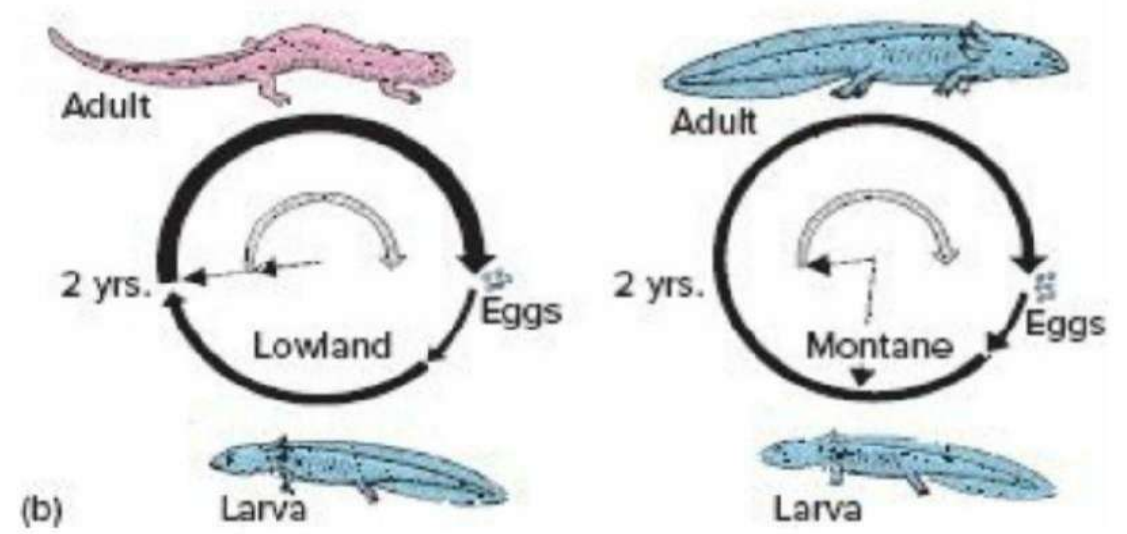
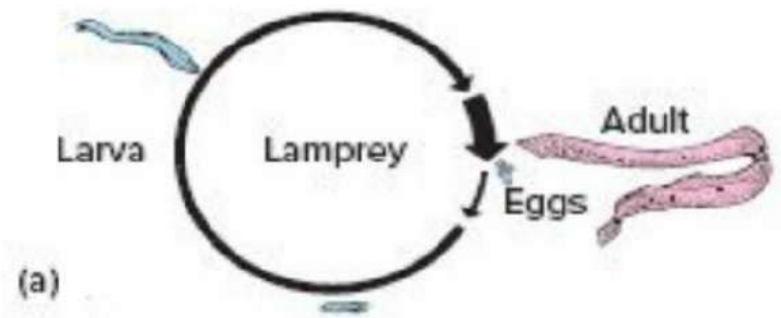




TYPES OF PAEDOMORPHOSIS

Paedomorphosis

- The evolutionary process in which larval or juvenile features of an ancestral organism are displaced to the adult forms of its descendants.
 - If the period of growth of the descendant form is stopped prematurely: **progenesis**
 - If onset of growth is delayed: **postdisplacement**
 - If the rate of growth is less in the descendant than in the ancestor: **neoteny**



PROGENESIS

- ▶ There is an early cessation of somatic development. Growth stops at a relatively earlier age, the individual becomes sexually mature at that earlier age and therefore possesses, as an adult, juvenile features.
- ▶ Relative to somatic development, sexual maturity is accelerated.
- ▶ Progenesis is found in some amphibians and insect lineages.
- ▶ **EARLY OFFSET**

NEOTENY

- ▶ Features grow at a slower rate, compared to their rate in an ancestor.
- ▶ Normal sexual maturity overtakes slowed somatic development, producing a paedomorphic adult.
- ▶ EXAMPLE:
- ▶ *Necturus maculosus*, *Ambystoma tigrinum*
- ▶ **SLOW RATE**

POST DISPLACEMENT

In post displacement , a feature appears late in development, relative to its time of appearance in an ancestor. Starting late, the feature does not reach adult form by the end of maturation , keeps the juvenile quality, and becomes a paedomorphic feature in the adult.

LATE ONSET

Peramorphosis

- Phylogenetic change in which individuals of a species mature past adulthood and take on traits which haven't been seen yet.
 - if the period of growth in the descendant is extended: **hypermorphosis**
 - if the onset of growth occurs earlier in the descendant than in the ancestor: **predisplacement**
 - if the growth rate is increased: **acceleration**

PERAMORPHOSIS

- ▶ Building new adult morphologies by exaggeration or extension of ancestral adult morphologies occurs through several processes, wherein a feature grows longer, grows faster, or begins development earlier.
- ▶ Accordingly there are 3 types:
 - A. HYPERMORPHOSIS: Ontogeny is longer and offset is late
 - B. ACCELERATION: Grows faster
 - C. PREDISPLACEMENT: Begins development earlier

NOTE: BY THESE THREE PROCESSES, A CHARACTER OR FEATURE BECOMES EXAGGERATED IN THE FINISHED ADULT, COMPARED TO ITS DEVELOPMENT IN THE ANCESTORS.

HYPERMORPHOSIS

1. In hypermorphosis the period of growth in descendants is extended.
2. Here the ontogeny is longer and offset is late, so that allometric growth of parts continue beyond the normal endpoint of ancestors.

LATE OFFSET

ACCELERATION

The character grows faster during ontogeny, i.e. the growth rate is increased, compared to its pace in the ancestor.

FAST RATE

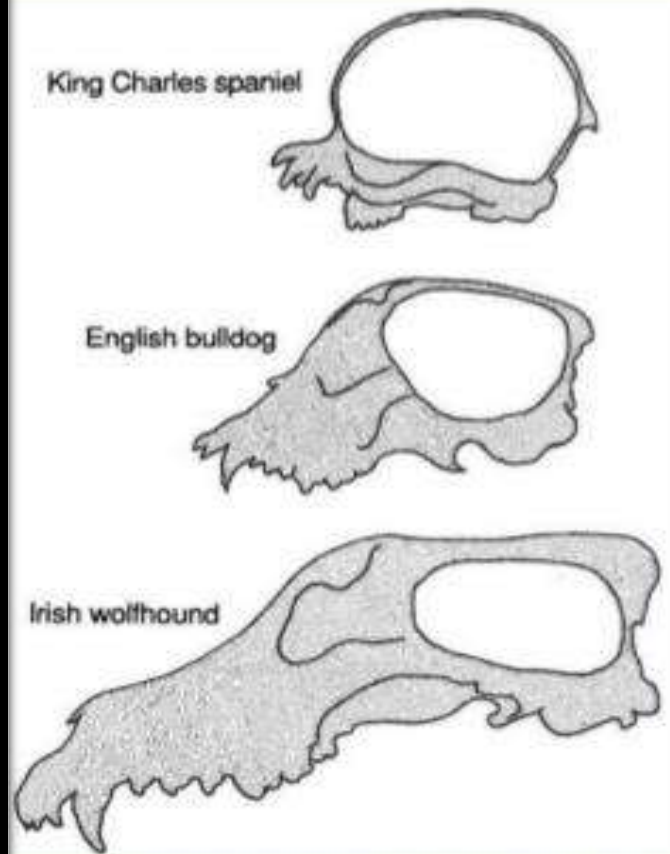
PREDISPLACEMENT

1. Here the onset of growth occurs earlier in the descendant than in the ancestor.
2. So, the descendant is more advanced in its development than its ancestor at a similar stage.
3. Starting earlier, the character has a head start and is relatively ahead of other developing tissues.

EARLY ONSET

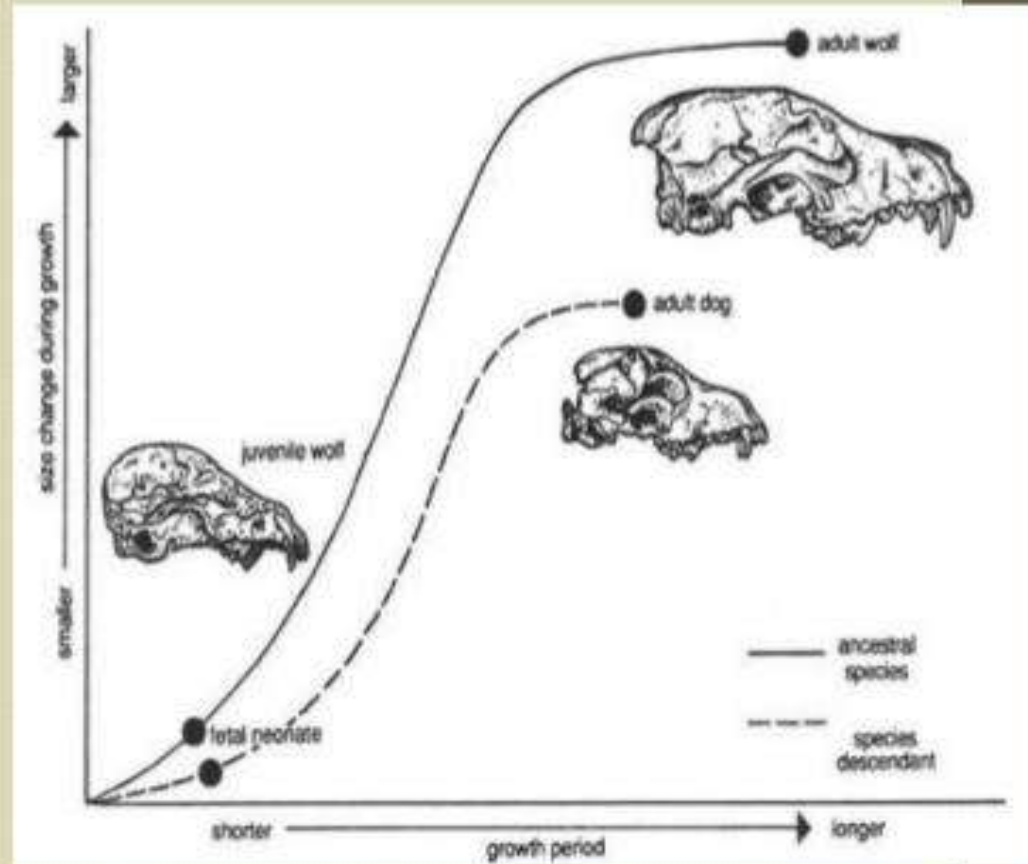
EXAMPLE: EVOLUTION OF THE DOMESTIC DOG FROM THE WOLF BY PAEDOGENESIS

Structural modifications of modern breeds of domestic dog, *Canis familiaris* can be explained by changes in the rate of development during domestication from the wolf *Canis lupus*.



(Kenneth J. 2012)

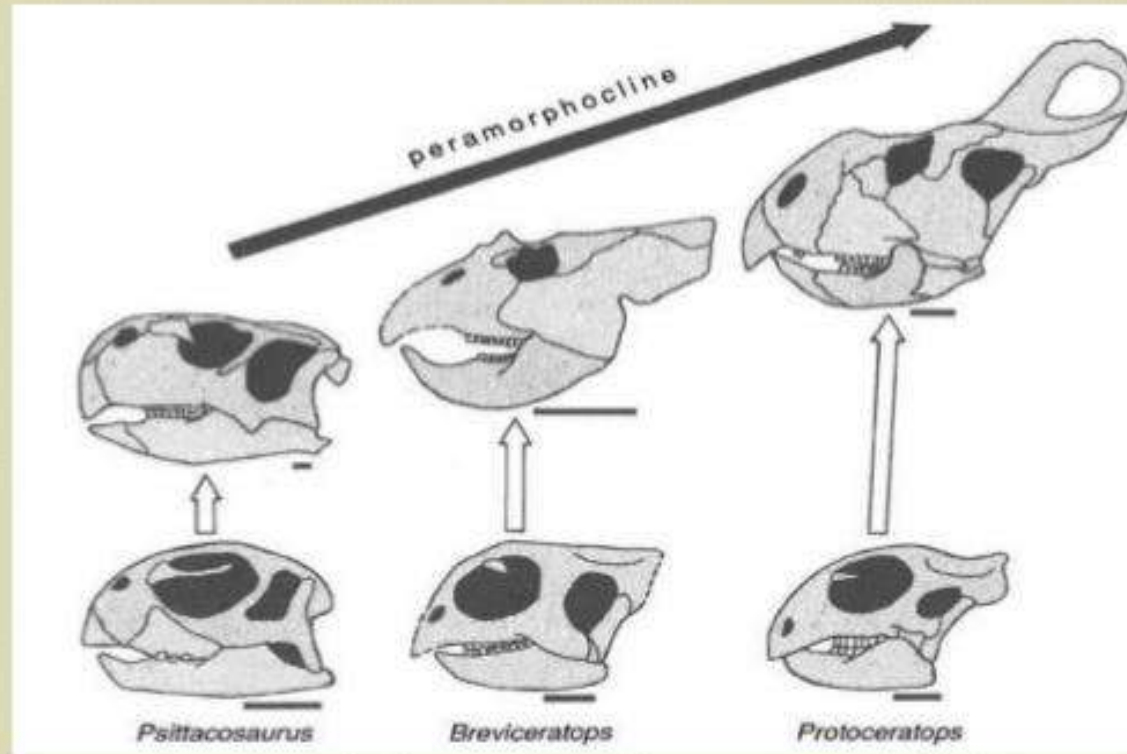
Differences in shape of the skull between three different breeds of dogs



Evolution of the domestic dog from the wolf by pedomorphosis

EVOLUTIONARY SIGNIFICANCE OF HETEROCHRONY

- ▶ Heterochrony is determined on a relative basis: descendant compared to ancestor or more formally, ingroup compared to outgroup.
- ▶ It is an ontogenetic change with phylogenetic consequences.
- ▶ As heterochrony links ontogeny with phylogeny, it has often been the center of debates over the processes behind evolutionary changes.
- ▶ New and sometimes dramatic evolutionary novelties of adults may be built out of changes in the timing of developmental events.
- ▶ As these changes result from shifts in existing ontogenies, new morphologies can arise rapidly on an evolutionary timescale, producing new adaptive possibilities.



(Kenneth J. 2012)

Peramorphic evolution of protoceratopsian dinosaurs