PHYLUM: ECHINODERMATA, HEMICHORDATA, CHORDATA

SYMPLESIOMORPHIES

- Tripartite coelom
  - Body cavities in triploblastic animals formed in different ways
  - Traditionally, **coelom** formation was one character used to separate **protostome** and **deuterostome** lineages
  - **Tripartite coelom** forms by enterocoelic (Archenteric) pouching from wall of primitive gut (**archenteron**) which forms during **gastrulation**
    - pouches pinch off from get + detach →"mesodermal"→opening in center is coelomic cavity
  - 3 coelomic spaces: anterior **protocoel** (**prosome**), middle **mesocoel** (**mesosome**), posterior **metacoel** (**metasome**)
- Deuterostome development
  - During development: animal embryos go from single cell of fertilized egg to final **triploblastic** form through series of transformation
    - Changes: appearance of single tissue layer (**ectoderm**) in the **blastula** stage; formation of 2 epithelial layers of **ectoderm** and **endoderm** during **gastrulation**; addition of **mesoderm** between the 2 to complete the **triploblastic** condition
    - In **coelomate** animals body cavity forms in block of **mesoderm**
  - Traditionally: 2 variations of this development pattern define 2 great lineages of animals
    - In deuterostomes: showed **radial cleavage** of embryonic cells; **blastopore** became anal opening to digestive tract and tripartite **coelem** formed by enterocoelic pouching
  - 4th characteristic was: embryonic cells demo'ed regulative development (aka indeterminate cleavage)
    - The one characteristic that now seems to be diagnostic for the 2 groups is the fate of the **blastopore**: mouth (**protostome**) or anus (**deuterostome**)
- Dipleurula larva
  - Presence of dipleurula larva as an **ancestral characteristic** for **deuterostomes** = controversial
  - Seen as counterpart to **trochophore** larval stage of **protostomes**, the dipluerula was guessed to be either ancestral to all deuterostomes or only echinoderms
  - The **planktonic** dipleurula larva has ring of **cilia**, neotroch, which borders a ciliated oral field surrounding the mouth; food trapped in the neotroch is passed to cilia in oral field + toward mouth for ingestion

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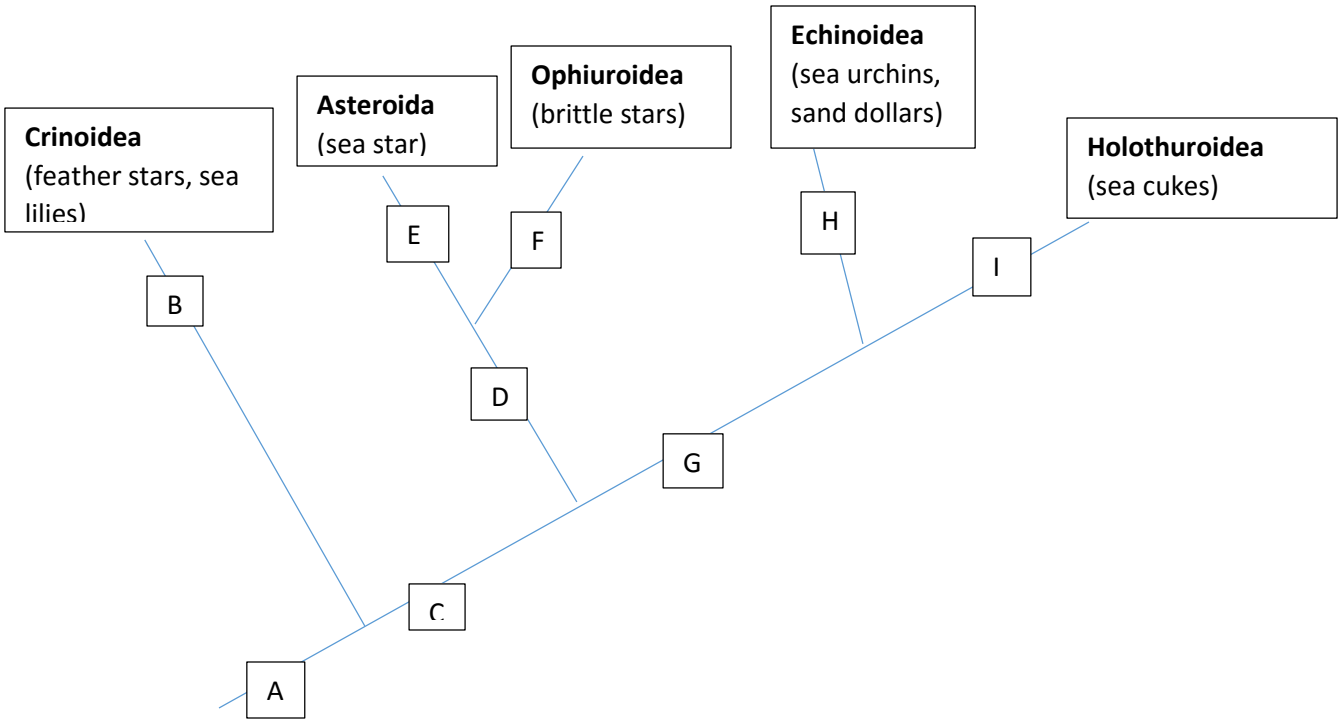
CLADOGRAM



A: water vasc system: secondary pentaradiate symmetry; calcareous skeleton of stereom spicules; mutable connective tissue

B: Arms with gonads inside + open ciliated grooves for feeding; loss of external madreporite

C: position of anus changes to side opposite mouth (now oriented down towards substrate); errant lifestyle with suckered tube feet (locomotion rather than feeding); madreporite between c and d ambulacra

D: Body plan includes five distinct arms creating a star-shaped body.

E: Five arms are broadly connected to the central disk of the body.

F: The arms, sharply delineated from the central disk, are articulated and vertebraelike plates permit their movements. The anus is lost, and the madreporite is on the oral surface.

G: Water vascular system; secondary pentaradiate symmetry; and a calcareous endoskeleton of stereom spicules; mutable connective tissue.

H: The skeletal plates are fused into either a spherical or disk shape.

I: The skeletal plates are reduced in size, and the madreporite is located internally. The body is elongated along the oral-aboral axis and the animals tend toward bilateral symmetry.

PHYLUM: ECHINODERMATA

AUTAPOMORPHIES

- Water vascular system
    - Tripartite coelom
    - Mesocoel used to form unique water vasc system
    - Tube feet extending from **ambulacral groove**
    - **Madreporite** found on aboral surface
- Pentaradiate symmetry
    - unique to echinoderms
    - larvae are bilaterally symmetric → metamorphosis → radially symmetrical adults
    - ancient echinoderms were suspension feeders → developed tube feet to catch foot → food moves along tube feet and ciliated groove (**ambulacral groove**) to mouth
- Calcareous endoskeleton of stereom spicules
    - Spicules of calcite microcrystals formed from calcium carbonate (sometimes magnesium carbonate)
    - Spicules arranged in 3D hollow array → **stereo**
    - **Sclerocytes** produce original spicules + continue to move throughout lattice structure of **stereom** → repairing/enlarging spicules as echinoderm grows
    - large structures (spines and plates) are many **ossicles** fused together with interconnecting ligaments:
- Mutable connective tissue
    - "catch connective tissue"
    - Can change mechanical properties from firm/stiff to flexible/soft in secs/mins
    - **Collagen** is part of connective tissue; associated with stiffeners and plasticizers
    - Under **nervous** control
    - Use is varied: in sea cukes it forms a close association with muscle of body wall
        - In brittle stars it is part of ligaments between vertebrae-like **ossicles** of arms (explains why arms break off so easily)
    - Collagen also imp in movement of sea urchin spines → walking across substrate

PHYLUM: ECHINODERMATA

- Sea stars, sand dollars, sea urchins, brittle stars, cucumbers, basket stars

- Usually found in shallow waters
    - Sea cucumbers and lilies found in abyssal depths of ocean
- ***Pentaradiate symmetry (5 arms & legs)***
    - Bilateral symmetric planktonic larval stage
- Ancient echinoderms: attached to bottom floor with mouths facing up
    - Tube feet on arms used mucus to collect food floating to ocean bottom/suspended in ocean currents
- ***Water vasc system formed from mesocoel of tripartite coelom*** = deuterostome
    - Extends throughout body: canals + tubes
    - Visible externally with opening (madreporite) + tube feet
        - **Tube feet** move by contractions of internal ampullae extending the outer podium + attaches to substrate; in some species tube feet hold on with suction
        - No tube feet in brittle stars; modified in cukes to work with **hydrostatic skeleton**
    - **Perivisceral cavity** formed from **metacoel** and fluids in it
    - Water vasc has similar composition to surrounding ocean water (presence of proteins + coelomocytes)
    - GAS EXCHANGE: occurs across surface of **dermal branchia** + **tube feet**
    - Both body cavities lined with **cilia** to circulate fluids within
    - EXCRETION: simple diffusion across **tube feet** + **dermal branchiae**
    - 3rd coelomic space forms hemal system (wtf is this? Biologists do not know)
- ENDOSKELETON: formed from porous, calcareous **ossicles** → fused into complex plates or separated and articulating with each other
    - Some have plates completely surrounding animal (i.e. sea urchin + sand dollar)
    - Others have reduced plates + embedded in muscular body wall (sea cukes)
    - **Collagenous** ligaments connecting developing **ossicles** can change from stiff to flexible (regulated by nervous system); this moves plates attached to it + results in movement of body/parts of it
- SURFACE: calcareous spines + cilia
    - **Cilia** sweep it free of debris
    - **Spines** and pincerlike **pedicellariae** stop larger things from settling on organism
        - Some use spines to move
- DIGESTIVE SYSTEM: complete; tubular; digestive **ceca** next to **gonads** to facilitate nutrient transfer for **gamete** formation
- NERVOUS SYSTEM: ring surrounding mouth + radial nerves extending down arms; NO BRAIN
- **Dioecious**
- Can detach arm to get away from predators and regrow it
- **Gonads** are permanent or seasonal; **gametes** released into surrounding sea water →external fertilization
- Different types of larvae for classes BUT ALL ARE CILIATED + development follows **deuterostome** pattern
    - **Pelagic** for a time, then settles to bottom + completes **metamorphosis** to adult

PHYLUM: ECHINODERMATA

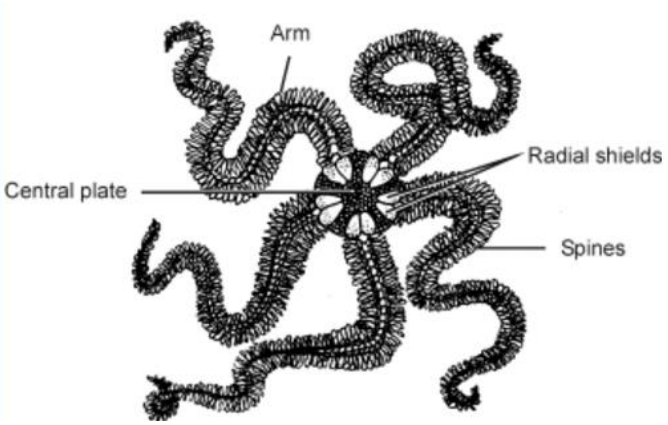
CLASS: CRINOIDEA

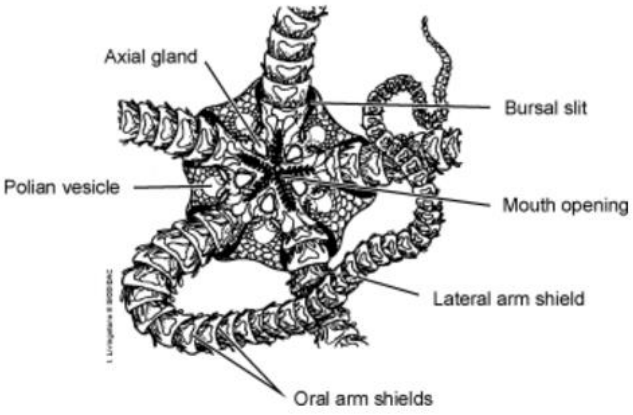
- Incl some of the most ancient echinoderms; most described species are fossils (600 myo)
- 650 species; all marine
- **Feather stars** live on coral reefs; **sea lilies** in deeper parts of oceans
- Sea lilies are perm stuck to substrate by long stalk (like ancestral echinoderms)
- Feather stars only perm stuck to substrate during larval stage; as adults use flexible **cirri** to anchor or crawl
- Sea lily stalk and feather star cirri are both made of calcareous plates connected by mutable **collagenous** tissue (can stiffen or soften; = movement controlled by nervous system) = **autapomorphy**
- Crinoid mouth is in center of membranous upper oral surface (**tegmen**) covering cup-shaped calyx of calcareous plates with organ systems inside
- Anus is on **tegmen** to one side at top of anal cone (to prevent contamination of ingested food)
- 5-100s of delicate arms; **pentaradiate** symmetry noticeable when looking @ base of branching arms where attaches to calyx
    - Each branching arm has 2 rows of small lateral branches (**pinnules**): increases SA for food capture
    - Triplets of **tube feet** on either side of open ciliated **ambulacral groove** of **pinnule** trap food in mucus + flick it to **ambulacral groove** where cilia propel down groove into pinnule, down arms, onto mouth
    - **Water vasc system** is different than other echinoderms: tube feet <u>do not</u> have **ampullae** → have open (vs closed) **ambulacral grooves**, water vasc system <u>does not</u> have **madreporite**
    - sea water enters system through stone canals that connect directly to surface
- internal organs include:
    - complete gut: makes loop around inside of calyx before ending in anus
- **perivisceral cavity** in calyx is continuous with canals running length of each arm; coelomic fluid circulates nutrients in body and out arms
- GAS EXCHANGE: diffusion across body wall and **tube feet**
    - Nitrogenous wastes may be removed by diffusion or **coelomocytes** that circulate in perivisceral fluid
- DIOECIOUS and can regenerate + sexually reproduce
- When attacked: mutable **collagenous** tissue liquefies + arms easily discarded + regrown later
- GONADS: no permanent gonads; form seasonally on walls of **perivisceral cavity** releasing **gametes**
- External fert. is followed by **indirect development** with **bilaterally symmetric**, larval stage that uses **cilia** to swim before settling to bottom to undergo **metamorphosis** into stalked crinoid adult

PHYLUM: ECHINODERMATA

CLASS: OPHIUROIDEA

- Brittle stars

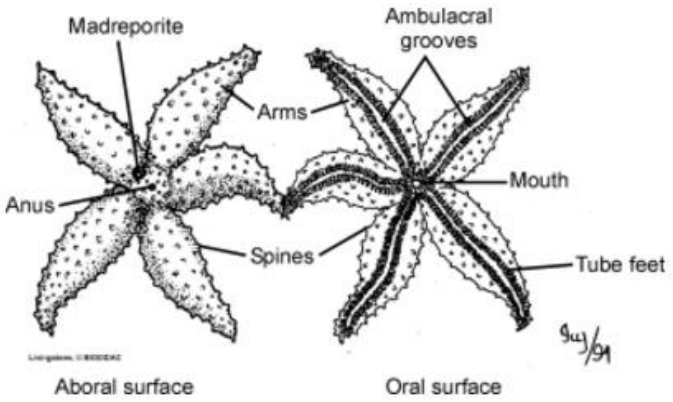




- Largest echinoderm class: 2k living species
- Found in all parts of ocean: shallow tidal areas to **abyssal** depths
- 2 types: brittle stars (central disk 1-3 cm diameter) and basket stars (12 cm diameter) with coiling tentacles
- NO DERMAL BRANCHIAE, PEDICELLARIA, OR ABULACRAL GROOVE
- Can sprint across ocean bottom using flexible arms
- Tube feet NOT used in locomotion (except in small juvies + some sm burrowing species)
- Each arm made of series of interlocking plates: create vertebral **ossicles**
    - Each **ossicle** articulates with adjacent ones by muscles in core of arm + mutable **collagenous** tissue to create serpent-like movement of arms
    - Spines along sides of arm provide traction + protect tube feet near lateral edges of arm
- Well-defined, flattened central disk
    - No openings in aboral surface
    - Aboral surface can be covered in calcareous plates, shields, spines
    - Oral surface: complex series of plates surrounds mouth + forms 5 oral shields + five jaws + teeth
    - **Madreporite** located on oral surface
    - Variety of feeding strategies: scavenging, substrate feeding, filter feeding
- **Tube feet** lack ampulla; play imp role in trapping food + use mucus to collect food then pass to mouth
    - Basket stars entangle prey with flexible arms + bring food to mouth (tube feet not involved)
- **COELOM** is much smaller than other echinoderms
    - Large stomach fills central disk
    - Only 1 opening: short esophagus + mouth; NO INTESTINE, NO ANUS
- GAS EXCHANGE + elimination of METABOLIC WASTES: simple diffusion @ imp site: 10 ciliated invaginations (**bursae**) + bursal slits on **oral surface** where arms meet central disk
- Surface of brittle star covered in 100s of sm light detecting lenses → flattened **compound eye**: may be able to see; nervous system more complex than thought?!?!?!
- **DIOECIOUS**; **gonads** form on coelomic side of **bursa**; **gametes** released into bursal cav + out to surrounding seawater; external fert but some species will brood fert'd eggs in **bursa**
    - early dvlpmt follows **deuterostome** pattern: ciliated freeswimmin larva→metamorphosis→adult

PHYLUM: ECHINODERMATA

CLASS: ASTEROIDEA



- Sea stars

- Arms inc in diameter as they fuse with central disk
- 1600 species in shallower coastal waters of oceans
- Size + # of arms varies; usu 12-24 cm diameter (up to 1m)
- Tube feet extend from **ambulacral groove** on oral surface + protected by moveable ambulacral spines
- Thick body wall: has calcareous **ossicles** forming skeletal mesh held by connective tissues
    - Circular + longitudinal muscles flex/bend arms
    - Outer surface covered with **ciliated epidermis** and studded with **spines** (formed by underlying dermal **ossicles**)
    - **Cilia** keep surface clear of debris; spines work with **pedicellaria** to stop lg things from settling on surface
    - **Dermal branchiae** on aboral surface = extensions of underlying **perivisceral coelom**; use simple diffusion for GAS EXCHANGE and elimination of METABOLIC WASTES
        - Perivisceral cavity is internally lined with **cilia** to circulate coelomic fluid → coelomic + water vasc sys fluid = main circulatory medium
        - Both fluids similar in comp to surrounding sea water; exchange between the 2 occurs across **ampullae** of **tube feet** that penetrate **perivisceral coelom**
- WATER VASC SYSTEM opens up to outside through **madreporite** on aboral surface
    - System of canals + tubes links tube feet to ambulacral groove
    - Each **tube foot** acts as **hydrostatic skeleton**: when **ampullae** contract, valve to lateral canal closes + fluid inside extends tube foot
        - Once tube foot hits substrate, muscles in tip lift the center to create suction (holds foot in place)
        - Longitudinal muscles in foot contract + bend foot to pull/push animal
        - Tube feet coordinated by radial nerves: run down each arm + connect to nerve ring surrounding mouth
        - Tube feet at tip may be modified as eyespots
- MOUTH → esophagus → stomach (cardiac on oral side + aboral pyloric) → ducts of pyloric connect to paired pyloric **ceca** suspended in **perivisceral cav** in each of 5 arms
- ANUS on aboral surface connects to pyloric stomach by short intestine
- Carnivores: snails, bivalves, worms, corals, sponges, other echinoderms
    - Swallow whole (pyloric stomach inverts to surround prey + pulled inside or digested externally)
- **DIOECIOUS**; paired **gonads** in each arm; **gametes** released into surrounding waters; external fert (some brood eggs)
- Development follows **deuterostome** pattern; planktonic larva → metamorphosis → adult
- Can regenerate lost/damaged arms

PHYLUM: ECHINODERMATA

CLASS: OPHIUROIDEA

- Sea urchins; sand dollars
- Sea urchins: **ambulacral zones** alternate around surface of circular test; aboral surface reduced to set of plates that surround anus
- Sand dollars: have become bilaterally symmetric; ambulacral zones on aboral surface; mouth and anus on what used to be oral surface
    - Body is not part of hydrostatic skeleton; no musculature for body wall
- **DIOECIOUS**; **gonads** suspended in body cav; **gametes** released through **gonopores** in each of 5 genital plates; external fert; development follows deuterostome pattern resulting in free-swimming larva that settles to substrate → metamorphosis → adult
- Reg urchins live on ocean floor inside solid **test** of 20 rows of calcareous plates aligned along oral axis of animal; plates covered by ciliated **epithelium**; 2 rows of plates in ambulacral region have small holes where **tube feet** exted
    - Each ambulacral zone consists of paired rows of plates
- SEA URCHINS: MOVEABLE SPINES covering body; "legs" that walk
- Spine + **pedicellaria** = many shapes + sizes; some venomous
- Sea urchins = grazers feeding on any organic materal; **aristotle's lantern**
    - Food: pharynx (inside lantern) → esophagus → long intestine that winds around inside of shell, folding back on itself → connects with anus on aboral surface
    - First ½ of intestine: incl siphon that removes water from ingested meal
    - Nutrients diffuse from gut to coleomic fluid
    - GAS EXCHANGE: diffusion across surface of **tube feet** and **peristomial gills**
    - METABOLIC WASTES: same as gas eschange
    - NERVOUS SYSTEM: ring surrounding pharynx + connected to radial nerves running down center of ambulacral zones
- Irreg urchins: adapted to burrowing; move using flattened spines that cover the **test**
    - Spines in front dig/loosen substrate; posterior spines push animal forward
    - Shell is perforated by **lunules**: stabilize urchin in fast water; involved with food collection using **tube feet** that project into **lanule** opening
    - **Tube feet** not restricted to ambulacral zones: found all over body of irreg urchins (function differs depending on location)
    - As sand dollar digs, large particles of sand can't fall between spines covering aboral surface (small particles able to pass are propelled by **cilia** to edges of sand $ or through **lanules** to oral surface/mouth
    - Mouth located in center or slightly forward of center; modified **Aristotle's lantern**
        - Pharynx inside lantern leads to winding intestine that connects to anus @ posterior edge
    - **Coelomic fluid** is main circ fluid; GAS EXCHANGE + METABOLIC WASTES elimination occur across flattened **tube feet** in petaloids (ambulacral zones)

PHYLUM: ECHINODERMATA

CLASS: HOLOTHUROIDEA

- Sea cukes
- Elongated along aboral axis + cylindrical body
- Lay on side with mouth facing forward
    - Side laid on always the same; **tube feet** in 3 **ventral ambulacral grooves** on that side are better developed than in 2 dorsal ambulacral grooves
- **Secondary bilateral symmetry!**
- Introvert consists of 10-30 tentacles surrounding central mouth; both introvert + tentacles are extended by hydrostatic pressure + retracted using muscles
- Body wall: thick; **ossicles** reduced to small plates embedded in wall; includes circ muscles that combine with 5 internal bands of longitude muscles + fluid-filled **perivisceral coelom** to form **hydrostatic skeleton** used in LOCOMOTION and BURROWING
- Mucus on tentacles collects food from substrate/suspended in water
    - Food → tentacle → placed in mouth → pharynx wipes food off + covers tentacle with new mucus
- Strengthening calcareous ring surrounding ring canal of **water vasc system** surrounds pharynx + is attachment site for longitude muscles
    - Some species: pharynx leads to shitty esophagus + stomach
- Long intestine is anchored to body wall by mesenteries + winds through coelomic cav leading to anus (located inside **cloaca** or **vent**)
- Body wall too thick for gas exchange
    - **Respiratory trees** open in **cloaca** and extend length of body with branches reaching throughout cavity, sucking water in/out
    - Also used for elimination of nitrogenous wastes by simple diffusion
- Sea cuke's **hemal system** = most developed of any of echinoderms
    - **Dorsal** + **ventral** vessels next to intestine connect to smaller vessels + extend into lumen of intestine + are presumably the site of nutrient uptake
    - Other parts of hemal system are connected to **resp trees** + may be involved in gas exchange
    - Fluid in hemal system similar in comp to fluid of large **perivisceral coelom**; the 2 fluids exchange material by simple diffusion across common surface
- Soft body of cuke = tastey meal for predator??? → NO → **evisceration** of toxic or sticky **cuvierian tubules** or parts of digestive tract/resp tree/gonads
    - When attacked/disturbed: internal organs are shot out of **cloaca**; cuke escapes due to distraction (predator either eating it or freakin out cause like, wtf)
- Regenerative powers + lost organs + tissues grow back
- **DIOECIOUS**; large perm **gonad** releases **gametes** to surrounding seawater where fert occurs
- Development follows **deuterostome** pattern: after swimming for awhile, ciliated larva settles → metamorphosis → adult