# The Story So Far

have now covered all major phyla but one

and most minor phyla

have moved from very **simple body plans** without true tissues or organs

to **complex body plans** with well developed digestive, respiratory, circulatory, nervous, endocrine, excretory and reproductive system

from **sessile** animals with **radial** symmetry to highly **motile** animals with **bilateral** symmetry and a distinct **head**

from **acoelomate** to **pseudocoelomate** to **eucoelomate** animals

the complex animals we have discussed so far were **protostomes**

ie. **mouth** develops first during embryonic stagess

all the remaining phyla are **deuterostomes**

ie. **anus** is first to develop

**echinoderms, arrow worms, acorn worms & chordates**

# Phylum: Echinodermata

means "prickly skin"

6225 living species; >20,000 fossil species

"If there are animals from another planet already here, they're probably starfish."

"Echinoderms are the Bohemians of the animal kingdom"
-Burnet & Matsen

include: starfish, sea cucumbers, basket stars, brittle stars, sea lilies, etc

has an extremely abundant and diverse fossil record

15 classes of extinct species

→ more extinct classes than any other animal group

much more diverse fossil record than species existing today

all marine; found in all oceans at all depths

some of the most abundant of all marine invertebrates

→ unable to osmoregulate; even rare in brackish waters

almost all are **bottom dwellers**

a few are pelagic swimmers

a few are commensal

in general they are not often prey to other species

mostly drab colors

but a few are red, orange, purple, blue, etc

**Distinctive Characteristics of Phylum:**

1. most with **pentamerous** (=pentaradial) **radial symmetry**
2. no distinct head or brain (no cephalization)
3. most have **endoskeleton** of calcium plates
4. unique **water vascular system** for feeding and movement
5. **dermal branchiae** for gas exchange
6. no real circulatory system
7. no excretory system
8. sense organs poorly developed
9. **pedicellariae** for protection

## Origin of Echinoderms

the origin of the phylum is obscure

earliest known echinoderm was *Arkarua* from Vendian (560 M Y ago)

echinoderms counter the direction of the story of evolution so far

→in fast paced world they live in the slow lane

echinoderms current body plan probably evolved from a bilateral ancestor which became sessile:

fossil record shows that attached forms were once plentiful

radial symmetry is an adaptation toward a sessile existence

eg. sponges, cnidaria

conditions seem to have favored survival of motile descendents

only major invertebrate phylum with affinities for vertebrates

→ deuterostome, bilateral, coelomate

## Body Form

most evident feature: **radial symmetry**

no distinct head

→**oral** vs **aboral** surface

radial symmetry is a secondary trait

→ larvae are bilateral then after metamorphosis they become radial

in most its **pentamerous radial symmetry**

## Body Wall

### epidermis

outer surface covered by **epidermis**

made up of: epithelial cells
ciliated mucous cells
ciliated sensory cells

nerve plexus in basal part of epidermis

### dermis

below epidermis is thick dermis

made of connective tissues

lots of collagen fibers

secretes skeletal pieces = **ossicles**

= **endoskeleton**

**ossicles** are bony plates made of **calcium crystals**

each ossicle represents a single crystal of magnesium rich calcite ($6(Ca,Mg)C0_3$)

formed within cells of dermis

in many classes ossicles have bony projections for defense

unlike any other phylum, echinoderms can vary rigidity of dermis

pliability of collagen fibers is under nervous control

= "catch collagen"

soft and pliable → rigid

→allows animal to hold various postures for long periods without muscular effort

beneath dermis is layer of outer **circular** and inner **longitudinal muscle**

true **coelom** lined with **peritoneum**

## Movement

movement & food gathering done predominantly by **water vascular system**

a second, separate coelomic compartment unique to echinoderms

derived from coelom and lined with ciliated epithelium

the whole system operates hydraulically

filled with fluid (mainly sea water and some proteins and cells

internal canals connect ot the outside through the **madreporite**

leads to **stone canal** (contains calcareous deposits)

joins **ring canal** just inside and around the mouth

long **radial canals** extend into each arm

in arm, **lateral canals** branch off radial canals

have valves to prevent backflow

lead to small muscular sacs that serve as fluid

reservoirs

= **ampullae**

connected to muscular **tube feet**

tube feet are concentrated in **ambulacral groove**

the tip of the tube feet are flattened, forming **suckers**

suctionlike cups can produce strong force

**tube feet** used to cling to substrates, move and to feed

most echinoderms don't have large muscles

muscles mainly used to move **tube feet**

but some also attached to ossicles to allow them to bend and flex

water vascular system also compensates for the absence of a blood circulatory system

## Feeding & Digestion

echinoderms are particle feeders, scavengers or

predators

no parasitic species

simple, usually complete digestive tract

but functional anus is often reduced

**stomach** has 2 chambers: **cardiac** & **pyloric**

digestive enzymes are secreted into stomach by **pyloric caecae**

## Respiration

tiny saclike projections extend through epidermis

= **dermal branchae** (or papulae)

→ exchange respiratory gasses

→ get rid of ammonia (N-wastes)

the same functions are also shared by **tube feet** in most groups

## Circulation

echinoderms rely mainly on **coelomic circulation** for transport of gasses and nutrients

ciliated lining circulates fluids around body cavity and into dermal branchiae

coelomic fluid contains amoeboid cells

they do have a blood vascular system (= **hemal system** )with heart but its usually rudimentary is rudimentary

and its function unclear

→ may play some role in distributing nutrients

## Nervous System

no brain or centralized processing area

**circumoral ring** and **radial nerves** branching from it

helps coordinate movement of arms and movement of the starfish in general

tube feet are innervated by nervous sysem

→ enables all feet to move in single direction

if circumoral ring is cut, podia in all arms become uncoordinated; no movement is possible

few specialized sense organs

have some simple **tactile**, **chemical** and **photoreceptors** and **statocysts**

## Protection

in many starfish the body surface bears small jaw-like **pedicellariae**

some are stalked, some sessile (unstalked)

→ protect against animals and debris that settle on the animals surface

## Excretion

removal of nitrogen wastes (mainly ammonia) is through the **body surface**, **dermal branchiae** and **tube feet**

some amoeboid cells can also engulf nitrogen wastes and move them to the outside through the dermal branchiae or tube feet

## Reproduction & Development

sexes typically separate → dioecious

external fertilization

produce characteristic ciliated, free-swimming, planktonic larva

= **bipinnaria**

bilateral symmetry

undergoes metamorphosis to become radially symmetrical adult

early developmental stages are similar in all classes

some can also reproduce **asexually** by **fragmentation**

many also have excellent powers of **regeneration**

→ can regenerate from 1/5$^{th}$ of oral disc & a single arm

but may require up to a year

some deliberately cast of an arm as a means of asexual reproduction

don't seem to age → can liver forever?

## Ecology

a wide variety of other animals make their homes in or on echinoderms, including:

algae, protozoa, ctenophores, turbellaria, barnacles, copepods, decapods, snails, clams, polychaetes, fish and other echinoderms

## Echinoderm Classification

### Class: Asteroidea

(starfish, sea stars, sea daisies),
1500 living species

### Class: Ophiuroidea

(brittle stars, basket stars, serpent stars)
>2,000 living species;

### Class: Echinoidea

(sea urchins, heart urchins, sand dollars & sea biscuits)
950 living species

### Class: Holothuroidea

(Sea Cucumbers)
1150 living species

### Class: Crinoidea

(sea lilies, feather stars)
625 living species

# Class Asteroidea
## (sea stars, starfish)

~1500 species

free moving

inhabit all seas except low salinity areas

bottom dwellers

- mostly found on hard rocky surfaces

many live in deep ocean

- also common along littoral zone in coastal waters
  - where they may congregate in very large numbers

1 cm to 1 M diameter

- eg. giant *Pycnopodia* has over 20 arms and is the size of a manhole cover

often brightly colored: red, orange, blue, purple, green etc

best representatives of the basic features of the phylum

body composed of rays (arms) projecting from a central disc

arms not sharply set off from central disc

in some arms are very short

eg. *Culcita* → a pentagon with no arms

mouth and 100's of tube feet underneath

typically pentamerous symmetry

most with 5 arms

sunstar up to 40 arms

some have up to 50 arms

## Oral Surface

**mouth** in center of oral surface

wide furrows project from mouth into each arm = **ambulacral grooves**

each groove contains 2-4 rows of **podia** (=**tube feet**)

margins of each groove are guarded by moveable **spines**

tip of each arm has 1 or more tentacle-like sensory tube feet and a red pigment spot (=eye spot)

## Aboral Surface

inconspicuous **anus** in center of disc

large sievelike **madreporite** toward one side

aboral surface bears numerous **pedicellariae**

keeps integument free of sponges, corals

also used in feeding and defense

## Movement

mainly by tube feet

can adhere to any solid surface by the **suction** created and slowly creep along

~few cm/minute

## Feeding and Digestion

many sea stars are **scavengers**

a few are **suspension feeders**

feed on small plankton and organic debris

mucous strands carry food to the mouth

most asteroids are **carnivores**

feed on molluscs, crustaceans, polychaetes and other echinoderms

use **chemoreceoptors** to detect and locate prey

some can locate buried prey and dig down to get them

eg. some swallow prey whole and regurgitate undigested ossicles & spines, etc

eg. some attack larger seastars and begin eating the end of an arm and work their way up

eg. many are able to evert their stomachs through the mouth to engulf and eat prey

eg. some feed exclusively on bivalves

→ some, such as asterias, are notorious predators of oysters

wraps itself around its prey

exert steady pull on valves

[force of 12.75 newtons (equivalent to human lifting 1000lbs wit 1 hand)]

~ a half hour the adductor muscles of bivalve fatigue and relax slightly

only need 0.1mm gap to insert stomach and digest oyster

takes 2.5 - 8 hrs to digest a bivalve

digestive system is arranged radially

**mouth** at the center of the disc

leads to short **esophagus**

opens to large **stomach** that fills most of the inside of the oral disc

stomach divided into large **cardiac region** and small, aboral **pyloric region**

**pyloric ceca** (digestive glands) , 2 per arm, drain into pyloric region

products of digestion in stomach are carried to pyloric caecae to complete digestion and absorption

short tubular **intestine** opens through the **anus** on aboral side

## Respiration

**dermal branchiae** (papulae) extend through ossicles to surface of the skin

these plus **tube feet** provide most of the gas exchange for sea stars

in burrowing species, dermal branchiae are protected

in channels below umbrella-like spines

## Reproduction & Development

### Asexual reproduction

many starfish regularly reproduce asexually

→ central disc divides in half and animal breaks into two parts;

each regrows missing part

starfish can also **regenerate** from an arm

or others an arm and a small piece of the central disc

### Sexual Reproduction

most are dioecious

gonads in small area at base of each arm

when filled with eggs sor sperm they almost completely fill arm

some lay egg masses

others brood eggs

a few are **viviparous**

but most produce free swimming larvae

gametes released through pores near base of each arm

1 breeding season per year

1 female may shed 2.5 M eggs

larvae are planktonic, free swimming **bipinnaria** larva

metamorphosis converts bilateral larva to radial juvenile

## Examples of Sea Stars:

## eg. sea Daisies

2 known species

discovered in 1986

→ inside a piece of wood collected a half mile below surface

at first given their own CLASS; genetic analysis shows them to be asteroids

disc shaped animals with fringe of short spines

most are <1cm in diameter

contain tube feet around the periphery of the disc

lack arms, mouth, gut and anus

ventral surface may actually be the lining of the stomach which digests food externally

→covered by membranous **velum** which absorbs nutrients

# Class: Ophiuroidea
## (brittle stars, basket stars, serpent stars)

~2000 sp

not as diverse in structure as asteroids

but probably the most advanced class of echinoderms

also, the most active of the phylum

found in all types of **marine benthic habitats**

mainly **benthic**

tend to be secretive

in cracks and crevices on hard substrates

some can burrow

a few can swim

up to 12 cm diameter

most are fairly drab, a few are highly colored

leathery skin and few cilia

have **arms** with **central disc** but:

long thin arms sharply set off from disc

no ambulacral groove

→ tube feet (podia) play little role in locomotion

visceral organs are confined to central disc

typically 5 arms

but in basket stars they repeatedly branch to produce tentacle like mass

## Movement

**water vascular system:**

madreporite opens on oral surface

tube feet have no ampullae

tube feet mainly used in feeding;

not used much for locomotion

**muscles** are much more important in this group

locomotion by snake-like arm movements

**ossicles** of arms are arranged into flexible columns

(called “vertebrae”) connected by muscle strands

can rapidly clamor over ricks and seaweed

no arm preferences

→ can move easily in any direction

## Feeding & Digestion

brittle stars are **carnivores**, **scavengers**, **deposit feeders** or **filter feeders**

deposit and suspension feeders collect small organic particles from the water or sediment and use mucous strands to send food toward mouth

basket star extends it arms into the water to catch plankton

some carnivores use their arms to capture prey and “hand” it to mouth

others”ambush” their prey

use arms to hold central disc off grand to form a kind of shelter

when fish takes an interest in the area under the starfish it quickly wraps its arms around it

mouth on oral side has 5 jawlike plates

digestive system does not extend into arms

digestive system has sack like stomach,

no intestine or anus

→ ie. incomplete digestive tract

## **Respiration**

no dermal branchiae

brittle stars also have internal sacs called **bursae**

5 pairs of invaginations open toward oral surface at genital slits

**bursae** are connected to outside by slits on margins of each arm

water circulates in and out of the bursae for gas exchange

many species can actively pump water in and out of bursae

can also use tube feet for respiration

## Circulation

hemal system is reduced as in starfish

## Nervous System

same as asteroids

## Excretion

bursae may also be main excretory organ

## Reproduction & Regeneration

### sexual reproduction

mostly dioecious, a few species are monoecious

gametes discharged into bursae then through thegenital slits to the outside

some brood their young in the bursae

most species produce a free swimming larva = ophiopleuteus

it metamorphoses into the juvenile

### asexual reproduction & autotomy

brittle stars can spontaneously cast off arms

the cast of pieces can regenerate into whole brittle stars

# Class Echinoidea
## (sea urchins, heart urchins, sand dollars & sea biscuits)

~950 sp.

widely distributed in all seas

all are **benthic**

remain close to the substrate

typical urchins seem to prefer hard substrates

some, eg sand dollars and heart urchins like to burrow in softer sandy substrates

compact body enclosed within a test (or shell) of closely fitting ossicles or plates

plates are sutured firmly together

most are more or less hemispherical in shape

no arms, but 5 **ambulacral areas** on test through which **very long tube feet** extend

many have developed a secondary bilateral symmetry

with numerous long moveable spines

most 6-12 cm dia; a few to 36 cm

many colors: brown, black, purple, green, white, red

## Body Form

**oral side:**

mouth contains a comlex chewing mechanism of 5 converging teeth attached to muscle bands

**= Aristotle's lantern**

used to scrape and chew algae from rocks

around mouth are circle of heavy modified **tube feet**

also a ring of **gills**

**aboral side:**

**anal region**

**genital opening**

**madreporite**

## Movement

use very long tube feet and prehensile spines

in most urchins, **moveable spines** cover most of the

body

have **ball & socket joints** with tubercles on test

## Feeding & Digestion

most sea urchins are **grazers**

scrape algae from substrates with teeth

a few boring sea urchins feed on encrusting algae on walls of their burrows

## Respiration

mainly by tube feet

in sand dollars the respiratory podia are arranged in flower petal pattern on aboral surface

some have modified tube feet that form branched gills

**Hemal System** and **Nervous System** are similar to basic plan

## Protection

**spines:**

collagen fibers can make spines stiff and erect for protection

in some urchins spines are hollow and can inject a painful poison

**pedicellaria:**

all echinoids have **pedicellariae**

some types contain poison glands

pedicellaria are also used to keep surface clean

# Class: Holothuroidea
## (Sea Cucumbers)

~ 1150 sp

rule the deep ocean benthos

→ make up 90% of biomass on deep ocean floor

often on sandy or muddy bottoms

some crawl on sea floor

others hide beneath rocks

some are burrowers

range from 3 cm to 1 M long

most are black, brown, or olive green

sea cucumbers are among the strangest of the echinoderms:

like sea urchins have no arms

have ambulacral areas instead

tend toward **bilateral symmetry**:

polar axis is elongarted so some become

long and wormlike or

"cucumber shaped"

"U-shaped"

with mouth and anus are on opposite ends

bottom side = "sole" on which they crawl

body has a leathery appearance

in most the ossicles are greatly reduced to microscopic plates embedded in body wall

a few are covered in armor of calcareous plates

mouth is always surrounded by 10-30 **tentacles** (modified tube feet) which are part of the water vascular system

tentacles are highly retractile

→ can be completely retracted into mouth

tube feet can also be modified into sensory papillae, fins, sails, etc

## **Body Wall**

nonciliated **epidermis** with thick **dermis** below

microscopic **ossicles** embedded in dermis

beneath dermis is layer of **circular** then **longitudinal muscle**

## Movement

large fluid filled coelomic cavity serves as a **hydrostatic skeleton**

relatively sluggish

lie on bottom or burrow into mud

many hard bodied forms live beneath stones or in coral crevices

there are a few deep water pelagic (swimming) forms

move by wavelike contractions of body wall

have tube feet modified into fins, sails, or medusa-like bells

## Feeding & Digestion

mainly **deposit feeders** and **suspension feeders**

use **tentacles** to collect food and deliver it to **mouth**

mouth opens into a muscular **pharynx**

then to **esophagus** and **stomach**

some holothurians lack stomach

most have a long, looping **intestine**

leads to **anus** which opens into **cloaca**

**cloaca** = chamber in which digestive system, excretory system (if present) and reproductive system all open into

## Respiration

most have a **respiratory tree** consisting of two highly branched tubes

its attached to the cloaca

pumping action of cloaca circulates water through it

a tropical pearlfish makes its home in the respiratory tree of some sea cucumbers

leaves at night to search for food

## Circulation

water vascular system is similar to other classes

but **madreporite** is not on the surface of the body but in the coelom

→its filled with coelomic fluid rather than sea water

coelom is connected to sea water via ducts in the wall of the cloaca

holothuroideans have the best developed **hemal system** of all echinoderms

lack beating heart

**peristalsis** of dorsal vessel circulates blood

blood is like coelomic fluid

involved in some transport of gasses and nutrients

## Nervous System

as in other classes

## Excretion

respiratory tree also serves as main excretory organ

## Protection

many sea cucumber are capable of **evisceration**

the front or back end ruptures and the internal organs are expelled

seems to be a seasonal phenomenon

possibly when food is scarce or in order to eliminate wastes stored inside the internaltissue

the organs are later regenerated

may be a protective mechanism

a few sea cucumbers posess a large mass of white, pink, or red tubules (= **tubules of Cuvier**) attached to the base of their respiratory tree

when irritated or attacked, the anus is directed toward the intruder and the tubules are shot out of the anus

in some the tubules are sticky

in others they release a toxin

small crabs and lobsters may be rendered completely harmless and helpless

the sea cucumber later regenerates the tubules for the next attack

## **Reproduction**

most are dioecious; a few are hermaphrodites

with single gonad

only group of echinoderms with single gonads

some brood their young inside coelom

most have external fertilization

free swimming larva = **auricularia**

# Class: Crinoidea
## (sea lilies, feather stars)

~625 species

an ancient group; many fossil species

some are stalked sessile animals

others are free living and motile

→ can swim or crawl short distances

many are deep water forms

most live at depths of 100 M or more

but a few are found in the intertidal zone

**Body Form**

flower shaped body

sometimes attached to the end of a stalk

body disc, = **calyx**, is covered in leathery skin covering calcareous ossicles

upper surface of calyx bears mouth and anus

arms have pinules giving feather-like appearance

stalk if present, sometimes has **cirri**

no madreporite, spines or pedicellariae

the water vascular system uses coelomic fluid

→no madreporite to take in seawater directly

## Feeding and Digestion

crinoids are suspension feeders

very slow metabolism
→can live for 1000's of years

## Reproduction

dioecious

either brood eggs or release them to produce **doliolaria larva**

# Ecology

sea stars are often the top predators in some benthic communities

though unpalatable to most organisms to some they are the preferred meal:

eg. some fish with strong teeth

eg. sea otters

# Economic/Human Impacts

1. echinoderms never attack humans

don't transmit any diseases

although handling poisonous forms can kill

2. "crown of thorns" starfish destroys Pacific coral reefs

feed on coral polyps

sometimes attack in "herds"

the number of reef attacks is increasing

sometimes results in extensive damage

very expensive to control outbreaks

3. sea urchins destroy kelp forest

but are preyed on by sea otters

4. predatory starfish can devastate commercial clam or oyster beds

eg. a single starfish can eat a dozen clams or oysters in a day

sometimes an infestation is treated with quicklime

→ destroys dermal branchiae and kills animal

→ but also kills many other soft bodied invertebrates;

but not the oysters who temporarily close their shells

5. as food:

eg. in China and Pacific Islands sea cucumbers are boiled and dried and eaten as a delicacy or used as a food flavoring

in some areas collecting has severely depleated their populations

eg. roe (gonads & eggs) are sold, raw or roasted, as a delicacy in Japan and in sushi restaurants

>30M pounds of urchins were harvested in 1986

6. echinoderms have been widely used in developmental research

"we know more about the embryology of echinoderms than probably any other embryo"