# GLG 430/598 Paleontology

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TODAY:

Lecture: Information encoded in skeletons (Chapter 2, Textbook)

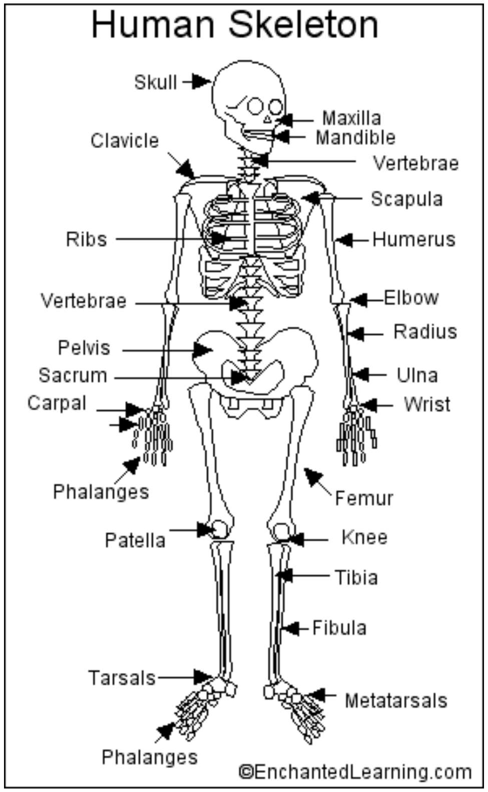
Lab: Skeletal growth in animals

THURSDAY:

Lecture: Sources of variation  in populations (Chapter 2, Textbook)

## Why study skeletons?

- Skeletons provide the basic data of paleontology.
- Understanding skeletal growth and development is requisite for reconstructing the paleobiological meaning of morphology.
- In many instances, the skeletal remains of a fossil organism record important aspects of its developmental history, or ontogeny.
- Integrated over time, comparative studies of skeletal development provide basic information needed to interpret evolutionary change and phylogeny.




"Lucy" 3.2 Ma

# In Short…

- Skeletons record important information about the paleoecology of organisms, (i.e., how they interacted with their physical and biological environments), as well as insights into the growth and development of species, their population dynamics and evolutionary history.

# Functions of Skeletons

- Organisms with mineralized skeletons exhibit an astonishing range of forms, all of which serve three main functions for the organism (see Currey, 1970 for detailed discussion):
  - Support of the body.
  - Mechanical advantage, as levers for muscles to operate against during movement.
  - Protection against injury by predators, external forces (e.g. wave energy, etc.).
  - Desiccation resistance, or protection against other physical and chemical factors of the environment.

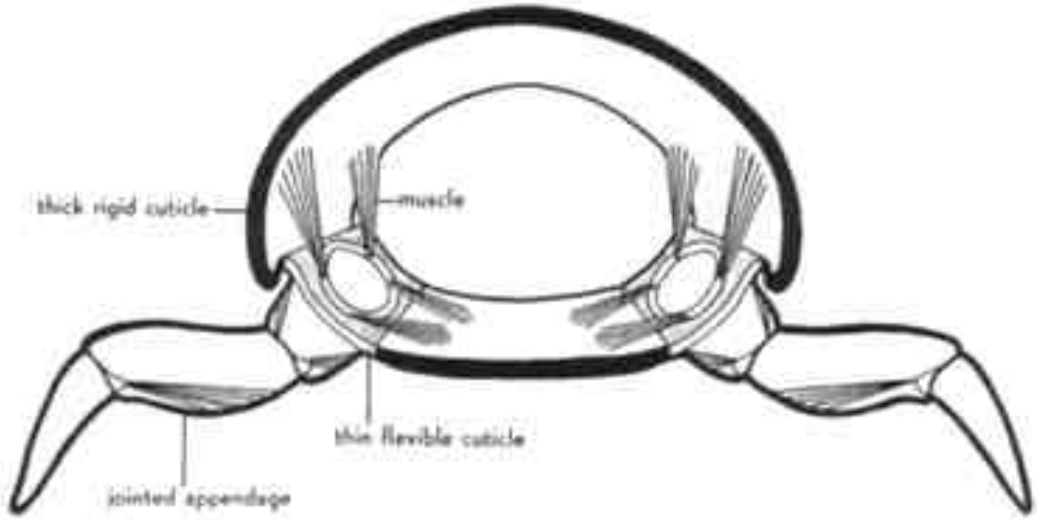
# Types of Skeletons

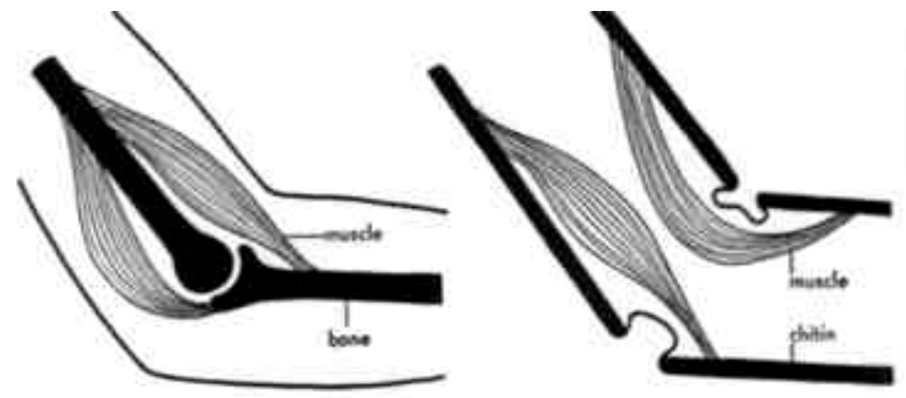
- ***Internal:*** Formed within the tissues of the organism (***Endoskeleton***).
- ***External:*** Formed outside the tissues of the organism (***Exoskeleton***).

Skeletons in Arthropods and Vertebrates

- Jointed skeletons
- Muscle attachments on skeletal surfaces across joints
- Systems based on mechanical leverage

Exoskeleton




Endoskeleton

# Types of Skeletons

- ***Permanent:*** Skeleton retained throughout the life of the organism, versus…
- ***Transient:*** Skeleton periodically replaced (molted).

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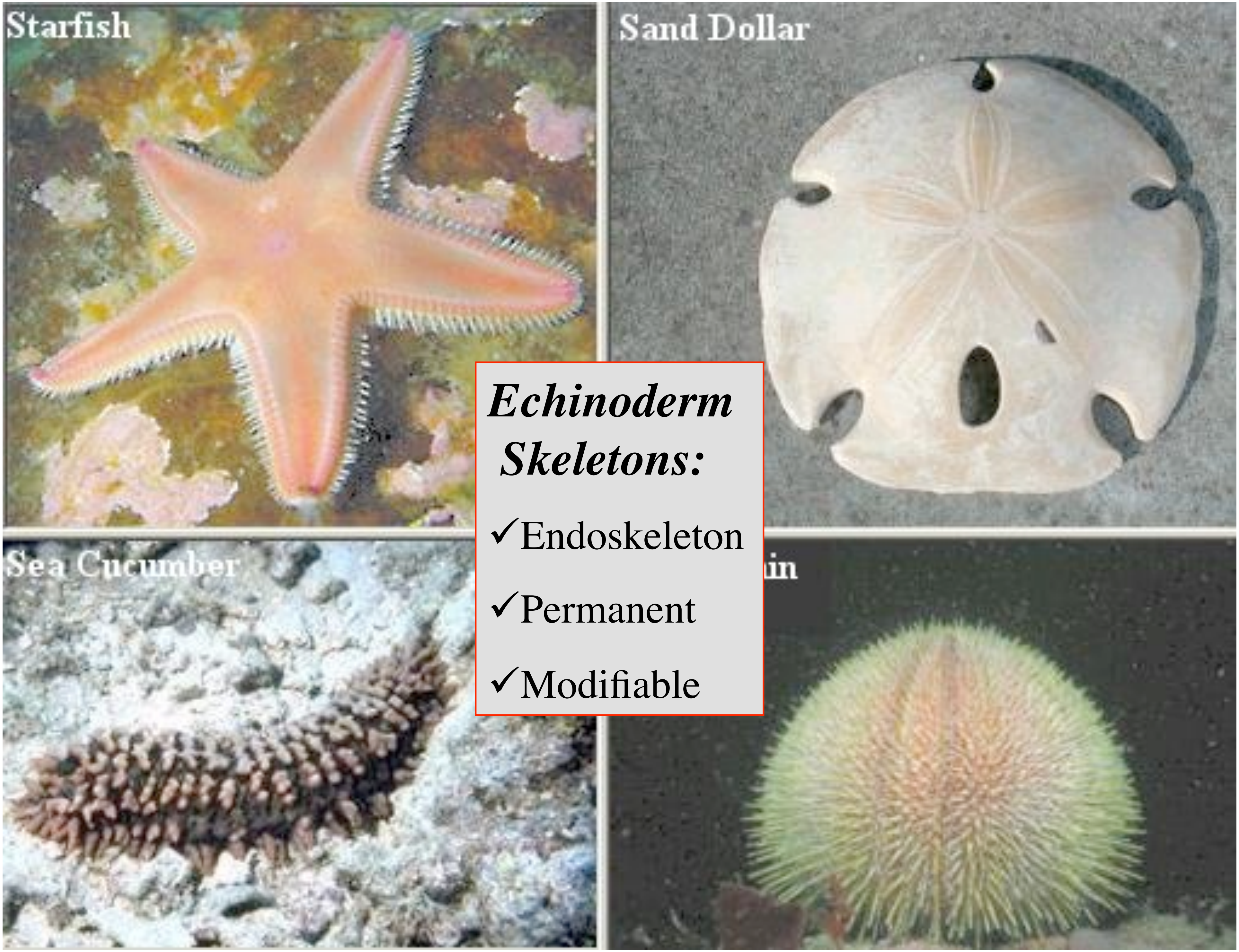
- ***Modifiable:*** Shape of skeleton can be modified after skeleton is grown, versus…
- ***Immutable:*** Shape of skeleton cannot be modified after it is grown.

# *Arthropod Skeletons:*

✓External

✓Transient

✓Immutable




***Echinoderm Skeletons:***

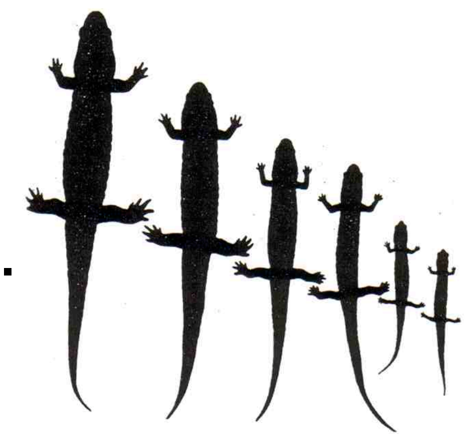
- ✓Endoskeleton
- ✓Permanent
- ✓Modifiable

# What are skeletons made of?

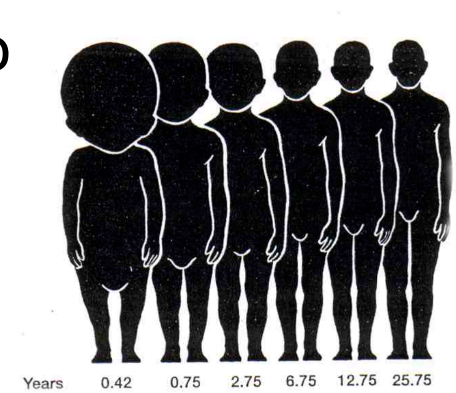
- Most mineralized skeletons consist of mineral grains embedded in an organic matrix of collagen, or polysaccharides.
- The three most common skeletal minerals, in order of decreasing abundance, are calcium carbonate (calcite or aragonite; $CaCO_3$), calcium phosphate (apatite; $CaPO_4$) and silica ($SiO_2$).
- Collagen is the important organic constituent of bones or shells, while polysaccharides make up the organic matrix of arthropod skeletons (as chitin) and plants (as cellulose).
- See examples provided.

# Modes of Skeletal Growth

During the ontogeny of an organism, growth of the various parts of the skeleton can occur in one of two ways. The first way is called:



***Isometric growth***, which is growth that occurs with no change in shape, i.e., the ratio of two measurements from an organism's skeleton does not change as it grows larger.



# Log-spiral Growth

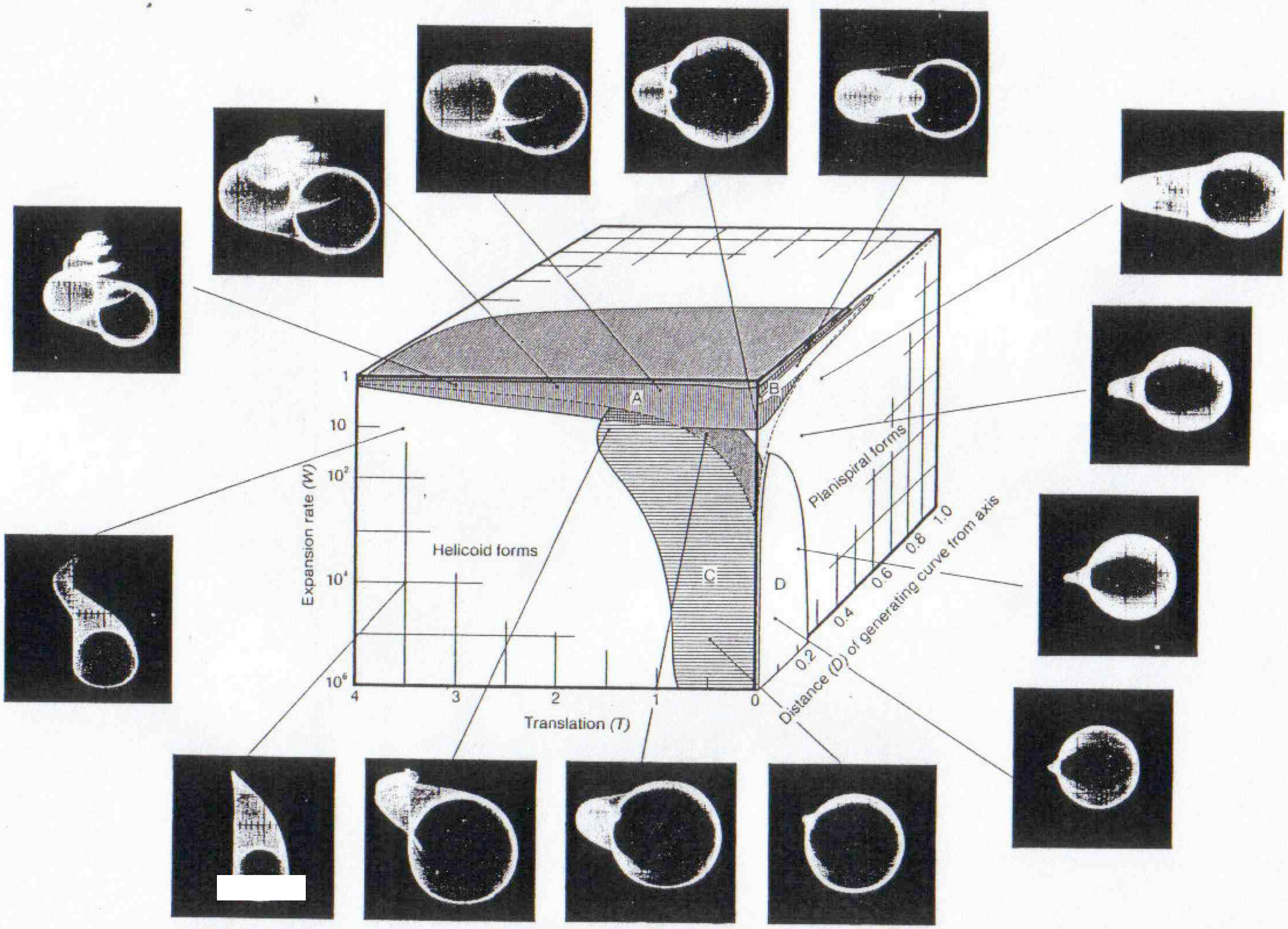
***Log spiral growth*** is a special type of isometric growth which can be described by the equation:

log r ▪ akn

In this equation, r = radius of a spiral, a and k = constants and n = number of turns.

Log spiral growth is common among members of the Phylum Mollusca (e.g., clams, snails, cephalopods) and the Phylum Brachiopoda.

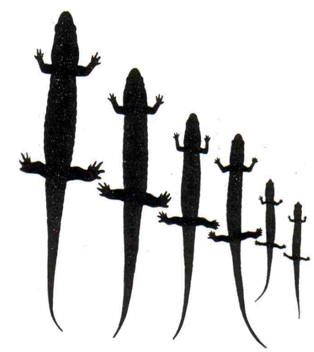
It has the advantage that as size increases in these groups, shape remains essentially constant (see R. McNeil Alexander, 1971).



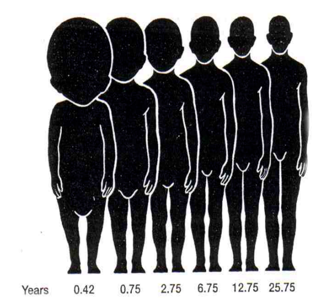

Approximate distribution of form types among four major animal groups having a coiled shell.
Labelled regions: A, gastropods; B, coiled cephalopods; C, bivalves; D, brachiopods. (From Raup, 1966.)

# <u>Anisometric Growth</u>

The second major type of growth is called: Anisometric (or allometric) growth which involves a change in the shape of the organism during ontogeny. This is reflected by changes in the ratio of two skeletal measurements as we progress through various growth stages from juvenile to adult.



In the animal world, anisometric growth is much more common than isometric growth. Allometric growth is a type of anisometric growth that can be described by the equation:



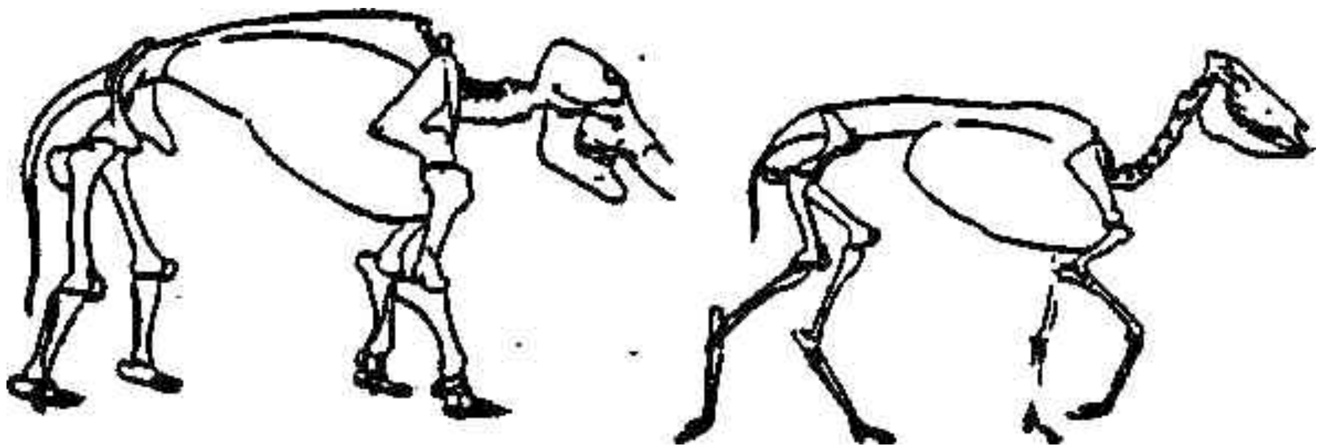

$$Y = bX^a$$

(Where Y and X are linear measurements of the skeleton and a and b are constants).

# Why Allometric Growth?

- As the overall size of an organism increases during growth,
  - Linear dimensions of the body (height, for example) increase at a certain rate…
  - Surface area of the body and its organs increases as a square function…
  - Body volume, and therefore mass, increases as the cube of the linear dimensions.
- The larger the organism, the more disproportionate is the ratio between the linear dimensions of the skeleton, the surface area of digestive or respiratory organs, and the volume, or mass of tissues which must be supported by these organs.
- The increase in volume of the body that occurs with increasing size is usually compensated for by changes in shape as the various linear dimensions of the body and the surface area of supporting skeletal and other organ systems, increase disproportionately.

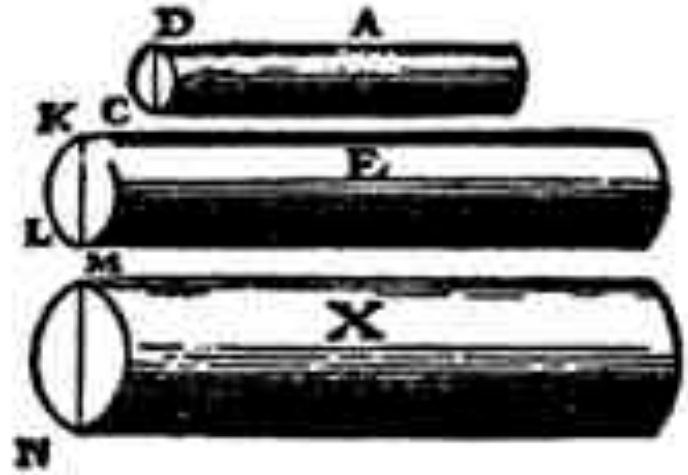
Question: Why is the body shape of horses and elephants so different?

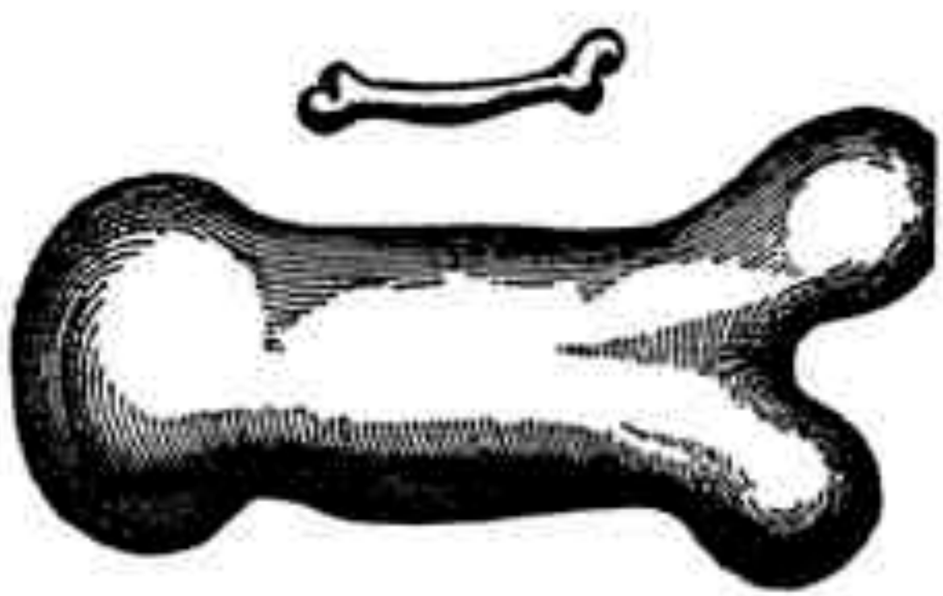


Left: Mastodon (extinct elephant group).
Right: Neohipparion (extinct horse).

***The shapes of animal bones change during growth. Why?***

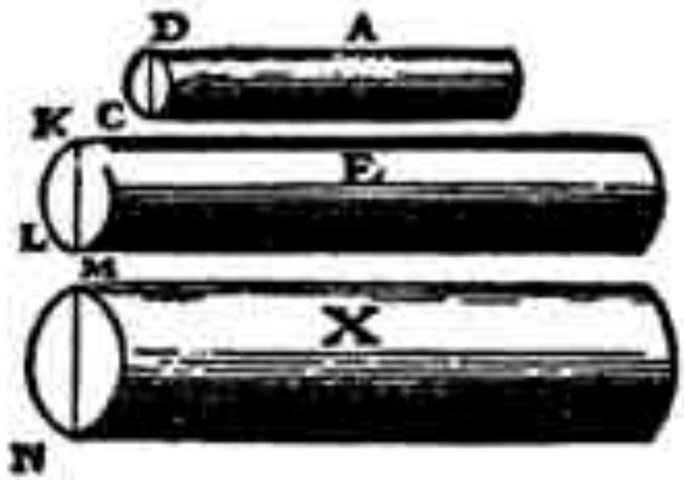
Pause here and discuss!

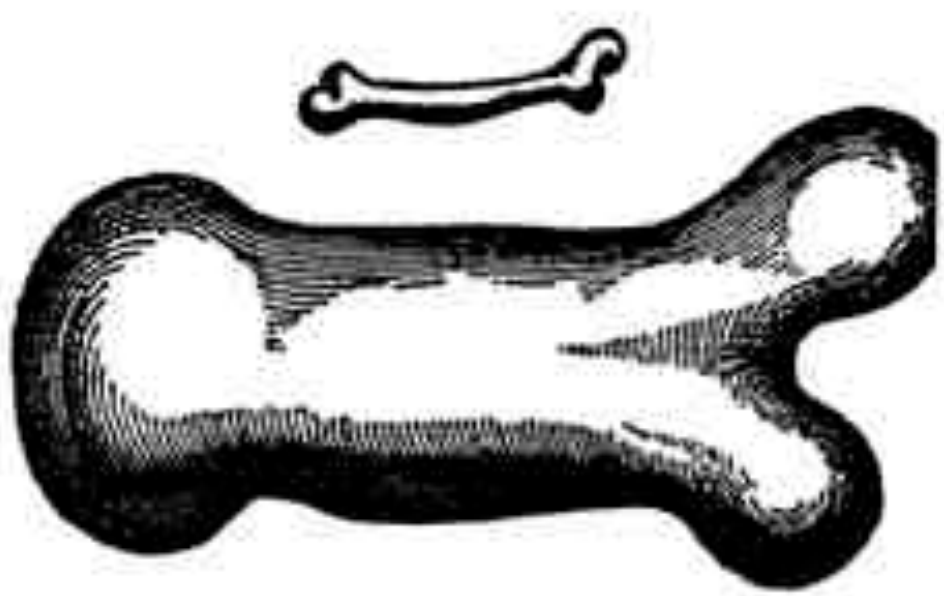


## *Answer:*

- The ability of a bone to support weight is proportional to its cross sectional area.
- As an animal grows, its linear dimensions increase according to a square, but its volume, by the cube.
- This creates a disproportionate increase in size versus weight over time.



# The Coelom

- A coelom is basically an internal fluid-filled body cavity in triploblastic animals.
- Coeloms are known to function in a variety of ways, including:
  - locomotion
  - respiration
  - reproduction
- However, in the earliest animals, which lacked mineralized skeletons, perhaps the most important function of the coelom was as a hydrostatic skeleton for burrowing.

# The Appearance of Burrowing Animals

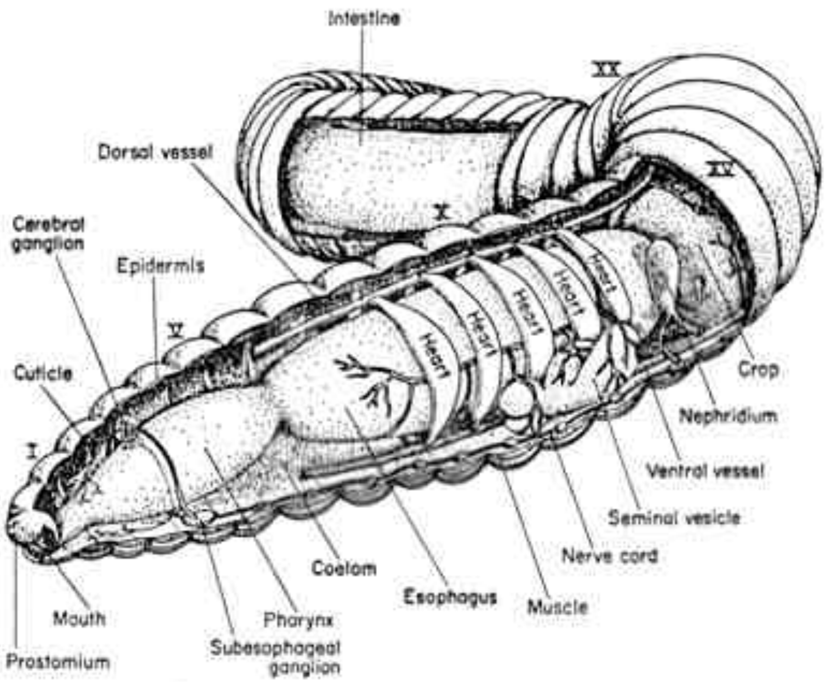
- Prior to the late Proterozoic, organisms were all soft-bodied and lacked rigid skeletons.
- In some groups, however, movement was aided by a peristalsis, organized around a fluid-filled body cavity or coelom.
- The coelom could be deformed by waves contraction of the muscles in the body wall and made to operate like a hydrostatic skeleton.
- This system enabled bottom-dwelling organisms to effectively burrow within sediments.

# Planolites: Simple, unbranching burrows

# More on Coeloms…

- The locomotory functions of internal body cavities are especially well-displayed by annelid worms, where the body (and coelom) is segmented.
- During locomotion, lateral appendages work in conjunction with side to side (lateral) movements of the body and peristaltic waves of contraction and relaxation of the body wall, to propel the animal through sediments.
- Hydrostatic skeletal systems have been modified in a wide variety of ways to function for locomotion in living invertebrate groups. During this course, we will explore the functions of the coelom in different invertebrate phyla.

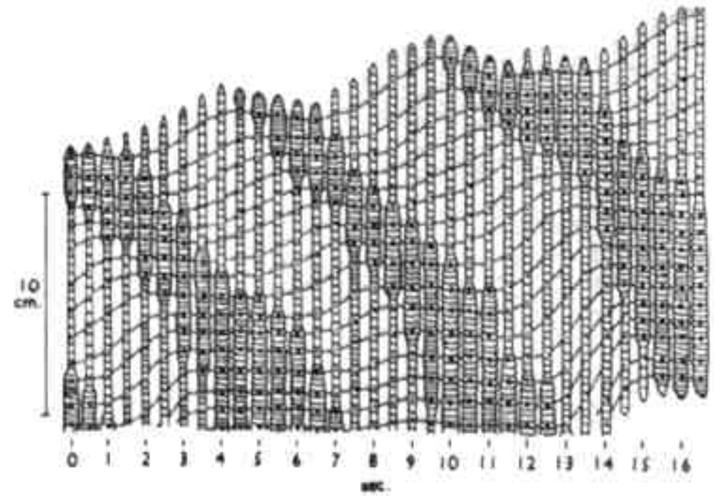
# *Anatomy & Locomotion in Annelids*




*The internal anatomy of an earthworm.* (Reproduced, with permission, from L. S. Dillon, *Principles of Animal Biology*, New York: The Macmillan Company, copyright 1965.)

**Basic modular organization with segmented coelom & serial repetition of organs**

**Muscular Peristalsis**




Stages in the locomotory cycle of an earthworm

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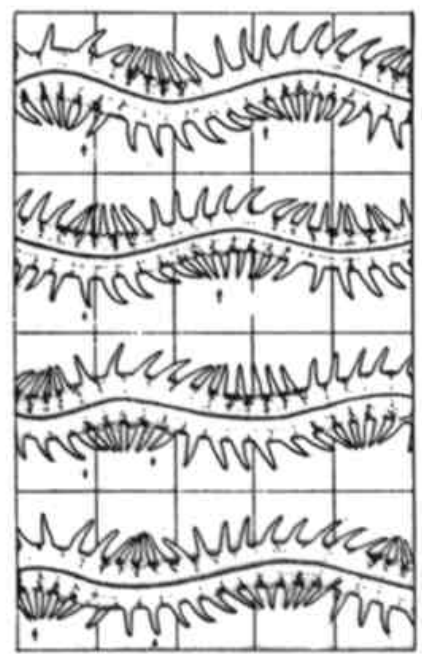
**Serpentine Body Motion & Parapodia**



# Why Burrow?

- Some advantages of burrowing into sediments (or boring into hard rocks):
  - Sediments contain organic detritus that can be utilized for food.
  - Burrowing  affords protection from some predators.
  - Burrowing allows a 3-dimensional use of the environment, opening up a much larger habitat volume for occupation.
  - Note: We will learn more about coelomates in upcoming laboratory exercises on the invertebrate phyla.

# The Cambrian Explosion

- The base of the Cambrian marks the first appearance of organisms with hard, mineralized skeletons.
- This singular event is marked by the so-called Cambrian explosion, nearly 100 million years after the appearance of Ediacaran fauna- the first animal fossils.
- The earliest skeletal fossils were small conical, tubular, or coiled shells resembling mollusks, along with unusual forms of uncertain origin that may have been scattered dermal plates that were originally embedded in the body wall (see text: 326-327).
- These small shelly fossil assemblages were replaced over a period of about ten million years or so by the major invertebrate phyla, which dominated the remainder of the Paleozoic.
- The Cambrian explosion of skeletal animals included all of the major invertebrate phyla (e.g. Arthropoda, Annelida and other vermiform phyla, Brachiopoda, Bryozoa, Mollusca, Echinodermata and Hemichordata).