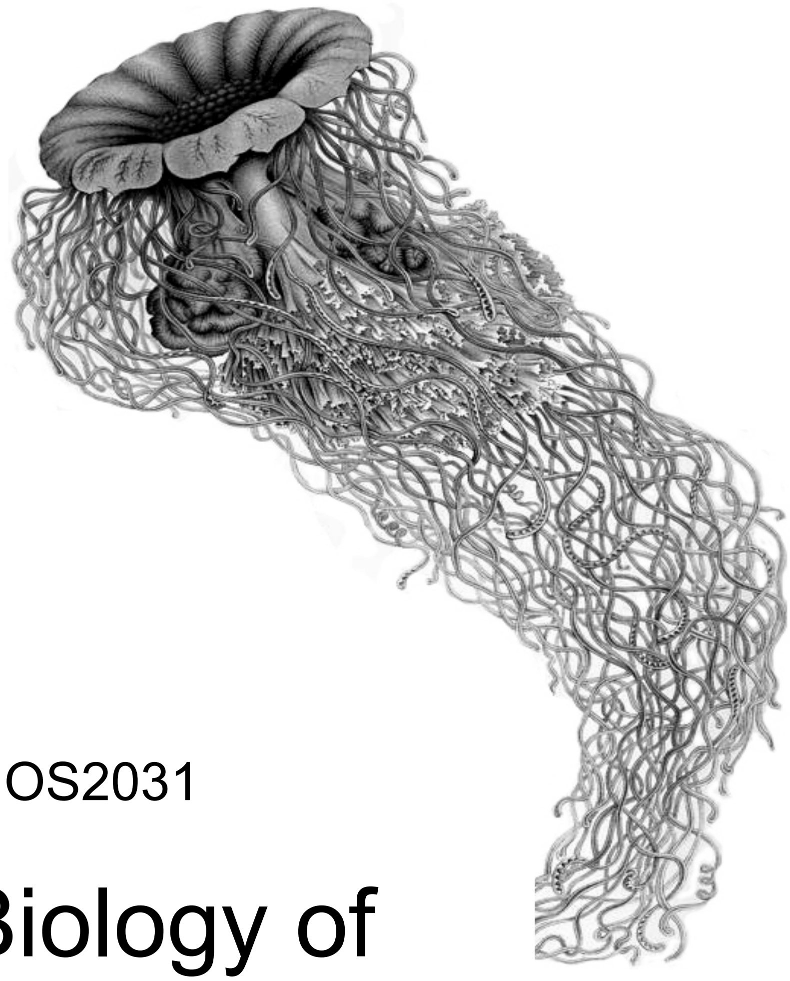
Faculty of Science
School of Biological, Earth and Environmental Sciences



BIOS2031

Biology of invertebrates

Term 3 2022

- Contributions from: Associate Professor Alistair Poore, Associate Professor Tracy Ainsworth, Professor Iain Suthers, Associate Professor Paul Gribben, Professor Gerry Cassis.
- Special Topic Lectures from; Associate Professor Suhelan Egan, Professor Torsten Thomas, Dr Mark Brown, Dr Michael Kasumovic, Dr Russell Bonduriansky, Dr Laura Parker, Dr Jon Daly.
- Discussion Group Guest Lecturers will be invited to the online laboratory sessions each Friday 9am -1pm.

BIOS2031

BIOLOGY OF INVERTEBRATES

Table of contents

Course information

NB: Some of this information is available on the UNSW Virtual Handbook[1]

Year of Delivery	2022			
Course Code	BIOS2031			
Course Name	Biology of Invertebrates			
Academic Unit	School of Biological, Earth and Environmental Sciences			
Level of Course	2nd year, undergraduate			
Units of Credit	6 UOC			
Session(s) Offered	Term 3			
Assumed Knowledge, Prerequisites or Co-requisites	BIOS1101			
Hours per Week	7			
Number of Weeks	10			
Commencement Date	Monday September 12th			
Summary of Course Structure (for details see 'Course Schedule')				
Component	**HPW**	**Time**	**Day**	**Location**
Lecture 1 – WK TOPIC	1		BEFORE FRIDAY	Online
Lecture 2 - WK TOPIC	1		BEFORE FRIDAY	Online
Lecture 3 – SPECIAL TOPIC RESEARCH	1		BEFORE FRIDAY	Online
LABORATORY	**3**	**9AM -1 PM**	**FRIDAY**	**LAB 6**
Field trip / RESEARCH WEEK			**SIMS Chowder Bay**	**SIMS Chowder Bay**
TOTAL	5			

Staff Involved in the course

Staff	Role	Name	Contact Details
Course Convenor		Assoc. Prof. Tracy Ainsworth	Tracy.ainsworth@unsw.edu.au
Additional Teaching Staff	Lecturers	Assoc. Prof. Russell Bonduriansky Prof. Gerry Cassis Assoc. Prof. Paul Gribben Prof. Iain Suthers	r.bonduriansky@unsw.edu.au g.cassis@unsw.edu.au p.gribben@unsw.edu.au i.suthers@unsw.edu.au
	Tutors & Demonstrators	Jesse Bergman Thomas Mesaglio	
	Technical & Laboratory Staff	Rochelle Johnston	rochelle.johnston@unsw.edu.au Ph: 9385 8054
	Other Support Staff	Suzy Evans	s.evans@unsw.edu.au

[1] UNSW Virtual Handbook: http://www.handbook.unsw.edu.au/2015/index.html

Course details

Course Description[2] (Handbook Entry)	A study of invertebrate diversity emphasising their evolution, morphology, behaviour, and relationships to marine, freshwater and terrestrial environments. Invertebrate conservation and applied aspects of invertebrate biology are included. Practical work includes examining living and preserved specimens (including dissections) in the laboratory and the field, and techniques for invertebrate identification.
Course Aims[3]	This course involves a study of invertebrate animals presented as a series of lectures, practical sessions and a field survey. Each of these aims to provide an understanding of the diversity, morphology, and functional biology of the major invertebrate groups. Our expectation is that you will have gained an appreciation of the huge diversity of invertebrates and will have developed a framework enabling you to make sense of them.
Student Learning Outcomes[4]	By the end of the course, we expect you to: • be able to classify typical organisms into their major taxonomic groupings (usually phylum and class but down to order or lower categories in some groups such as insects and crustaceans). Conversely you should know the morphology and diagnostic characters of typical members of the major taxa. • be familiar with the habitat, structure, feeding, reproduction and development of the major invertebrate groups. • be able to argue for the need for detailed information on the biology of invertebrates for other biological sciences, and for application to environmental, agricultural and medicinal problems.

Graduate Attributes Developed in this Course[5]

Science Graduate Attributes[5]	**The level of FOCUS** *0 = NO FOCUS* *1 = MINIMAL* *2 = MINOR* *3 = MAJOR*	**Activities / Assessment**
Research, inquiry and analytical thinking abilities	3	Practical reports, Field trip report, Invertebrates in the news web assignment (all assessed)
Capability and motivation for intellectual development	3	Self-guided practical classes, Field trip, Links in course materials to current research activities at UNSW
Ethical, social and professional understanding	2	Links in course material to impacts of invertebrates on broader society (agriculture, medicine, culture)
Communication	3	Written reports (for scientific and popular audiences)
Teamwork, collaborative and management skills	2	Group project, Group activities on field camp (all assessed)
Information literacy	2	Computer-based interactive keys to invertebrate identification

2 UNSW Virtual Handbook: http://www.handbook.unsw.edu.au/undergraduate/courses/2017/BIOS2031.html
3 Learning and Teaching Unit: https://teaching.unsw.edu.au/about-teaching
4 Learning and Teaching Unit – Learning Outcomes: https://teaching.unsw.edu.au/starting-learning-outcomes
5 Access the contextualised Science Graduate Attributes and your mapped courses: http://www.science.unsw.edu.au/future-students/graduate-attributes (Mapped courses are available at this site)

Major Topics (Syllabus Outline)	Diversity, structure, feeding, reproduction and development in the major invertebrate groups. The use of this information for understanding invertebrate evolution, reproduction and communication. The application of invertebrate biology to applied problems (incl. conservation, pollution, invasive species) See course schedule for further details.
Relationship to Other Courses within the Program	Due to their very high diversity, abundance and importance to society, many other areas of the biological, environmental, agricultural and medical science rely heavily on fundamental knowledge of invertebrates. Other courses offered within the School of Biological, Earth and Environmental Sciences that will assume basic knowledge of invertebrate biology include: • BIOS2011 Evolutionary and physiological ecology • MSCI2001 Introductory marine science • BIOS2021 Genetics • BIOS3011 Animal behaviour • BIOS3601 Advanced field biology • BIOS3081 Ocean to estuarine ecosystems • BIOS3091 Marine and aquatic ecology • BIOS3221 Assembling the tree of life • BIOS3171 Evolution Many honours and postgraduate projects conducted within the school use invertebrates as the subjects of their research (see Further research in invertebrate biology at the back of this manual).

Rationale and strategies underpinning the course

Teaching Strategies	The **lectures** consist of two types: **1) lectures that focus on a particular group of animals** 2) **lectures that focus on a particular theme, drawing upon knowledge of many invertebrate groups.** The first 2 lecture of the week aims to describe the classification and evolutionary relationships of invertebrates within the given group, their external and internal morphology, feeding behaviour, reproduction and development. The third lecture of the week explores themes (e.g., reproduction, conservation) that are common to all invertebrates. The **practical sessions** provide an opportunity to observe and examine living and preserved specimens of invertebrates covered in the lectures. ***This is essential for the appreciation of the anatomy, size, and complexity of the organisms***. In some laboratories, dissection is used to examine the internal anatomy of some of the larger organisms and to introduce you to methods of examining gross morphology. For the smaller organisms, microscopic examination is used to study both living and preserved animals and sectioned material is used to study their internal anatomy. The **field trip** if conducted examines invertebrates in their natural habitats. You will collect animals from several different habitat types and examine; 1) their diversity and 2) their structure, feeding and reproduction in relation to their habitat. The field survey offers a much wider range of living material than can be provided in laboratory sessions. T he diagnostic features learned in the lectures and practicals will be put to use in identifying the animals which you collect.

Rationale for learning and teaching in this course[6,7]	The lecture and practical material is designed to give students an understanding of the biological diversity of invertebrates, but also strong reasons why it is important to science and society to have this understanding. As a consequence, the course material will frequently make the links between invertebrate biology and research in other sciences (including current research at UNSW), and between human activities and applications. The use of live animals where possible, visually rich lecture material and interactive activities, aim to encourage appreciation of, and enthusiasm for, invertebrate animals.

Reflecting on your teaching
[6]http://teaching.unsw.edu.au/guidelines

Draft BIOS2031 Course schedule 2022

Lectures

1. ONLINE Topic of the week
2. ONLINE Topic of the week
3. ONLINE Special topic research application

ALL LECTURES FOR THE WEEK MUST be reviewed prior to attendance at the laboratory session held every Friday 9am – 1pm.

WEEKLY Laboratory session is held 9am -1pm Friday K-E26-G007 - TchLab 6

You will find the lectures saved within the relevant moodle folder for the invertebrate group featured in the lecture and there is also online recordings of laboratory material available in moodle.

Special topic lectures on research underway at UNSW will be saved within EACH WEEKS MOODLE FOLDER AND IN the special topics folder of moodle

ATTEND THE LABORATORY DICUSSION EVERY FRIDAY 9AM TO SPEAK WITH THE LECTURERS AND ASK QUESTIONS

Important Dates in Term 3

Week 4 has a public holiday on Monday

Week 6 is the field trip week at Chowder Bay at The Sydney Institute for Marine Science

The science communication essay and Field trip invertebrate report are assessment tasks for the course

Week 10 is the Practical Exam held in laboratory 6

The practical exam will be held in the practical session for week 10 in Lab 6 Friday 9am-1pm.

T3 Final exam period occurs after week 10

Some of this information is available on the Virtual Handbook[7] and the UNSW Timetable[8].

[7] UNSW Virtual Handbook: http://www.handbook.unsw.edu.au/2015/index.html
[8] UNSW Timetable: http://www.timetable.unsw.edu.au/

Assessment tasks and feedback

Task	Knowledge & abilities assessed	Assessment Criteria	% of total mark	Date of		Feedback		
				Release	Submission	WHO	WHEN	HOW
Popular science article	Independent research on invertebrates. Ability to communicate scientific information for general public	Completion of task Extent of research Effective communication to a **popular audience**	**15%**	September 15th	**Before October 21st 5pm**	Tracy Ainsworth	Two weeks after submission	Marks and written comments
Invertebrate Biology Report	Knowledge of biological survey activities. Independent research. Ability to prepare scientific report	Completion of tasks, Correct analysis and presentation of results, Effective communication to a **scientific audience**	**15%**	September 15h	**Before November 4th 5pm**	Tracy Ainsworth	Two weeks after submission	Marks and written comments
Practical exam	Knowledge of invertebrate diversity, structure, feeding, reproduction and development	Correct and complete answers	**35%**	Week 10	**Week 10 must be completed in the FRIDAY practical session**	Tracy Ainsworth	One week after submission	Mark only
Final exam	Knowledge of invertebrate diversity, structure, feeding, reproduction and development. Ability to contrast functions and structures across invertebrate groups.	Comprehension of all material covered in lectures and practical classes	**35%**	Date set by exam office				

Popular science article

(15% of your final grade)

While they often go unnoticed, invertebrates influence the lives of humans in many ways. Invertebrates may be damaging pests in agricultural systems, vectors of important diseases (e.g., mosquitoes carrying malaria), an inspiration for design or the source of irrational fears (e.g., spiders and arachnophobia).

In this article, you are required to achieve 4 key learning objectives:

1. Independently research the ways in which the lives of invertebrates and humans interact
2. Write an article suitable for a popular science audience.
3. Demonstrate scientific knowledge of the invertebrate group researched
4. Argue to a wide audience how this knowledge is valuable.

This project aims to achieve 3 things:

- emphasise the links between the biology of invertebrates and human activities
- provide experience in independent research
- provide experience in the communication of scientific information to a broad audience

You have a choice of THREE topics for your popular science essay

Topic 1: Inspired by invertebrates

The enormous diversity of form and function among the invertebrates are a great source of inspiration for those looking to nature for advances in technology.

Explore some examples of how technology has been inspired by invertebrate biology.
(*do not cover biomimicry)*

Topic 2: Invertebrates and human health
Invertebrates are a common source of disease, either as parasites or as vectors of diseases caused by microbes. They also play an important role in assisting with human health issues (e.g., as a source of novel drugs**).**

Explore some examples of how invertebrates role in disease and human health.

Topic 3: Invertebrates in popular culture
Invertebrates are a common source of inspiration for movies, literature, artworks and songs. Those that feature more often are usually those that have more influential interactions with humans (e.g., not too many songs about deep sea worms, but plenty of movies about spiders).

Explore the traits of invertebrates that make them an attractive source of inspiration in art and popular culture.

Word limit: 1000 words: Instructions for submitting the article on Moodle will be provided in Week 1 and a guide to a good essay format is included in the page below.

The project is due BEFORE 5 pm October 21st

You can submit anytime from semester start until October 21st 5pm

The article is worth 15% of your final mark.

Remember that copying text from books or web sites is unacceptable – see notes on academic honesty (below).

You cannot submit an essay that has been submitted for assessment within another course or that you have not researched and written yourself.

Look at articles in magazines like *New Scientist* or online science communication blogs for ideas on formatting a popular science article.

Articles are also provided on the Moodle page with links to several popular science publishers.

Each essay must include:

1. A title that reflects the topic and relevance to the topic area listed above
2. **A focus on ONLY one or two examples of invertebrates**, *not a survey of the entire field*
3. **Detail on which aspects of the group's biology**, e.g., *morphology, reproduction, feeding or behaviour,* make it relevant to its influence on human activities. You can include drawings or figures *you have prepared yourself* do not copy figures from sources.
4. Some images or drawings to illustrate the organisms
5. A list at the end of reference material (journal articles, books and web sites) used to complete the article. Cite reference material in the text as you would for a formal scientific report.

Tips on how to write a good sci-com essay

1. **Structure and plan your essay** in advance list out the topic, main points and take-home message before you start to write and use it as a framework or guide to structure your thoughts into a logical progression from start to finish

2. **Remember to tell a story**, introduce the topic, provide the evidence and facts to support why the topic is important, and then have a take home message or 'call to action' remember that the essay should end with the reader knowing why they had to read this article now

3. **Plan each paragraph**, make sure the first sentence introduces the paragraph the middle sentences provide the details, and the last sentence summaries the details and provides a link to the next paragraph

4. **Think about the ABT rule** – **AND BUT THEREFORE** – for storytelling.
This method provides a framework to ***build interest, ask a question and resolve an idea***.
Link ideas together "AND" Provide a question, hypothesis, or problem "BUT" and resolve the information into a take home message "therefore".

5. Popular science writing is **targeted to a general audience –** people interested in science but not necessarily people who read scientific content. The language used should not include acronyms, technical terms or specialist knowledge, all background provide should give the reader everything they need to know to understand your essay.

6. A good popular science article is

- **educational and provides evidence for the facts used;**
- **is a learning experience for the reader;**
- **is engaging and interesting**;
- **has a reason for the reader** – why did the reader need to know the information provided, for example, why is the topic interesting or relevant for the reader?

Is there are call to action for the reader to use the information? Is the information informative and entertaining?

<u>Invertebrate Biology Report</u>

<u>(15% of final grade)</u>

You are required to submit a report using

Exercise (1) Invertebrate Biology Information Sheet

Exercise (2) Field Survey BioBlitz

Exercise 1) Invertebrate Biology Information Sheet - A one -age biological report for an invertebrate observed within the SIMS chowder bay fieldtrip in week 6, **for the invertebrates** featured in (2) the filed survey bioblitz (you must include at least 1 invertebrate page)

<u>AND</u>

Exercise 2) Practice a Field Survey Bioblitz – attempt an invertebrate field survey conducted in your area using an easy to access location, such as backyard, urban footpaths, local park, sandy beach or similar, safe, location of your choosing.
Exercise 2 is worth 5% of the report grade

<u>Exercise 1) Invertebrate Biology Information Sheet</u>

Here you need to ***select at least 1 invertebrate*** that you have observed during the field trip and is featured in your Bioblitz (exercise 2) and prepare an information sheet on the invertebrate.

Each invertebrate biology information sheet must provide:

1) A drawing/illustration of the invertebrate including all labels identifying the biological features of the invertebrate. The drawing must be clear and accurate representation of the body plan, shape, and distinguishing features. At least 5 biological features should be labelled

2) Identify the correct and full taxonomic classification for the organism (Phyla, Class, Order, Family, Genus, Species)

3) 100-word description of the habitat the organism was found in and how a feature of the body plan reflects, or uses, the habitat the organism lives. For example, use of filter feeding; why is broadcast spawning effective.

Exercise 1 should be included and references your exercise 2 report below as Figure 1. Invertebrate taxa surveyed, and included in your results and discussion section of the Bioblitz report.

Exercise 2) Field Survey (BioBlitz) of Invertebrate taxa.

BioBlitz of a habitat of your choosing (within a group or individually during the 2 day field trip) and safely undertake a BioBlitz within a timed survey where you report on the quantification of invertebrates within a clearly defined habitat area using a repeatable survey methodology that you outline and discuss within your report.

(Exercise 2) BioBlitz report is in the style of a research article with

1) Introduction
2) Methodology
(*you can include a figure demonstrating your survey method*)
3) A combined Results and Discussion
(*with figures on your recorded taxa, analysed collected data*)
4) References

Things to discuss in your report:

- *What is the habitat*
- *What is your bioblitz/research question*
- *What are the invertebrates targeted and the habitat they occupy*
- *Did your methodology work, can it be repeated, how could it be improved, what are the limitations of the survey you conducted*
- *What did we learn about the invertebrate and how it occupies its niche habitat*

Section 2 of the exercise should not exceed 1000 words
(not including figures, tables and references).

The report is due by **5pm November 4th 2022**
and is worth **15% of your course mark**.

FIELD TRIP

BioBlitz of Chowder Bay

WEEK 6

One of the problems of nature conservation is that information on the biodiversity of a given area is often lacking. One approach to this problem is the ***BioBlitz, a period of intense sampling with the aim of recording all the living species in the area***.

In recent years, this concept has been used in many countries worldwide and often involves a partnership between scientists and the general public. The activities gather important scientific information, but also act to engage the public in the need to study and conserve biodiversity.

You will conduct a BioBlitz of marine and/or terrestrial environments.

At Chowder Bay in Sydney Harbour (**Week 6 field trip Thursday 20th and Friday 21st October**) has excellent access to a variety of habitats (forest, parkland, intertidal rocky shores, sandy beaches, subtidal reefs and seagrass beds).

The specific objectives are to:

1. survey the diversity of terrestrial and marine invertebrates, examining species in their natural habitats,

2. gain experience in identifying invertebrates, and,

3. examine the relationship between habitat and invertebrate structure, function and/or reproduction**.**

Location. Field work will involve sampling marine and terrestrial environments at Chowder Bay.

Safe Field Working Practices: Ensure you work with others to assist you and ensure your safety; do not handle invertebrates only observe count and photograph specimens; ensure you check the local conditions, including all conditions that could impact your safety such as the weather, tide conditions when nearby water ways; always wear personal protective equipment such as enclosed shoes, hats and sun protection if working outdoors.

If you wish to snorkel on the field trip contact the course coordinator at least 1 week before the field trip Tracy Ainsworth tracy.ainsworth@unsw.edu.au

Schedule

Thursday 20th October 2022

9:30 – Meet near the bus stop at Chowder Bay
9:30 – 10:30 – Organise sampling equipment and establish team strategies
10:30 – 4:30 – Field work, report planning, data collection

AND

Friday 21st October 2022

9:30 – Meet near the bus stop at Chowder Bay
9:30 – 10:30 – Organise sampling equipment and establish team strategies
10:30 – 4:30 – Field work, data collection, data analysis

How to get there

The Sydney Institute of Marine Sciences is at:
Building 22
Chowder Bay Road
Mosman, NSW
Ph: 9969 2664

Information on access by bus and car parking options will be provided prior to the trip.

Emergency contact: BEES School Office, 9385 2015 or 9385 2961

Things to bring

Food: You can bring your own lunch or purchase lunch from the cafes on site.

Clothing: Be prepared for hot or cold/wet weather as we work rain or shine. *Be prepared for rain!* Bring hats, water bottles, sun cream, sensible clothes for field work (i.e., clothes that you won't mind getting dirty and that will protect you). Long pants and sleeves are recommended to protect against prickly plants and biting insects. Thongs are not appropriate!

Equipment: pencils, paper, course manual, dissecting kit, snorkel gear (if snorkelling you must provide your own equipment and must have approval to snorkel prior to attending the fieldtrip)

Laboratory tasks and practical exam

The practical classes will expose you to a great range of live and preserved invertebrates.

Classes are divided into several components, each relating to one of the following aspects (not all components will be presented in every practical):

- Diversity
- Structure
- Feeding
- Reproduction and development
- Behavioral observation/experiment
- Invertebrate research at UNSW

Within each component there are several tasks

(e.g., 1.5G Sea anemones).

These may involve;
1) written questions,
2) providing a labelled diagram of an organism or structure,
3) providing the results of a short experiment, or
4) providing illustrated notes on a particular aspect of feeding, reproduction or behaviour.

The tasks are designed so that it is clear what we expect you to learn from each specimen or display and these have been recorded and are available for you tom undertake each week of the course.

THE LIVE LABORATORY DISCUSSION WILL ALSO BE HELD EVERY FRIDAY 9AM-1PM IN TEACHING LAB 6.

RECORDINGS OF THE LABORATORY CONTENT ARE ALSO AVAILABLE ONLINE IN MOODLE.

Laboratory session each week will

1) Introduce you to your lecturers from the weeks' lectures
2) Provide you with specimens and laboratory tasks
3) Give you the opportunity to ask questions and discuss the material each week.
4) Complete the tasks in the laboratory manual which should be used to review the course content for the practical examination at the end of the course.

POD THE LAB is also available on the BEES Podcast channel

What is Pod The Lab?

- Easily accessible online study resource
- Podcasted discussion forum with academics in the course that is linked to the laboratory material in the course
- Targeted our undergraduate Invertebrate biology audience
- **RSS feed** for easy to access, downloadable/stored material to review weekly content at anytime
- Material remains available throughout the course

https://rss.com/podcasts/unsw-bees

Practical Examination

IN WEEK 10 a selection of the tasks that you undertake each week will be included in the practical exam, along with new displays.

The practical examination aims to test student
1) ability to identify invertebrates,
2) knowledge of the distinguishing characters of the major taxonomic groups, and
3) knowledge of the structure and function of invertebrates covered in the practical classes.

The practical exam will be held during the final laboratory week (Week 10).

The practical exam is worth 35% of your course mark.

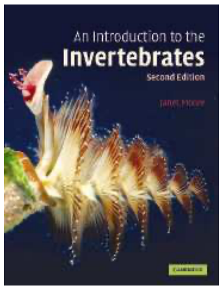
Final theory examination

The final exam, worth **35% of your course mark**, will test knowledge of the lecture and practical material. The emphasis will be on issues covered in the course that allow us to contrast the biology of different invertebrate groups, rather than the details of a single taxonomic group (e.g., you will not get a question like “Tell us everything you know about snails”).

As with all exams, take care in reading the question and allocate your time in accordance with how many marks are allocated to a given question. Past exams are available on the course web site.

Attendance at exams is expected. Booking an overseas trip during the exam period is not considered a valid excuse for missing an exam.

Resources

Text Books	Moore, J (2006) *An introduction to the invertebrates*. Second edition, Cambridge University Press. Availability: UNSW bookshop, UNSW library, Open Reserve 
Course Manual	You are reading it! (also available as pdfs from the course web site)
Required Readings	Moore (2006)
Additional Readings	You will find useful information in many other invertebrate texts. You may find the taxonomy used in these texts differs from that in Moore (2006) and that used in this manual. Some very good ones are: Anderson, DT (2001). *Invertebrate zoology*. 2nd edition. Oxford University Press, South Melbourne. Anderson, DT (1996) *Atlas of invertebrate anatomy*. University of New South Wales Press, Sydney. Brusca, RC, W Moore and S Shuster. 2016. *Invertebrates*. 3rd Edition, Sinauer Associates, Sunderland. (or earlier editions) Ruppert, EE, RS Fox and RD Barnes. 2004. *Invertebrate biology*. Thomson (any edition - there are 7). Pearse, V, J Pearse, M Buchsbaum and R Buchsbaum. 1987. *Living invertebrates*. Blackwell Scientific Publishing.
Recommended Internet Sites	**Course web page (Moodle)** Slides from lectures, your results from tests and reports, and other useful resources will be posted throughout the session on the BIOS2031 web page. You will need to log on (using your student number and zpass) to Moodle at https://moodle.telt.unsw.edu.au/ The course web site has a list of other useful sites for invertebrate biology. **Lobsters to leeches Facebook page** This page, maintained by Assoc. Prof. Poore, features weird and wonderful invertebrate news from UNSW and around the world. Access at https://www.facebook.com/Lobsters.to.leeches (you don't have to join Facebook).

Required Equipment, Training and Enabling Skills

Equipment Required	You must bring the following to all lab classes: • Laboratory coat – no admittance without lab coat • Closed footwear, no thongs, sandals or bare feet • Dissection instruments - including scissors, forceps, probes and scalpel (+scalpel handle) • Sharp HB pencils, plain paper and a ring binder with your name prominently placed • This laboratory manual

Enabling Skills Training Required to Complete this Course	Students are required to observe OHS regulations during the fieldtrip and practicals. (Safety should be your top priority during fieldtrips and lab classes. If you are unsure of any procedures, please consult with staff).

Course evaluation and development

Student feedback is gathered periodically by various means. Such feedback is considered carefully with a view to acting on it constructively wherever possible. This course outline conveys how feedback has helped to shape and develop this course.

Mechanisms of Review	Last Review Date	Comments or Changes Resulting from Reviews
Major Course Review	2004	Course entirely revised in 2004 with the aims of simplifying the presentation of course material, organisation of practical classes along functional themes, aligning assessments to desired activities in practical classes, and relating invertebrate biology to other sciences and the wider society.
	2008	The change from 14 week to 12 week sessions has involved the removal of two practicals and submission of one rather than two laboratory reports.
	2008, 2011, 2014	New field trips
CATEI[9]		The course was evaluated with CATEI in 2007- 2009,2011 and 2014. While the responses were overwhelmingly positive (96–100% of the respondents satisfied with the quality of the course), several changes resulting from these evaluations have been implemented. The most important of these is a reduction in the time spent on the field trip (2 days rather than 4) keeping the time spent in proportion to the value of that report for the overall course mark, and changes to the assessment structure.

Administration matters

Expectations of Students	Attendance at practical classes is compulsory and material will not be presented at other times. Less than 75% attendance will result in an unsatisfactory fail. Any problems or queries with assessment should be addressed to the course convenor, Associate Professor Poore.
Assignment Submissions	Submitted assignments are to be placed in the assignment box at the BEES Undergraduate Office (Rm G27). Assignments must fulfil conditions of the BEES Assignment cover sheet, which must be

[9] Science CATEI procedure: http://teaching.unsw.edu.au/catei

	attached. The cover sheet lists penalties for late submission, and there is a declaration stating that you have kept a copy and that the report is your own and has not been previously submitted for assessment. **School policy for late report submission** For reports submitted up to seven (7) days late, a **10% per day penalty applies. Reports submitted more than seven (7) days late will not be marked.** If medical grounds preclude submission of a report by the due date, contact should be made with the course convenor as quickly as possible. A medical certificate will be required for late submission on medical grounds and must be appropriate for extension period.		
Occupational Health and Safety[10]	Information on relevant Occupational Health and Safety policies can be found at: • http://www.safety.unsw.edu.au/ • http://www.bees.unsw.edu.au/health-and-safety		
Assessment Procedures	The final examination will be scheduled by the Examinations Office. Students should be available for examination throughout the entire UNSW end-of-session examination period. Supplementary examinations will only be granted to students who miss the final examination due to illness or other unexpected reasons outside their control. A student who wishes to apply for a supplementary examination should contact the course coordinator as soon as the problem becomes apparent, and should apply for special consideration. (Special consideration cannot be given for students who have planned or wish to plan any holiday trips or return flights home before the end of the examination period.) If a supplementary examination is granted, it will normally be held before the beginning of the next session. Until then, you should maintain a current address with SIS, and be available for contact and assessment. For information on examinations see https://student.unsw.edu.au/exams The conditions for special consideration are given at https://student.unsw.edu.au/special-consideration		
Equity and Diversity	Those students who have a disability that requires some adjustment in their teaching or learning environment are encouraged to discuss their study needs with the course Convenor prior to, or at the commencement of, their course, or with Disability Support Services (http://www.studentequity.unsw.edu.au/) Issues to be discussed may include access to materials, signers or note-takers, the provision of services and additional exam and assessment arrangements. Early notification is essential to enable any necessary adjustments to be made.		
Grievance Policy[11]	**School Contact**	**Faculty Contact**	**University Contact**
	BEES Grievance Officer A.Prof. Jes Sammut j.sammut@unsw.edu.au Tel: 9385 8281	A/Prof Chris Tisdell Associate Dean (Education) Tel: 9385 6792 cct@unsw.edu.au	Compass University Counselling Services[12] Tel: 9385 5418

[10] UNSW Occupational Health and Safety: http://www.safety.unsw.edu.au/

[11] UNSW Grievance Policy: http://www.gs.unsw.edu.au/policy/index.html

Special consideration and further assessment 2022 T3

Students who believe that their performance, either during the session or in the end of session exams, may have been affected by illness or other circumstances may apply for special consideration. Applications can be made for compulsory class absences such as (laboratories and tutorials), in-session assessments tasks, and final examinations.

Students must make a formal application for Special Consideration for the course/s affected as soon as practicable after the problem occurs and within three working days of the assessment to which it refers.

Students should consult the “Special Consideration” section of the UNSW current students’ website for further information https://student.unsw.edu.au/special-consideration.

How to apply for special consideration

Applications must be made via Online Services in myUNSW. **You must obtain and attach Third Party documentation before submitting the application. Failure to do so will result in the application being rejected.** Log into **myUNSW** and go to **My Student Profile tab > My Student Services channel > Online Services > Special Consideration.** After applying online, students must also verify supporting their documentation by submitting to UNSW Student Central:

- Originals or certified copies of your supporting documentation (Student Central can certify your original documents), and
- A completed Professional Authority form (pdf - download here).

The supporting documentation must be submitted to Student Central for verification **within three working days** of the assessment or the period covered by the supporting documentation. Applications which are not verified will be rejected.

Students will be contacted via the online special consideration system as to the outcome of their application. Students will be notified via *their official university email once an outcome has been recorded.*

Supplementary examinations:

The University does not give deferred examinations. However, further assessment exams may be given to those students who were absent from the final exams through illness or misadventure. Special Consideration applications for final examinations and in-session tests will only be considered after the final examination period when lists of students sitting supplementary exams/tests for each course are determined at School Assessment Review Group Meetings. Students will be notified via the online special consideration system as to the outcome of their application. **It is the responsibility of all students to regularly consult their official student email accounts and myUNSW in order to ascertain whether or not they have been granted further assessment.**

For T3 2022, BEES Supplementary Exams will be scheduled for January 2023

Further assessment exams will be offered on this day ONLY and failure to sit for the appropriate exam may result in an overall failure for the course. Further assessment will NOT be offered on any alternative dates.

UNSW academic honesty and plagiarism

What is Plagiarism?

Plagiarism is the presentation of the thoughts or work of another as one's own.
*Examples include:

- direct duplication of the thoughts or work of another, including by copying material, ideas or concepts from a book, article, report or other written document (whether published or unpublished), composition, artwork, design, drawing, circuitry, computer program or software, web site, Internet, other electronic resource, or another person's assignment without appropriate acknowledgement;
- paraphrasing another person's work with very minor changes keeping the meaning, form and/or progression of ideas of the original;
- piecing together sections of the work of others into a new whole;
- presenting an assessment item as independent work when it has been produced in whole or part in collusion with other people, for example, another student or a tutor; and
- claiming credit for a proportion a work contributed to a group assessment item that is greater than that actually contributed.†

For the purposes of this policy, submitting an assessment item that has already been submitted for academic credit elsewhere may be considered plagiarism.

Knowingly permitting your work to be copied by another student may also be considered to be plagiarism.

Note that an assessment item produced in oral, not written, form, or involving live presentation, may similarly contain plagiarised material.

The inclusion of the thoughts or work of another with attribution appropriate to the academic discipline does *not* amount to plagiarism.

The following website is a resource for students on plagiarism and academic honesty.

https://student.unsw.edu.au/plagiarism

The Learning Centre also provides substantial educational written materials, workshops, and tutorials to aid students, for example, in:

- correct referencing practices;
- paraphrasing, summarising, essay writing, and time management;
- appropriate use of, and attribution for, a range of materials including text, images, formulae and concepts.

Individual assistance is available on request from The Learning Centre.

Students are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting, and the proper referencing of sources in preparing all assessment items.

* Based on that proposed to the University of Newcastle by the St James Ethics Centre. Used with kind permission from the University of Newcastle
† Adapted with kind permission from the University of Melbourne

<u>If you are wondering what to do each week here is the weekly schedule for BIOS2031</u>

1) Go to the Weeks toggle in the Moodle page for BIOS2031 – *e.g*. Find Week 1

2) Review the 3 lectures available for the week.
   There are 2 lectures in support of the laboratory content and 1 special topic lecture
   The lectures are provided as recorded lectures and lecture slides

3) Prepare questions for the ***The Lab*** session held in every Friday 9am

4) Attend the Friday laboratory session in teaching Lab 6 held from 9am

5) Review the recorded laboratory content for the week provided in the laboratory session folder in preparing your study material for the end of term examinations.

6) Complete the course manual questions for the week

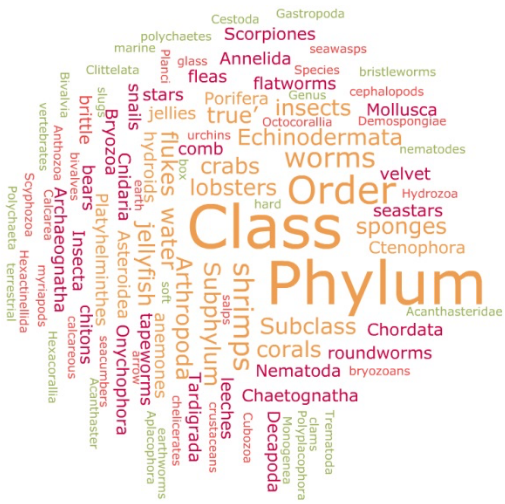
Practical classes

***The* practical classes are three hours in duration in teaching laboratory 6 in the Biological Sciences Building (E26).**

You are required to join Friday 9am-1pm to meet your lecturers, ask questions, and received guidance on the laboratory content.

Learning names

At first glance, learning invertebrate biology can be daunting due to the large number of unfamiliar organisms, names and structures. Learning of the scientific names for the major groups of invertebrates is essential to this understanding. Put simply, it allows us to organise our knowledge in a logical fashion. While we acknowledge that learning many names can be difficult, an attempt to learn the important groups will assist in all aspects of the course.



The groups we expect you to remember are included in the tables in the diversity section of each practical. It is more important that you can remember and identify the large groupings (phylum and class) than minor differences among closely related species.

Please complete the demonstrations in the practicals and supplement this with your own research and reading, to complete the tasks outlined in this course manual.

The completed course manual will provide you with a guide for the material you need to revise to undertake the course practical exam please ensure that you complete the questions especially those listed in blue

Scientific illustration

Many aspects of invertebrate biology are best learnt visually, by reference to labelled photographs or illustrations. This includes your learning from textbooks, but also the material you will learn in practical classes. **Clear labelled diagrams are often the easiest way for you to remember invertebrate structures, life cycles or even various behaviours. The process of drawing ensures that you carefully observe the given specimen**.

Your illustrations will be essential for your revision of the material covered in the practical classes.

Successful drawings for this purposes will:

- be in pencil, not pen
- be on plain, not lined, paper
- be large and clear
- include a title with full classification of the organism and what is shown (e.g., dissection or longitudinal section or transverse section; dorsal or lateral view etc).
- have structures labelled with a ruled line connecting them to the structure concerned. Label-lines should not cross.
- include additional notes/observations that will help you interpret the illustration.
- include an approximate scale so that the size of the organism can be estimated. For the compound microscope one ocular unit @ 4 X = 25 μm; @ 10 X = 10 μm, @ 40 X = 2.5 μm, @ 100 X = 1 μm.
- involve the specimens actually observed (not simply copied from text books)

IF we return to the laboratory you will need to understand microscope use

Observing some specimens will require the use of dissecting or compound microscopes. Follow these steps when using the Olympus compound microscopes to view specimens and avoid damage to the slide or microscope:

- Please use both hands to carry it carefully to your desk.
- Plug in and switch on the lamp,
- Start off with the 4X objective
- Adjust the condenser and iris diaphragm, - In practical terms the iris should be approximately half open, and the condenser racked down for 4X, and nearly all the way up for 40 and 100X.
- Focus with the coarse and fine controls
- These new microscopes are par-focal, meaning that you may confidently swing in new objectives to move to higher magnification without smashing the objective into the slide. Nevertheless, always check and slide in the next objective cautiously. You only need to slightly fine-focus for the new objective – reckless focusing will smash the glass slide (prepared, commercial slides cost around $10 each).

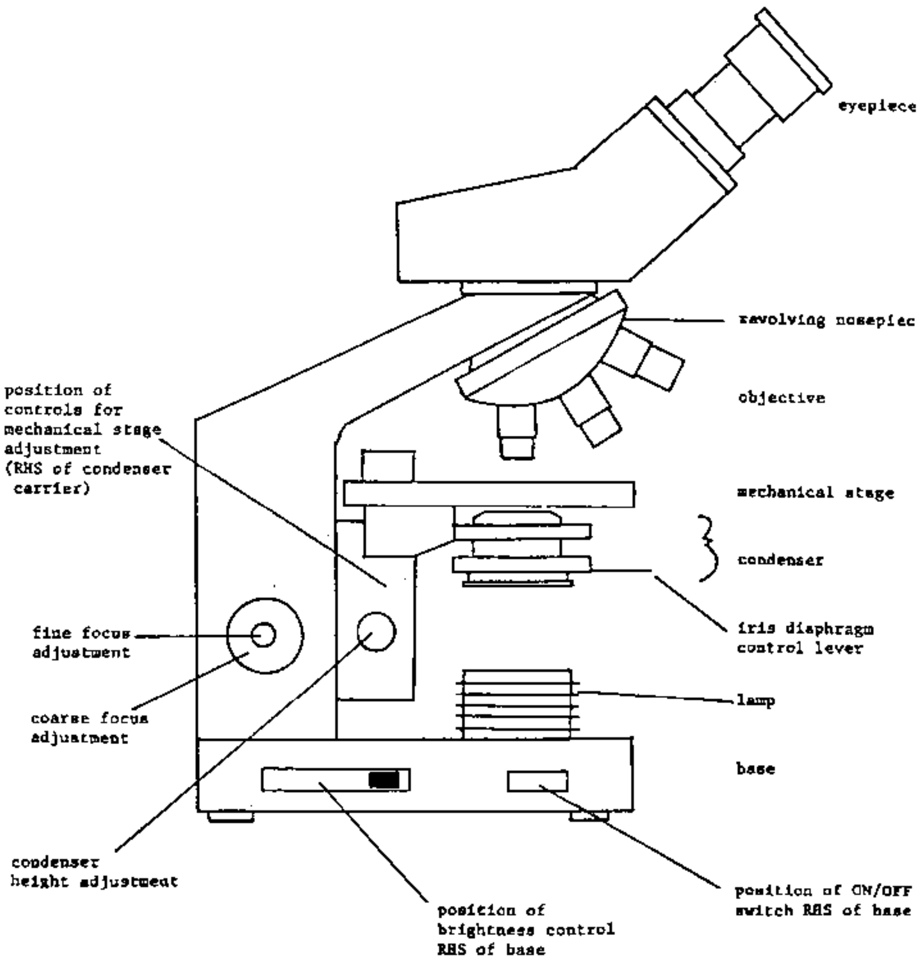
Automatic pre-focusing: This lever (inside ring of left hand focusing knob) locks the microscope at a particular coarse focus position to prevent further upward travel of the stage by means of the coarse adjustment knob. It prevents damage to objectives as a result of focusing the specimen slide up through the objective lens. It does not restrict fine focusing.

Aperture iris diaphragm: The lever on the condenser controls the aperture iris diaphragm adjustment. The iris diaphragm should be adjusted to match the numerical aperture of the objective in use in order to get the best result. However, since the image usually lacks contrast a compromise is made and the diaphragm is stopped down to about 70% of the objective numerical aperture.

Remove the eyepieces: the circle of light represents the exit pupil of the objective. Adjust the diaphragm using the condenser lever until the iris impinges on the exit pupil by about 1/3. This should always be done when objectives are changed.

13

Microscope Diagram



WEEK 1

PORIFERA, CNIDARIA AND CTENOPHORA

Sponges grow in the ocean. That just kills me.
I wonder how much deeper the ocean would be if that didn't happen.
Steven Wright

Excluding single-celled protists, approximately 96% of all described species (about 1.3 million) are invertebrate animals. **The study of invertebrate biology is therefore the study of biodiversity itself.**

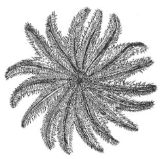
We will start our tour of the invertebrate world with t***he simplest multicellular animals, the sponges***, and then consider ***two phyla of radially symmetrical animals with just two body layers, the cnidarians (jellyfish, corals etc) and ctenophores (comb jellies)***.

Biological classification Before we start, a quick refresher on how animals are classified.

Organising our knowledge often involves classifying similar objects into groups (e.g., we find books organised by topic in the local book store). Organising our understanding of species is no exception. Species are arranged in groups (***taxa, plural; taxon, singular***) in a hierarchical system (e.g., species belong to a genus, (genera, plural) belong to families and so on).

The major levels of the hierarchy are as follows:

Eg: Common name: Crown of Thorns seastar



Kingdom	Animalia
Phylum	Echinodermata
Class	Asteroidea
Order	Valvatida
Family	Acanthasteridae
Genus	*Acanthaster*
species	*planci*

Note that the **genus and species names are in *italics*** and that **genus names (but not species names) are capitalised**.

You will also see other taxonomic categories such as Subclass, Suborder or Superfamily.

Note that the membership of all higher taxa (above species) is chosen by biologists.

The rules for naming species within this scheme are held in the **International Code of Zoological Nomenclature.**

Taxonomy, phylogeny and systematics

Provide definitions of the following words that all relate to the biological classification of life on Earth:

Taxonomy

Phylogeny

Systematics

List examples of what characteristics of organisms we should use to place species within the same taxonomic group? (*e.g., should we place all green animals in one group?).*

Why is it important that we classify invertebrates?

Give examples of other **biological or environmental sciences that are dependent on the taxonomic knowledge of invertebrates**.

What is a phylum?

The highest taxonomic grouping within the animal kingdom is that of the phylum (phyla, plural). Each phylum represents animals with a **shared evolutionary history that differ in fundamental aspects of their body plans**.

For the specimens the have been recorded in the laboratory, draw the phyla that are represented and note how many of each phyla, and each body type.

In this course, we will examine the biology of 14 of the 32 known animal phyla:

Phylum	Common names
Porifera	sponges
Cnidaria	hydroids, jellyfish, corals, anemones
Ctenophora	comb jellies
Platyhelminthes	flatworms, flukes, tapeworms
Chaetognatha	arrow worms
Mollusca	snails, bivalves, cephalopods, chitons
Annelida	earth worms, leeches, polychaetes
Bryozoa	bryozoans
Nematoda	roundworms
Onychophora	velvet worms
Tardigrada	water bears
Arthropoda	insects, crustaceans, myriapods, chelicerates
Echinodermata	seastars, urchins, sea cumbers, brittle stars
Chordata	ascidians, salps, vertebrates

Phylogenetic tree of animal life

Throughout the course, it will be good to **return to this figure and place each animal group within our view of evolutionary relationships among the phyla**.

Below is a recent understanding of how animal phyla are related (with the ones we will cover in bold), *but note there is still uncertainty for many groups*.

Note the major lineages that contain:

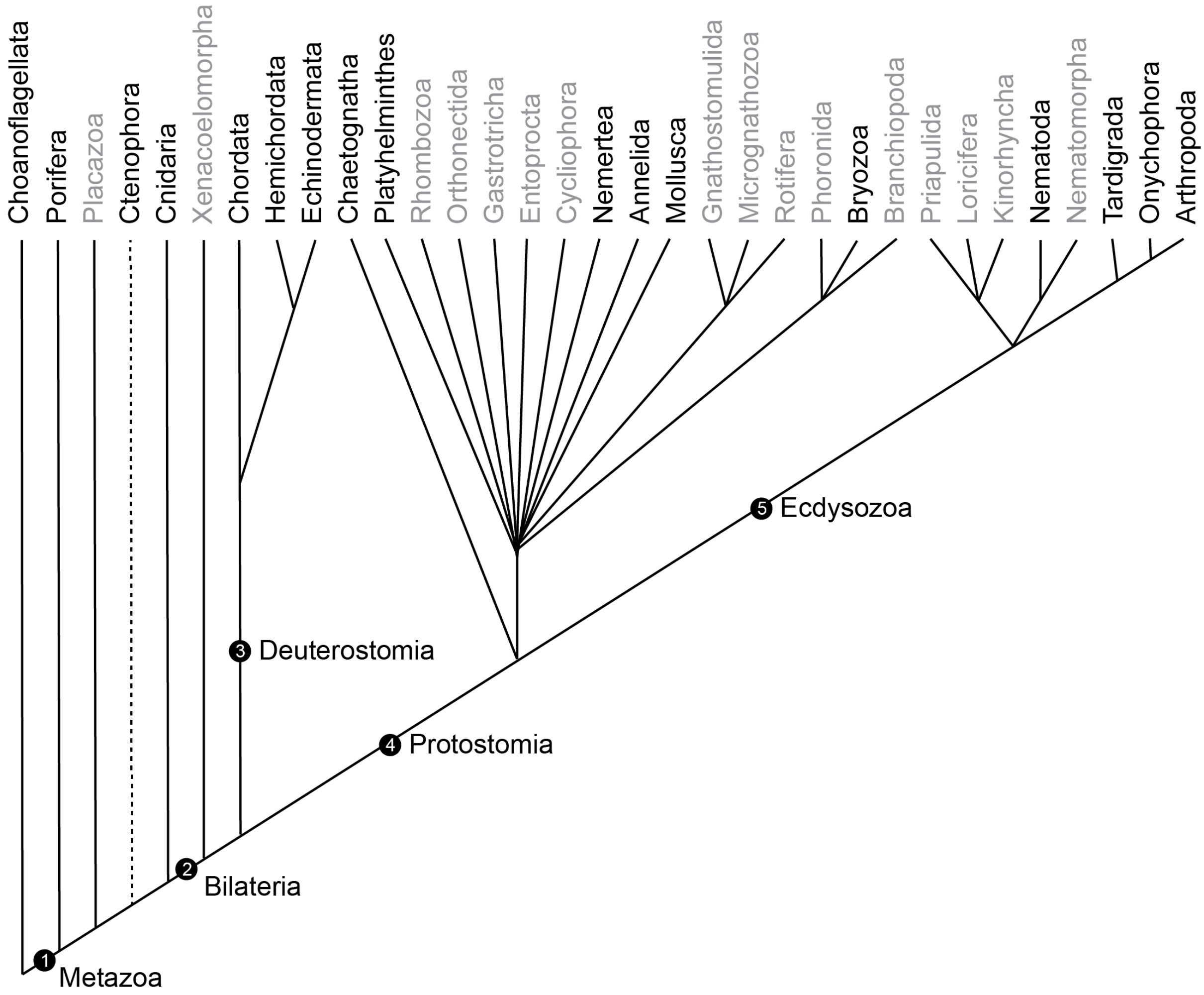
1. **multicellular animals (Metzoa)**
2. **bilaterally symmetrical animals with three body layers (Bilateria)**
3. **deuterostomes**
4. **protostomes**
5. **animals that moult a multi-layered cuticle (Ecdysozoa)**

Make notes and drawings that allow you to distinguish between animals

that are radially vs. bilaterally symmetrical.

Make notes on which phyla have

ectoderm, endoderm and mesoderm.



Consensus tree of animal phyla modified from Brusca *et al.* (2016).

Sponge and cnidarian diversity

The **sponges** (Phylum Porifera, ~8500 spp., *porus,* hole; *ferre,* bearing, L) are among the simplest multicellular animals. Most sponges inhabit hard substrates in shallow marine waters. A few live in deeper waters (most of the glass sponges) or in fresh waters.

Phylum	Class	Common names
Porifera	Calcarea	calcareous sponges
	Hexactinellida	glass sponges
	Demospongiae	

Class Calcarea. Skeleton of calcium carbonate spicules. Exclusively marine, may be asconoid (tube shaped), syconoid (tube with thick body wall) or leuconoid (branched network) body construction.

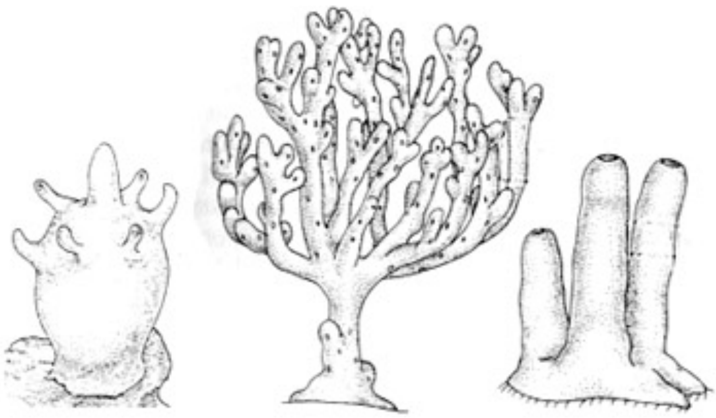
Class Hexactinellida. Skeleton of six-rayed siliceous spicules. Usually syconoid. Exclusively marine.

Class Demospongiae. Skeleton of siliceous spicules (not six-rayed), spongin fibres or both. Contains 95% of sponge species. If spicules are present they are usually of two types; small spicules embedded in the "tissues" and large spicules which make up the main skeletal framework. This class includes most of the common Australian species of sponges. Leuconoid body form.

Sponge diversity.

Examine the range of live and preserved sponges provided

Make notes on how could you identify these sponges to class?



What are the following body construction terms referring to

- **asconoid**
- **syconoid**
- **leuconoid**

The **cnidarians** (Phylum Cnidaria, ~11000 spp., *cnida*, a nettle; Gk) are aquatic (mostly marine) organisms. They include animals commonly referred to as **jelly fish, sea anemones, corals and hydroids. They display two main body forms – polyp or medusa**.

The **combjellies** (Phylum Ctenophora, 187 spp., *ktenes*, a comb; *ophora*, carrying; Gk) are a small **phylum of jelly-like marine organisms**. The body is divided into **eight sections by ciliated bands (the ctenes or combs) which provide locomotor power**.

Phylum	Class	Subclass	Common names
Cnidaria	Hydrozoa		hydroids
	Scyphozoa		jellyfish
	Cubozoa		box jellyfish, sea wasps
	Anthozoa	Octocorallia	soft corals, sea pens, sea fans
		Hexacorallia	hard corals, anemones
Ctenophora			comb jellies

Class Hydrozoa. Polyp or medusoid form, mesogloea never cellular, gastrodermis lacks nematocysts, gonads usually epidermal. Marine and freshwater. Polyps, may be solitary or colonial.
Class Scyphozoa. Medusoid form dominant, polyp stage reduced, mesogloea cellular.
Class Cubozoa. Medusoid form dominant, bell has four flattened sides; bell margin bears four tentacles or clusters of tentacles.
Class Anthozoa. Polyp form, medusoid stage absent, exclusively marine.
Subclass Octocorallia. Polyp with eight pinnate tentacles, almost all are colonial.
Subclass Hexacorallia. Polyp with multiples of 6 non-pinnate tentacles.

Cnidarian diversity.

<u>Examine the cnidarian specimens in the online display.</u>

Review the
1) **provided live specimens in the laboratory,**
2) **the preserved specimens, and**
3) **the specimen skeletons**

Make labelled illustrations of a representative species from different classes and subclasses that are provided

Keep your labelled illustrations to review at the end of the course

.

Hydra
Hydra is a genus of abundant **freshwater hydroids**.

Draw and sketch a specimen of the *Hydra* and identify

tentacles,

basal disc,

column and mouth

Which body form does *Hydra* possess?

Review and examine the transverse or longitudinal sections of *Hydra* and **note the**

outer epidermis,
the inner gastrodermis and
the layer of mesoglea between them.

Identify as many different types of cell as possible.

Note the lack of mesenteries in the gastrovascular cavity compared to the other classes.

Make drawings that illustrate the body wall structure.

The blue bottle, *Physalia*
'Blue bottles' or 'Portuguese man of war' are pelagic colonies of polyps, where each polyp has specialised for either feeding, or stinging, or reproduction, and one polyp forms the float. *Physalia* commonly wash up on Sydney's beaches and can cause painful stings to swimmers.

Examine **the preserved *Physalia* specimen and identify**

the dactlyozoid and
the gastrozoid.

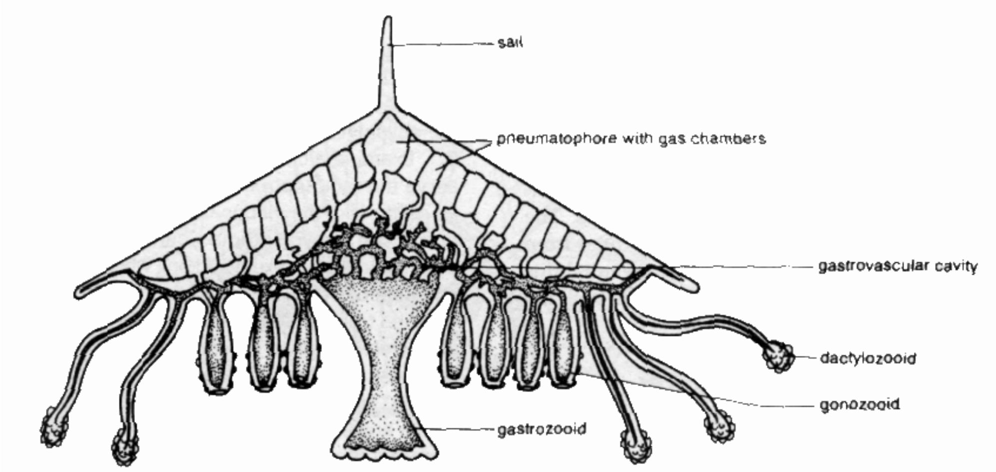
Note in particular the large nematocysts on the dactylozoids.

What class do these organisms belong to?

By-the-wind sailor, *Velella*
This is another pelagic hydroid that you may see washed up on local beaches.
Identity

the sail,
the gastrozooid,
the gonozooid and
the dactylozooids.

What are the benefits of dispersing with the wind?



From Wallace & Taylor 2003

Scyphozoans

These are the familiar jellyfish that occur the oceans worldwide.
The dominant body form is the medusa.

Examine the preserved specimens. Identify and describe the position of the mouth, the oral arms, and the tentacles.

How do jellyfish move in the water column given that they have no skeleton for muscles to act against?

How do they maintain their buoyancy?

What sensory abilities do they possess?

Sea anemones

Actinia tenebrosa is an abundant anemone on intertidal rocky platforms in south-eastern Australia.

Examine and sketch the specimen of *Actinia*.

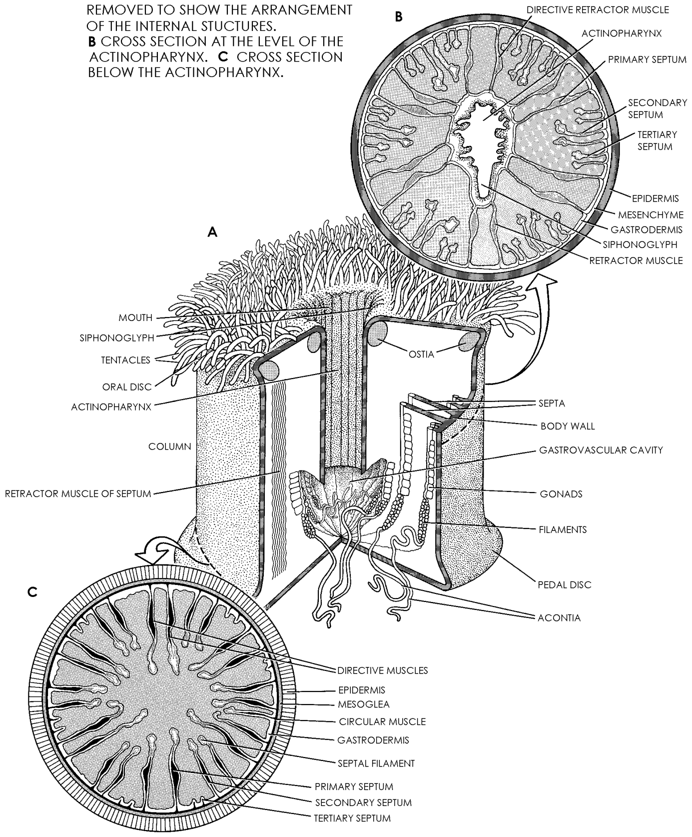
Notice the general body shape, the tentacles, oral disc.

The mouth opens into the gastrovascular cavity via a tubular pharynx. The mouth may be differentiated at one, two or three places to form ciliated grooves, the siphonoglyphs, which run down the length of the pharynx.

Examine the prepared slide of TS and LS the sea anemone *Metridium*.

Take particular note of the arrangement of the mesenteries.

Make a drawing of the TS only.



METRIDIUM. **A** ADULT WITH SECTION REMOVED TO SHOW THE ARRANGEMENT OF THE INTERNAL STUCTURES. **B** CROSS SECTION AT THE LEVEL OF THE ACTINOPHARYNX. **C** CROSS SECTION BELOW THE ACTINOPHARYNX.

Calcification in the cnidarians
Internal skeletons of calcium carbonate occur in the hard corals and in one group of hydrozoans (Order Milleporina).

Examine the skeletons provided and take note the variety of shape and form.

Consider and describe the relationship of the skeleton to the living polyps.

What is the ecological importance of this ability to secrete calcium carbonate?

Why is ocean acidification due to increased atmospheric CO_2 a problem for coral reefs?

Feeding Modes

Sponges are sessile filter feeders. The cavities within the body are lined with specialised cells possessing flagella called choanocytes.

Water flow within sponges

Examine the animation of sponge structure and water flow within sponges.

Make a diagram that summarises the patterns of water flow.

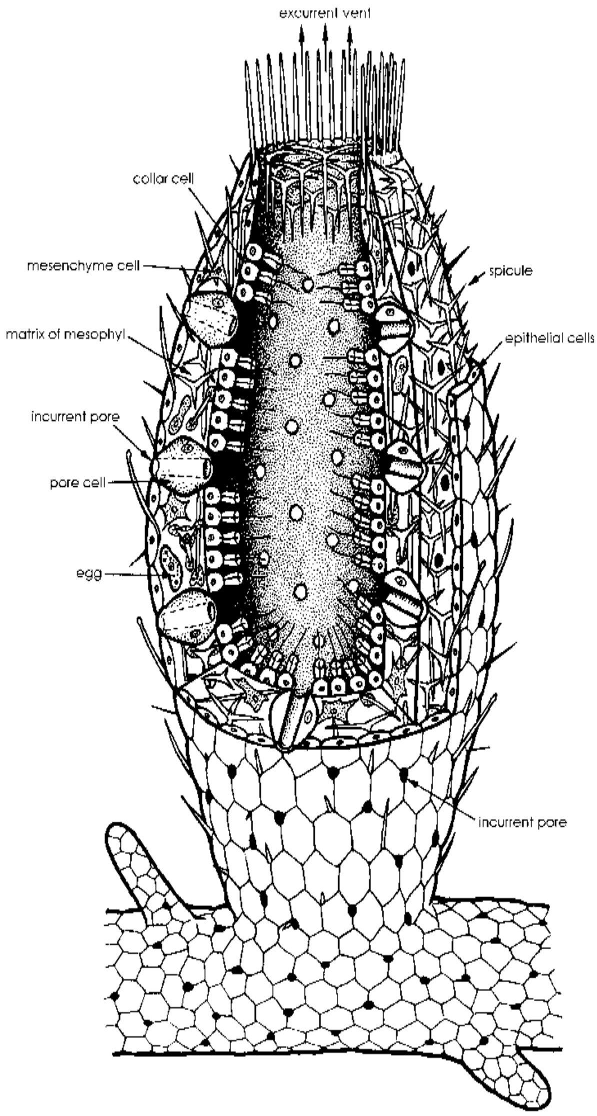


Diagram of a **simple sponge**.

Cnidarians have a mouth and an internal cavity, but no anus, for the digestion of food (gastrovascular cavity), **Make a drawing of the Cnidarian polyp body structure**

Refer to your illustrations and makes notes to understand how cnidarians feed.

Nematocysts

Nematocysts are stinging cells characteristic of the Cnidaria.

What is the function of nematocysts?

What is the mode of action of the toxins?

Photosynthesis by symbionts
Many cnidarians are reliant on photosynthesis by symbiotic microalgae.

Which of the cnidarians groups support these symbionts?

Where do the symbionts live?

Why are extreme temperatures problematic for coral reefs?

Reproduction and development

Sexual reproduction in sponges results in the production of a free-swimming flagellated larva. Eventually the larva undergoes metamorphosis and becomes a sedentary adult. Freshwater sponges and some marine forms also reproduce asexually by means of gemmules. These are highly resistant structures from which sponge cells emerge when conditions are favourable.

Sponge reproduction

Examine the demonstration slide of *Grantia* larvae which shows the larvae in the lumen of the flagellated chambers within the sponge.

Examine the slides of gemmules.

Make a labelled diagram illustrating sexual and asexual reproduction in sponges.

Cnidarians may reproduce asexually and/or sexually. Asexual processes involve the addition of polyps in colonial forms, and budding. Sexual processes usually involve the production of larvae (planula) and alternation between polypoid and medusoid body forms.

Reproduction in anthozoans

Anthozoans lack the medusa stage, with polyps producing gametes that fuse to become a planula larva. These larvae then settle on the substrate to form a new anemone or coral colony.

What is the importance of dispersive larvae for sessile invertebrates?

Why are corals often involved in mass spawning events?

Invertebrate research at UNSW

Restoring sponge communities

Johnston, EL and GF Clark. 2007. Recipient environment more important than community composition in determining the success of an experimental sponge transplant. *Restoration Ecology* 15: 638–651.

Genomics of bacteria living in sponges

Thomas, T., D Rusch., MZ DeMaere., PY Yung., M Lewis., A Halpern, KB Heidelberg, S Egan, PD Steinberg & S Kjelleberg. 2010. Functional genomic signatures of sponge bacteria reveal unique and shared features of symbiosis. *The ISME Journal* 4: 1557-1567.

Threats to coral reefs from ocean acidification

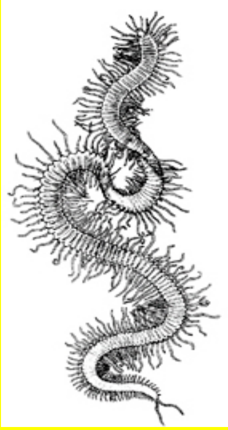
Shaw, EC, BI McNeil, B Tilbrook, R Matear & ML Bates. 2013. Anthropogenic changes to seawater buffer capacity combined with natural reef metabolism induce extreme future coral reef CO_2 conditions. *Global Change Biology* 19: 1632–1641.

Identifying the chemical cues for larval settlement

Tebben, J, D Tapiolas, C Motti, D Abrego, A Negri, L Negri, PD Steinberg & T Harder 2011. Induction of larval metamorphosis of the coral *Acropora millepora* by tetrabromopyrrole isolated from a *Pseudoalteromonas* bacterium. *PLoS ONE* 6: e19082.

<u>WORMS</u>

And when the doctor said I didn't have worms any more, that was the happiest day of my life.
Ralph Wiggum in the Simpsons



There are at least ten phyla of unrelated invertebrates that are commonly called worms. We will consider the three most diverse and abundant phyla of worm-like animals: flatworms, nematodes and annelids.

Diversity

The **platyhelminths** (Phylum Platyhelminthes, ~10000 species, *platy*, flat; *helmin*, worm, Gk) are a large group of free-living and parasitic worms. They are bilaterally symmetrical, dorsoventrally flattened and show signs of cephalisation (many have eyespots and chemoreceptive organs at the anterior end). They range in size from < 1 mm to 15 m.

Phylum	Class	Common names
Platyhelminthes	**Turbellaria**	**flatworms**
	Monogenea	**flukes**
	Trematoda	**flukes**
	Cestoda	**tapeworms**
Nematoda		**nematodes, roundworms**

Class Turbellaria. Mostly free-living flatworms with ciliated epidermis. Marine, freshwater and terrestrial.
Class Monogenea. Small ectoparasites of vertebrates (especially fish). An attachment organ at the posterior end.
Class Trematoda. Leaf to worm-like endo- and ectoparasites with ventral attachment structures.
Class Cestoda. Elongate endoparasites of vertebrates with anterior attachment structure (scolex).

Platyhelminth diversity
Examine representatives of each class listed above from the display.
Make a table with the diagnostic characters of each class.

Examine the living turbellarians on display.
Take particular note of their mode of locomotion.

Is there an anterior end?

How do they move?

The **roundworms** (Phylum **Nematoda**, 25000 spp. - *nema*, a thread, Gk) are unsegmented worms which lack appendages. They are elongate and cylindrical. They include free-living and parasitic species and are extremely abundant in nearly all terrestrial, marine and freshwater habitats. One study found 90000 nematodes in a single rotting apple!

Living nematodes

Examine a drop of the culture of *Rhabditis aceti* from the screen shown from under the microscope.

Note particularly the mode of locomotion, in relation to the longitudinal muscles, in comparison to that you may have seen in an earthworm (which has circular and longitudinal muscles).

Where does this organism live?

The **annelids** (Phylum **Annelida**, 16500 spp., *annulatus*, ringed, Gk) are segmented worms that occur in terrestrial, marine and freshwater environments. They are particularly abundant in terrestrial (earthworms) and marine (polychaetes) sediments. The leeches are ectoparasites of vertebrates and invertebrates. They range in size from minute members of the meiofauna to giant earthworms greater than 3 m.

Phylum	Class	Subclass	Common names
Annelida	**Polychaeta**		**bristleworms**
	Clittelata	**Oligochaeta**	**earthworms**
		Hirudinea	**leeches**

Class Polychaeta. Free-living or tube-dwelling worms that may be distinguished from the other annelids by the presence of paired, fleshy appendages called parapodia. These protrude laterally from each segment and bear chaetae (bristles). Predominantly marine.

Class Clitellata. Segmented worms lacking parapodia and with greatly reduced chaetae.

Subclass Oligochaeta. Comprises the earthworms and many species of freshwater worms (a few are marine). They lack parapodia and the chaetae are fewer in number and often smaller than in the polychaetes. Adult earthworms have a glandular clitellum which wholly or partly surrounds several segments.

Subclass Hirudinea. These worms lack both chaetae and parapodia. They have two suckers; an anterior one which surrounds the mouth and another at the posterior end. They also differ from oligochaetes and polychaetes in having the coelom largely filled with cells (botryoidal tissue).

Polychaete diversity

REVIEW the live and preserved polychaetes and make notes and/or sketches that illustrate the diversity of body shapes, tubes (if present) and life styles.

In what habitats would you find mobile vs. sedentary polychaetes?

Structure

While all have a worm-like body, **the three phyla we consider today are fundamentally different in the organisation of their tissues**.

External structures Review, examine and illustrate a preserved tapeworm.

Notice that the body is made up of a linear series of proglottids that become progressively larger posteriorly.

The anterior end of the animal consists of a microscopic scolex which bears hooks and/or suckers.

Are there any obvious sense organs?

Where are the youngest proglottids found?

Why don’t we classify tapeworms with the segmented worms (Phylum Annelida)?

Examine the external features of the live and/or preserved earthworms.

Identify the mouth, anus, dorsal and ventral surfaces, clitellum, openings of reproductive organs and sperm grooves. **Locate the setae; how many are on each segment? Make a labelled drawing of these features.**

Examine a whole mount of a leech and **identify the anterior and posterior suckers, dorsal eyes, gut with caeca to store blood and reproductive organs**.

The segmentation is usually obscured and the annuli which can be seen on the surface are not segments. Note that there are several annuli per segment.

Make a labelled diagram of a leech that includes the diagnostic features of this subclass. List how leeches differ from flukes?

Body layers

Platyhelminthes have a solid body construction with no body cavity (i.e., they are acoelomate). They have well developed organ systems derived from the three tissue layers.

Nematodes possess a pseudocoel, a cavity between the gut and body wall which is not lined with mesoderm tissue.

The annelids have a true coelom.

Examine the TS specimen through 3 regions of a freshwater turbellarian.

Note the epidermis, the gastrovascular cavity, circular and longitudinal muscle.

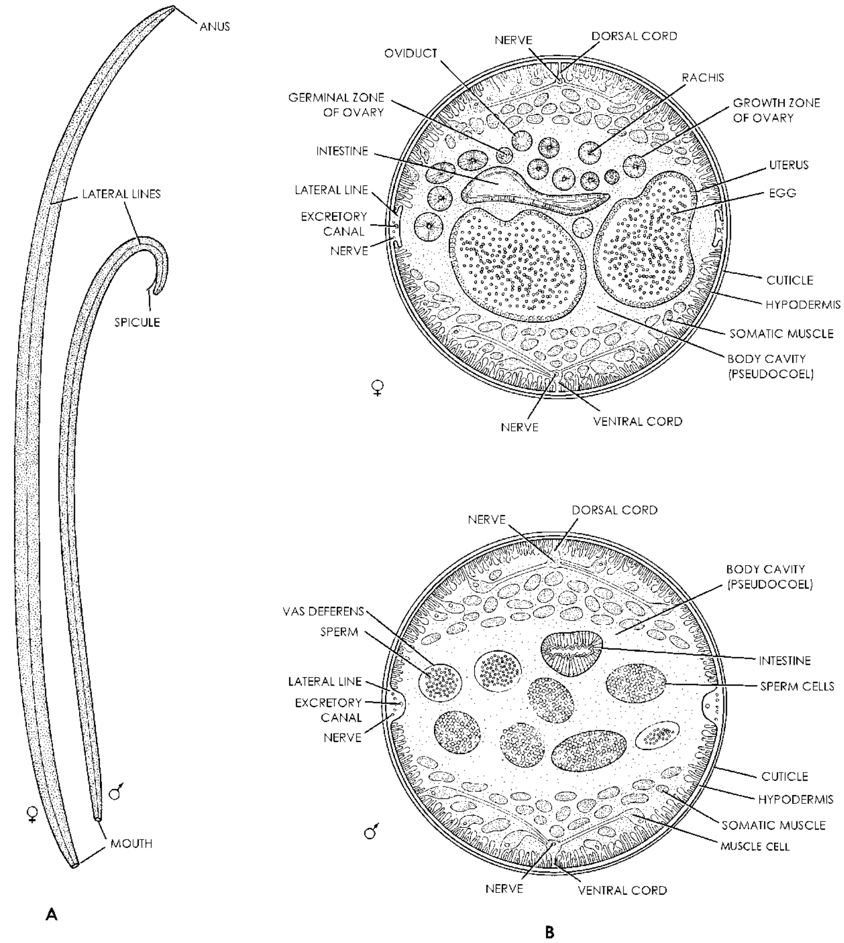
Examine the prepared TS of male and female specimens of the nematode *Ascaris*.

Make illustrations that would allow you to identify the body layers, digestive systems and reproductive organs.

How does the internal structure of flatworms, nematodes and earthworms differ?

Examine the prepared slides of the TS from an earthworm, a polychaete and a leech.

Identify the circular muscle layer, longitudinal muscle layer or blocks, and transverse muscle (leech only).



ASCARIS. **A** MALE AND FEMALE WORMS. **B** CROSS SECTION OF A MALE AND FEMALE WORM.

Locomotion in annelids

The musculature of annelid body walls consists of an outer layer of circular muscle and an inner layer of longitudinally arranged fibres. A rigid skeleton is absent and instead the coelomic fluid is used as the basis of a hydrostatic skeleton

Examine the locomotion of the live annelids available in the recording from the laboratory.

Leeches can move by looping and swimming - observe these two patterns of locomotion.

Illustrate the looping pattern

Illustrate the swimming pattern

Examine the computer animation of earthworm and polychaete locomotion.

How do annelids move?

With reference to the arrangement of their muscles, how does their locomotion differ from that of nematodes?

Digestive, circulatory and nervous systems

Examine prepared display slides of the Chinese liver fluke *Opisthorchis sinensis* (Trematoda).

Illustrate and identify the anterior sucker, mouth, pharynx, oesophagus, intestine, intestinal caeca, testes, sperm ducts (vasa deferentia), seminal vesicle, genital pore, vitelline glands (along each side of body), oviduct, ovary, shell gland, uterus, genital pore.

How has the body been modified for a parasitic lifestyle?

Annelids have a large fluid filled cavity between the musculature of the gut and body (the coelom). The nerve cord is ventral lying under the gut.

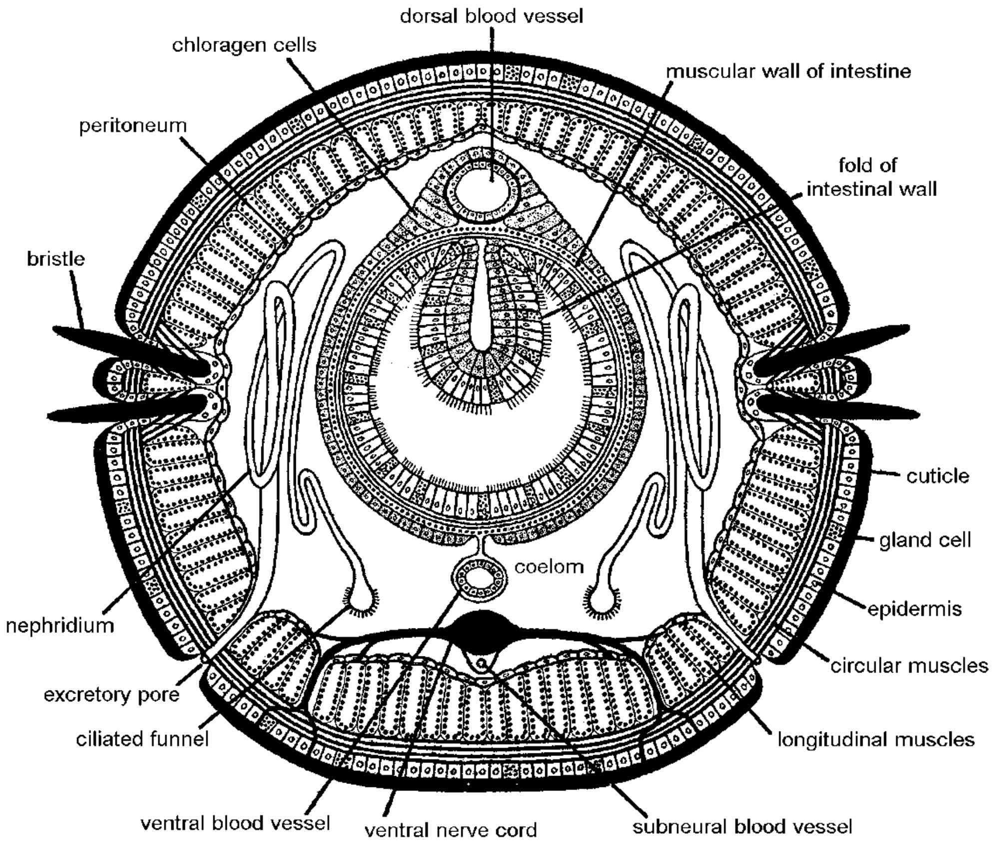
Examine the prepared slides of transverse sections through

a polychaete

an oligochaete

a leech.

Identify the following structures: cuticle, epidermis, coelom (botryoidal tissue in leech), gut and gut musculature, typhlosole (in intestinal sections), dorsal, ventral and subneural blood vessels, ventral nerve cord and giant fibres, nephridia.



Cross-section of the earthworm.

Feeding

Predatory worms

Free-living turbellarians are usually predatory.

What do they eat?

How do they digest food without an anus?

Parasitic worms
The flukes and tapeworms (Classes Monogenea, Trematoda and Cestoda) are exclusively parasitic.

List the major modifications of

- body shape
- digestive system
- sensory systems

associated with a parasitic mode of life.

How do these parasites gain their nutrition?

How do tapeworms avoid being digested?

Which human diseases result from platyhelminth infection?

Leeches are well known ectoparasites of vertebrates. Other members of this subclass are predators or scavengers on small invertebrates.

What structures are associated with parasitism in leeches?

What similarities exist between leeches and parasitic worms in other phyla?

Why have leeches been used in human medicine?

Why do leech bites itch?

Deposit feeding
Oligochaetes and polychaetes include many species that consume soils and sediments to extract their organic content.
What morphology and life style is associated with deposit feeding?

Filter-feeding polychaetes
Many species of marine polychaetes are filter feeders – extracting organic material from the water column. Examine the examples of filter-feeding polychaetes.
What structures are modified for this mode of feeding?

Reproduction and Development

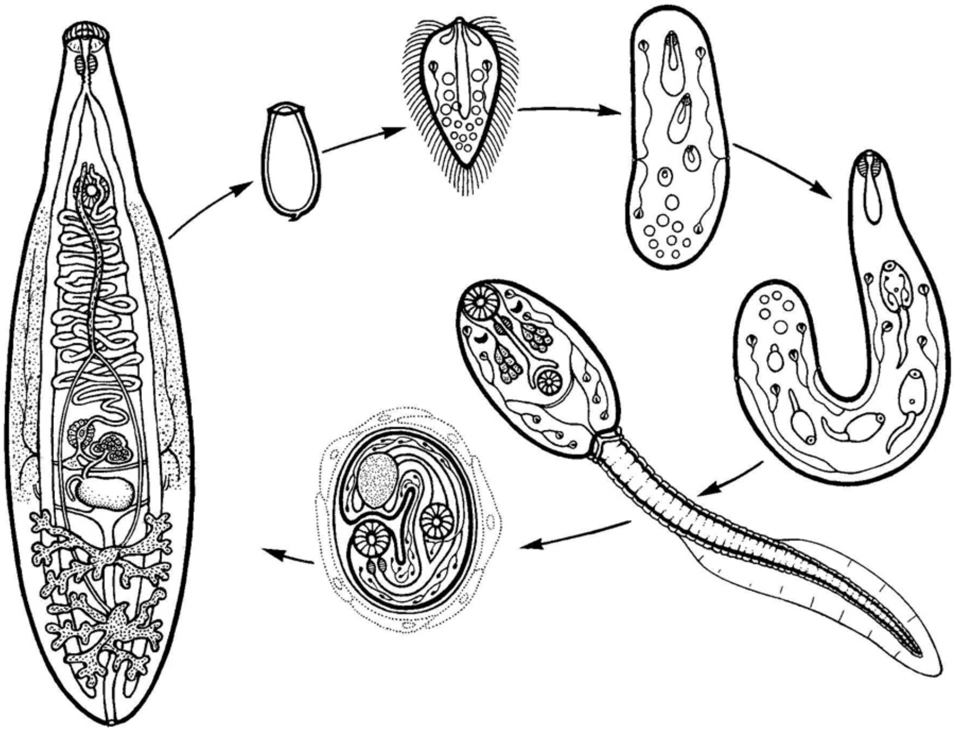
Many parasitic platyhelminths have complex life histories with several different life history stages that may occur in several different hosts.

Fluke life histories
The typical life cycle of endoparasitic trematodes involves several hosts. The definitive host, harbours the adult worms. Eggs from the adults leave the definitive host and hatch on reaching water to give a free-living, swimming, ciliated embryo, the miracidium, which locates and enters an intermediate molluscan host. Within this host it undergoes extensive asexual reproduction via the stages of sporocyst and rediae to produce numerous cercariae, which then emerge from the snail. Cercariae are free-living, swimming larvae, which locate and enter either a second intermediate host or the definitive host to complete the cycle.

Create an illustrated life history diagram of a typical fluke by examination of slides of the redia, cercaria, metacercaria and sporocyst.

Include notes on where each stage is likely to be found. How are the stages transferred among hosts?

Watch the *Schistosoma* life history animation on the computer



Life cycle of a trematode

Make your own notes on how the different stages occupy hosts and host tissues:

Tape worm reproduction display

Examine the slides of mature and gravid proglottids of *Taenia* and **identify the main features of the reproductive organs.**

Examine the demonstration slide of hydatid cyst of *Echinococcus* and **identify the cyst wall and daughter cysts.**

Look also at the museum specimens of hydatid cysts embedded in a liver.

Sketch the demonstration slide of the *Echinococcu*s.

How can humans become infected with hydatids?

Annelid life histories

Polychaetes are predominantly dioecious, and have external fertilisation followed by larval stage known as a trochophore.

In contrast, the earthworms and leeches (Class Clittelata) are hermaphrodites with direct development.

Examine the prepared slide of a trochophore larva. Make a life history diagram of a typical marine polychaete.

For an the earthworm, make a life history diagram that includes details of how these worms mate and how offspring are produced.

Invertebrate research at UNSW

Contaminant effects on filter feeders

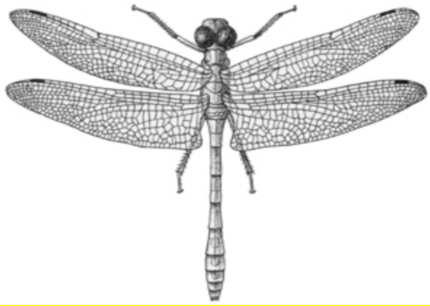
Hill, NA, CK King, LA Perrett and EL Johnston. 2009. Contaminated suspended sediments toxic to an Antarctic filter feeder: Aqueous- and particulate-phase effects. *Environmental Toxicology and Chemistry* 28: 409–417.

Bird dispersal of freshwater nematodes

Green, AJ, KM Jenkins, D Bell., PJ Morris and RT Kingsford. 2008. The potential role of waterbirds in dispersing invertebrates and plants in arid Australia. *Freshwater Biology* 53: 380–392.

INSECTA

Time flies like an arrow, fruit flies like a banana.
Groucho Marx



In this and the **following three practicals we will consider the most diverse of all the animal phyla, the arthropods** (Phylum Arthropoda, *arthro*, jointed; *pod*, foot). There are well over 1 million described species of arthropods – about 85% of all described species – in every conceivable habitat. Estimates for numbers of undescribed species are as high as 100 million species!

Diversity

Before we consider the arthropods, we will briefly consider the two phyla that are the **most closely related to the arthropods**.

These are the **velvet worms** (**Phylum Onychophora**, 110 spp., *onchyo*, talon; *phora*, bearer, Gk) and the **tardigrades** (**Phylum Tardigrada**, 800 spp, *tardus*, slow; *gradus*, step, Gk).

Phylum	Subphylum	Class	Order	Common names
Onychophora				velvet worms
Tardigrada				water bears
Arthropoda	Hexapoda	Entognatha	Collembola	springtails
			Protura	proturans
			Diplura	diplurans
		Insecta		insects

Phylum Onychophora. Segmented animals with features shared by both annelids and arthropods. Occur in moist terrestrial habitats. 5 mm – 15 cm

Phylum Tardigrada. Tiny animals with short cylindrical bodies, four pairs of non-jointed legs. Occur in aquatic or moist terrestrial habitats

Phylum Arthropoda. Subphylum Hexapoda. Arthropods with three body segments (head, thorax, abdomen), single pair of antennae, three sets of mouthparts (mandibles, maxillae and labium), three pairs of thoracic limbs and a gas exchange system of trachea and spiracles.

Velvet worms and water bears

Examine the preserved specimens, slides displayed on the screens and illustrations provided of these two unusual phyla related to ancestral arthropods.

In what habitats would you be likely to see onychophorans?

What attributes are worm-like and what attributes are arthropod like?

Tardigrades are well known for their ability to withstand extreme conditions. They may undergo **cryptobiosis**.

What is this and why would it be useful for these organisms?

Springtails

The **subphylum Hexapoda** (*hex*, six; *pod*, foot) includes the most familiar arthropods – the insects – along with some small, less familiar groups. Of these, you are most likely to encounter the springtails (Order Collembola, 6000 spp.).

Examine the live springtails on display and observe their movement.
Examine a preserved specimen, or slides, and **identify the furcula (springing organ)**.

In what habitats are springtails commonly found?

What do they eat?

Why aren't they insects?

Class	Subclass	Order	Common names
Insecta	Archaeognatha	Archaeognatha	bristletails
	Zygentoma	Thysanura	silverfish
	Pterygota	Ephemeroptera	mayflies
		Odonata	dragonflies, damselflies
		Plecoptera	stoneflies
		Blattodea	cockroaches
		Isoptera	termites
		Mantodea	mantids
		Phasmida	stick insects
		Dermaptera	earwigs
		Orthoptera	grasshoppers, crickets, katydids
		Phthiraptera	lice
		Thysanoptera	thrips
		Hemiptera	aphids, cicadas, ‘true’ bugs
		Neuroptera	lacewings
		Coleoptera	beetles
		Siphonaptera	fleas
		Diptera	‘true’ flies
		Trichoptera	caddisflies
		Lepidoptera	butterflies, moths
		Hymenoptera	bees, wasps, ants, sawflies

Subclasses Archaeognatha and Zygentoma. Primitive wingless insects.

Subclass Pterygota. Insects with paired wings (may be secondarily lost or modified in some taxa).

The recognisable groups of insects are primarily orders – many of these you know already (e.g., beetles, flies, butterflies, grasshoppers).

Research these orders to become familiar with the different body structures

Insect diversity

Examine the range of preserved specimens from various orders in the insect display.

Make notes and drawings of representative specimens from <u>five orders</u>.
Include the diagnostic characters for each order selected

What are the Big 5 insect orders in terms of species richness?

1.
2.
3.
4.
5.

Structure

Body segmentation

The insects are characterised by having a body divided into three regions:

the head, thorax and abdomen

Label the body segments in the 5 drawings you have completed in the page above

Diversity of limb function

Arthropods are defined by the presence of their jointed limbs. These limbs serve a wide variety of functions and have been heavily modified in some species.

Using online content, MOODLE, and the displays available make notes and diagrams that illustrate the diversity of limb function in the following:

foreleg in a praying mantis

foreleg of an ant

hindleg of a water beetle

foreleg of a mole cricket

hindleg of a grasshopper

hindleg of a honey bee.

Flight

Insects were the first flying animals and the only invertebrate group with the ability to fly.Most insects have two pairs of wings attached to the thorax.

Examine the wing structure in a butterfly, a dragonfly, and fly and a beetle.
How have the wings been modified in the true flies and in beetles?

What are the advantages of flight?

Is the absence of wings on fleas and lice a primitive or derived trait?

Have wings evolved only once in insects?

Sensory organs

Using the display on screen from the laboratory dissecting microscope, examine and make notes on the:

the compound eye of a dragonfly

the ocelli of a cicada.

Would you expect dragonflies to have good vision?

What is an ommatidium?

What is the function of the ocelli?

Respiration in terrestrial environments

Insects respire through tiny tubes that are invaginations of the body wall (the tracheal system).

Examine the larva of the curl grub for the opening to this system (the spiracles).

Why aren't there beetles weighing 10 kg or butterflies with 2 m wingspans?

Respiration in aquatic environments

Many insects have aquatic larvae which retain the air-filled tracheal system. The system, however, is sealed to prevent flooding and gas exchange occurs between the air in the tracheae and the water. To facilitate this the animals have tracheal gills, usually outgrowths of the body wall with a very thin cuticle and a rich supply of tracheal tubes.

Examine and make notes on the respiratory structures in the larvae of one of the following specimens

stoneflies,

mayflies, or

dragonflies.

What are some of the other ways in which insects respire underwater (e.g., water scorpions, diving beetles)?

Feeding- Insect mouthparts

Insect heads support the following paired structures:

1. **compound eyes and ocelli**
2. **antennae**
3. **labrum ("upper lip")**
4. **mandibles**
5. **maxillae**
6. **labium**

Examine and illustrate, the large models of the heads of either

butterfly (O. Lepidoptera),
cockroach (O. Blattodea),
mosquito (O. Diptera)

and identify each the structures listed above.

Define homologous.

Herbivorous insects
A large proportion of insects are herbivores, feeding on plant material in various ways.
Examine the mode of feeding and mouthparts of ONE the following herbivores: a scale insect, an aphid, a beetle, and a caterpillar.

Insect ectoparasites

There would be few humans that have not been food for insects at some time during their lifetimes.

Which insect orders include species that are external parasites of vertebrates?

Examine the whole mount of a flea.
What are the diagnostic characters of this order?

How do they feed?

Reproduction - structures

Insects are dioecious (sexes on separate individuals) and most are oviparous (egg laying). The gonads are simple paired structures with a single opening.

Examine the illustrations and/or demonstration of the generalised male and female internal reproductive structures.

Identify and note the function of the following structures: ovary, spermathecae, accessory glands, oviduct, testis, seminal vesicle.

What external structures on the abdomen can be used to identify the sex of an insect?

Hemimetabolous development

Insects with hemimetabolous development (incomplete metamorphosis) hatch into juveniles that resemble the adults but lack wings and sexual structures. They then pass through a series of instars before reaching maturity.

Illustrate the developmental sequence in a selected insect that undergoes hemimetabolous development.

Provide an example of an insect order that has this form of development?

Holometabolous development

Insects with holometabolous development (complete metamorphosis) hatch into larvae with little resemblance to the adult form. The larval stage ends with pupation, followed by the pupal stage in which the insect is often immobile and housed in a protective cocoon. Ultimately the adult from emerges from the pupa.

Make notes and illustrations on the life histories of ONE following holometabolous insects: a fly (e.g, mosquito), a bee, or a butterfly.

What adult structures are lacking in these larvae?

Provide an example of an insect order that has this mode of development?

Parthenogenesis
Many insects are parthenogenetic – able to produce offspring in the absence of sex.

Examine the live aphids and look for winged vs non-winged individuals.
Describe the life history of aphids.

Invertebrate research at UNSW

Systematics, biodiversity and biology of true bugs

Cassis, GC & C Symonds. 2012. Systematic revision and phylogeny of the Australian myrmecomorphic seed bug genus *Daerlac* Signoret (Insecta: Heteroptera: Rhyparochromidae: Udeocorini). *Invertebrate Systematics* 26: 41–66.

Traumatic insemination in bugs

Tatarnic, NJ & G Cassis. 2010. Sexual coevolution in the traumatically inseminating plant bug genus *Coridromius. Journal of Evolutionary Biology* 23: 1321–1326.

Diet effects on sexual performance in flies

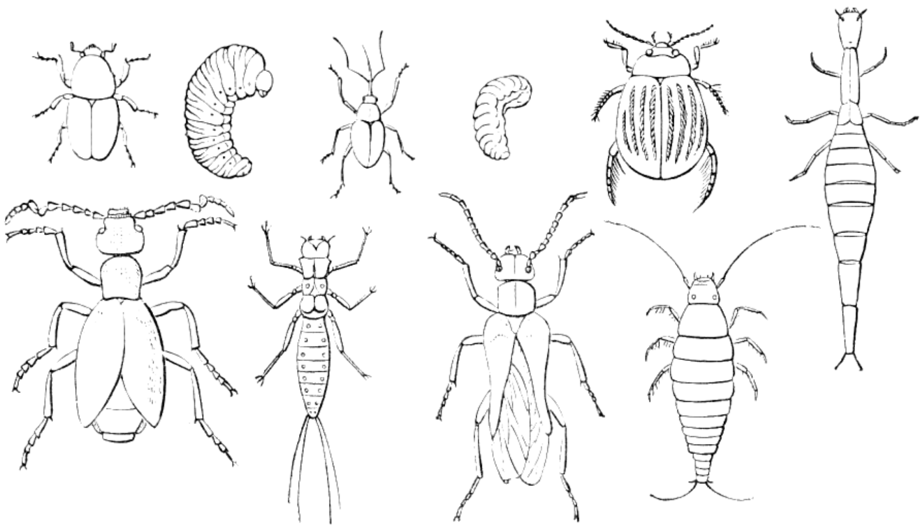
Sentinella, AT, AJ Crean and R Bonduriansky. 2013. Dietary protein mediates a trade-off between larval survival and the development of male secondary sexual traits. *Functional Ecology* 27: 1134-1144.

Evolution of aging in crickets

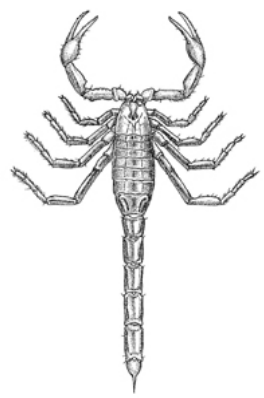
Lailvaux, SP, F Zajitschek, J Dessman & R Brooks. 2011. Differential aging of bite and jump performance in virgin and mated *Teleogryllus commodus* crickets. *Evolution* 65: 3138–3147.

Sex in stick insects

Burke, NW, A Crean & R Bonduriansky, 2015. The role of sexual conflict in the evolution of facultative parthenogenesis: a study on the spiny leaf stick insect. *Animal Behaviour*, 101: 117-127.



CHELICERATA AND MYRIAPODA



O, full of scorpions is my mind, dear wife!.
William Shakespeare in Macbeth

Diversity

The **chelicerates** (Phylum Arthropoda, Subphylum Chelicerata, 70,000+ spp., *cheli*, a claw; Gk) are a very large and mainly terrestrial group of arthropods (yet with a distinctive marine, evolutionary origin). The most diverse chelicerates are the familiar arachnids (spiders, scorpions etc).

The **centipedes and millipedes** (Phylum Arthropoda, Subphylum Myriapoda**,** 11460 spp. *myria*, numberless; *pod*, a foot, Gk) are terrestrial arthropods common in soil, among leaf litter and under rocks or logs.

Phylum	Subphylum	Class	Order	Common names
Arthropoda	**Chelicerata**	**Merostomata**	**Xiphosura**	**horseshoe crabs**
		Pycnogonida		**sea spiders**
		Arachnida	**Scorpiones**	**scorpions**
			Pseudo-scorpiones	**pseudoscorpions**
			Araneae	**spiders**
			Opiliones	**harvestmen**
			Acari	**mites, ticks**
	Myriapoda	**Chilopoda**		**centipedes**
		Diplopoda		**millipedes**

Subphylum Chelicerata. Arthropods with no antennae, six pairs of appendages: chelicerae, pedipalps and four pairs of walking legs.
Class Merostomata. Prosoma covered by large carapace, pedipalps like walking legs. Occur on marine soft sediments.
Class Pycnogonida. Greatly reduced body, proboscis. Exclusively marine.

Class Arachnida. Possess book lungs and or tracheae, chelicerae and pedipalps are modified as small feeding and/or reproductive limbs.

Subphylum Myriapoda. Arthropods with many uniramous appendages (> 3 pair of walking legs) and a single pair of antennae. Body is divided head and trunk regions. Have a tracheal system. Mandibles not jointed
Class Chilopoda. Long flattened bodies with one pair of legs per segment.
Class Diplopoda. Body often round in cross-section with each trunk segment bearing two pairs of legs.

Chelicerate diversity
Examine one specimen from 2 different orders listed above and make an illustration of each.

For each note, where can you expect to find this invertebrate?

What characters are most important for identifying chelicerates to the ordinal level?

Sea spiders

Examine the preserved pycnogonids (sea spiders) from Sydney Harbour.

Note the 4 walking limbs. The location of the chelicerae and pedipalps is vestigial, variable and/or uncertain! Reproductively mature specimens have a pair of ovigerous (egg carrying) limbs between the first walking limb and proboscis.

Make a labelled drawing that would distinguish these animals from real spiders.

What do these animals eat?

Structure. Chelicerate bodies are split into two parts:

- the prosoma (head/thorax) and
- the opisthosoma (abdomen).

They have six pairs of appendages:
1) the chelicerae (pre-oral),
2) pedipalps, and
3-6) walking limbs.

Horseshoe crabs.

Examine the preserved specimens of the horseshoe crab *Limulus*.

Note these are small individuals, adults reach "dinner plate" size.
Note the heavily calcified carapace which is hinged at the junction of prosoma and opisthosoma and which bears the eyes. On the ventral surface, note the pre-oral chelicerae, five pairs of walking legs on the prosoma and the book gills on the opisthosoma.
Which limbs are chelate?

Note the location of the chelicerae and "pedipalps" for comparison with the arachnids.

External structure of the arachnids – Display Specimens

Examine a large, preserved spider and **identify the following**;

eyes, prosoma, opisthosoma, chelicerae, pedipalps, walking legs (4 pairs), spiracles of lungs/tracheae, and spinnerets.

Examine a preserved scorpion and **identify**:

chelicerae, pedipalps (chelae), 4 pair walking legs, pectines (sensory appendages), spiracles of book lungs, sting on telson.

Examine a pseudoscorpion and **identity**:

chelicerae, pedipalps, 4 pair walking legs.

Note how the opithosoma differs from a scorpion.

Examine a specimen of a harvestman and note the extremely long slender legs and globular body.

Are both prosoma and opisthosoma visible?

Examine the whole mount of a mite and **identify**:

the body (prosoma and opisthosoma fused), chelicerae and pedipalps.

List how does the function of the chelicerae and pedipalps vary among the arachnid classes?

Myriapod structure

Examine the preserved and live centipedes and millipedes shown on screen with a binocular microscope.

Identify poison claws and spiracles in the centipedes.
Draw and illustrate the diagnostic features of each of these classes.

What four characters distinguish a millipede from a centipede?

1.

2.

3.

4.

What distinguishes them from the insects and chelicerates?

Feeding

The chelicerates are predominantly predators, with the exception of the order Acari which also includes many herbivorous and parasitic species. In the Myriapoda, centipedes are fast-moving predators, while the millipedes are slow moving herbivores or detritivores.

Silk and spider webs
Examine the webs built by the live spiders on display.
What external structures are involved in the preparation of these webs?

Briefly describe four different ways in which silk is used for prey capture.

1.

2.

3.

4.

Sensory systems
Arachnids usually have eight eyes. **Examine the eyes of a jumping spider.**

How and why do these differ from those of web-building spiders?

What is the function of the pectines in scorpions?

What other sensory systems are involved in prey capture in arachnids?

Parasitic mites and ticks

Examine the mouthparts of the tick and make a drawing.

What other structures or behaviours are associated with a parasitic way of life?

What diseases are carried by parasitic mites and ticks?

Reproduction and development

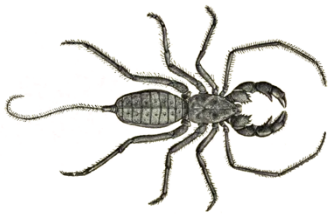
Arachnids are predominantly dioecious with direct development. With the exception of mites (which have a six-legged stage), offspring resemble the adult form.

Sexual dimorphism in spiders
Male and female spiders often differ greatly in size (e.g., orb-weavers).

From the specimens on display, **identify which external structures differ between the sexes**. **How are these structures used in mating?**

How do male spiders avoid being consumed by the female?

Readings- Invertebrate research at UNSW



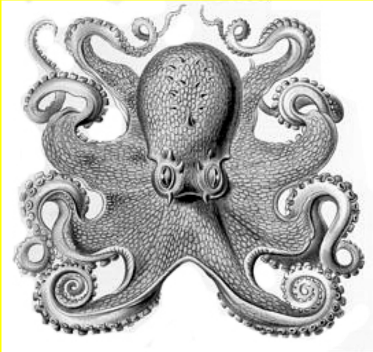
Courtship displays in peacock spiders
Girard MB, MM Kasumovic & DO Elias. 2011 Multi-modal courtship in the peacock spider, *Maratus volans* (O.P.-Cambridge, 1874). *PLoS ONE* 6(9): e25390.

Can small spiders still get the girl?
Kasumovic MM & F Seebacher. 2013 The active metabolic rate predicts a male spider's proximity to females and expected fitness. *Biology Letters* 9: 20121164.

Diet and pesticide effects on spider silk
Benamú, M., M Lacava, LF Garcia, M Santana, J Fang, X Wang, & SJ Blamires. 2017. Nanostructural and mechanical property changes in spider silk as a consequence of insecticide exposure. *Chemosphere* 181: 241-249.
Blamires, SJ, M Hasemore, PJ Martens & M Kasumovic. 2017. Diet-induced covariation between architectural and physicochemical plasticity in an extended phenotype. *Journal of Experimental Biology* 220: 876-884.

MOLLUSCA

I will not eat oysters. I want my food dead. Not sick. Not wounded. Dead. Woody Allen



Diversity

The molluscs (Phylum Mollusca, 93000 spp., *molluscus*, soft, L) include the familiar snails, slugs, clams, squid and octopus.
They are most abundant in a wide range of marine habitats, but there are also freshwater and terrestrial species.

Phylum	Class	Common names
Mollusca	Aplacophora	
	Polyplacophora	chitons
	Gastropoda	marine and terrestrial slugs and snails
	Bivalvia	clams, mussels etc.
	Scaphopoda	tusk shells
	Cephalopoda	squid, cuttlefish, octopus, nautilus

Class Aplacophora. Small, elongate, worm-like molluscs with terminal mouth and anus. Body surface with spicules.
Class Polyplacophora. Dorsoventrally flattened, littoral, molluscs covered dorsally with eight articulated shell plates.
Class Gastropoda. Asymmetrical molluscs with the body contained in a spirally coiled shell. Generally show torsion. Shell reduced or lost in some taxa. Note that many texts will divide the gastropods into three subclasses (Prosobranchia, Opisthobranchia and Pulmonata). These are no longer considered valid groupings.
Class Bivalvia. Bilaterally symmetrical molluscs with bivalved shells and reduced head.
Class Scaphopoda. Molluscs with a tapered tusk-shaped shell open at both ends. Head reduced and bearing tentacles.
Class Cephalopoda. Cephalisation marked, the head bearing well developed eyes and a number of tentacles. Foot is reduced and forms part of the siphon. Shell is reduced and internal, or absent, except in the nautiloids.

Mollusc diversity
Examine the live and preserved specimens available at your station and review the content available in moodle.

Make notes and diagrams that would allow you to identify of the following

a chiton

a gastropod

a bivalve

a cephalopod

Structure

Molluscs are morphologically diverse, ranging from minute snails to 20 m giant squid.
Describe the body features of Molluscs:

- **Unsegmented**

- **coelomate animals**

three distinct regions

- **head**
- **muscular foot**
- **and visceral hump**

Body regions: OBSERVE **several different live gastropod species** as they move across a glass plate (or watch them move on the side of an aquarium tank).

Observe and describe how contraction in the foot allows locomotion.

Mantle and mantle cavity: The mantle is a sheet of skin that covers the dorsal body wall. There is usually a cavity between the mantle and the visceral mass. This cavity holds the ctenidia (gills).

Using the diagrams and available specimens, make notes and drawings that indicate the number and position of the mantle cavity and ctenidia in

Chitons

prosobranch and pulmonate gastropods

bivalves

and cephalopods

Examine the computer animation of locomotion in the squid.

Contraction of the mantle tissue leads to what two important functions?

What modifications to the respiratory structures are seen in the terrestrial gastropods?

Shell structure: The external mantle secretes a calcareous shell in many species of molluscs. **Compare the structure of shells in:**

a chiton

the live gastropods,

bivalves

How does this shell structure relate to <u>habitat and lifestyle</u>?

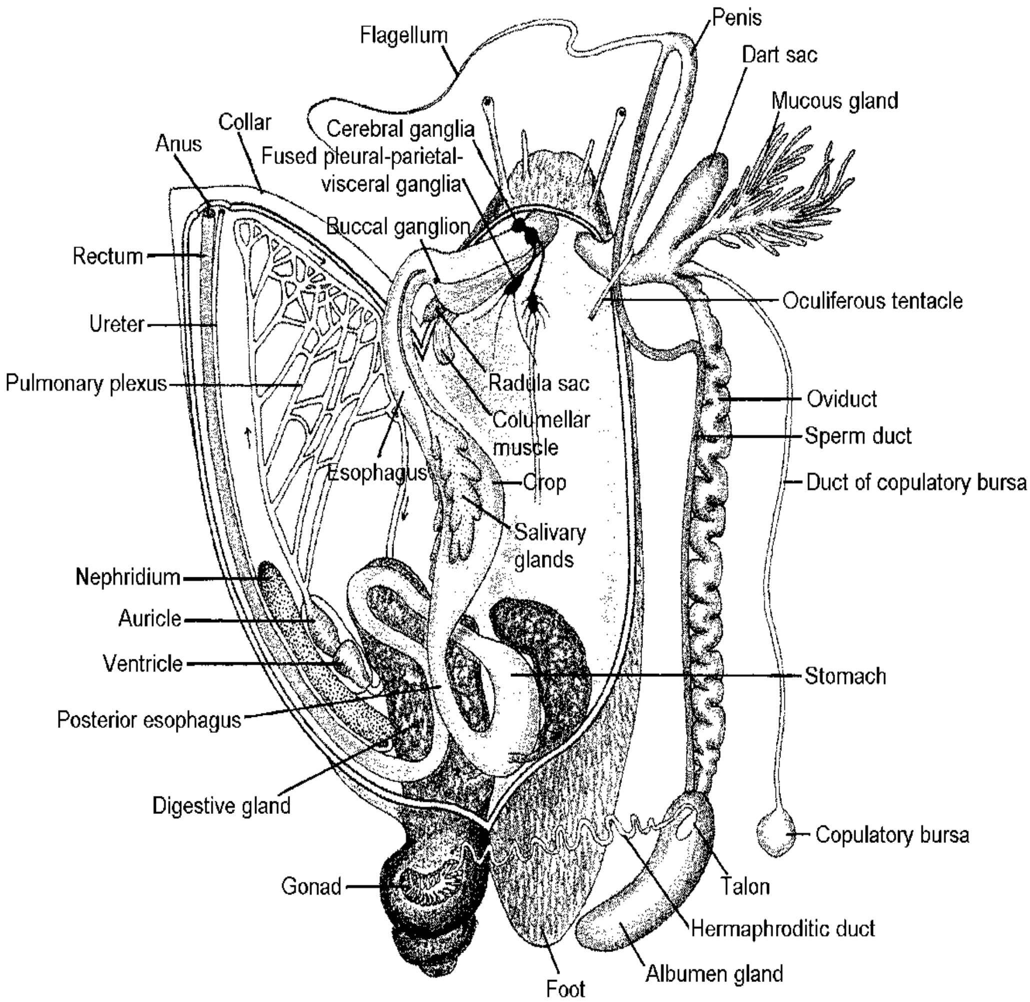
Gastropod internal structure
Examine the demonstration model of the garden snail, *Helix aspersa*.

Note the following external structures:

- **head which bears two pairs of tentacles, the anterior labial tentacles and the posterior ocular tentacles (eyestalks), and the mouth which is ventral**
- **the foot**
- **dextral shell**
- **collar which may project beyond the aperture of the shell in an expanded snail. The collar secretes the periostracum and prismatic layers of the shell. The respiratory aperture (pneumostome) is large and round and is found on the right side of the collar. The anus opens directly below the respiratory aperture and close above is the small excretory pore.**
- **common genital aperture near the base of the right eyestalk.**

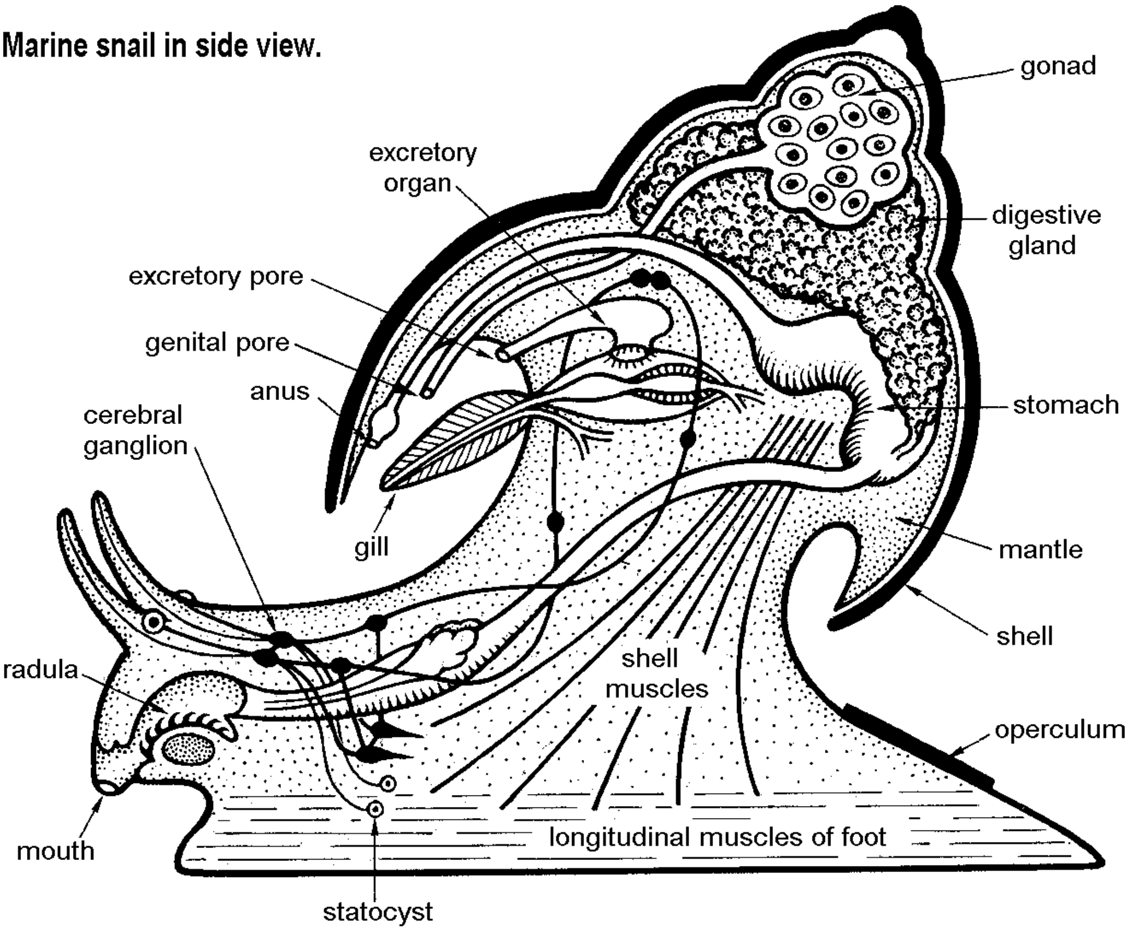
Note the location of the following internal structures:

- **triangular kidney**
- **the pericardium enclosing the two chambered heart**
- **lobes of the digestive gland**
- **buccal mass into which the mouth opens**
- **the short, narrow oesophagus - notice the cerebral ganglia**
- **the crop**
- **the large salivary glands which are attached to the crop but which discharge their secretion into the buccal cavity.**



Dissection of the land snail. *Helix.*

Marine snail in side view.



Feeding

Molluscs consume either large food particles (e.g., herbivorous and predatory gastropods) or remove tiny particles of organic material from the water column (e.g., suspension feeding bivalves).

Radulae. The molluscan radula is an important feeding organ which consists of an elongated cartilaginous odontophore (the base) over which is stretched a toothed belt (the radula proper). The radula displays a wide variety of forms which relate to the type of food eaten.

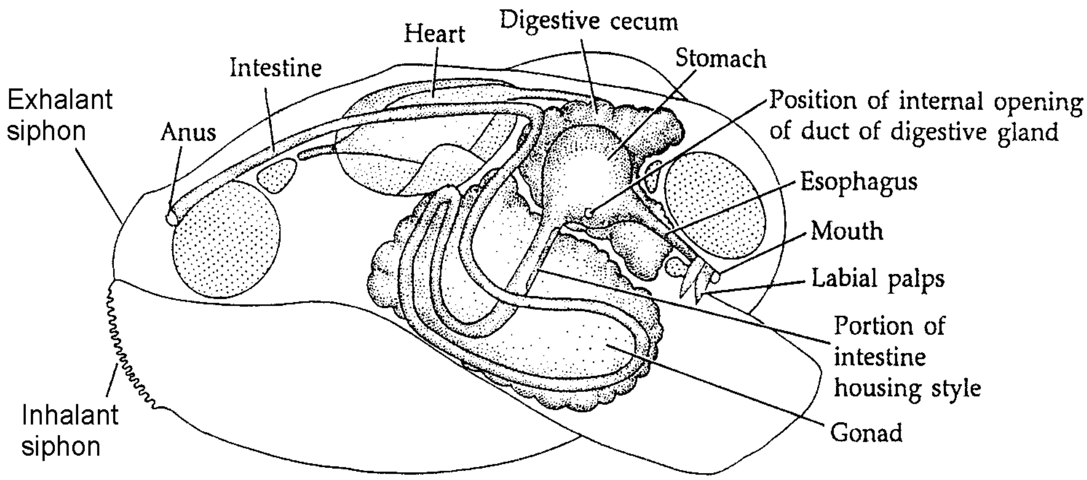
Examine and compare the prepared slides of a radula on the screen from

***Helix* (a terrestrial herbivore)**

***Cellana* (a marine limpet that scrapes rock to obtain microalgae).**

Suspension feeding in bivalves. Study the computer animations of water flow in a clam and filibranch bivalve.

Make notes and drawings that illustrate how suspension feeding bivalves are able to extract particles from the water column and transfer them to their digestive systems.



Heart
Digestive cecum
Stomach
Intestine
Exhalant siphon
Anus
Position of internal opening of duct of digestive gland
Esophagus
Mouth
Labial palps
Portion of intestine housing style
Gonad
Inhalant siphon

Reproduction and development

Ancestral molluscs were dioecious with paired gonads. Hermaphroditism has developed in some groups (e.g., garden snail) and the gastropods have lost one of the gonads.

Mollusc development may be **direct or involve two larval stages**.

The first larval stage is a free-swimming, ciliated, **trochophore**, similar to that of annelids, indicating a relationship between the phyla. The trochophore stage is followed by the more developed veliger larva of the gastropods and bivalves, with a foot and shell. This stage settles to the bottom as a young adult.

Prepare a life history diagram of a marine gastropod from OBSERVING the specimens and diagrams on display.

Invertebrate research at UNSW

Oysters as biomonitors

Edge, KJ, EL Johnston, AC Roach & AH Ringwood. 2012. Indicators of environmental stress: cellular biomarkers and reproductive responses in the Sydney rock oyster (*Saccostrea glomerata*) *Ecotoxicology* 21: 1415–1425.

Gall, ML, AGB Poore & EL Johnston. 2012. A biomonitor as a measure of an ecologically-significant fraction of metals in an industrialized harbour. *Journal of Environmental Monitoring* 14: 830–838.

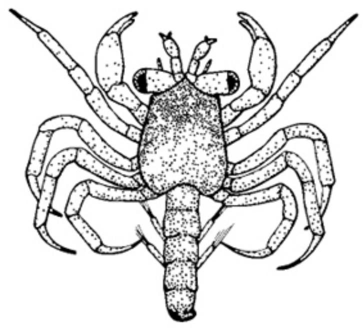
The importance of grazing molluscs in shaping marine environments

Poore, AGB, AH Campbell, RA Coleman, GJ Edgar, V Jormalainen, PL Reynolds, EE Sotka, JJ Stachowicz, RB Taylor, MA Vanderklift & JE Duffy. 2012. Global patterns in the impact of marine herbivores on benthic primary producers. *Ecology Letters* 15: 912–922.

Engineering urban marine structures to benefit oysters

Strain EM, RL Morris, RA Coleman, WF Figueira, PD Steinberg, EL Johnston &MJ Bishop. in press. Increasing microhabitat complexity on seawalls can reduce fish predation on native oysters. *Ecological Engineering*.

CRUSTACEA



As to the fauna, it might be counted by thousands of crustacea of all sorts, lobsters, crabs, spider-crabs, chameleon shrimps…
Jules Verne in 20000 Leagues under the sea.

Diversity

The Crustacea (Subphylum Crustacea, >67000 spp., *crust*, a crust or rind, L) is a large and primarily aquatic group of arthropods. They are predominantly marine, but some groups have successfully colonised freshwater and terrestrial habitats.

Subphylum	Class	Subclass	Order	Common names
Crustacea	**Branchiopoda**		**Anostraca**	**fairy shrimps**
			Notostraca	**tadpole shrimps**
			Cladocera	**water fleas**
	Malacostraca		**Stomatopoda**	**mantis shrimps**
			Amphipoda	**amphipods**
			Isopoda	**isopods, slaters**
			Euphausiacea	**krill**
			Decapoda	see next table
	Ostracoda			**ostracods**
	Maxillipoda	**Copepoda**		**copepods**
		Thecostraca		**barnacles**

Class Branchiopoda. Small freshwater and marine crustaceans with flattened limbs.
Class Malacostraca. This is a very large class containing most of the larger and more familiar crustaceans. Marine, freshwater and terrestrial forms. Share a 5-segmented cephalon, 8-segmented thorax (pereon), and 6-segmented abdomen (pleon).
Class Ostracoda. Small crustaceans enclosed in a bivalved carapace. Marine, freshwater and terrestrial forms**.**
Class Maxillopoda. Mostly small marine and freshwater crustaceans with shortened bodies and reduced number of limbs. Much variation on the basic body plan of 5 cephalic, 6 thoracic and 4 abdominal segments.

Order	Suborder	Infraorder	Common names
Decapoda	**Dendrobranchiata**		**prawns**
	Pleocyemata	**Caridea**	**shrimps**
		Astacidea	**crayfish, 'clawed' lobsters**
		Achelata	**spiny lobsters**
		Anomura	**hermit crabs, squat lobsters**
		Brachyura	**'true' crabs**

Crustacean diversity. The crustaceans are arguably the most difficult group that we cover in this course to fully understand. It is hard to see how a minute copepod or sessile barnacle can possibly be related to a large lobster.

Make notes and sketches from the range of preserved and live material at your station and on display, and video footage on the screen and available on moodle, so that you could identify each of the taxa by sight.

Can you identify some characteristics that define/differentiate each group ?

fairy shrimps

tadpole shrimps

water fleas

mantis shrimps

amphipods

isopods

krill

ostracods

copepods

Barnacles

Prawns

Shrimps

Crayfish

Lobsters

Spiny lobsters

Hermit crabs

Lobsters

‘True’ crabs

Structure

No group of plants and animals on the planet exhibit the range of morphological diversity seen among the extant Crustacea. Martin and Davis, 2001.

Body segmentation. The basic body plan of the crustacean is a head followed by a many-segmented trunk region.

The trunk region is usually divided into thoracic and abdominal regions.

The body may be covered by a

cephalic shield ***(write a definition)***

carapace ***(write a definition)***

Limb structure and function. Crustacean limbs are primitively biramous (two branches), typically with a pair on every segment. This basic plan has been heavily modified in most groups and limbs show a similar high diversity in function.

Illustrate examples of limbs that are biramous, and some that are secondarily uniramous.

From the live and/or preserved specimens that are available at your station make notes and drawings on an example of at least 2 of the following:

a walking limb

a swimming limb

a feeding limb

a respiratory appendage

Structure and function of crustacean antennae. The presence of two pairs of antennae is a diagnostic character of the crustaceans. While most have a sensory function, others have other functions.

What is the function of the cladoceran and copepod antennae?

Observe the antennae of the live crabs on the video footage.

Why do they continually flick their antennae?

Calcification of the exoskeleton. Crustacean exoskeletons are commonly strengthened by calcium carbonate.

Review the crustacean carapace provided at your station.

What crustacean do they come from and why?

Draw the body plan of the crustacean, labelling the identifiable body parts.

Once you have identified the crustacean place some broken pieces of the crustacean carapace provided into vinegar and observe the bubbles of CO_2 produced.

What are the benefits of calcification?

What structures would you expect to be most heavily calcified?

Feeding

there is a great diversity of feeding modes associated with the morphological diversity in the crustaceans.

Crustacean mouthparts

Several appendages from the head and thorax are involved in manipulating food.

In most cases, crustacean heads have five appendages:

1. **first antenna**
2. **second antenna**
3. **mandibles**
4. **first maxilla**
5. **second maxilla**

Appendages from the thorax – maxillipeds – may also be used.

In the **decapods, there are three maxillipeds**, with the remaining **five pairs of thoracic limbs giving 10 walking legs**.

What is the function of the mandibles?

Filter feeding

The barnacles are sessile filter feeding crustaceans common on marine hard substrates (natural and artificial).

Observe the feeding of the live barnacles provided.

Note how the two movable plates on the top of the animal open and the nature of the feeding movements.

What structures are used in capturing food particles?
Make a labelled drawing of the stalked barnacles illustrating the cirri, stalk and plates.

Parasitic crustaceans
There are parasitic species among the isopods, amphipods, copepods and barnacles.

Examine the preserved specimens of fish lice.

Note that these live within the pharynx or branchial chambers or on the outer surface of their fish hosts.

Identify - What order are these species in?

Reproduction and development.

Most major life history strategies are represented among the Crustacea. The sexes are usually separate, but some taxa are hermaphroditic. We will consider the reproduction and development of only a few representative groups.

Decapod life histories. In the decapods, only the dendrobranchiate prawns hatch as a nauplius. Hatching is delayed in most decapopds until after the nauplius stage is completed and the first larval stage is a protozoea or zoea.

Male and female crabs may be distinguished by the width of their abdomen. Fertilisation is internal and eggs are brooded by the female. Eggs hatch into a very distinctive zoea which then moults into a megalopa larva.

Make an illustrated life history diagram that outlines all the stages of crab reproduction and development.

In lobsters and in prawns the first stage is called a mysis. The spiny lobsters produce a remarkable phyllosoma larva which may be present in the plankton for 24 months. In freshwater decapods (e.g., the yabby) virtually all the larval stages occur in the egg and the offspring resemble their parents after hatching.

Barnacle life histories. Barnacles are hermaphrodites with internal fertilisation. The life history involves a nauplius and cypris stage.

Make an illustrated life history diagram that outlines all the stages of barnacle reproduction and development.

Why are they hermaphroditic?

Which stage selects the substrate for settlement?

Life histories of amphipods and isopods. Amphipods and isopods are very abundant in most marine habitats. They have direct development with eggs being brooded by the female and hatching into offspring that resemble their parents.

Why do we consider isopods to be pre-adapted for life on land?

Parthenogenetic crustaceans. Many cladocerans alternate between parthenogenetic and sexual reproduction. Sex is unknown in some groups of ostracods.

Observe the live water fleas on display and look for a female brooding offspring.

Draw illustrations of the body structure

Research and make notes on :
Why would parthenogenesis be advantageous for these species?

Invertebrate research at UNSW

Heavy metal pollution in Sydney Harbour

Roberts, DA, EL Johnston & AGB Poore. 2008. Biomonitors and the assessment of ecological impacts: Distribution of herbivorous epifauna in contaminated algal beds. *Environmental Pollution* 156: 489–503.

Tongue-biting parasitic isopods

Heagney, EC, BM Gillanders and IM Suthers. 2013 The effect of parasitism by a blood-feeding isopod on the otolith chemistry of host fish. *Marine & Freshwater Research* 64: 10–19.

Grazer impacts on giant kelps and seagrass beds

Poore, AGB, L Gutow, J Pantoja, F Tala, D Jofre Madariaga & M Thiel. 2014. Major consequences of minor damage: impacts of small grazers on fast growing kelps. *Oecologia* 174: 789-801.

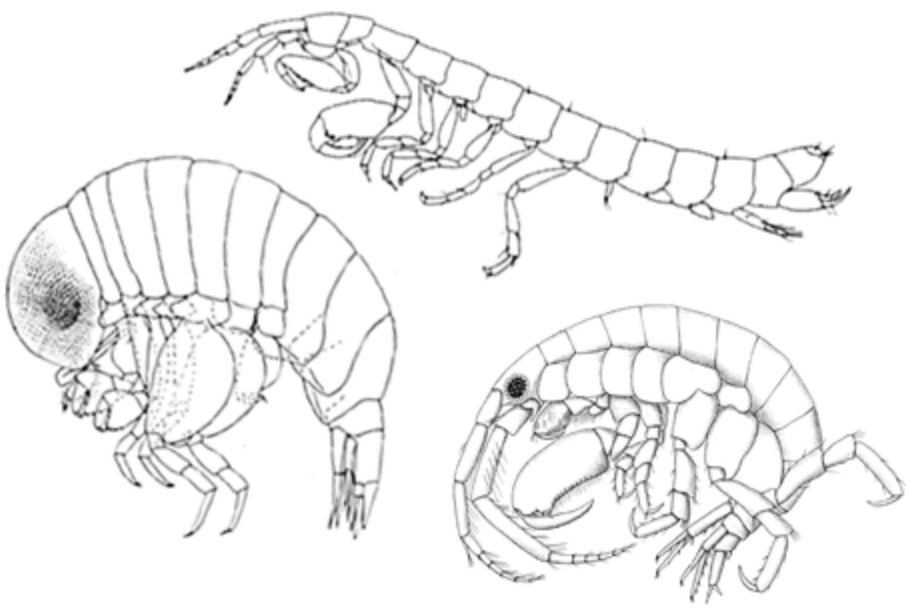
Cook, K, MA Vanderklift & AGB Poore, 2011. Strong effects of herbivorous amphipods on epiphyte biomass in a temperate seagrass meadow. *Marine Ecology Progress Series* 442: 263–269.

Surgery without stiches: biomaterials from crustacean shells

Foster, LJR & E Karsten. 2012. A chitosan based, laser activated thin film surgical adhesive, 'SurgiLux': preparation and demonstration. *Journal of Visual Experiments* (68): e3527.

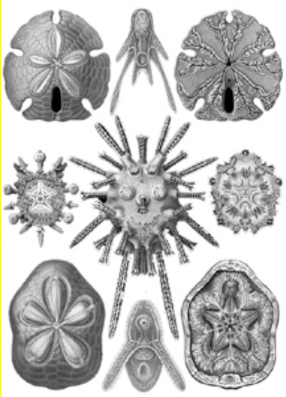
Effects of urbanisation on ghost crabs in Sydney

Stelling-Wood, TP, GF Clark & AGB Poore. 2016. Responses of ghost crabs to human modification of urban sandy beaches. *Marine Environmental Research* 116: 32-40.



ECHINODERMATA

We strolled a long way, and loaded ourselves with things that we thought curious, and put some stranded starfish carefully back into the water - I hardly know enough of the race at this moment to be quite certain whether they had reason to feel obliged to us for doing so, or the reverse.
Charles Dickens in David Copperfield.



Diversity

The echinoderms (Phylum Echinodermata, 7000 spp., *echino*, spiny; *demato*, skin; Gk) are an exclusively marine group of mostly benthic (bottom-living) animals (a few specialised sea cucumbers are pelagic).

Phylum	Class	Common names
Echinodermata	**Asteroidea**	**sea stars**
	Ophiuroidea	**brittle stars**
	Echinoidea	**sea urchins**
	Holothuroidea	**sea cucumbers**
	Crinoidea	**sea lilies**

Class Asteroidea. Star-shaped echinoderms. The body wall contains many ossicles and/or spines in a leathery dermis. The arms are wide and the coelomic cavity is spacious.

Class Ophiuroidea. The ophiuroids have five well defined arms radiating from a central disk. The ambulacra are closed and the coelom is reduced.

Class Echinoidea. Globose or flattened disc-like organisms without arms. There is a complete endoskeleton or test of fused ossicles, generally covered in spines.

Class Holothuroidea. Echinoderms without arms and elongated along the oral/aboral axis. The skeleton consists of microscopic spicules in a leathery integument and the oral podia are modified as tentacles.

Class Crinoidea. Primitive forms with body as calyx and oral surface uppermost. Arms with many pinnules.

Echinoderm diversity
Examine the live and preserved specimens in the display from a range of echinoderms.

Make notes and diagrams that would allow you to identify species of each of the five classes. List the diagnostic characters of each class.

What habitats are each of these groups found in?

Class Asteroidea

Class Ophiuroidea

Class Echinoidea

Class Holothuroidea

Class Crinoidea

Structure

Symmetry and body surfaces
The echinoderms are one of the few phyla that are **radially symmetrical**.

Which are the other phyla?

As such, we need some new terminology to apply to the body parts.

We refer to **oral surfaces which contain the mouth**, and
aboral surfaces on the opposing side.

There is usually **five sets of body parts termed arms or rays**.
The region with tube feet are the **ambulacra**, and the regions between are **interambulacra.**

Label the oral and aboral surfaces and ambulacra on drawings of specimens from each class.

Class Asteroidea

Class Ophiuroidea

Class Echinoidea

Class Holothuroidea

Class Crinoidea

Internal skeleton. Echinoderms have an internal skeleton of **calcareous ossicles**. These range from **tiny spicules in the holothurians to large rigid tests in the echinoids**.

Examine the slide of holothuroid spicules

Examine the slide of a TS of a seastar arm

Examine slides of the tests of various sea urchins and sand dollars.

List how the arrangement of these skeletal elements vary among the 5 classes?

How do the regular and irregular echinoids differ?

Water vascular system

The unusual water vascular system is unique to the echinoderms. It is a system of internal canals and external tube feet (podia).

Use the model of the seastar, the slide of a TS of a seastar arm, and the illustrations of its water vascular system to identify the following components:

- **radial canal**
- **ring canal**
- **ampulla**
- **tube feet (podia)**
- **stone canal**
- **madreporite**
- **Polian vesicle**

Observe the number and activity of the tube feet on the living sea stars and urchins.

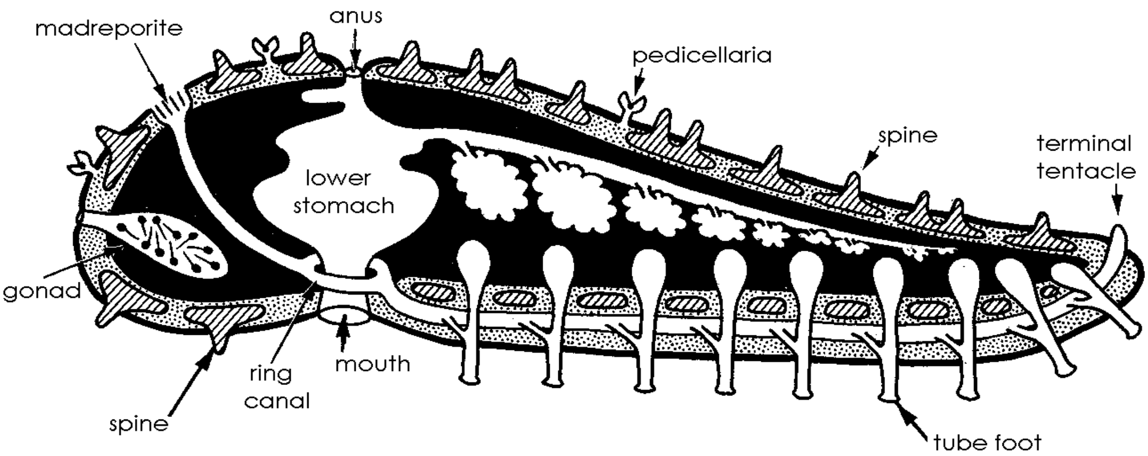
Look at the living specimens of a seastar, ask the staff member to turn it upside down and determine how it rights itself.

Explain the process it uses:

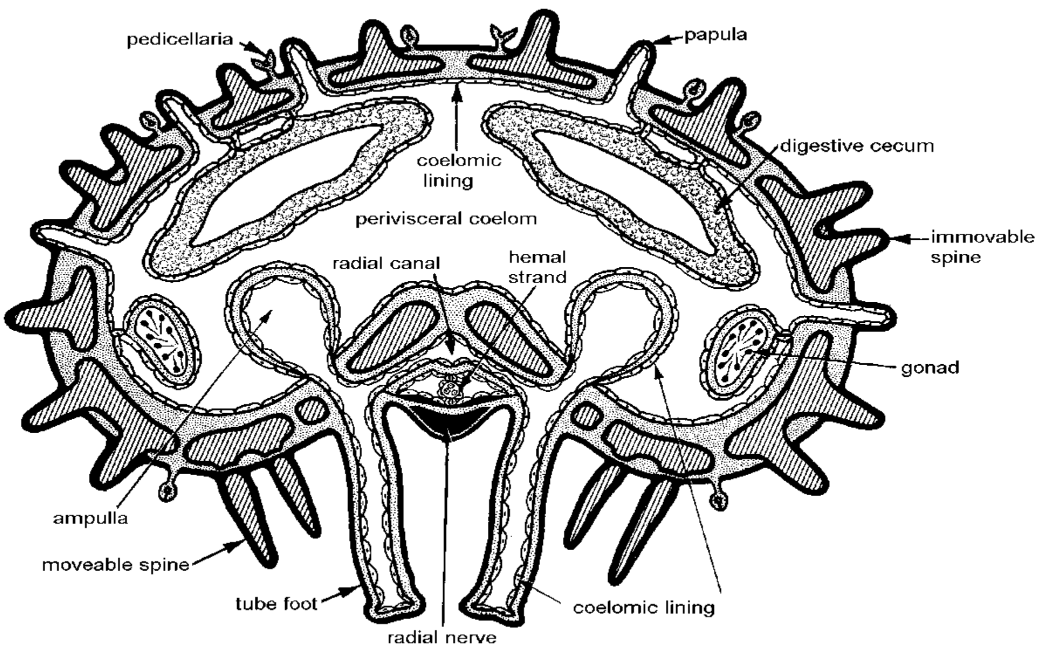
Research and make your own notes on how the water vascular system used by echinoderms?

Review the body plan provided below as you inspect the live specimens, note where the following structures are found on the live specimen:

- **Mouth**
- **Intestine with anus**
- **Tube foot**
- **Spine**
- **Terminal tentacle**
- **Gonads**



Longitudinal section of arm of sea star.



Cross-section of arm of sea star.

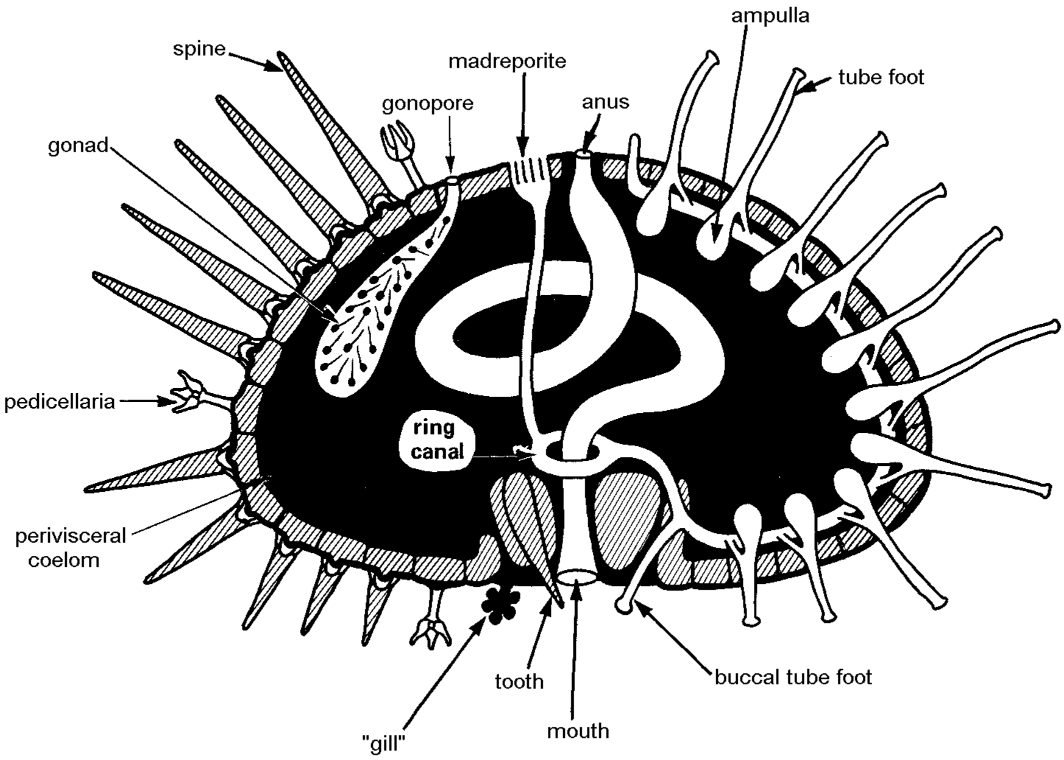
External structures of an urchin

Examine the live specimens on display

Can you identify the following on the live specimen?

- **Peristome and mouth**
- **Peristomial gills**
- **Periproct and anus**
- **Madreporite**
- **Ambulacral areas and podia**
- **Pedicellariae**
- **Spines**

Research and outline - What is the function of the pedicellariae?



Section of a sea urchin

Feeding

Predatory seastars. Sea stars are important predators in many marine habitats.
Watch footage of predatory crown of thorns starfish (coralivorous sea star) on the screens

Given that they have no structures to grind food, how do they obtain their nutrition?

Urchin herbivory. Sea urchins are important grazers of macroalgae and seagrasses in many marine habitats. **Food is gathered with a unique internal jaw apparatus known as Aristotle's lantern**.

Examine the skeletal elements of Aristotle's lantern and the computer animation of urchin feeding to understand how this works.

Development

Echinoderms are mostly **dieocious with external fertilisation and planktonic larval stages**.

Echinoderms, **like the chordates are deuterostomes**.

Early cell division thus involves radial cleavage and the formation of the anus from the blastopore.

Eggs hatch into a variety of larval forms. **Unlike the adult form, echinoderm larvae are bilaterally symmetrical**.

Prepare a life history diagrams for

- **a seastar**

Prepare a life history diagrams for

- **an urchin**

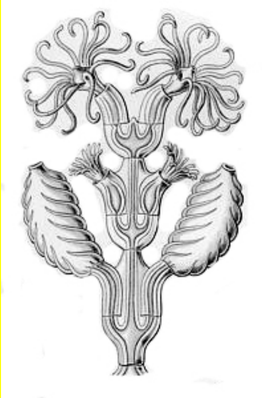
Invertebrate research at UNSW

Urchins in a changing ocean
Foo, SA, SA Dworjanyn, AGB Poore & M Byrne. 2012. Adaptive capacity of the habitat modifying sea urchin *Centrostephanus rodgersii* to ocean warming and ocean acidification: performance of early embryos. *PLoS ONE* 7: e42497.

The mechanical strength of sea urchin spines
Tsafnat N, JD Fitz Gerald, HN Le & ZH Stachurski. 2012. Micromechanics of sea urchin spines. *PLoS ONE* 7(9): e4414.

Weird urchin defences
Sheppard Brennand, H, AGB Poore & SA Dworjanyn. 2017. A water-borne pursuit-deterrent signal deployed by a sea urchin. *The American Naturalist* 189: 700-708.

CHORDATA AND BRYOZOA



The evolutionary lineage that includes ourselves and the echinoderms – the deuterostomes – also includes several other smaller phyla. We will consider the non-vertebrate chordates and two other phyla that you will encounter in marine environments.

Diversity

The **chordates** (**Phylum Chordata**, 50000, *chorda*, string, Gk) include the familiar ***vertebrates*** (***Subphylum Vertebrata***; mammals, birds, fish, reptiles and amphibians etc.), ***but also a several groups of marine invertebrates***, these are sessile or planktonic filter feeders.

The **arrow worms** (**Phylum Chaetognatha**, 100 spp., *chaeto*, bristle; *gnatho*, jaw, Gk) **are non-segmented coelomates** living permanently in the plankton.

The **bryozoans** (**Phylum Bryozoa**, 4500 spp., *ecto*, outside; *procta*, anus, Gk) **are sessile colonial filter feeders** that occur predominantly in marine environments (a few occur in freshwater).

Phylum	Subphylum	Class	Common names
Chordata	Urochordata	Ascidiacea	ascidians, sea squirts
		Thaliacea	salps
		Appendicularia	larvaceans
	Cephalochordata		lancelets
Chaetognatha			arrow worms
Bryozoa			bryozoans

Subphylum Urochordata. Sessile or planktonic filter feeders showing the chordate characters of a pharynx with slits, a dorsal hollow nerve cord and a notochord at some stage in their life cycle.

Class Ascidiacea. Sessile filter feeders with incurrent and excurrent siphons directed away from the substrate.

Class Thaliacea. Solitary or colonial planktonic filter feeders with incurrent and excurrent siphons at opposite ends.

Class Appendicularia. Solitary with adults retaining larval characters.

Subphylum Cephalochordata. Fish-like chordates with notochord, gill slits and dorsal nerve cord but no vertebra.

Chordate diversity.

Examine the range of live and preserved urochordates.

Draw the specimens and note how can you distinguish the classes?

Class Ascidiacea

Class Thaliacea

Class Appendicularia

Structure *(Specimens on display)*

The structure of a solitary ascidian

The solitary ascidian *Pyura stolonifera* (also known as cunjevoi) is abundant in the intertidal region of southern Australia.

Observe the specimens provided

Note the two siphons.

The branchial (inhalant) siphon is located at the anterior end and is directed parallel to the long axis of the body.

The atrial (exhalent) siphon indicates the dorsal side of the animal.

Determine the anterioposterior axis of the specimen on display and draw the body plan.

How are these animals bilaterally symmetrical?

note the axis of symmetry on your drawing.

Which side is left, and which is right?

Colonial ascidians, observe the display of live colonial ascidian colony (*if available*).

Can you see the branchial basket (pharynx) through a transparent test?

Does each zooid have both a branchial and atrial siphon?

Solitary and colonial salps.

Sketch the individual salps, *Thalia*.

Typically these bloom in late winter, spring and can have bright blue guts. Some species of salp can get to be as big as a shoe-box (e.g. *Thetys*, or *Cyclosalpa*).

Observe the colony of *Pyrosoma*.

Remember the anecdote about *Pyrosoma* and the Vietnam War – these are highly bioluminescent and become as big as 5 metres long!

Note the many individuals living in the tunic wall secreted by the colony. Buccal siphons are on the outside and atrial siphons pass exhalant water to the central cavity. This exits at the rear of the colony and is responsible for propulsion.

Appendicularians or larvaceans

Examine the drawings and some specimens of larvaceans, make notes on the body structure.

note the notochord running the length of the otherwise fibrous tail.
They are the most specialized and evolved of the urochordate clade. While small, they have incredible growth rates and probably important prey for larval fish.

Bryozoan structure

Draw a colony of the encrusting bryozoan *Watersipora subtorquata* and the arborescent *Bugula neritina*, viewed on the screen from under the dissecting microscope.

Label individual zooids and their primary orifice.
Can you see a lophophore (feeding apparatus)?

Where does it extend from?

Do the zooids differ in size?

Feeding

Filter feeding in ascidians

Examine the computer animation of a filter feeding ascidian on the screen.

What effect might this feeding method have on the biological and chemical attributes of an enclosed body of seawater.

Reproduction and development

Sexual reproduction in the bryozoans

If available, observe the spawning of the bryozoan *Bugula neritina* or *Watersipora subtorquata*.

What induces this spawning event?

What would be the equivalent cue under natural field conditions?

You will have approximately 20 larvae placed into a small petri dish.

Describe the swimming and exploratory behaviour of the larvae as observed through a dissecting microscope.

Record the length of time from spawning until larvae begin to settle.

What changes take place as larvae settle?

Sexual reproduction in the urochordates
Observe the live tadpole larvae of *Pyura stolonifera* (if available). If not available observe the photographs and diagrams of ascidian larvae.

Draw an ascidian larvae and identify the chordate features.

What happens to each of these chordate features when the larvae settles and metamorphoses into an adult ascidian?

Sexual and asexual reproduction in salps

In the next section you will read about the role of salps in climate change, due to their fantastic growth rates and reproductive rates, due to their ability to feed on marine bacteria (at 500,000 per millilitre of seawater, it must be an unlimited carbon resource!).

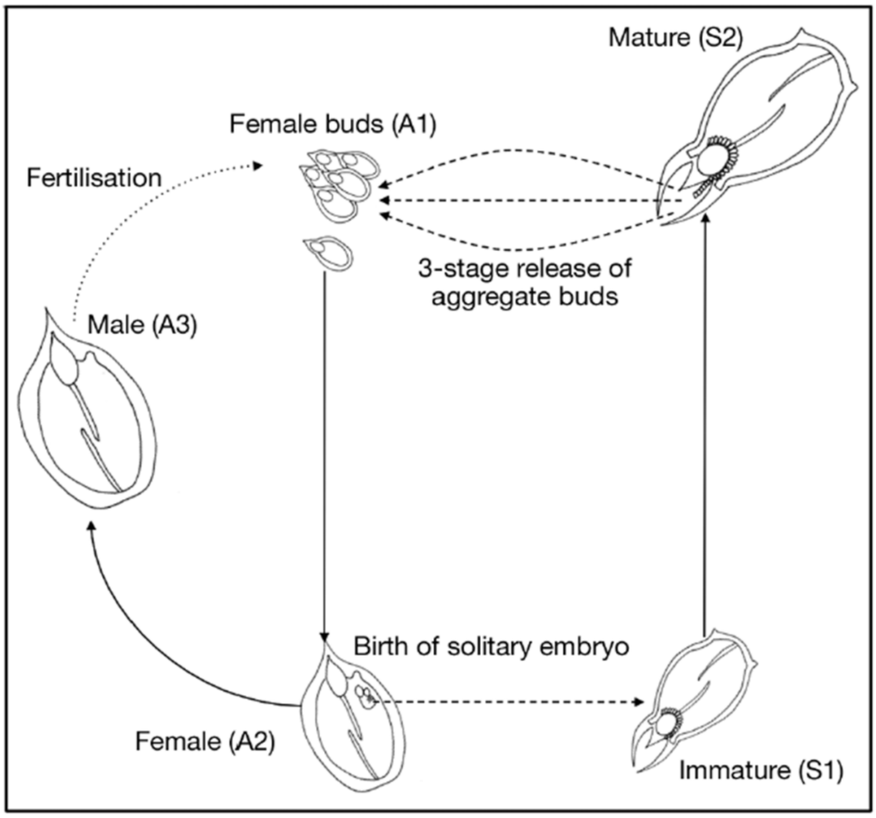
Their reproductive rates are achieved by an alteration of asexual and sexual life cycles (reminiscent of the jellyfish lifecycle – recall the planktonic medusa, sexual stage and the benthic polyp, asexual strobila). Salps have and their relatively fast sinking rates to the sea floor and may contribute to the global carbon flux.

Note the life cycle of salps below.

Three displays of *Thalia* show the immature solitary stage;

the gravid solitary stage with the asexually produced "buds" coiled up ready for release (usually in the early morning, 3 am); and

the buds grown up as the sexual stage (initially female with a single embryo; subsequently become male to fertilise new buds).



Life cycle of *Thalia democratica*, the common salp off Sydney's beaches in spring.

Invertebrate research at UNSW

Sensitivity of native vs. introduced bryozoans to pollution

Piola, RF & EL Johnston. 2009. Comparing differential tolerance of native and non-indigenous marine species to metal pollution using novel assay techniques. - *Environmental Pollution* 157: 2853–2864.

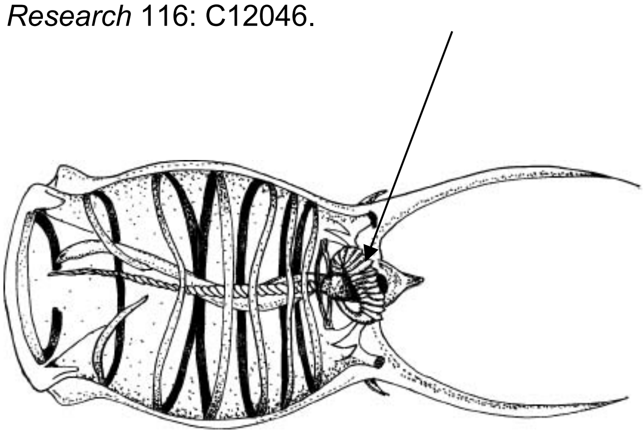
Ecology of bryozoans in the Antarctic

Clark, GF, JS Stark & EL Johnston. 2017. Tolerance rather than competition leads to spatial dominance of an Antarctic bryozoan. *Journal of Experimental Marine Biology and Ecology* 486: 222-229.

Effects of salps on pelagic ecosystems and carbon flux

Henschke, N, JD Everett, ME Baird, MD Taylor & IM Suthers. 2011. Distribution and life history stages of the salp *Thalia democratica* in relation to water masses of the western Tasman Sea. *Marine Ecology Progress Series* 430 49–62

Everett, JD, ME Baird & IM Suthers. 2011. Three-dimensional structure of a swarm of the salp *Thalia democratica* within a cold-core eddy off southeast Australia.*Journal of Geophysical Research* 116: C12046.



INTERACTIVE KEYS ADDITIONAL EXERCISE

Bugs are not going to inherit the earth. They own it now. So we might as well make peace with the landlord T. Eisner

The identification of invertebrates has traditionally involved the use of dichotomous keys (*dichotomous*=branching). These involve the user making a series of decisions about characters that the organism possesses, leading toward an identification. Each decision usually involves a choice between two alternatives (a couplet). For example, the following is part of a key to genera of marine amphipods.

1. Uropod 1 peduncle with distoventral spur .... go to 2
Uropod 1 peduncle without spur or spur reduced, rounded .... go to 7
2. Gnathopod 1 palm transverse or nearly so .... go to 3
Gnathopod 1 palm acute .... go to 5
3. Antenna 2 peduncular articles 3-5 not densely setose .... go to 4
Antenna 2 peduncular articles 3-5 densely setose .... *Plumithoe*
4. Mandibular palp present............ *Peramphithoe*
Mandibular palp absent .... *Sunamphitoe*
5. Uropod 3 rami broad. Telsonic lobes small .... go to 6
Uropod 3 rami narrow. Telsonic lobes absent............ *Ampithoides*
6. Accessory flagellum with 1-2 articles .... *Cymadusa*
Accessory flagellum with 3 to 6 articles............ *Paragrubia*
7. Gnathopod 1 palm transverse, slightly obtuse or absent .... go to 8
Gnathopod 1 palm acute .... go to 10
....etc.

In recent years, the development of computer-based interactive keys offers an alternative to written, dichotomous keys. In such keys, each species is entered into a database that holds the all of the characters and character states for that species. For example:

	Leg number	Head
Species A	6	wide
Species B	8	narrow
Species C	6	narrow

In this example, leg number and head are characters while 6 and 8, and wide and narrow, are their character states respectively.

In an interactive key, the user may start by selecting any character (rather than starting at 1, above) and chose the character state that best suits their organism. Once a selection has been made, the program excludes all species that do not match the selection. In the example above, selecting leg number=6 excludes species B. The user then selects further characters until only one taxon remains (e.g., leg number=6 then head=wide would lead to the identification of species A).

Computer based interactive keys make use of digital images and photographs to illustrate the states available for each character. They may also contain multimedia content to provide further information on the invertebrate group identified.

Advantages over traditional keys include the following:

- ability to use any characters in any order (e.g., the above dichotomous key would be useless if the user did not know what a uropod was).
- avoid the problem of unanswerable couplets – if the user cannot select among the choices for a given character (e.g., if the legs were missing), they can move on to another character.
- the user can select several character states if they are unsure of the correct one.
- numerical characters (e.g., number of leg segments) can be used directly.
- ability to use only a subset of the key (e.g., exclude all those species that do not occur in given country).
- the program can identify user errors (e.g., making a selection of character states that result in impossible organisms).
- keys may be simply maintained and updated as new information is obtained (e.g., further species discovered or improved character data).
- the program can advise the user on the best selection of characters (i.e., those that will result in a correct identification with the least number of steps).
- the provision of text, illustrations, sounds and/or video to accompany the characters or taxa selected.

Using keys to identify invertebrates

This practical will form an introduction to the use of written, dichotomous keys and computer-based interactive keys. We will use the software package Lucid (developed by the Department of Entomology, University of Queensland) to demonstrate the use of interactive keys

At the end of this practical you should:

- be confident in using a dichotomous key
- be able to state the distinction between interactive keys and written dichotomous keys
- be familiar with the use of an interactive key to insect orders
- be confident identifying the major insect orders

The “specimens” you are required to identify will be provided during the practical.

Written keys

Use the dichotomous key in Harvey and Yen (1989) to identify each specimen to order. The key to the insects starts on page 22. Write down all of steps that you take so that any mistakes can be identified if you end up at the wrong order.

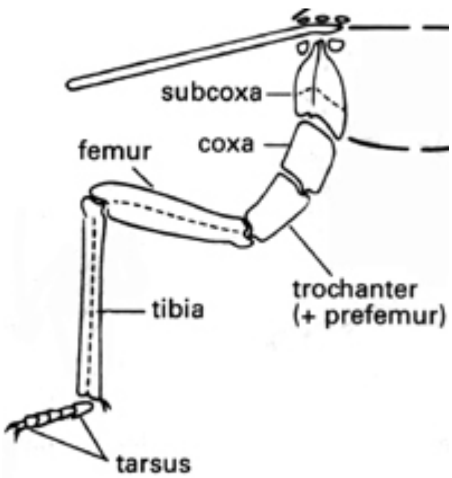
Remember that keys work by a process of elimination, telling you what taxa your specimen is not rather than what it is. The key may arrive at an identification even if the specimen belongs to a taxon that is not in the key. It is therefore important to check that your identification fits all of the characters for that specimen. Check your identification with the descriptions in the available literature.

Interactive key to insect orders

Use the Lucid key to insect orders to identify each specimen to order. Write down all of steps that you take so that any mistakes can be identified if you end up at the wrong order. Check your identification with the pictures and available information for the order chosen.

Before you start, use the tutorial in Lucid to familiarise yourself with the user interface and available commands. (useful tip: CTRL-mouse click enlarges the pictures).

This figure illustrating the names of insect leg segments should prove helpful.



Further information:

- Harvey, MS and AL Yen (1989) *Worms to wasps. An illustrated guide to Australia's terrestrial invertebrates*. Oxford University Press, Oxford.
- Dallwitz MJ *et al.* 2000. Principles of interactive keys. Available at http://biodiversity.uno.edu/delta/www/interactivekeys.htm
- Links to several interactive keys available free on the internet are available in the Resources section of the course web site.

Further research in invertebrate biology

The following academic staff and their research groups in the School of Biological, Earth and Environmental Sciences use a wide variety of invertebrates for pure and applied research. Many honours and postgraduate projects within the school rely on the knowledge of invertebrates that you would have gained throughout this course.

Associate Professor Russell Bonduriansky	topics: evolutionary theory, sexual conflict, ageing, environment and phenotype invertebrates studied: flies, crickets
Associate Professor Stephen Bonser	topics: plant ecology, evolution of plant-insect interactions invertebrates studied: insects
Professor Rob Brooks	topics: ecology and evolution of sexual reproduction, life history theory invertebrates studied: crickets, flies, beetles, harlequin bugs
Professor Gerry Cassis	topics: systematics, diversity, evolution and conservation of Australasian insects invertebrates studied: bugs, other insects
Dr Malte Ebach	topics: systematics, biogeography, palaeontology invertebrates studied: trilobites
Professor David Eldridge	topics: soil ecology, landscape degradation invertebrates studied: ants, termites, other soil invertebrates
Associate Professor Paul Gribben	topics: community ecology, invasive species Invertebrates studied: molluscs
Professor Emma Johnston	topics: ecotoxicology, ecology of sessile invertebrates, invasive species invertebrates studied: bryozoans, ascidians, barnacles, flatworms etc.
Dr Mike Kasumovic	topics: sexual selection, behaviour invertebrates studied: spiders, crickets
Professor Richard Kingsford	topics: wetland ecology and conservation invertebrates studied: freshwater invertebrates
Professor Angela Moles	topics: global patterns of herbivory invertebrates studied: insects
Dr Terry Ord	topics: behaviour, communication invertebrates studied: insects
Associate Professor Alistair Poore	topics: marine ecology, plant-herbivore interactions, human impacts invertebrates studied: crustaceans, urchins, gastropods etc.
Associate Professor Jes Sammut	topics: aquaculture; coastal management; diseases in fish and shellfish invertebrates studied: shrimps, oysters
Professor Peter Steinberg	topics: marine chemical ecology, biofouling, biotechnology, subtidal ecology invertebrates studied: barnacles, urchins, gastropods, bryozoans, sponges etc.
Professor Bill Sherwin	topics: conservation genetics invertebrates studied: fruit flies, prawns
Professor Iain Suthers	topics: biological oceanography, fisheries, estuarine food webs invertebrates studied: zooplankton (copepods etc), bivalves, prawns
Professor Torsten Thomas	Topics: microbiology, symbioses Invertebrates studied: sponges
Dr Adriana Verges	topics: climate change, fish ecology, seagrass beds invertebrates studied: urchins, gastropods