METAZOA

ZOO-1011
Unit 3

Krishna Das
Assistant Professor
Department of Zoology
Mangaldai College

Learning Objectives

1. Introduction to Metazoa
2. Characteristics of Metazoa
3. Symmetry in Metazoa
4. Evolution in the symmetry in Metazoa
5. Significance of the symmetry in Metazoa

Introduction

- In the two kingdom classification, the unicellular 'animals' used to be clubbed together under a single phylum Protozoa that constituted sub-kingdom - Protozoa. The rest of the animals, all **multicellular**, were grouped under the sub-kingdom **Metazoa** under various phyla (the corresponding grouping for plants was Protophyta and Metaphyta).
- However, under the present concept of Five Kingdom Classification, this grouping has no relevance. Still, we often continue to use the term Metazoa to refer to the Animalia of the five kingdom classification.
- Although all metazoans share some characteristic features, their body plans differ in symmetry, internal organization, developmental patterns and modes of formation of body cavity. These differences provide us a means of grouping them or organizing them into different phyla.

Characteristics of Metazoa

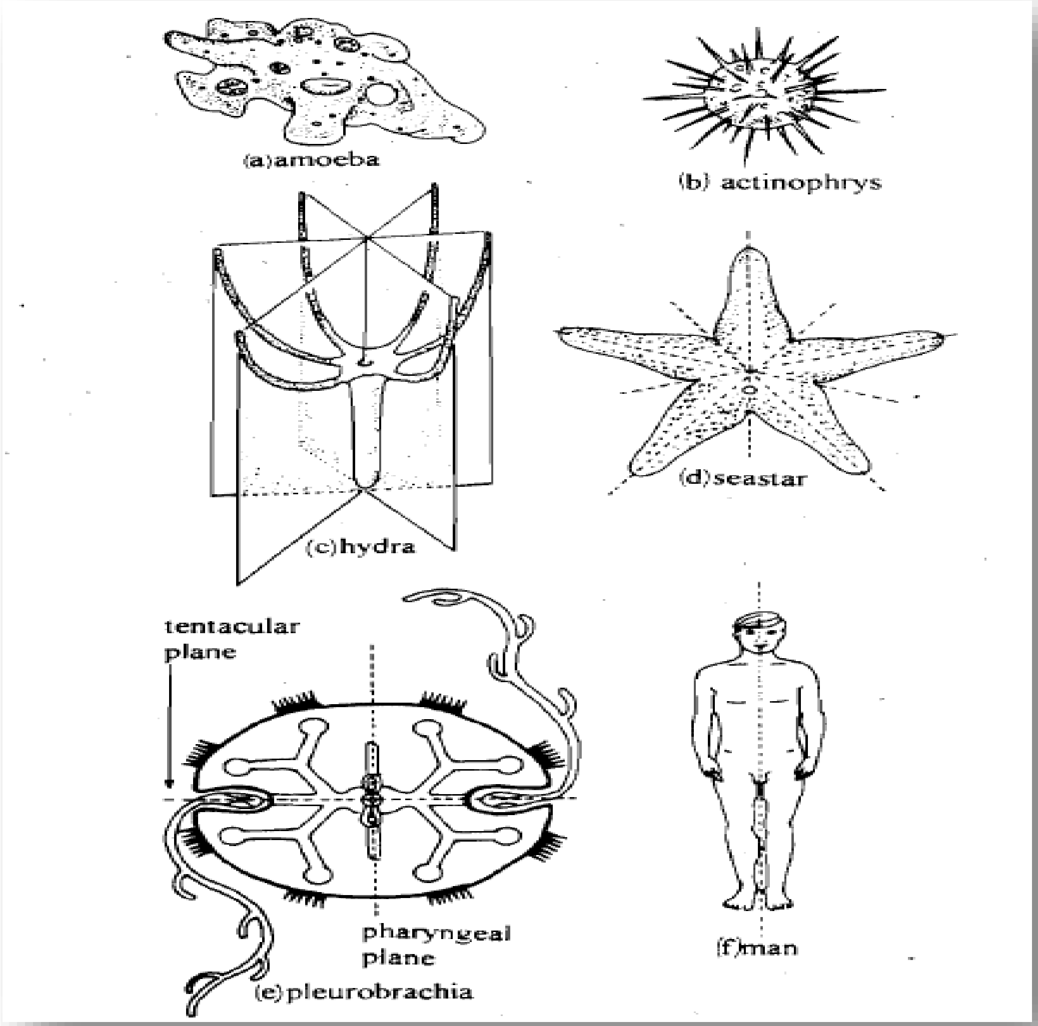
1. Members of Metazoa possess a **complex multicellular structural organization** which may include the **presence of tissues, organs and organ systems.**

2. In the life history of metazoans, typically a fertilized egg passes through a blastula stage in the course of its early embryonic development before changing into an adult.

3. Since metazoans are multicellular they are **relatively larger** in size than unicellular protozoans. Naturally, their nutritional requirements are more and they have to search for food. Consequently, **locomotion in metazoans is highly developed** and for this purpose they have evolved contractile muscular elements and nervous structures.

4. The ability for locomotion has influenced the shape of the metazoan animals which in turn has **conferred specific types of symmetries to metazoan groups.**

5. Most of the metazoans show differentiation of the **anterior end or head (cephalization);** associated with cephalization, there is the centralization of the **nervous system** in the head region.



Different types of body symmetries a) asymmetrical b) spherically symmetrical,
(c-d) radially symmetrical. (e) biradially symmetrical (f) bilaterally symmetrical

Symmetry in Animals:

All living organisms have some body shape and form. The general body plan of animals may be organized in one of several ways.
Arrangement of parts or organs on either side of an imaginary dividing line or around a common axis or radially around a point so that opposite parts are mirror images of one another is called symmetry.
There are two broad divisions of symmetry,
(i) primary, or embryonic
(ii) secondary, or adult. .
The latter may or may not be the same as the primary one.
For example, **the larva of starfish is bilaterally symmetry but the adult starfish is radially symmetrical**. The primary symmetry is bilateral and secondary symmetry is radial.
With regard to symmetry animals can be basically of five types (i) asymmetrical (ii) spherical (iii) bilateral (iv) radial and (v) biradial,

SYMMETRY IN METAZOAN

- Nature offers innumerable instances of symmetry, and because "*symmetry is a theme that spans the human life world, technology, culture and nature*", the symmetry properties of organisms are particularly captivating for naturalists.
- The **German biologist E. Haeckel** considered symmetry as one of the most fundamental properties of organism form, and as a primordial criterion for ranging the **diversity of living beings into a hierarchy**.
- In common usage, symmetry denotes the balanced distribution of equivalent or corresponding entities.
- **Symmetry of biological structures can be defined as the repetition of parts in different positions and orientations to each other.**
- Three major fundamental types of symmetry are classically recognised among adult metazoans **(asymmetrical, radial, bilateral),** to which adds the more anecdotical **spherical** symmetry.
- The symmetry of an animal body is one of the basic features characterizing the body plan in different metazoan clades.

Asymmetrical metazoans

- Some creatures are asymmetrical : no matter which way we try to divide them through the middle, no two halves would appear alike.
- In simpler words : **these are animals which cannot be cut into two identical halves through any plane or axis (longitudinal, sagittal or transverse). Organisms that lack any point, axis or plane of symmetry are said asymmetrical.**
- Examples include the **majority of the sponges belonging to the class Demospongiae and the simple amoeboid *Trichoplax* (“phylum Placozoa”).** Amoeba and most of the poriferens are examples.

Asymmetrical metazoans

188 *M. Manuel / C. R. Biologies 332 (2009) 184–209*

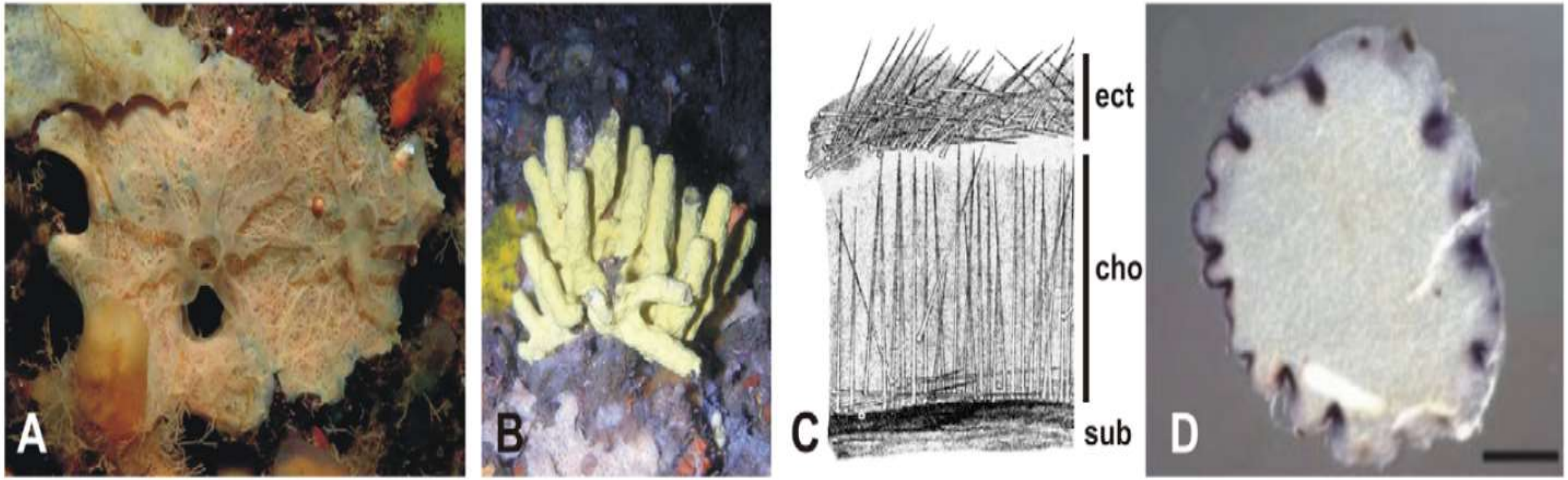


Fig. 2. Examples of asymmetrical metazoans. **A**: *Hexadella racovitzai* (Demospongiae). **B**: *Aplysina cavernicola* (Demospongiae). **C**: vertical section in the body of the encrusting sponge *Protosuberites prototipus* (Demospongiae) showing clear baso-apical differentiation of the skeleton architecture (cho: choanosomal skeleton; ect: ectosomal skeleton; sub: substrate). **D**: *Trichoplax adhaerens* (Placozoa) (the blue staining reveals *Not* expression) (A and B: pictures taken during the Porifera Training Course in Marseille, July 2005, respectively by Bernard Picton and Thierry Perez; C: adapted from [181]; D: from [126]).

Spherical symmetry

Fig. 3. Example of a spherically symmetrical sponge, *Tethya aurantium* (Demospongiae). On the right, intact sponge (alcohol preserved); on the left, the sponges has been partially dissected to show the skeleton tracts (made of spongin and siliceous spicules) radiating from the centre. Note in addition that the sponge body is covered by a cortex containing a special skeleton (scale bar: 1 cm).

Spherically (or centrally) symmetrical organisms have **one point of symmetry and an infinite or multiple number of axes and planes of symmetry.**

The animals with spherical symmetry can be divided into identical halves along a number of planes which pass through the centre or in other words every plane through the centre will yield two halves which arc mirror images of each other.

Whereas spherical symmetry is rather common among unicellular eukaryotes (and a few multicellular ones, e.g. the green alga *Volvox***),** it is almost inexistant among adult metazoans, apart from exceptional instances of centrally radiating skeleton architecture **in demosponges (e.g. genus *Tethya*,**

Cylindrical symmetry

- **In cylindrical (= axial) symmetry, there is a single symmetry axis, invariance in all rotations that contain this axis, and an infinite number of planes of reflection symmetry (all planes that contain the axis of symmetry).**
- Cylindrical symmetry is rare among adult metazoans, the only clear instances being **calcisponges** with an asconoid aquiferous system (Fig. 4A) and the body column of **cnidarian polyps in the classes Hydrozoa** (Fig. 4B) and Cubozoa.

Cylindrically symmetrical metazoans

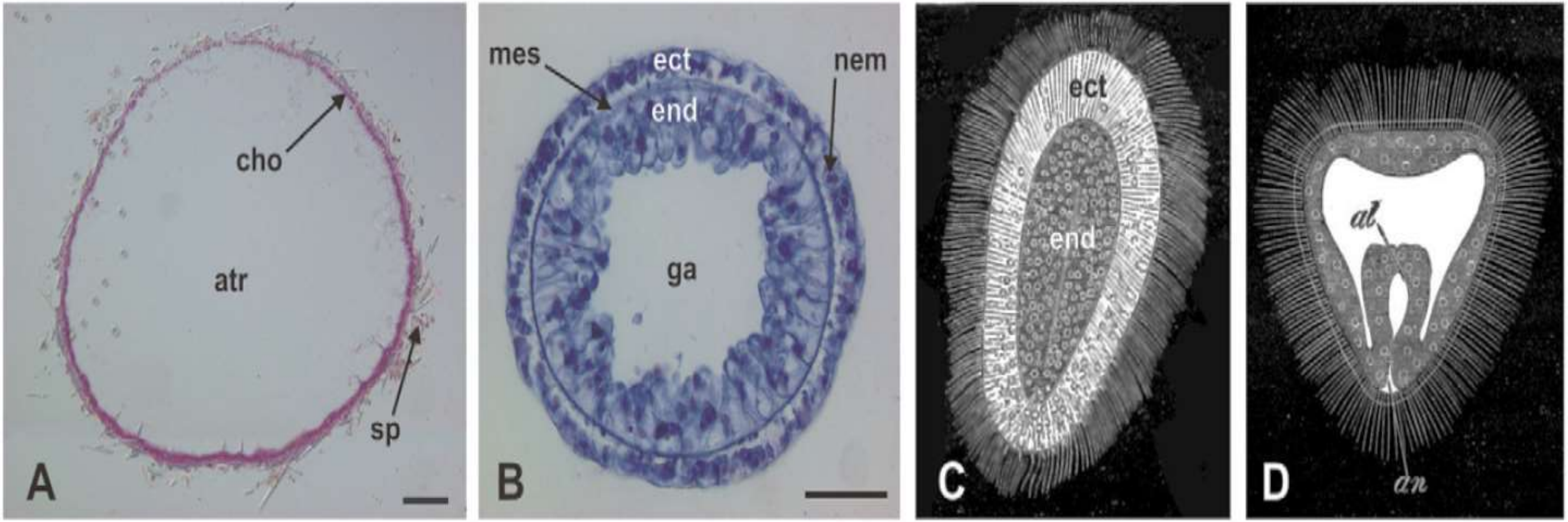


Fig. 4. Examples of cylindrically symmetrical metazoans. **A**: transverse section in *Leucosolenia variabilis* (Calcispongia), an asconoid calcareous sponge (atr: atrial cavity; cho: choanoderm; sp: spicules). The thin external epithelium or pinacoderm is not visible (scale bar: 100 µm). **B**: transverse section in the body column of *Hydra* (Hydrozoa, Cnidaria) (ect: ectoderm; end: endoderm; ga: gastral cavity; mes: mesoglea; nem: nematocysts) (scale bar: 50 µm). **C**: longitudinal section in the planula larva of *Chrysaora* (Scyphozoa, Cnidaria) (ect: ectoderm; end: endoderm). **D**: longitudinal section in the early gastrula of *Serpula* (Annelida, Bilateria) (al: archenteron; an: anus) (A and B: original pictures; C and D: from [10]).

Radial symmetry

- **Radial symmetry is the symmetry in which the parts are so arranged around a central axis or shaft, like the spokes of a wheel, that any vertical cut through the axis would divide the whole animal into two identical halves.**
- *n*-radial symmetry corresponds to the repetition (*n* times) around an axis of the same set of anatomical structures (called an antimere), which in mathematical terms corresponds to invariance in *n* rotations. There is a single axis of symmetry and a discrete (*n*) number of planes of symmetry.
- The *n* value is usually indicated by a prefix. For example, **tetraradially symmetrical bodies (e.g. most cnidarian medusae)** admit four symmetry planes and are invariant in four rotations. The starfish and their relatives have a modified form of radial symmetry. They can be divided along 5 planes, each giving two distinct halves. This is known as **pentamerous** symmetry.
- Radially symmetrical animals include many **hexactinellid sponges** (Fig. 5A), **calcisponges** with a syconoid aquiferous system (Fig. 5B), **homoscleromorph sponges** (Fig. 5C and D), **ctenophores** (Fig. 5E), **most cnidarians** (Fig. 5F), and, among the **Bilateria, adult echinoderms.**

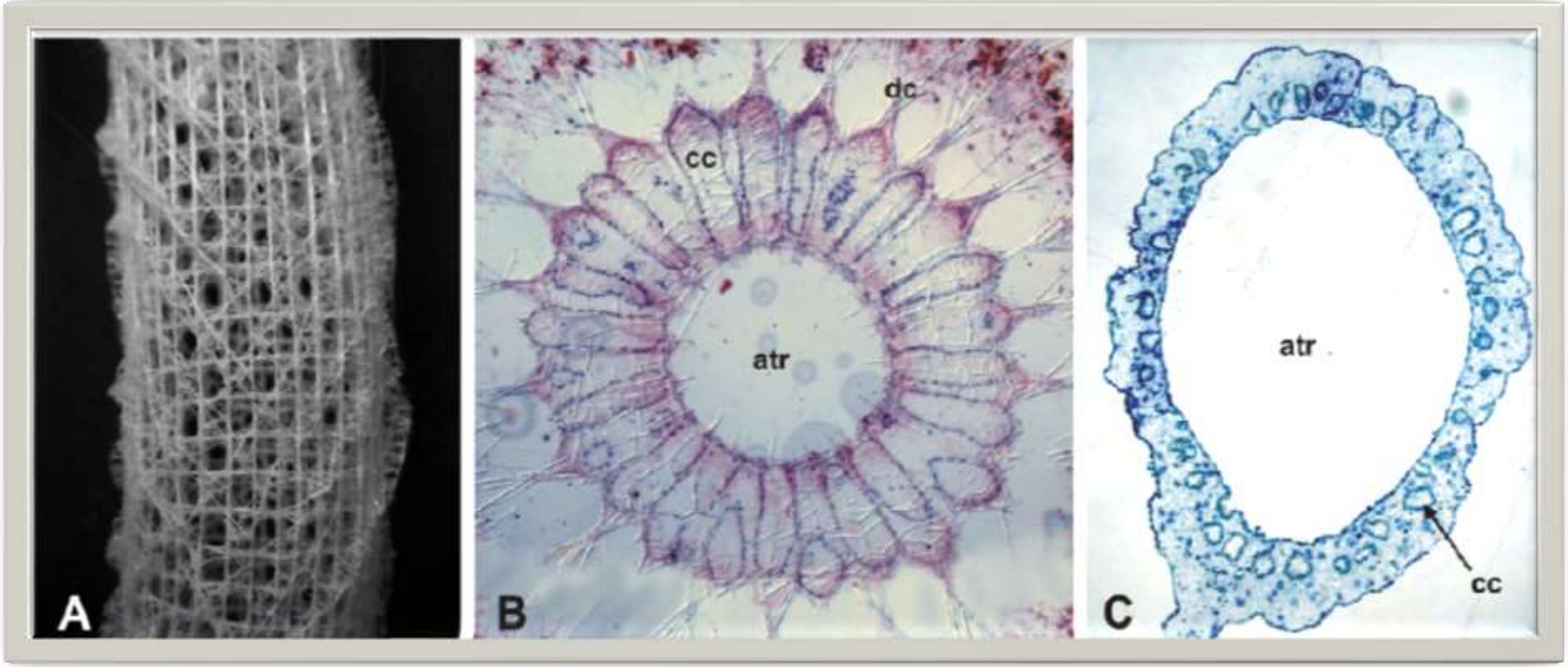
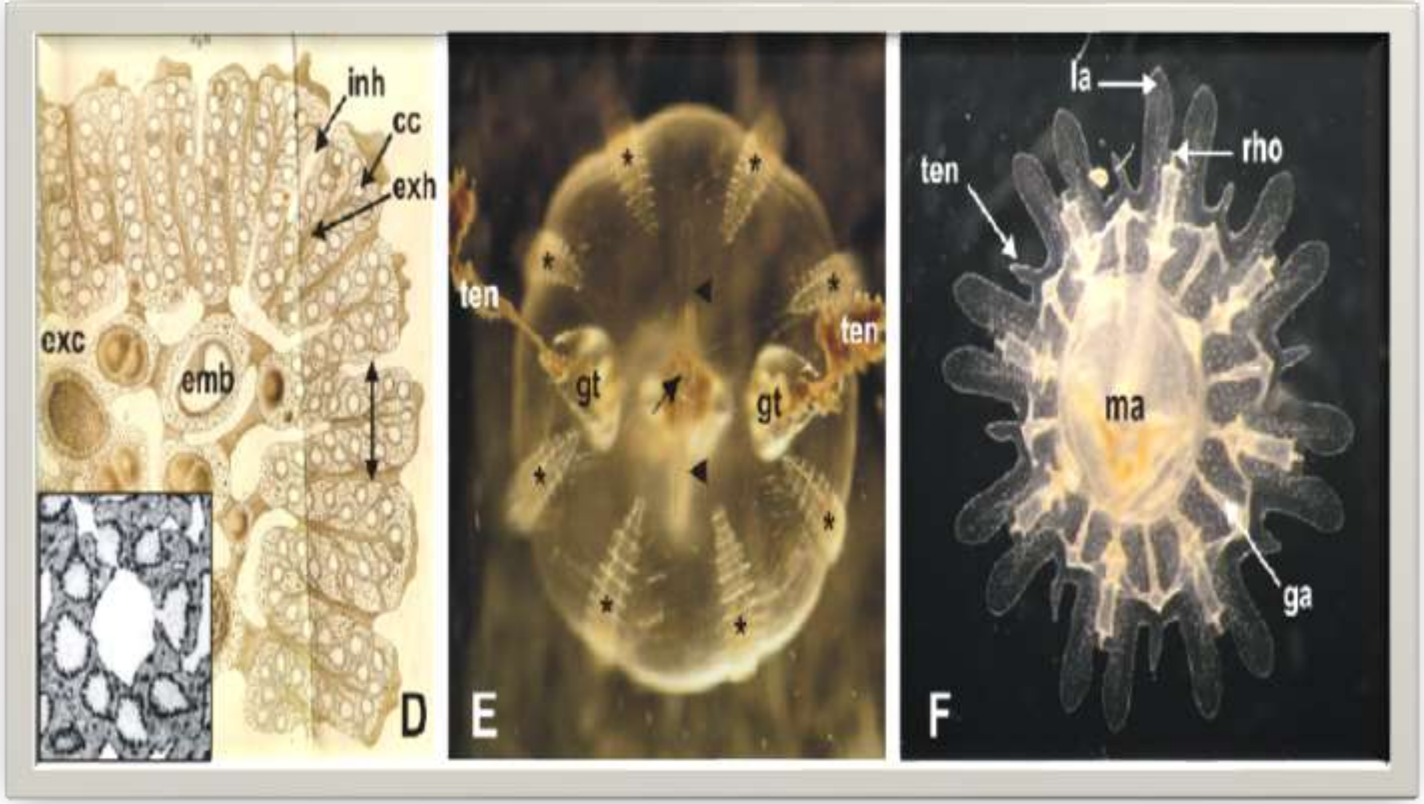


Fig. 5. Examples of radially symmetrical metazoans.
A: external morphology of the siliceous skeleton of the **glass sponge *Euplectella* (Hexactinellida).**
Note that in addition to **multiradial symmetry,** this complex skeleton architecture also shows translational and helicoidal symmetries.
B: transverse section in ***Sycon raphanus*** **(Calcispongia)**, a syconoid calcareous sponge (atr: atrial cavity; cc: choanocyte chamber; dc: distal cone)
C: transverse section in an asexual reproductive bud **of *Oscarella tuberculata*** **(Homoscleromorpha**) (atr: atrial cavity; cc: choanocyte chamber), showing a syconoid-like organisation of the aquiferous system.



D: drawing of the adult body of ***Oscarella tuberculata* in section (Homoscleromorpha**), showing the sylleibid organisation of the aquiferous system, i.e. with spherical choanocyte chambers branched to radiating exhalant canals.The detailed picture (box) corresponds to the section plane indicated by the double arrow on the drawing (cc: choanocyte chamber; emb: embryo; exc: exhalant cavity; exh: exhalant canal; inh: inhalant canal).

E: ***Pleurobrachia pileus* (Ctenophora),** aboral view showing elements of octoradial symmetry (the eight comb rows, indicated by stars) and biradial symmetry (gt: tentacle sheath; ten: tentacle; and the polar fields indicated by the arrowheads). Elements of tetraradial symmetry are not visible. The arrow points to the apical sense organ.

F: **young medusa (post-ephyra) of *Aurelia aurita* (Scyphozoa, Cnidaria)** (ga: gastrovascular canal;

Bilateral symmetry

- Bilaterally symmetrical animals have the **major axis running from head (anterior) to tail (posterior).** They have a **ventral (lower) and dorsal (upper) surface that are different from each other**. They have only two sides that look alike, the right and left. **The animal can be divided into just two identical halves through a plane which passes from anterior to posterior end.**
- Almost all animals including human beings except for sponges, ctenophores and cnidarians show bilateral symmetry. Adult echinoderms, though radially symmetrical (pentamerous) have larvae that are bilateral. This is because they have evolved from bilaterally symmetrical ancestors.
- In general, bilateral animals that adopt a sessile existence commonly exhibit a shift towards radial symmetry. The shift may be slight as in acorn barnacles where only protective circular wall plates are arranged radially or the shift may be profound as in the case of sea stars or starfishes.
- Bilateral animals are called **Bilateria.** Bilateral symmetry is simply defined by the existence of a single symmetry plane, which divides the body into two mirror halves. There is no symmetry axis. Bilateral symmetry is particularly pronounced in the Bilateria, where the body polarity axes are called antero-posterior (AP) and dorso-ventral (DV). Besides the Bilateria, bilaterality also occurs in some cnidarians.

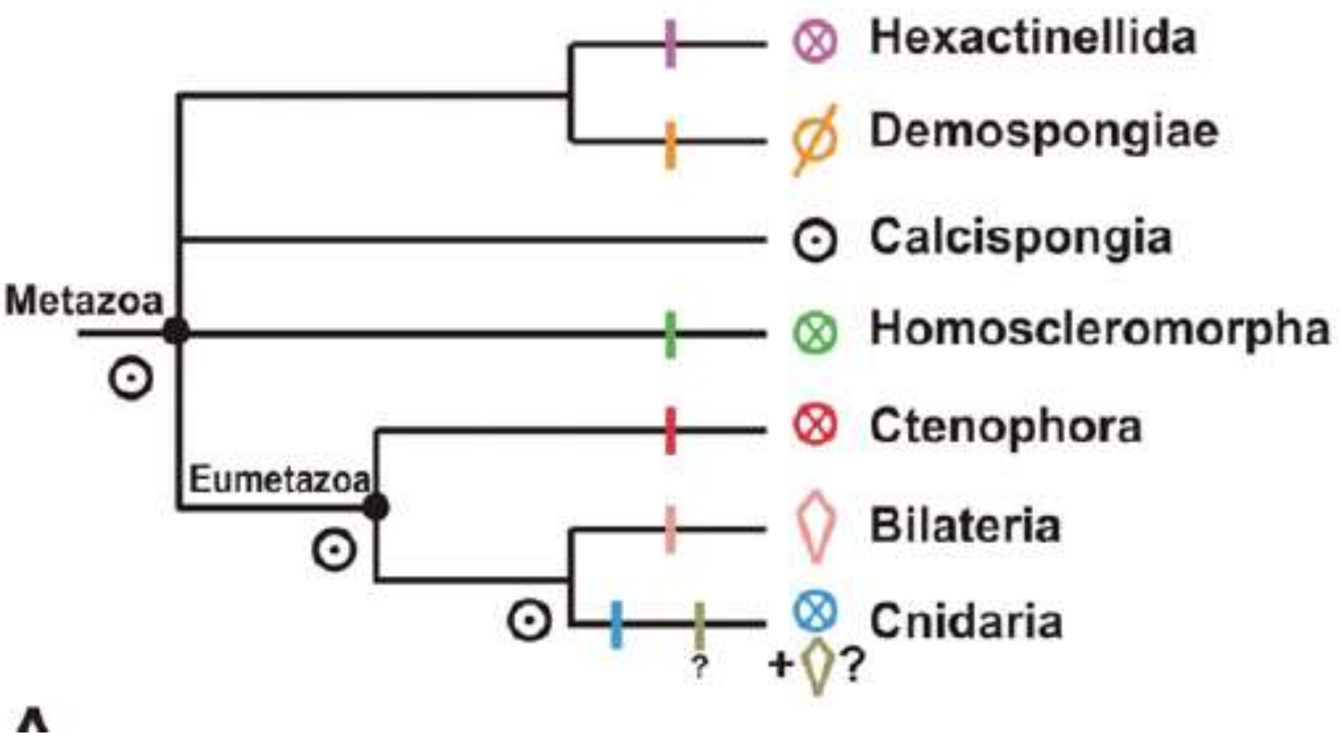


Fig. 6. Scenarios for the evolution of the types of symmetry

Symbols: ∅: asymmetry; ⊙: cylindrical symmetry; ⊗: radial symmetry; ◊: bilateral symmetry.

Biological significance of the various types of symmetry

- **Each of the symmetry types is connected with a definite type of environment and with a definite type of lifestyle.** But, there is no simple rule linking each type of symmetry to a particular life style or environment.
- Thus, cylindrical symmetry has totally different adaptive values in non-bilaterian larvae (where it is associated with directional locomotion without preferential orientation with respect to gravity), in asconoid calcisponges (where it corresponds to unidirectional water flow within a simple fixed tube) and in the bodycolumn of hydrozoan and cubozoan polyps (where it is the mere consequence of diploblasty, small size and anatomical simplicity).
- Radial symmetry is a form of multimery (repetition of parts) in which all parts are faced with equal environmental characteristics. Apart from that, radiality has totally disparate adaptive values among concerned groups. The radial symmetry of syconoid sponges results from a particular mode of aquiferous system organisation, and thereby its functional significance relates to **hydrodynamics**.

- The complex multiradial architecture of the hexactinellid sponge skeleton is designed to provide **mechanical stability at minimal cost. The radial arrangement of tentacles in cnidarian benthic polyps and pelagic medusae allows prey capture in all directions**. There are also instances of radially disposed structures used in **locomotion, either unidirectional (as for the ctenophore comb rows) or multidirectional (as for the sea star arms).** In still other cases, radial external **ciliated structures are used for generating vertical water currents**.
- Bilaterality is usually said to be fundamentally linked to **directional locomotion with preferential orientation with respect to gravity**, but in fact this is true only of the Bilateria, with the AP axis generally corresponding to the direction of main body length and to the direction of locomotion (with the mouth located anteriorly), while the DV axis is usually oriented with respect to gravity, the ventral side facing the substrate. This particular significance of **bilaterality in the Bilateria may in part explain why they are the only**

Conclusion

- That each of the symmetry types may be associated with various *ad hoc* functionalities suggests that symmetry is not strictly constrained biologically, and that body symmetry was affected by multiple adaptive and/or exaptive (having a function that was not brought about by natural selection) changes during evolution.

Concept Check

Match the term on the left with correct statement from the list on the right.

(a) Asymmetrical	i) Can be divided into many identical halves.
(b) Bilaterally symmetrical	ii) Can be divided into two identical halves but not more.
(c) Biradially symmetrical	iii) Echinoderms
(d) Pentamerous radial symmetry	iv) Ctenophores
(e) Spherical	v) Cannot be divided into two identical halves

Assignment

- Prepare a table as per the following format.

S. No.	Type of Symmetry	Examples
1.	Asymmetrical	a)Hexadella sp. (Demospongiae) b)Aplysena sp. (Demospongiae) c) Protosuberites sp. (Demospongiae) d) Trichoplax sp. (Placozoa)

Suggested Readings and References

- Isaeva, V. V., & Kasyanov, N. V. (2021). Symmetry transformations in metazoan evolution and development. *Symmetry*, *13*(2), 160.
- Signor, P. W., & Lipps, J. H. (1992). Origin and early radiation of the Metazoa. *Origin and early evolution of the Metazoa*, 3-23.
- Jefferies, R. P. S. (2007, September). Two types of bilateral symmetry in the Metazoa: chordate and bilaterian. In *Ciba Foundation Symposium 162‐Biological Asymmetry and Handedness: Biological Asymmetry and Handedness: Ciba Foundation Symposium 162* (pp. 94-127). Chichester, UK: John Wiley & Sons, Ltd..
- https://egyankosh.ac.in/bitstream/123456789/16480/1/Unit-3.pdf
- https://youtu.be/3drtbPZF9yc?si=wUsawL8VZytR4sUK

Thank you