Biology 1100 Activity Guide:
Laboratories, Field Trip, Assignments

This package provides guidance to activities not in your laboratory manual.

Learn to Use a Stereoscope

Purpose: Develop the knowledge and skills to effectively use a stereoscope.

- Get a stereoscope and a power cord from the cabinet.

➔ Carry the microscope with two hands (see Figure).

- Plug in the scope without obstructing a walkway (move tables as necessary).
- Clean lenses and stage with *lens paper*.
- Place an object on the stage (#5). There is an insert plate over the light source.
- Switch the light "on" by pressing the key M (mode)(#4).

  ➔ Press Key M repeatedly to explore the 4 different light modes.

Press M	→	Reflected light	→	Light comes from **above** the insert plate
Press M again	→	Transmitted light	→	Light comes from **under** the insert plate
Press M again	→	Both transmitted and reflected lights	→	All the lights are on
Press M again	→	No light	→	Standby mode

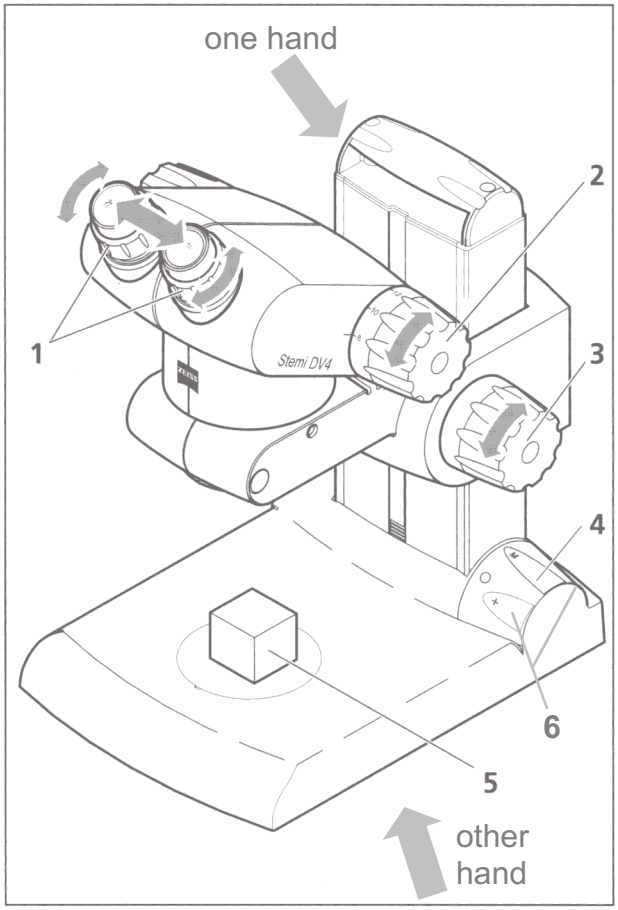
- Select the best viewing mode.
- Look through the ocular lenses and adjust them until you see only one circle of light (#1).
- Use key + and – to adjust the light intensity (#6).
- Locate the magnification knob (#2) and the focusing knob (#3).
- Find object at the lowest magnification, 8X on the magnification knob.
- Focus with the focusing knob.
- Raise magnification to the maximum, 32X, and focus.

  ➔ If the stereoscope is aligned this way, the image sharpness (focus) will be retained over the entire zoom range.

Prepare to return the microscope to the cabinet

- SALT FREE!! Use a freshwater-wet paper towel to remove seawater, and then dry.
- Disconnect the cord from the scope and roll the cord loosely.
- Return both stereoscope and cord to the cupboard.
- Make sure to put the dustcover back on.
- Return your scope to the same cupboard where you found it.

  DO NOT FORCE TOO MANY SCOPES ONTO THE SAME SHELF!



1. Adjustable ocular lens (2X)
2. Magnification knob (8X – 32X)
3. Focus knob
4. Light mode selector
5. Object on Stage
6. Light intensity buttons + (increase) and – (decrease)

Stereoscope

Questions:

1. What do you observe when you move…
   a. The magnification knob up and down (zooming in and out)?

   b. The focus knob?

2. Why would you choose a dissecting scope over a compound scope to make observations of a small animal like a barnacle?

3. Observe algae on a watch glass. Which lighting works best?

Assess Your Lab Partner's Microscope Skills

- ❑ Approaches microscopes enthusiastically but calmly
- ❑ Removes protective cover from microscope and leaves cover in cabinet
- ❑ Lifts, holds and carries microscope with two hands, one supporting the base and one under the arm
- ❑ Places microscope carefully on desk or counter
- ❑ Plugs in scope without obstructing walkway (moves tables as necessary)
- ❑ If necessary, rotates head 180° to viewing position by loosening screw one-quarter turn, then retightening
- ❑ *Does not* turn condenser screws or field diaphragm
- ❑ Checks all lens surfaces for cleanliness. Cleans as needed with lens paper.
- ❑ Assumes ergonomic viewing posture
- ❑ Adjusts oculars to proper viewing angle
- ❑ Turns adjustable ocular to place "o" on white slash
- ❑ Checks, turns rheostat counter clockwise to minimize brightness
- ❑ Turns on power
- ❑ Uses turret to engage low power (5x) objective lens
- ❑ Turns rheostat clockwise until optimum light level reached
- ❑ Adjusts interocular distance so that one circle viewed
- ❑ Places cleaned slide upon stage, with proper use of clip
- ❑ Raises stage to approximate viewing height
- ❑ Places subject in center of field of view
- ❑ Adjusts light with iris diaphragm and rheostat
- ❑ Focuses with coarse focus
- ❑ Both eyes open, face relaxed
- ❑ Centers subject
- ❑ Uses turret to engage 10x objective lens

- Focuses with fine focus
- Adjusts light level
- Centers subject
- Looking from the side, focuses turret to engage 40x objective lens
- Focuses with fine focus
- Adjusts light level

Prepares to return microscope to cabinet

- Turn turret to rotate low power objective to the outside
- Drops stage to lowest position
- Removes slide from stage and returns to storage
- Turns down rheostat to minimum (counter clockwise)
- Turns off power
- Rotates head 180° by loosening screw one-quarter turn, then retightening
- Unplugs scope
- Cleans all lens surfaces with lens paper
- Cleans and dries stage and other parts of scope as necessary
- Lifts, holds and carries microscope with two hands, one supporting the base and one under the arm
- Carefully places microscope back in cabinet
- Covers microscope with protective cover

Laboratory: Vertebrates

Learning Objectives: during this laboratory, you can expect to

1. review classification of vertebrates
2. summarize major characteristics of vertebrate taxa
3. identify and describe local marine vertebrates
4. in teams, present above information to classmates
5. gather above information from classmates

Text Reference: Chapter 34 in Campbell and Reece.

Lab Manual Reference: Exercise 18.3, pp 489-497 (lancelet and pig only);
Table 18.2, pp 500-501.

Other References: Marine species information cards from Gloria Snively.
Local field guides available in class.
BC Species at Risk pamphlets

***Session Protocol*:**

We'll begin with a presentation that parallels your textbook, chapter 34, about the history and diversity of chordates and vertebrates.

You will then be assigned to a team and a vertebrate group. Your task:

1. Review information in your textbook about your assigned vertebrate group.
2. Gather information about your animals:
   - From your textbook
   - From your lab manual, if applicable
   - Collect specimens available in class. Find jars, prepared dissections, skeletons and posters.
   - Find relevant species from the marine species information cards and the *BC Species at Risk* pamphlets.
3. Prepare and present your collected information, guided by the table below.
4. Collect data from other groups, guided by the table below.

Make a table like this one for each vertebrate group, and fill it in.

Name	**Description**	**Of Interest**
Vertebrate Group:		
Scientific and common names of one marine representative:		
Scientific and common names of one BC endangered representative:		

Observation and Drawing
Enhance your descriptions with drawings. Make drawings at least one-third of the page. With a line extending out to the right, draw attention to creature features that interest you. At the end of the line, name the feature if you can, but more importantly, comment on its adaptive significance…why that feature might be of importance to the organism's survival.

Return specimens as directed at the conclusion of our session.

Laboratory: Observation and Identification of Intertidal Organisms

This and other marine biology labs borrow heavily from the Biology 140 course at UBC. Thanks Carol Pollack, Kathy Nomme and Gordon McIntyre!

***Learning Objectives**:* during this laboratory, you can expect to

1. List and discuss abiotic factors important to the intertidal community
2. Review classification of organisms
3. Use the stereoscope
4. Estimate the real size of creatures viewed under the microscope
5. Produce accurate, labelled drawings of specimens
6. Describe general features of some common marine autotrophs and heterotrophs
7. Use a dichotomous key to identify intertidal organisms

***Text References for this lab and other marine labs and the upcoming field trip**:*

	Campbell and Reece	Nybakken and Bertness
Marine ecosystem	Chpt 50:1092-1093, 1096	Chpt 6:277-304
Macroalgae	Chpt 28:560-562; 567-569	
Invertebrates	Chpt 33	
Phytoplankton	Chpt 28:559-560	
Zooplankton	Chpt 28: 563	
Abiotic and biotic factors	Chpt 50, 53	Chpt 6:267-271
Classification	Chpt 25: 496	

Other references for real west coast people:

Guide to Intertidal Invertebrates by Tom Carefoot, distributed in class
Cobblestone Hotel, from *Beach Explorations* by Gloria Snively, pages following
From Whelks to Whales by Rick Harbo
Exploring the Seashore by Gloria Snively
Seashore Life of the Northern Pacific Coast by Eugene Kozloff
The Beachcombers' Guide to Seashore Life by Duane Sept

Presentation and Discussion:

Class and reading will inform you about major aspects of the abiotic (physical) environment that limits distribution of local marine life. Here is a list of some headers for your note making:

- open ocean zones: pelagic, bathypelagic, and abyssal
- coastal waters: straits, fjords, sounds, passes, narrows, and estuaries
- upwelling
- intertidal zone
- high and low energy shorelines
- substrate types: sandy, mud, rocky, cobble, reefs
- benthos, where benthic (bottom-dwelling) organisms live
- tides
- temperature
- salinity
- pH

- desiccation

Then we consider biotic consequences of these abiotic factors, the structural and behavioural adaptations of creatures to handle their physical environment. With this background, we can then consider these important ecological concepts:

- intertidal zonation (pattern of distribution)
- biodiversity
- adaptations
- dominant species
- relative densities
- dispersion patterns
- community relationships
    - niches
    - trophic relationships
    - habitats
    - competition
    - predation
    - symbioses

Identification

Identification results in a specific scientific name, a genus and species, which an organism shares with no other. That scientific name is used to avoid confusion, since the same common name may be applied to a number of different organisms, and certain organisms may go under a number of different common names. In addition to its specific name, an organism is classified in a hierarchy that lets us organize creatures by their degree of relatedness. Here's an example:

Domain:	Eukarya
Kingdom:	Animalia
Phylum	Echinodermata
Class	Asteroidea
Order	Forcipulatida
Family	Asteriidae
Genus	*Pisaster*
Species	*ochraceus*

Sure, the instructor will help you pronounce all this.

Use a **dichotomous key** as a tool to identify organisms. It's called *dichotomous* because you follow it by choosing between (usually) two opposite options. This will be demonstrated before you go ahead and use the key found on some of the following pages.

You will identify six different organisms, three macroalgae and three invertebrates. Six stations will have each of the species to identify, so work with your group at one station.

Make a table like this one, and fill it in.

Scientific name and common name, if available	Autotroph or heterotroph?	Interesting creature features

Observation and Drawing

To further your growing habit of careful observation, we offer you three local intertidal organisms.

- a copepod, *Tigriopus*
- a seaweed
- a shore crab

Use the stereoscope to enhance your observations. Take care that power cords do not cross walkways. Remember to clean off saltwater as soon as you notice it: freshwater-towel, then dry. Continue to ask for assistance in the use of the stereoscope.

- Devote a standard page for each of the three creatures. Title this page with the common and scientific name of the organism.
- Make a **careful** drawing of it, at least one-third of the page. Indicate **scale** with a ruler. With a line extending out to the right, draw attention to **creature features** that interest you. At the end of the line, name the feature if you can, but more importantly, comment on its **adaptive significance**…why that feature might be of importance to the organism's survival.
- Indicate the **region**, pelagic or benthic that the creature inhabits. Look carefully, and then ask if you need coaching. You may refer to the information cards at the stations. See if you can describe the creature's **habitat**, a more specific address than its region.
- Is it an autotroph (makes it's own food) or a heterotroph (needs to eat something)?

Remember clean-up procedure:

- Make sure all microscope parts are clean and dry. Return the microscope and cord to the cabinet. Cover the microscope.
- Return specimens. Wash your glassware in fresh water and leave it to dry as instructed.

Key to Some of the Most Common Intertidal Marine Life at Figurehead Point, Stanley Park, Vancouver, British Columbia

1a Plant-like: green, brown, olive, red, or purple with leaf-like parts or grows as a crust……..…...**go to 2**
1b Animal-like: variously coloured, may be attached to a rock or motile……**go to 12**

2a Grass-like, with veins and roots, grows in mud or sand..**eelgrass, *Zostera marina***
2b Not grass-like, no veins, grows on rock……..…**macroalgae**….**go to 3**

3a Bright green……**green macroalgae, Chlorophyta**…..**go to 4**
3b Red, red-brown, orange or purple…...…**red macroalgae, Rhodophyta**…..**go to 5**
3c Olive, light brown or dark brown……**brown macroalgae, Ochrophyta**….**go to 9**

4a Green blade, broad, thin and flat……..…..**sea lettuce, *Ulva lactuca***
4b Green blades, long, narrow and tubular…...**green string lettuce, *Ulva intestinalis***
(formerly *Enteromorpha)*

5a Dark red to orange crust on rock ……...**go to 6**
5b Red or purple blade growing from a short stipe ……**go to 7**

6a Rust or orange-red crust, not spongy to touch…..**red rock crust, *Hildenbrandia sp.***
6b Dark red crust, slightly spongy to touch….**Turkish washcloth** (sporophyte stage)
Mastocarpus papillatus (formerly *Petrocelis)*

7a Dark red blade covered in small bumps…**Turkish washcloth** (gametophyte stage)
Mastocarpus papillatus (formerly *Gigartina)*
7b Red, red-brown, orange or purple blade smooth……..…….**go to 8**

8a Dark red-purplish iridescent blade, several cells thick ……..…**iridescent seaweed**
Mazzaella splendens (formerly *Iridaea)*
8b Light reddish brown blade, one or two cells thick…….....**nori, *Porphyra sp.***

9a Olive to brown blades with two or more branches…....**rockweed, *Fucus gardneri***
9b Olive to brown blades with no branches……..**go to 10**

10a Olive to brown blades, many from a float (bulb)...**bull kelp, *Nereocystis luetkeana***
10b Olive to brown blade single ……..……**go to 11**

11a Olive to brown single blade not ribbed……..**wrack kelp, *Laminaria sp.***
11b Olive to brown single blade with many ribs…...**seersucker kelp, *Costaria costata***

12a Animal with irregular shape, permanently attached to rock ……**go to 13**
12b Animal with regular elongated or circular shape, attached or motile**.**……..**go to 14**

13a Animal spongy-feeling, encrusted on protected rock…....**purple intertidal sponge *Haliclona?permollis***
13b Animal plant-like, branched, hanging on protected rock...……**hydroid, *Obelia sp.***

14a Animal with circular, rounded, or oval shape……..**go to 15**
14b Animal with elongated shape……...……**go to 38**

15a Animal with circular shape, permanently attached to rock or kelp……. **go to 16**
15b Animal with circular, rounded, or oval shape, not permanently attached or attached by threads……...……..**go to 20**

16a Circular attached animal white, lace like, flat, usually on kelp…….…..
kelp-encrusting bryozoan, *Membranipora, serrilamella*
16b Circular attached animal white or coloured, not flat……**go to 17**

17a Circular attached animal white, hard to touch……..**barnacles**……...**go to 18**
17b Circular attached animal white or coloured, soft to touch..**sea anemones**..**go to 19**

18a Barnacle about 1 cm wide, straight-lined pattern where inner plates meet, found at higher beach levels…….……....**small acorn barnacle, *Chthamalus dalli***
18b Barnacle about 2 cm wide, curved-lined pattern where inner plates meet, found at higher beach levels, but below *Chthamalus*…..**acorn barnacle, *Balanus glandula***
18c Barnacle about 6 cm wide, heavy ribs down sides, found at lower beach levels….
thatched barnacle, *Semibalanus cariosus*

19a. Anemone gray-green, surrounded by sand or mud…….**burrowing anemone *Anthopleura artemisia***
19b Anemone with red, pink or white, sometimes tan, on rock …….…….……
painted, fish-eating, or rose anemone, various *Urticina sp.*

20a Circular or rounded motile animal with projecting arms, spines or legs.……
crabs, sea stars and sea urchins……..**go to 21**
20b Rounded or oval shaped animal without projecting arms, spines or legs.……..
snails, sea slugs, clams and chitons…. **go to 27**

21a Rounded motile animal with long spines all over…….…….....**green sea urchin *Stronglyocentrotus droebachiensis***
21b Circular motile animal with radially projecting arms…..…...**sea stars**…..…..**go to 22**

22a Sea star with more than 20 arms……...**sunflower star, *Pycnopodia helianthoides***
22b Sea star with 5 arms…….……**go to 23**

23a Sea star skin smooth or not bumpy……..….**go to 24**
23b Sea star skin rough or bumpy…….……..……**go to 25**

24a Sea star skin soft, thick arms, mostly dark grey……**leather star, *Demasterias imbricata***
24b Sea star skin hard, thin arms, bright to pale orange…….**blood star, *Henricia leviuscula***

25a Sea star on mud or sand…….…..**pink star, *Pisaster brevispinus***

25b Sea star on rock or in tidepool……..**go to 26**

26a Sea star purple, rarely orange, often in clumps ……....**purple star, *Pisaster ochraceus***
26b Sea star colour variable, usually gray-green……..**mottled star, *Evasterias troschelii***

27a Shelled oval shaped animal without projecting arms, spines or legs……...**go to 28**
27b Soft-bodied oval shaped animal without projecting arms, spines or legs, with snail-like foot ……..….**sea slugs**……**go to 36**

28a Single shell coiled or cone-shaped…….**snails**…….**go to 29**
28b Two-part shell circular or oblong…….....**clams and mussels**…….**go to 30**
28c Eight-part shell oblong……**chitons**…….**go to 33**

29a Shell coiled…….……**periwinkle**…..***Littorina sp.***
29b Shell cone-shaped…….……**limpet** (a number of genera and species)

30a Two-part shell, oblong, blue/black, sometimes brown, attached to rock by threads… **Pacific blue mussel**…***Mytilis sp***.
30b Two-part shell, circular, white to tan, not attached to rock……....**clam**…….**go to 31**

31a Clam shell heavily ribbed……**Nutall's cockle**…..***Clinocardium nutallii***
31b Clam shell not heavily ribbed……..**go to 32**

32a Clam shell with light ribs and light concentric rings, fine teeth along inside margin…. **Pacific littleneck clam**, ***Protothaca staminea***
32b Clam shell with no ribs and obvious concentric rings, smooth white interior…….. **Washington butter clam**, ***Saxidomus gigantea***

33a Chiton with eight shell parts covered, dark orange……..**giant Pacific chiton *Cryptochiton stelleri***
33b Chiton with eight shell parts exposed……..……..…….**go to 34**

34a Chiton with bristly girdle ……..……..**hairy or mossy chiton**…..***Mopalia sp.***
34b Chiton with smooth girdle……..……**go to 35**

35a Chiton with smooth girdle and colourful, lined shell parts……..…...**lined chiton *Tonicella lineata***
35b Chiton with smooth black girdle and white shell parts……..…**black leather chiton *Katharina tunicata***

36a Sea slug cream and brown, to 3 cm long……**barnacle-eating nudibranch *Onchidoris bilamellata***
36b Sea slug white or yellow, 4 cm or longer……...…….**go to 37**

37a Sea slug white with yellow margin……..**yellow-rimmed nudibranch *Cadlina luteomarginata***

37b Sea slug lemon-yellow…….…..……**Monterey sea lemon, *Doris monteryensis***

38a Elongated animal worm-like……**go to 39**
38b Elongated animal not worm-like…….…… **go to 44**

39a Worm not segmented……**go to 40**

39b Worm segmented, may be in a tube…….**go to 41**

40a Unsegmented worm, very long, thin, tubular and slimy……..……...**ribbon worms**
most commonly with mussels, the **green ribbon worm, *Emplectonema gracile***
40b Unsegmented worm, broad, thin, flat……**polyclad flatworms**
on the underside of rocks near the low tideline, very difficult to identify to species

41a Segmented worm mobile, not in a tube……..**go to 42**
41b Segmented worm not mobile, in a tube……..**go to 43**

42a Mobile worm with scales on its back…….…….**scaleworm** (several species)
most commonly, **fifteen-scaled worm, *Harmothoe imbricata***
42b Mobile worm without scales on its back……**clamworm**
(and *many* other species of polychaetes), most commonly, ***Nereis sp***.

43a Worm tube thick and rubbery, sticking up……**Vancouver feather duster**
Eudistylia vancouveri
43b Worm tube hard and shell-like, encrusted on rock…..…….**calcareous tube worm**
Serpula columbiana

44a Elongated animal soft-bodied with tube feet…….**sea cucumbers**…….**go to 45**
44b Elongated animal not soft-bodied or has fins……..…**go to 46**

45a Sea cucumber bright orange, 5 rows of tube feet symmetrical along body…….
orange sea cucumber, *Cucumeria miniata*
45b Sea cucumber variably orange-red, tube feet all on one side…...**giant sea cucumber**
Parastichopus californicus

46a Elongated animal with fins……..**fish**……..**go to 47**
46b Elongated animal with exoskeleton……..…….**crustaceans**……..**go to 48**

47a Fish eel-like, dark or grey, wiggles, under rocks…….……...**high cockscomb**
Anoplarchus purpurescens
47b Fish not eel-like, grey or banded, scoots, in tidepools……**tidepool sculpin**
Oligocottus maculosus

48a Crustacean in a snail shell (unless you remove it) ……..…**hermit crab**, ***Pagurus sp.***
48b Crustacean not in a snail shell……..**go to 49**

49a. Crustacean flattened side to side (laterally compressed)…….**shrimps and amphipods**
…….**go to 50**

49b Crustacean flattened top to bottom (dorsoventrally compressed) … **crabs and isopods**
……**go to 51**

50a Laterally compressed crustacean swims on its side, less than 2 cm long….. **amphipod**
50b Laterally compressed crustacean on its legs, not on its side, more than 2 cm long…..
shrimp…….probably ***Heptacarpus sp.***

51a Dorsoventrally compressed crustacean with many segments with legs for each….
isopods…… **go to 52**

51b Dorsoventrally compressed crustacean with carapace (shell)……..**crabs**…. **go to 53**

52a Isopod to 1 cm long, grey……...…**stubby isopod**, ***Gnorimosphaeroma oregonensis***
52b Isopod to 4 cm long, red, green or brown with rounded end…….
rockweed isopod, ***Idotea wosnesenskii***

53a Crab larger than 10 cm across carapace…….……..**go to 54**
53b Crab smaller than 10 cm across carapace…….……**go to 55**

54a Large brick-red crab with black tips on claws……....**red rock crab, *Cancer productus***
54b Large grey-brown crab without black tips on claws…..**dungeness crab, *Cancer magister***

55a Small crab found in large groups…….**go to 56**
55b Small crab found singly……...**go to 57**

56a Small group crab greenish, bristles on legs..**green shore crab, *Hemigrapsus oregonensis***
56b Small group crab purple, no bristles on legs……**purple shore crab, *Hemigrapsus nudus***

57a Small solitary crab without black tips on claws……a variety of kelp, spider or decorator crabs…….***Pugettia, Scyra, Oregonia spp.***
57b Small solitary crab with black tips on claws……..…..**go to 58**

58a Small crab, black claw tips, red, rounded carapace, with hairy legs……
pigmy rock crab, *Cancer oregonensis*
58b Small crab, black claw tips, dark, angular carapace, with smooth legs……
black-clawed crab *Lophopanopeus bellus*

Beach Explorations by Gloria Snively

Snively’s stuff.

Field: Intertidal Ecology and Diversity

at Figurehead Point, Stanley Park

Date: Time: (3h)

Intertidal Zone: the area between the high and low tides. It can be divided into high, middle, and low zones. Below the low zone lies the subtidal. Above the high is the spray zone.

Intertidal Zonation: the pattern of distribution of organisms in the intertidal zone.

Purpose: **1:** Explore seashore biodiversity
2: Identify adaptations of organisms to intertidal habitats.
3*:* Identify variables important in the distribution and abundance of organisms

Bring:

Waterproof footwear in the following order of preference:

hip waders…gumboots…hiking boots…running shoes with two pairs of socks and plastic bags between the socks and over the outer pair

- An identification guide such as:
  - *Guide to Intertidal Invertebrates* by Tom Carefoot, distributed in class
  - Your key from the lab, Observation and Identification of Intertidal Organisms
  - *From Whelks to Whales* by Rick Harbo
  - *The Beachcomber's Guide to Seashore Life* by J. Duane Sept
  - *Exploring the Seashore* by Gloria Snively
  - *Seashore Life of the Northern Pacific Coast* by Eugene Kozloff

Clipboard and paper and pencils.

Species survey sheets (attached)

Seasonally appropriate and waterproof clothes and hat

Come prepared for any weather conditions…the tide waits for no one!

VCC Will Bring: buckets calipers line shovel hip waders thermometers refractometers sampling quadrats

How to Get To Lumberman's Arch: Refer to the map. From campus, go west (left) on Great Northern, turn north (right) on Main Street, then west (left) over the Georgia viaduct. Find Georgia Street and continue into Stanley Park. Park at the bottom of the hill, past the aquarium. Car pool, offer gas money. Pay parking at $2/h is in effect during the day.

Beach Behaviour: Respect the environment and the marine organisms. Use all of your senses to gather information, but avoid unduly disturbing organisms. When you turn a rock over, replace it to its original position. That's someone's home! Collect organisms only when cleared by or requested by an instructor.

Learning Objectives:

1. Identify and describe the natural history of at least six common organisms you encounter in the intertidal zone.
2. Make careful and accurate drawings of these organisms.
3. Measure salinity with a refractometer and measure temperature of air and water with a thermometer.
4. Measure sizes of barnacles and mussels and correlate their sizes to their locations in the intertidal zone.
5. Make concise and organized field notes.
6. Identify eight factors, six abiotic and two biotic, that influence the distribution of intertidal organisms.
7. Recognize intertidal zonation and explain how environmental factors affect distribution of intertidal organisms.

Part 1: Marine Intertidal Biodiversity (2 marks each = 12)

Complete the species survey sheets on the following pages. Your notes fall under five headings:

- **Identity**. Use your key to find the common and scientific names of each six organisms. If the key doesn't do it, use field guides and instructors.
- **Category**. Your six organisms are to include two motile (moving) animals, two sessile (attached) animals, and two macroalgae.
- **Drawing**. Make a careful and accurate drawing of each of the organisms. Measure each organism's dimensions with callipers, ruler, or the quadrat. Place a scale with your drawing so we know its actual size. You may wish to make a digital photograph and refine your drawing later.
- **Habitat description**. Describe the specific location where you find each organism. First estimate its distance from the sea wall (ok to be on the sea wall), then describe whether its under a rock, attached to the top of the rock, etc. You can't be too detailed.
- **Describe adaptations**. Carefully describe, using your drawing when appropriate, how each organism is adapted to survive in the intertidal zone. Examples are: large foot to hold on to rock, quick burrowing, slimy covering.

Name **Date** **Mark**

Field Entry 1: a motile intertidal animal

Species:

Habitat:

Drawing: (remember the scale)

Adaptations for intertidal survival:

Field Entry 2: a motile intertidal animal

Species:

Habitat:

Drawing:

Adaptations for intertidal survival:

Field Entry 3: a sessile intertidal animal

Species:

Habitat:

Drawing:

Adaptations for intertidal survival:

Field Entry 4: a sessile intertidal animal

Species:

Habitat:

Drawing:

Adaptations for intertidal survival:

Field Entry 5: a macroalgae

Species:

Habitat:

Drawing:

Adaptations for intertidal survival:

Field Entry 6: a macroalgae

Species:

Habitat:

Drawing:

Adaptations for intertidal survival:

Part 2: Barnacle/Mussel Survey (6 marks)

Barnacles, *Chthamalus dalli*, and mussels, *Mytilis* sp., are two abundant sessile intertidal filter feeders that attach to rock surfaces and one another. Both produce planktonic larval stages that settle wherever they can. Mussels, unlike barnacles, can move about prior to permanent settlement. Both organisms feed only when immersed. **Predict** (before you look!) where in the intertidal zone you would find the largest individuals, and why.

Now you will test your hypothesis. In groups of 3 or 4, measure the diameter of five of the largest barnacles and the length of five of the largest mussels from each of three sites with callipers as instructed. One site will be on the sea wall, one by the water's edge, and one in between. Fill in the following

Water's Edge		Mid-way		Sea Wall	
barnacle	**mussel**	**barnacle**	**mussel**	**barnacle**	**mussel**
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
Mean					
mm	**mm**	**mm**	**mm**	**mm**	**mm**

Does your data support your prediction?

Explain how your data support or do not support your prediction.

What is your next hypothesis?

Part 3: Abiotic Features of the Intertidal Zone (6 marks)

Record temperatures with a thermometer

1. Air temperature near a cluster of intertidal organisms with thermometer bulb dry:

2. Air temperature near a cluster of intertidal organisms with thermometer bulb wet:

3. Why measure wet and dry bulbs?

4. Water temperature at the ocean edge (submerge thermometer carefully):

5. Water temperature in a tidepool:

6. Which sites would have higher temperatures in the summer?

7. Which sites would have higher temperatures in the winter?

8. Why measure in these different locations?

Record salinity with a refractometer

An instructor will demonstrate the use of the refractometer.

1. Sample from a tidepool:

2. Sample from open water:

Identify two factors that lead to salinity fluctuations in the intertidal zone.

Part 4: Biotic Factors Determining Distribution (8)

While abiotic factors limit upward distribution in the intertidal zone, biotic factors limit downward distribution. **Competition** and **predation** are most important. Competition occurs when individuals of the same or different species seek the same resource, and that resource is limited.

Look around for and **describe** a specific case of **interspecific competition**. Then place a .5m^2 sampling quadrat over your case and describe one additional cases of interspecific competition within the quadrat.

What limiting resource(s) might initiate the competition in each of your cases?

How might this competition determine the distribution of the organisms you describe?

Within the same quadrat, describe evidence of **intraspecific** (within the species) **competition**.

Look around for and describe evidence of **predation**.

How might one of your examples of predation determine the distributions of predator and prey?

Use the space below to enter questions that you have about your intertidal experience. (2 marks)

Field Assignment:

Part 1 of your field assignment (marked out of 35; total mark, Parts 1 and 2 = 5%) is the submission of the completed data and the questions on these sheets. **Due on** _____ at the beginning of class. Part 2 will be given to you in response to Part 1.

Laboratory: Energy Acquisition in the Coastal Marine Ecosystem

The following write-up gives you background information, with text references, then asks you to complete tasks and answer questions at a series of five stations. Work with a group as you move from station to station, and make sure that you visit all of them.

***Learning Objectives**:* during this laboratory, you can expect to

1. Identify and describe some common phytoplankers and zooplankters.
2. Identify and describe adaptations of common phytoplankers and zooplankters for the capture of energy and food in the pelagic zone.
3. Identify and describe adaptations of common marine consumers for acquiring food.
4. Categorize marine organisms by their energy acquisition strategies.
5. Assign marine organisms to their trophic levels.

Text References:

	Campbell and Reece	Nybakken and Bertness
Photosynthesis	Chpt 10:181-185	
Feeding mechanisms	Chpt 41:844-845	Chpt 6:276
Productivity, producers, consumers	Chpt 53:1166-1168; Chpt 54: 1184-1194; Chpt 28: 555-563	Chpt 6:284-294; 331-333
crustaceans	Chpt 33:664-665	
mollusks	Chpt 33:650-653	
Decomposers, detrivores	Chpt 27:539, 544; Chpt 54:1184-1186	

Energy, along with essential nutrients, comes into the biological community through the work of autotrophic organisms, the **producers**. Producers produce food through the process of **photosynthesis**, fixing carbon from carbon dioxide in the air, combining it with water using the energy from the sun, storing the food as starch, fats or oils.

Four groups of producers dominate the marine environment:

- **Phytoplankton**: microscopic, single-celled organisms floating free and drifting with the tides and currents.
- **Seaweeds**: three groups (red, green, and brown) of macroscopic organisms that attach to the sea bottom, mostly in shallow water.
- **Benthic diatoms**: microscopic, single-celled organisms found on seaweeds and other substrates.
- **Sea grasses**: two species of eelgrass live on sandy substrates in the Vancouver area.

Phytoplankton are the earth's dominant aquatic producers in marine and fresh-waters. However, macroalgae, benthic diatoms, and seagrasses dominate production on the coast. We live next to a very nutrient-rich coastal environment. Run-off from the land and upwelling from the seafloor bring nutrients that foster high productivity.

What You Should Know About Energy Acquisition by Producers

Producers absorb solar energy, which initiates the complex process of **photosynthesis**. Photosynthesis results in the production of **glucose**; the bonds that hold the carbon atoms of glucose in place represent the trapped energy of the sun. In eukaryotes, **chloroplasts** are the organelles in which photosynthesis takes place.

The first set of photosynthetic reactions (which you'll learn about in more detail in Biology 1200), involves the **absorption** of light by **photosynthetic pigments**. These pigments vary more in marine producers than in terrestrial plants, and this variability is used to classify algal phyla. These different types of **chlorophyll** absorb slightly different wavelengths of light. Many marine algae use **accessory pigments** (blue, red, brown) to help trap light energy.

Sunlight availability varies with the time of year, depth, weather, tidal cycle, and turbidity, both mineral (run-off) and biological (density of plankton). Producers are adapted for efficiency of light capture at molecular to macroscopic levels.

Station 1: Microscopic Producers: Microalgae

Phytoplankton inhabit the photic zone of the open ocean. Most are unicellular that exist as unicells or in chains. **Diatoms** and **dinoflagellates** dominate the phytoplankton.

Diatoms belong to the phylum Bacillariophyta (*phyte* means plant). They live in glass houses…shells of perforated silica…of varied and sometimes elaborate architecture. Unlike most other photosynthesizers, they store the products of photosynthesis as energy-rich fats and oils. **Benthic diatoms** coat the surfaces of rocks, mud, sand, seaweed, and sea grasses along the shore. They secrete slime that helps them attach to and move across these surfaces.

Dinoflagellates belong to the phylum Dinoflagellata. Two flagella protrude from a distinctively shaped cellulose shell. When they swim, the flagella make them spin (that's how they got their name: *dinos* means whirling in Greek). Rapid population growth, or planktonic bloom, results in a toxic event called red tide (though it isn't necessarily red and it's not a tide). Some dinoflagellates are heterotrophs.

Station one consists of microscopes set up to view fresh preparations of benthic diatoms and pelagic phytoplankton. Make two drawings, to scale. Draw one of the organisms viewed under each of the microscopes. Estimate the actual size of the organism.

What adaptations help pelagic phytoplankters remain in the photic zone?

Station 2: Macroscopic Producers: Macroalgae

More than 600 species of benthic macroalgae inhabit the nutrient-rich shores of British Columbia. They are grouped into three phyla based upon their photosynthetic pigments, as follows.

Phylum of algae	**Type of chlorophyll**	**Accessory pigment**
Green (Chlorophyta)	a and b	Beta-carotene (orange/red)
Red (Rhodophyta)	a	r-phycocyanin (blue) r-phycoerythrin (red)
Brown (Phaeophyta)	a and c	Fucoxanthin (brown)

Green algae ally closely with land plants and taxonomists often include them in the plant kingdom. Green algae live in a variety of habitats, from marine and fresh waters to damp soil, rocks, trees, and snow ("pink snow" is a green algae, *Chlamydomonas*).

Most red algae are relatively small marine seaweeds. Some, such as *Pophyra* (=*nori* that forms the wrap of your maki) looks brown.

The brown algae, or kelps, are larger than the other seaweeds, and more structurally complex. Most are found in temperate waters, and BC boasts the world's greatest kelp diversity. Some can weigh a tonne, and grow the better part of a metre on a spring day.

Choose one of the macroalgae at Station 2. Draw it, then label it with its identity, size, and its main parts: holdfast, stipe, and blade. Answer these questions:

1. What features of the algae enhance light absorption?
2. How do macroalgae maintain their position in their natural habitat?
3. How is your specimen adapted to deal with desiccation?
4. How is your specimen adapted to deal with predation?
5. Compare how macro and micro algae remain in the photic zone?
6. What advantage do a variety of pigments give producers?

Consumers take many forms and roles as they feed on other organisms, their wastes, or their bodies. Marine food chains are often longer than terrestrial ones, and consumers may occupy more than one trophic level. **Primary consumers** feed upon producers. **Secondary, tertiary or quaternary consumers** appear as we go up the food chain. Some consumers fit into more than one trophic level. Important categories of these heterotrophs in our marine ecosystem include:

- **Zooplankton** drift around with the phytoplankton and eat them and one another. Zooplankters range in size from microscopic to macroscopic, and include larval stages of many marine animals and 60-metre-long strings of jelly. Those that spend their entire lives in the plankton are called holoplankton; those that stay there through portions of their lives, however brief, are called meroplankton.
- **Grazers** clip or graze benthic diatoms or macroalgae off of rocks or other surfaces. Examples include periwinkles, chitons, and giant green isopods.
- **Detrivores** feed upon detritus: dead or decaying material. This category includes invertebrates and vertebrates, such as shore crabs, and sometimes, northwestern crows. Detrivores usually break apart their food before ingestion.
- **Decomposers** also feed upon dead or decaying material, but from within or upon, using enzymes to break down organic chemicals to simpler and smaller forms. Bacteria and fungi are decomposers.

- **Filter or suspension feeders** strain out microscopic to small macroscopic organisms from the water. Local examples include mussels, barnacles, some worms, herring, grey whales, and many more. Where rich water moves as much as it does in our area, many creatures specialize as soup-strainers!
- **Predators** have many strategies for obtaining prey. Currently, many ecologists include all organisms that collect or capture prey as predators. This may cause confusion, e.g.: filter feeding can be predation.

What You Should Know About Energy Acquisition by Consumers

Producers make food for their own growth, repair, and reproduction. Without them, however, all of us consumers would perish, because we can't make our own food. Whether we eat producers or other consumers or both, we derive our energy and nutrients from the chemicals packaged by other organisms. Consumers need to detect their prey, safely acquire it, and then break down complex chemicals to simpler ones so that they can perform the life processes. You will learn the details of cellular respiration, wherein glucose is metabolized for energy, in Biology 1200.

Station 3: Zooplankton

View two preparations. First view assorted live zooplankters under the stereoscope. Prepare wet mounts, use depression slides with cover slips. Then observe either the coastal **copepod** *Tigriopus californicus* or the **brine shrimp** (sea monkey) *Artemia salina*, a denizen of very salty coastal lagoons and inland salt lakes. Use a watch glass and view under the stereoscope.

Draw one creature from each of your two preparations. Label with their names (if possible) and estimated sizes. Answer these questions:

1. How do the organisms swim? Label on your drawing.
2. What appendages might be used for feeding? Label on your drawing.
3. What appendages might be used in other ways for survival? Label on your drawing.
4. List swimming and feeding adaptations common to the specimens you observed.
5. How do they capture food?
6. Which animals are primary consumers and which secondary consumers? Describe differences between them.

Station 4: Grazers, detrivores, and decomposers

Grazer. Two species of periwinkles, *Littorina* spp., inhabit our intertidal zone. They use the large muscular foot characteristic of gastropod mollusks to move slowly over rocks and seaweeds. They use a toothed radula, a hard chitin/protein substitute for a tongue, to rasp food off surfaces. If you can get one to crawl on a piece of glass such as a microscope slide, you may witness the radula in action. Periwinkles avoid desiccation by seeking moist places when the tide is out, and by using a horny operculum to seal the opening in their shells. Periwinkles prefer to spend quite a bit of time out of the water.

Draw a periwinkle and label your drawing with its name, approximate dimensions, and adaptive features.

Detrivore. Examine the **Oregon shore crab**, *Hemigraspsus oregonensis*, a crustacean arthropod very common on our more silty rocky shorelines. While often eating detritus, they are opportunists who will also eat benthic diatoms and macroalgae.

Draw a shore crab and label your drawing with its name, dimensions, and adaptive features. Observe feeding and make note of which appendages the crab uses, and how it uses them.

Decomposer. The marine bacteria ***Caulobacter*** sp plays an important role in reducing waste build up and cycling nutrients in the marine ecosystem. These bacteria develop stalks by which they attach to small particles in the water. They then decompose the organic material into absorbable components.

Observe *Caulobacter* on display under the compound microscope. Trace a Petri dish onto your paper. This area represents your microscopic field of view. Note the magnification. Draw a few bacteria to scale. Estimate the size of a single individual.

Station 5: Filter feeders

The **blue mussel**, *Mytilus* sp. gathers in clumps to avoid predation, attaching to the substrate by a "beard" of byssal threads that it secretes. Observe its external structure, and learn to differentiate anterior, posterior, dorsal, ventral, left, and right. Observe the demonstration of how its filtering mechanism works. Draw the pattern of carmine particles that show how the mussel uses its gills to bring food to its mouth.

Barnacles lie on their backs and kick food into their mouths with their cirri. Observe these crustacean arthropods as they strain the water for food. Draw the barnacle and describe its feeding actions.

Baleen whales, such as the grey whales that migrate off BC's shores, we don't have, but lets talk about how these leviathans filter-feed.

Make a table comparing how grazers, detrivores, decomposers, and filter feeders obtain their food.

Laboratory: Marine Predators

In this lab you will learn more about a few intertidal predators from a slide show, recollections from our field trip to Figurehead Point, and a dissection of a pelagic predator, a squid. Following the lab, we will discuss marine food webs through a case study.

Learning Objectives: during this laboratory, you can expect to

1. describe features common to predators.
2. identify and describe adaptations of common marine predators for capturing prey.
3. improve skills with dissecting tools and the stereoscope.
4. manipulate a marine food web and use it to solve a puzzle.

Text References:

	Campbell and Reece	Nybakken and Bertness
Predation, keystone species	Chpt 53:1161-1162, 1168-1169	Chpt 6:286-290
Ecological efficiency and the pyramid of numbers	Chpt 54:11186-1190, 1191-1193	
Food webs	Chpt 53:1166-1168	

Part 1

First, view the slide show, and make comments from your intertidal observations.

Predator Name	**Prey**	**Habitat**	***Predator Style***
Purple sea star			
Green anemone			
Moon snail			
Striped seaperch			
Hydroid			
NW crow			

***Part 2*.**

You've identified a number of marine predators on our intertidal field trip. Make a list of them now on the table below, and fill in the blanks as above.

Predator Name	**Prey**	**Habitat**	**Predator Style**

***Part 3*.**

The squid, *Loligo opalescens*, belongs to the phylum Mollusca, class Cephalopoda. Squids, along with their cousins the octopuses, are considered the most sophisticated of mollusks, with highly developed nervous systems including the most advanced eyes of any invertebrate, and high intelligence. These squids swim in the pelagic zone of coastal BC, congregating to spawn subtidally along protected shores. This animal is a wonderfully equipped predator.

Obtain a specimen of a squid, freshly purchased at the market, for your group, along with dissecting instruments, a dissecting scope, and a *BioCam* guide to the squid. With the help of the *BioCam* guide examine the predatory adaptations of the squid.

1. With the aid of the *BioCam* guide, identify some of the major external features after orienting (tricky) the animal.
2. List adaptations of the arms for predation. View suckers under the stereoscope.

3. Note the eyes. How do the well-developed eyes and stereoscopic vision aid predation?

4. How is the squid adapted for efficient swimming? Comment upon the roles of the siphon and the fins.

Open the mantle cavity by cutting with scissors from ventral to dorsal. Pull out the "pen", an elongate, stiff, clear structure.

1. How does the pen contribute to efficient swimming?

2. Dissect the head to find the muscular buccal bulb that contains the beak and the radula. A poison gland may increase the effectiveness of a bite. Observe the beak and radula under the dissecting scope, then draw and describe how these mouthparts work.

3. What kinds of organisms would squid prey upon?

4. What would prey upon squid?

Part 4.

You will be presented with some information cards (thanks to U.Vic's Gloria Snivley} about local marine organisms. You will learn about them, then, make a likely food web linking them together.

Here's the puzzle. Steller's sea lions, large fish-eating predators, are suffering a serious decline in population size in the northeastern Pacific Ocean. Sea otter populations in Alaska are declining. Kelp beds are shrinking. People are fishing.

What's the story behind the population changes mentioned above? Why are the kelp beds shrinking?

The list of participants:

Steller's sea lions
Killer whales, top predators
Pollack, fished for making fake crab
sea otters
pacific giant kelp
sea urchins
human fishers

Literature Report

***Scope*.** Your literature research and report will provide you with background information about the organism that will be assigned to you for your Term Project.

***Prepare*.** Prepare for your literature search by completing the Library Research Activity at our library session.

You are required to cite three refereed sources, not counting your textbooks. Refereed articles are those reviewed by peer scientists. The majority of your citations, beyond the three required, must be from refereed sources. **Preferred**: one book and two journal articles.

All literature must be correctly cited and properly referenced; **this is essential in all academic writing. Use Pechenik, J.A. 2006. A Short Guide to Writing about Biology and Appendix A: 769-770 and 764-765 in your lab book by Morgan and Carter to assist you with citing references**.

Find books and articles online. Use the skills acquired during our session with the librarian to identify relevant literature about your organism.

- Find two or three books about your organism. Copy down the title, location, and call number of each book. To find books, record two or three possible search terms for your organism. Include broad terms.
- Find two or three articles about your organism. Record full citations. Library catalogues should give you locations and availability of articles. Some articles may be available on-line.
- Make use of the guides from our librarian and pp770-771 in your lab book (Morgan/Carter) if you use articles on the web. Use the web to find peer-reviewed resources. Other postings may be of interest, and may give you ideas for your experiment. These may be used and cited, but do not count toward the three reference sources required for the report.

***Find books and articles*.** Since our collection at VCC is small, plan to make a trip to the Woodward Biomedical Library at UBC (that's faster than an interlibrary loan and good experience). The B-line connects our campus to UBC with a 30-minute ride. You will be able to use books and journals at the Woodward Library, but you will not be able to check them out, so come equipped to gather your information there. UBC libraries have information packages that help you use their resources. Ask a librarian for assistance. (Caution: books that appear to be missing may well be there!) Woodward Library is open Monday - Thursday: 8am - 11pm, Friday: 8am - 6pm, Saturday: 10am - 6pm, and Sunday: 12noon - 6pm

***Gather your information*.** Begin by using your textbooks. Do not use general encyclopedias. Your report will include the following specific information about your organism. The list should look familiar!

- scientific and common names
- description, including how the animal senses and responds
- natural habitat
- abiotic factors affecting its growth, survival, reproduction and/or behaviour
- biotic factors, including how it feeds and otherwise interacts with organisms in its natural habitat

Write your report. You will submit a well written, 2-3 pages, double-spaced report, in paragraph form. (Note that this is not an experiment write-up.) Anything over 500 words, not including citations and reference list, will be returned to you without a mark. Use a word processor if you can. **Take great care not to plagiarize!** See the rules in Pechenik. Quality of writing matters!

Make sure that you keep a copy of your report.

Your report evaluation will include this list and mark scheme:

- 1 scientific and common names
- 3 description of animal
- 3 natural habitat, in detail
- 3 abiotic factors affecting its growth, survival, reproduction and/or behaviour
- 3 biotic factors, including how it feeds and otherwise interacts with organisms in its natural habitat
- 1 three refereed sources, correctly cited and properly referenced.
- 1 visit to Woodward Biomedical Library at UBC

Deductions: poor writing, presentation not to specs

The report, marked out of 15, counts 5 marks, 5% of your course mark.

The Animals for Term Projects

Green Shore Crab: *Hemigrapsus oregonensis*

Phylum Arthropoda
Class Crustacea

The most common of a number of small crab species that frequent the rocky shores at Figurehead Point, groups of the green or hairy-legged shore crab shelter under rocks at low tide. When the tide comes in, the crabs emerge and search for food, which can be almost anything, but consists primarily of seaweeds. Because they live in an environment that changes through tidal cycles and seasons, these hardy crabs can tolerate a wide variation of temperature, salinity, pH, oxygen concentration and moisture. They seem to thrive in our classroom marine aquaria.

Green shore crabs belong to the Order Decapoda, crustaceans possessing ten pairs of appendages, including mouthparts and antennae. Many of these paired appendages enable the crabs to sense their surroundings. Anteriorally, two antennules are equipped with temperature, touch and chemical receptors. Adults have a pair of compound eyes mounted on moveable stalks that give them wide-angle vision. Bristles on their appendages detect water motion and vibrations. Adaptations of paired appendages also facilitate locomotion, defence, aggression, feeding and mating.

These crabs go through a complete metamorphosis. Males inseminate females just after they molt their exoskeletons, when their armour is soft enough to penetrate. Females carry eggs under the abdomen that wraps back up to their bodies. Larvae very different from the adult go through a series of planktonic stages before settling to the substrate and looking like an adult: complete metamorphosis. Young crabs then molt repeatedly as they grow.

When you search for information on the behaviour and ecology of this species, investigate also its local cousin, the purple shore crab, *H. nudus*, and other closely related species. For information about response mechanisms that include anatomy and physiology, search more broadly about decapod crustaceans.

Copepod: *Tigriopus californicus*

Phylum Arthropoda
Class Crustacea

These abundant little creatures are widely distributed in splashpools on rocky exposed shorelines of the North American Pacific coast. They feed primarily upon algae and detritus, and also on suspended organisms; we feed our cultures the green alga *Tetraselmis.* When populations become extremely dense they may become cannibalistic. The diverse and abundant crustaceans of the subclass Copepoda assume a significant role in both fresh-water and marine ecosystems as primary consumers and prey.

The splashpool habitat endures harsh environmental changes with the daily tidal cycle, weather, and season. Especially during periods when high tides do not reach the pools, they can fluctuate greatly in temperature, salinity, pH, oxygen content and metabolites. *Tigriopus* migrate vertically in deeper pools with changing conditions. The hardiness of this animal allows us to culture it easily; it gets studied frequently and has been nicknamed the “oceanic white rat” or “marine fruit fly”.

Tigriopus has a short life cycle, moving from egg to adult in about 21 days at 20ºC. They undergo an incomplete metamorphosis, which means that the babies look somewhat similar to the adults. Look for eggs along the posterior part of the abdomen of the female.

When you search for information on the behaviour and ecology of this species, focus on *T. californicus*. For information about response mechanisms that include anatomy and physiology, search more broadly about copepod crustaceans.

Brine Shrimp: *Artemia salina*

Phylum Arthropoda
Class Crustacea

Brine shrimp (some people call them sea monkeys because of their twirling swimming motion) usually live in conditions of extreme salinity, such as the evaporating salt ponds of southern San Francisco Bay (from where we get our table salt) and the Great Salt Lake of Utah. They can tolerate wide temperature and salinity fluctuations, but die in fresh water. Aquarists know this animal as fish food. *Artemia* suspension feed upon phytoplankton; we feed our cultures *Tetraselmis*. Many organisms feed upon brine shrimp.

Brine shrimp belong to the primitive subclass Branchiopoda, where *branch* refers to breathing apparatus and *pod* means foot: they breathe through their appendages. Coloured by their blood, the animals get brighter red with increasing dissolved oxygen.

Because *Artemia* often live in ephemeral waters, they have evolved an egg that can survive desiccation as a dormant cyst for many years. Add water, and the cysts hatch into miniature brine shrimp that will undergo incomplete metamorphosis through a series of molts to the adult stage in about eight days.

When you search for information on the behaviour and ecology of this species, focus on *A. salina* and related *Artemia* species. For information about response mechanisms that include anatomy and physiology, search more broadly about brine shrimps. Be careful with your googling: many brine shrimp web sites sell them to you; others feature high school labs and high school student research that require your vigilance.

The Response of the Organism

Responses of organisms, including us, usually enhance the probability of survival. Ultimately, successful responses lead to opportunities for successful reproduction, the purpose of life (you may disagree that this is your purpose!). Organisms respond on two levels: proximal and ultimate.

Proximal means right now: the right thing to do to manage a comfortable niche. Organisms will move to a cooler location from one that is too hot. They will flee from a predator to be out of harm's way. They will have sex to resolve the need to have sex, and relax again. The phenotypic responses to reach *homeostasis* (steady state) are termed *adaptions*. These adaptive processes can be behavioural, physiological, and/or biochemical.

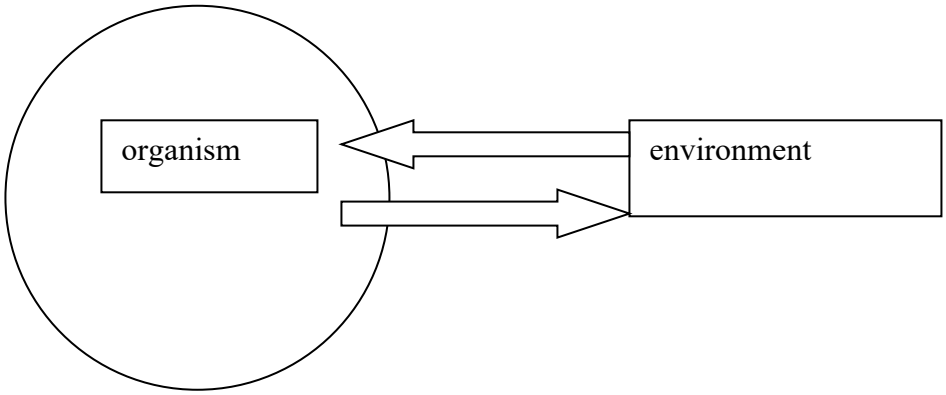
Ultimate responses are long-term, evolutionary. The organism moves to a cooler area because it has evolved internal systems that work best in the cooler conditions. The organism flees a predator, most often because its nervous system recognizes the danger. Sex happens because without it, the individual's unique genome would go extinct. An evolutionary response essentially reflects "species learning". These long-term responses are genotypic, and are called *adaptations*. Adaptations can be behavioural, physiological/biochemical, and structural.

Write now an *adaption* (proximal) that you have to your environment.

Now, write an *adaptation* (evolutionary).

For organisms to respond proximally to both abiotic and biotic environmental factors, they must receive information from their environment, process it, and respond to

the environment. The processing happens inside the organism and is based on an evolutionary response: an adaptation. The response should thus be adaptive: contribute to heightening the probability of survival. Consider the following model of response:



Now describe an example of how this model applies to one of your responses.

Your team will need to consider how this model applies to your experimental organism's responses. Knowledge of the processes behind your organism's responses will be important to setting up your experiment and interpreting your results. The general response processes for your crustaceans are quite similar, so general descriptions may give you sufficient information. However, you will need to consider response processes for the specific abiotic factor in your experiment. Investigate these processes for your organism, first in your texts, then by consulting other literature as necessary. Write a paragraph or two about your organism's response process to the environmental factor in your experiment by the time that you perform it. This information will become part of your final written and oral reports.

Experimental Design

Scope. This lab session introduces you to

1. your Term Project Team

2. protocols for carrying out a successful experiment.
3. the equipment and facilities available for your Term Project.

***Prepare*.** Prior to the lab session, read this and Lab Topic 1, Scientific Investigation, Exercises 1.1, 1.2 and 1.3, pages 1 -14 in Morgan and Carter's *Investigating Biology Laboratory Manual.*

Your Term Project Team was chosen randomly and your experimental species was assigned to your team randomly.

***Experimental Design*.** You will design an experiment to examine the effect of an environmental factor, such as temperature, salinity, oxygen concentration, light or pH, upon an organism's behaviour. Our experiments intend to not unduly stress the organisms, and to treat the animals with as much respect as the circumstances allow.

Your design will be one of two types:

1. **Measured –response**. You vary the level of the environmental factor encountered by the organism, and then measure a response by the organism.
2. **Preference-response**. You offer the organism choices of an environmental factor and record its preference.

***Beginning*.** Clarity and simplicity are keys to successful science. Repeat: **clarity and simplicity are keys to successful science**. Careful design leads to clear results.

Formulate your hypothesis. First we wonder, then we question, then we hypothesize. A hypothesis is a testable, educated guess, always made prior to the experiment. A good hypothesis is backed by a firm rationale. A good hypothesis tests easily.
What we normally call the hypothesis is more properly termed the **experimental** or **alternative hypothesis**. The experimental hypothesis makes a statement that reflects your best guess of the expected result. It is countered by the **null hypothesis**, a statement you can disprove, since it is impossible to test all the conditions necessary to prove a hypothesis. Hypotheses thus come in pairs:

H_O: the null hypothesis (no change, no choice), established to refute, and

H_a: the experimental or alternative hypothesis, (what I think will happen) supported when the null hypothesis is not supported, or disproved.

For example: H_O: increasing temperature does not affect shore crab ventilation rate
H_a: increasing temperature increases shore crab ventilation rate

So we design our experiments so that we can disprove, or refute, the null hypothesis, and support the experimental hypothesis. Note that we **never prove** the experimental hypothesis: we can only **support** it. If a hypothesis is repeatedly supported, and as attempts to falsify it repeatedly fail, it may come to be regarded as **theory**. In science, equate theory with law. However, even theories can be falsified, because we never know

what's around the corner or past today. If you wish to pursue this philosophical point, read Sir Karl Popper (1959), The Logic of Scientific Discovery.

The experimental hypothesis establishes a clear possible **cause and effect** relationship: If… then… followed by because, the **rationale**. (We don't have to use the terms if and then and because, if they are implicit.) Base the rationale on what you know, what you've read, and good logic.

We term the cause part, the **independent variable**: that which is the cause of the effect. The effect part we call the **dependent variable**: that which we can measure with the application of the independent variable. Cause: independent variable. Effect: dependent variable. In the example above, independent variable: increasing temperature, dependent variable: ventilation rate.

Where does your hypothesis come from? It will come from your observations, your class and field experiences, your literature search, your prior knowledge, and your imagination.

Once you have determined your independent variable, you need to determine the **range of the experiment**. In Biology 1100, **you will test three treatments**, or levels of application of the abiotic factor that you will vary. If we refer to the temperature affect on shore crab ventilation, then we might choose 5^{o}, 10^{o}, and 15^{o}. How do we select these temperatures? We check the literature and consider what you've seen of the thermal environment of the shore crab. We do not choose -5^{o} or 55^{o} because we want our subjects to emerge alive. Do not go beyond the usual natural limits of your independent variable in the ecosystem.

Predict the organism's response to the independent variable. Note that the experimental hypothesis above predicts a **direction of response**. Your literature research will help you make a reasonable prediction. Remain open to results that don't fit your prediction.

***Determine the experimental procedure*.** How will you test the range and levels of treatment? Remember that the only variable you want is the independent variable. As much as possible, everything else about the experiment should be the same. You may be constrained by cost, equipment, time and space. How will you measure the response? Perhaps we might place a drop of suspended carmine particles in front of the crab's gill bailers and measure how far the particles disperse within five seconds. Will the measurement procedure work? You'll have to find out. **Trial runs** help scientists determine if their procedures yield measurable results.

Controls. One type of experimental control removes the independent variable. With a variable such as temperature, this is not possible. In such a case, where the independent variable cannot be removed, we use a type of control called a **standard**. The standard for temperature for the crab experiment would be an average temperature that a shore crab would encounter. The treatment control in the experiment must not be confused with efforts to control extraneous variables.

Experimental replicates ensure that we don't conclude anything based on a single observation. Your "cause" may not be responsible for the measured effect. A chance occurrence may yield an atypical result. All treatments, including controls, must be set up more than once, at the same time. The more replicates, the greater the confidence in the reliability of your results. In practice, we need to limit the number of replicates. **Three is the minimum number of replicates**, including the treatment control, for each treatment in your experiment. They should all be done at the same time in the same way. Depending upon your experiment, subject, and time, you may be able to perform more replicates. More is better.

Experimental trials, unlike replicates, additional trials are the same experiment performed at different times. Additional trials allow the experimenter to demonstrate the reproducibility of results, thus building confidence in the validity of a hypothesis. Your group may perform two trials of the same experiment. If you modify your original hypothesis, or if you extensively modify your procedure, you will perform one trial each of two different experiments. Each trial of an experiment is analyzed and presented separately.

In summary, we might run two trials of our shore crab experiment, one this Thursday, and one next Thursday. In each trial, we would replicate each treatment three times: measure three crabs' ventilation rate at 5^{o}, three at 10^{o}, and three at 15^{o}. The treatment control would be the 10^{o} temperature, an average temperature that the crab would encounter.

Variability in data is expected in animal behaviour experiments. Replicates help us detect **experimental errors**. Even if our equipment is reliable and we prepare well and carefully follow good procedures, **biological variation among individuals** (genetic, age, gender, reproductive status) can lead to different responses even in identical conditions. Sometimes individual variation can mean large variation among experimental replicates. This data may be valid, simply reflecting reality.

Reduce experimental error by carefully following instructions for equipment use, coming into the lab well prepared and organized, and by controlling extraneous variables.

Reduce biological variability by using organisms of the same age, gender, and other similarities to one another. Or…choose another variable that leads to less variability in your results.

Choice experiments allow organisms to choose among items or environments. Data are collected as frequency events…how many individuals choose A over B or C.

For choice experiments, we make some modifications to the approach we use for measured-response experiments.

The **null hypothesis** predicts no choice, versus the experimental hypothesis predicts a particular choice.

The **range of the experiment** will be the different choice opportunities that you offer the organism. The choices should relate to the natural environment.

The **experimental procedure** requires a container that allows the organism to be an equal-opportunity chooser. The choices must be **simultaneous**, **distinct**, and **equal** in size or proportion. **Randomizing** the position of choices is very important. For example, if you present a crab with three choices of rock sizes to hide under, you could place them north, west, and east of the crab. You could roll a die to choose where the largest rock goes by assigning 1 and 2 to north, 3 and 4 to west, and 5 and 6 to east, and so on. You also have to consider **time**. As an example, you may limit a crab to three minutes to make a choice. If it hasn't, you would remove it and try another individual.

A separate **control treatment is unnecessary**.

Experimental replicates in choice experiments require adequate numbers. If you present three choices, use at least 15 individuals, one at time. If you placed more than one together, they might well affect one another's behaviour. Do not use an individual more than once (the data lose independence that way).

Experimental replicates are not averaged as they are in measured-response experiments. **In choice experiments, data from replicates are summed**.

Meet the equipment for your experiment. We have probes to monitor environmental variables. We're going to learn to use this hi-tech equipment! You'll be able to try them on your organisms. Make notes on the equipment and its use.

Time to plan your experiment. The first step is to come up with a question. How does environmental factor "x" affect organism "y"? Which level of environmental factor "x" would organism "y" choose?

Examine your work and readings on intertidal organisms, focusing on abiotic factors in their environments. Reduce the list to three or four factors that you think might influence your organism.

What materials or equipment might you need to vary these factors to generate a range or discrete choices?

Discuss how your organism might respond to each factor.

How would you measure each response? You want numbers…a quantifiable response. You will get ideas from your literature research.

Make tables summarizing your group discussion. Your first table should list your biological questions. Your second table should list abiotic factors, how you would generate a range or good choices of each factor, the organism's predicted responses, and how you would quantify these responses.

Now your group will **complete an "Outline of Experiment" form**. Each of you should leave with a copy. After you all work on your literature reports, and compare your findings, you may modify your plans. Having a draft will give you a solid framework from which to plan further.

On the form,

- Fill in the scientific name of your organism.
- Name the one abiotic factor that will be your independent variable.
- The range or choices should reflect normal ecosystem parameters. Avoid lethal extremes.
- Relate your experiment to the organism's usual reality: its natural environment.
- Review your hypotheses with the instructor.
- Make your predictions of responses as specific as you reasonably can.
- Chart out your procedure. Remember
    - The range of the factor.
    - The different treatments within the range.
    - How you will measure the effects.
    - A step-by-step description of the equipment to be used, the procedure to be followed, and the time required for each step.
    - The controls required.
    - The number of replicates that will be tested.
    - The natural variation in responses you might expect.
    - The possible sources of error you can minimize.

Outline of Experiment

Team Members:

	Print Your Name	**email**
	_____	_____
	_____	_____
	_____	_____
	_____	_____

Organism: _____

Independent Variable: _____

Range of Variable or Choices to be Tested: _____

Response of the Organism (Dependent Variable): _____

Biological Context/Reality Check: state the relevance of the independent variable to the organism in its natural environment.

Hypotheses:

H_o:

H_a:

Prediction about the Organism's Response:

Procedure:
Describe how you will set-up the three different experimental treatments or choices (independent variable).

Describe how you will measure the response of your organism (dependent variable).

Do you require a control or a standard treatment for your experiment? If so, describe it and explain why you require it.

What extraneous variables, abiotic and biotic, will you attempt to keep constant? Describe how you will do this.

How many replicates will you perform for each treatment level or for each choice experiment?

List and describe the equipment you will use.

Describe, step by step, your experimental procedure, including your method of recording data.

Assumptions:

Data Inconsistency:
What extraneous abiotic variables might lead to inconsistent data?

What kinds of biotic variability might lead to inconsistent data?

What potential sources of experimental error can you minimize?

Submit this form and make a copy for each team member.

Prepare for Your Experiment

Here's an example of hypothesis structure, procedure, data collection and organization, and initial statistic processing for a **measured-response experiment**.

The Effect of Diet on the Growth of Earthworms, Lumbricus terrestris

Hypotheses

H_o: Caloric intake does not affect the growth of earthworms.

H_a: Caloric intake does affect the growth of earthworms.

Procedure

We assigned eighteen adult earthworms, *Lumbricus terrestris,* randomly to three groups, each given a different caloric value of food per day. We established high intake at 3 kcal/worm/day, medium at 2 kcal/worm/day, and low at 1 kcal/worm/day. We considered the middle caloric value (2 kcal/worm/day) to be the treatment control because a previous study of earthworms kept at 20^o averaged this intake (Terrant 1999). We manipulated the caloric value by using different concentrations of sucrose in the food mixture of sucrose, soy protein, and fibre (Burrows *et al 2002)* while holding the weight and volume of food constant.

The earthworms were maintained in three separate 42 l aquaria with a planting soil (NuGrow) depth of 10 cm in a dimly lit room with a 12h photoperiod at 20^o. A grid pattern of cardboard dividers gave each worm a separate enclosure (see Fig. 1). We distributed the food evenly over the entire surface of the soil in each compartment each day, between 0900 and 1000h. Soil surface moisture level was maintained by measuring it each day and sprinkling water over it as necessary. We selected eighteen worms of approximately the same size from a population of fifty-six collected from a compost bin in Vancouver in June. On the first day of the experiment, we weighed each worm after blotting it in a paper towel for two seconds. Fourteen days later we recovered the worms and repeated the measurement procedure.

Data Table

Table 1. The Effect of Caloric Intake on Weight Gain of Earthworms in 14 Days. Recorded in mg.

	Treatment: **Caloric Intake**		
Replicate	**1 kcal/worm/day**	**2 kcal/worm/day**	**3 kcal/worm/day**
1	4	5	10
2	2	7	8
3	1	9	6
4	2	4	9
5	0	5	6
6	2	4	7
Mean Weight Gain	1.8	5.7	7.7
Observations	All worms seemed healthy	All worms seemed healthy. Replicate 6 seemed sluggish.	All worms seemed healthy. Replicate 1 seemed more active than the others.

Note that the data table has a clear title, headings for columns and rows, a row for the average value, and a space for comments. You will turn in one data table from your team for each trial, on the day of each trial. Make sure that you all retain copies. You must include a sample calculation for each table, as in the following example:

Mean weight gain = sum of values for each replicate/number of replicates

Mean value for 1 kcal/worm/day = (4+2+1+2+0+2)/6 = 1.8 mg

Calculating the Mean

The **mean** describes the average of a set of numerical data. It is probably the most common statistic used to describe data. Add all the individual data numbers together and divide by the number of replicates to arrive at the mean.

$$\bar{x} = \frac{\sum x}{n}$$ reads " the mean equals the sum of the data values divided by the number of replicates, or sample size,"

When you calculate the mean, do it separately for each treatment level, as shown above. Then you can compare means between the treatment levels. Later, you will learn to establish **statistical significance**: whether or not a difference in the means actually tells you that there is a real difference between the treatment levels. These procedures are called **statistical analysis**.

Now follows an example of hypothesis structure, procedure, data collection and organization, and initial statistic processing for a **choice experiment**.

The Effect of Soil Moisture on Habitat Choice of Earthworms, **Lumbricus terrestris**

Hypotheses

H_o: Soil moisture level does not affect the habitat choice of earthworms.

H_a: Soil moisture level does affect the habitat choice of earthworms.

Procedure

We tested fifteen adult earthworms, *Lumbricus terrestris* from a population of fifty-six collected from a compost bin in Vancouver in June. We considered the moisture level of the compost bin optimal for earthworms, so we offered the worms three choices: compost soil at the moisture level where we collected them, drier and wetter. We used the same compost soil, at a depth of 5 cm, for each of the three choices, which we established by either drying or wetting it to the desired levels, monitored with a hygrometer. For an arena, we arranged the soil in large stacking bowl (see Fig. 2) to offer the three choices. We shielded the bowl from incident light from windows so that light direction would not influence choice. We placed each worm, individually, in a center circle,10 cm in diameter, with only a thin sprinkling of soil, enough so that the worm could easily gain traction for its journey to one of the choices. We watched each worm until it crawled into one of the three choice areas, then recorded its choice. We tested each replicate once. If a worm failed to choose after five minutes, we placed it in an “out” container, recorded “no choice”, and selected another worm from our stock.

Data Table

Table 2. The Number of Worms Choosing Different Soil Moisture Levels within 5 Minutes in an Arena.

	Soil Moisture Level Selected			
	Level 1 (drier)	Level 2 (medium)	Level 3 (wetter)	Observations
Replicate 1	X			approached 3 first
Replicate 2		X		chose and stayed
Replicate 3		X		chose and stayed
Replicate 4		X		entered 2, left, then re-entered
Replicate 5	X			chose and stayed
Replicate 6		X		approached 3 first
Replicate 7	X			approached 3 first
Replicate 8			X	approached 1 first
Replicate 9	X			approached 3 first
Replicate 10		X		waited for 250 seconds before moving
Replicate 11		X		chose and stayed, wiggled a lot
Replicate 12		X		approached 3 first
Replicate 13	X			chose and stayed
Replicate 14		X		chose and stayed
Replicate 15		X		chose and stayed
Total	5	9	1	

Note here that each data point is not a number, it is a discrete event. We simply sum the frequency of these discrete data points to see how our sample behaved. We require a reasonable sample size to show us trends.

For more advice and examples for preparing your experiment and collecting data, consult Morgan and Carter (2005), Lab Topic 1, pages 1-13.

Experiment Proposal

***Scope and Objectives*:** This session provides opportunity for you to

1. Present your team proposal to your colleagues and instructors.
2. Receive feedback on your team proposal and presentation.
3. Provide feedback to other teams' proposals.
4. Modify and finalize your team's experimental design.
5. Submit a detailed equipment list for your team's experiment.
6. Submit the Outline of Experiment.

***Prepare*:**

Rehearse your presentation with your team. If you need a room to meet, check with the instructor or lab demonstrator to determine when a room is available.

Base your presentation on your Outline of Experiment form and your Literature Report. Appropriate sections of Pechenik (2006) may assist you.

***Present*:** Each group will be allotted **eight minutes** to orally present their proposal to the class. Each member of the group should make an equal contribution to the presentation, so you need to plan ahead. The Outline of Experiment Form should guide your presentation: address all the points covered on this form. The Experiment Proposal Evaluation Form will also help you plan your presentation.

Here are some presentation hints:

- Speak loudly, clearly, and not too quickly. Aim your voice at the person furthest from you.
- Refer to your notes but do not read them.
- Make eye contact with your audience.
- Watch your words: use terminology such as treatments, trials, replicates, etc. correctly.
- Define any special terms that may not be familiar your classmates.
- Use visual aids: flip chart, blackboard, overhead projector transparencies, and/or presentation software. Let the instructor know your needs for presentation equipment in advance.
- Anticipate questions that your classmates and instructors might ask.

***Receive feedback*:** A **five-minute** question-and-answer period follows your presentation so that your classmates and instructors can provide feedback. Listen carefully (be quiet!), maintain eye contact, make notes, acknowledge the questioner, and ask questions if you require clarification. Feedback may be not only about the content, but also about the effectiveness of your presentation.

Give feedback. The Experiment Proposal Evaluation Form will be used by the instructor to score your presentation, and by all of the class to facilitate their verbal feedback. When you ask for clarification of the presenters, paraphrase what you heard, and add phrases such as " Let me see if I understood what you said". Practice ownership language. "What I heard is…" rather than "you said this…"

Evaluation. An effective oral presentation of your proposal, following The Outline of Experiment Form and attending to The Experiment Proposal Evaluation Form counts for 5 marks for each team member. An individual on the team may lose marks if they do not participate equally with the rest of the team. (Don't fight for airtime!!!! Work this out in advance, including responses to questions.)

Revise the Outline of Experiment. After all teams have presented their proposals, your team will discuss the questions and suggestions that you have heard from your colleagues. Modify your plans as you see fit. Blank forms will be available.

Submit the Outline of Experiment. Make a copy for your team.

Submit an equipment list. Our laboratory demonstrators need to know what you need to carry out your experiment. Here are some items to consider:

- How many containers, and what size containers, will you need?
- How will you create the different treatment levels or choices?
- What do you need to measure the response of your organisms?
- What quantities of materials, for experimental and control replicates, will you require?
- Remember the size of our lab: your space will be limited.
- Keep costs down.

Make sure to check your equipment list with the instructor and lab demonstrator prior to submission. We want to ensure that we can meet your needs. Make a copy of the list for your team.

Experiment Proposal Evaluation Form

Content:	**Comments:**
Hypotheses: Clear statements for both H_o and H_a	
Biological Context: The experiment tests variables relevant to the natural history of the organism.	
Independent Variable: Experiment tests the effects of a single variable.	
Range of Treatments or Choices lie within the tolerance limits of the organism and seem relevant to the natural environment.	
Three Treatment Levels can be achieved and maintained and conducted during one lab session. **Three choices** are distinct, equal, and simultaneous.	
Identification of the Organism's Response is clearly defined. Only one kind of response is to be measured. A plan to record qualitative data is presented.	
Measurement of the Response looks like it will yield valid data. Observers likely to collect comparable data.	
Control Treatment: The independent variable is removed, or the standard treatment is "normal". In a choice experiment, choices are randomized.	
Number of Replicates: at least three for each treatment level, or at least 15 for choice experiments. Consideration of more.	
Assumptions are clearly stated and follow-up is planned.	
Extraneous Abiotic Variables are excluded or controlled. Manipulation of independent variable not likely to affect other variables.	
Sources of Possible Experimental Error planned to be limited.	
Sources of Biological Variability planned to be decreased.	
Presentation:	**Comment on Each Team Member:**
Clarity: Consider good pace, clear speech, projected voice, variable tone.	
Interaction with Audience: Lots of eye contact and minimal reference to notes. Moderate to high energy level.	
Organization: The presenter is well prepared and the presentation flows logically.	

Experiment Trial 1 and Data Analysis

***Scope and Objectives*:**

1. As a team, carry out your experiment.
2. Record your data on a data table.
3. Summarize your data by calculating means.
4. Improve your experiment by modifying its design.
5. Complete and submit Experiment Summary and Assessment: Trial One.

***Prepare for Trial 1*:** Meet with your team and ensure that you are prepared to effectively run your experiment. Generate a data table. **Each team member must have a data table.** This data table will be checked before you begin your experiment.

***Introduction to Data Collection and Initial Analysis*:** Your team has made initial observations of your animal, obtained some information from a literature search, formed hypotheses, and designed your experiment. You presented your proposal to your colleagues and instructors, and received feedback. Perhaps you modified your design. Now it's show time.

Your first trial is an experiment of an experiment. This means that you will now test how well your procedures and your animals generate acceptable results. Trial 1 will teach you how to modify your experiment to be more effective. All your experimental results and observations must be recorded in a data table. You will summarize your data, and then do initial statistics to begin your analysis. More sophisticated statistical analysis will follow. Experiments mark the beginning of more discoveries, usually by provoking more questions.

***Make Your Data Table*:** Place a table number (e.g., Table 1) and title at the top of the table. Units must be included for all rows and columns. The following pages give examples for measured-response and choice experiments. Make rows or columns for initial and final readings (if appropriate) for all replicates, experimental and control), as well as space for means. For a choice experiment, make rows or columns for all choice options, for replicates, and space for totals. Add a row or column for qualitative observations. Add a column for calculations if needed. Make a few additional copies of the blank table (especially important if you foresee adding replicates).

Clarity matters: confused data is lost data. Do not erase data. If necessary, neatly cross out items. Examine your table and ensure that you will be able to interpret this valuable **raw data**. Lastly, **make backup copies** of your completed table and disperse them: lost data is a killer! You will submit a copy of your data table along with your Experiment Summary.

***Initial Analysis*.** You will calculate the mean, or average value for each treatment of a measured-response experiment. Sum up the values for each replicate for a given treatment, and then divide by the number of replicates. Now you can compare the means for the different treatments to see if the organism's response differs. For a choice experiment, you will sum the totals for each choice option. You can compare the total number of choices for each option.

***Experiment, Trial 1*:** Gather your equipment; review your procedure. Assign specific tasks to each team member. If you are testing an animal's response to a range of an abiotic factor, test the extremes of the range on an individual animal before exposing subsequent subjects to those treatment levels. That way, you can revise the chosen levels if your subject tells you that the levels are too extreme! You need to note normal and abnormal behaviour. Make careful qualitative observations along with your numerical data collection.

Upon the conclusion of your experiment, clean up your area and wash your equipment. The lab demonstrator will tell you where to place your cleaned up equipment, and where to store materials for Trial 2.

***After Trial 1*:** It's time to de-brief. Discuss modifications necessary for Trial 2. If you make major revisions, such as new hypotheses and an entirely new experiment, consult the instructor and lab demonstrator.

***Equipment Lists*:** Submit a new list for Trial 2 before leaving the Trial 1 lab, even if the list is identical. If you require major changes, check with the lab demonstrator.

***Experiment Summary*:** Complete Experiment Summary and Assessment: Trial One and submit it along with your equipment list and data table.

***Look Ahead*:** Organize now. Prepare a data table for your next trial or next experiment.

You will receive instructions for performing statistical analyses and graphical presentation. For measured-response experiments, you will calculate means, variance, standard deviation, and 95% confidence limits. For choice experiments, you will use the χ^2 test.

You will need to extend your literature search to find articles more specific to your experiment. In your final report, you will cite literature beyond your initial literature report. Relevant articles may be about other animals' responses to the abiotic factors or choices you chose. Remember to discuss your literature needs with your colleagues; they may have located references that you can use. Apportion this work amongst your group. Begin this now!

Experiment Summary and Assessment: Trial One

Date: _____

Experiment Title: _____

Team Members Present for Trial One: _____

Hypotheses: State or restate if they have changed.

Independent Variable: Identify the range of treatments or choices in your experiment.

Independent Variable and the Natural Environment: Relate and explain discrepancies if they exist.

Response of the Organism: Briefly describe the behavioural, physiological and/or biochemical processes involved in the response that you are measuring.

State your Control or Standard Treatment:

Replicates: Indicate number. Will you increase the number of replicates? If not, explain.

Extraneous Variables: List those that seem important to your experiment and indicate how you keep them constant.

Sources of Error: List possible source of error (exclude "human error") and biological variability and suggest how these may have contributed to your results.

Procedures: List or illustrate the steps completed. State problems encountered and proposed solutions to these problems. Note any procedural changes planned for Trial 2 or a revised experiment.

Trial Two: Discuss what happens next week. Will you repeat Trial One? Will you repeat Trial One with modifications? Will you perform a new experiment?

Submit this summary and make sure all team members have a copy.

Statistical Analysis

Statistics describe what numerical data tell us. Statistical analysis tells us whether or not we can believe our statistics. Sort of. The sort of is about the probabilistic nature of statistical analysis. Researchers aim to be reasonably sure that they are not lying to you about their findings, and they err on the side of conservatism.

Professional biologists hire statisticians (if they can afford them). But that doesn't get us off the hook. We need to interpret data, and some knowledge of statistical analysis gets us underway. The following attempt to demystify statistical analysis relies heavily on Pechenik's *A Short Guide to Writing about Biology* (Pechenik, 2006) and UBC's *Biology 140 Laboratory Workbook.*

Statisticians use the word **population** to encompass all possible measurement values that may be considered to draw a conclusion, for example to get the average age of all Canadians the population would be all the people in Canada. Since we can rarely expect to measure an entire population, we draw a **sample**, a representative subset of the larger population. We refer to the number of subjects in the sample as the **sample size**. We need to ensure both an adequate sample size and a **random** representative sample, to avoid **bias**. We then apply statistics to describe our sample, which hopefully allows us to draw conclusions about our population.

In our Biology 1100 experiments we generate data that can be analyzed in either of two ways. We analyze **continuous data** with measures of central tendency and variation. **Measured-response experiments** yield data such as distances, time, amounts or rates, and these are continuous. **Choice experiments** give data recorded as frequencies, such as number of times an animal selects a particular habitat. These are discrete data amenable to the χ^2 test (chi-square, pronounced kye). After you apply the appropriate statistical test, you will have a basis for discussing the meaning of your results because you will know to what degree your data support your alternative (experimental) hypothesis.

Biological variability is a fact of life. If every replicate of a trial produced identical results, we wouldn't need statistical analysis. Variability simply happens. A number of factors contribute to this variability.

- Measurements tend to be imprecise.
- Individuals vary.
- Data is scattered.

So when we have continuous data, we begin with describing central tendencies, and the first statistic is the **mean**, or average. However, identical averages could arise from very different sets of data. The average height of people in a classroom could result from them all being identical in height, or some combination of the basketball and burrowing teams. Enter the **variance**. This statistic allows us to gain confidence in how well our mean describes our sample. The closer this value is to 0, the more the data cluster around the mean. If all the people in the room are indeed the same height, the variance = 0. We can summarize how much the individuals vary from the mean with the variance. Record how far each individual observation lies from the mean, square the value to get rid of the sign, and add them all together. The standard deviation, the standard error of the mean, and the 95% confidence interval all relate to the variance.

The **standard deviation**, a common measure of central tendency, is the square root of the variance.

The **standard error of the mean** is the standard deviation divided by the square root of the **sample size**, **N**.

The **95% confidence interval** equals approximately 2 standard errors around the mean, assuming a normal distribution, or bell curve. This means that if you were to perform 100 replicates, and calculate a mean result for each, you would expect to find the mean within this interval 95 times out of a hundred. When people talk about the **range** of data, they refer to the highest and lowest extremes of the data. The 95% confidence interval includes 95% of the range.

The χ^2 **test**, used for discrete data, is called a "goodness-of-fit" test because it generates a statistic that tells you the likelihood that your observed data match your expected data. Your expected data conforms to H_o, so if your observed data come close to matching, there is a "good fit", you support H_o, and you conclude that your animals didn't choose between options such as different habitats. However, if your observed data are a poor fit to expected values, your χ^2 value may allow you to reject H_o and support H_a, that your animals exhibit preferences of particular habitats.

Is the difference statistically significant? We need statistical analysis when we take sub samples from a population, i.e., when we can't measure *all* cases, when trials vary naturally, or measurements vary between replications.

What does the result of a statistical test allow you to say about your hypothesis? Statistical analysis tells us the degree to which we can be convinced that our results approach the truth (they can never tell us the truth).

H_o is the straw dog…we expect to reject it. The *p* value you read off of a table, from the number generated by your statistical test, must be small enough to reject the null hypothesis, it must tell you that the probability of it being supported by chance is very small. **Be careful!** When you reject H_o, that doesn't *prove* that it is incorrect. If the *p* value fails to reject H_o, that does not *prove* that H_o is correct. Similarly, when you support H_a, that does not *prove* that it is correct. When we support H_a we say that the data *supports* the alternative (experimental) hypothesis.

So a statistical test value close to 0 tells you that your data is consistent with H_o. A value very different from 0 suggests that H_o may be wrong, that the data are very different from what you would expect if H_o were true.

Any given test value has a certain probability of turning up, but some values are more likely to turn up than others. We assume that very unusual high values of a test occur < .05 (less than 1 in 20 times) when H_o is true, then H_o is probably incorrect, and we reject H_o. Since it is so rare to get a high value when H_o is true, then H_o is very likely false.

There is a risk of incorrectly rejecting H_o and incorrectly supporting H_a. The way we work it is: if *p* is high, it is the expected value if H_o were true. If *p* is low, we would

expect this rarely, and thus assume that H_o is not true, and we support H_a, our alternative or experimental hypothesis.

Experiment Trial 2

Scope and Objectives

1. As a team, carry out Trial 2 of your experiment.
2. Refine your analysis of data.
3. Prepare to present your results, in oral and written formats.
4. Submit a summary of your experiment.

Prepare for Trial 2

Carefully review any modifications in the procedure for your experiment and come to lab prepared and confident to perform Trial 2. Think about integrating your literature research with your experimental results, discussing your experiment with your team, and preparing oral and written reports.

You can expect Trial 2 to run more smoothly than Trial 1 because you've had practice with your equipment, your animal, and your team, and received feedback from your instructors. Incorporate minor procedural changes as warranted by your discoveries of unanticipated conditions or variables that affected your results in Trial 1. Make careful note of all procedural changes. An example of a minor change would be standardizing the size of your subject population because in measuring swimming speed, you found that larger individuals swam faster than smaller ones.

If you must make major adjustments or change your topic, you have a new experiment for Trial 2. Large changes must be discussed with your instructor.

If you carry out both trials in very much the same way, you might expect similar results. But sometimes that's not what happens! Keep careful records of all of your data for each trial, because you may want to refer to them later.

At the conclusion of your experiment, thoroughly clean your work area and materials and return equipment as instructed. Submit the Experiment Summary, keeping copies for each team member.

Experiment Summary and Assessment: Trial Two

Date _____

Experiment Title*:* _____

Team Members Present for Trial Two: _____

Hypotheses: Restate if different from Trial One.

Procedures: List or illustrate any procedural changes for Trial 2 or a revised experiment.

Response of the Organism: State qualitative observations.

Response of the Organism: Did your organism respond as predicted? Explain.

Response of the Organism: Relate your measurements and observations to your organism's behaviour in its natural environment.
Extrapolation: Discuss problems of generalizing from your results to the natural ecosystem.

Statistical Analysis: Name the statistical test that you will use to quantitatively analyze your results. Explain your rationale for choosing this test.

Submit this summary and make sure all team members have a copy.

Introduction to Statistical Analysis of Data for Measured-Response Experiments: Measures of Central Tendency and Variation, including Mean, Variance, Standard Deviation, and 95% Confidence Intervals

Read the choice experiment section as well as this one.

Mean

Do those mean values that you calculated represent real differences between the populations sampled (the different treatments)? Statistical analysis will tell you.

Each measured response must be **independent**. That means (sorry) that data from each individual used for calculation must be free from influence of other individuals. Further, no one individual can contribute more that one datum: no repeated measurements from the same individual.

As indicated above, means tell not the whole story. Consider the following data set taken from UBC's *Biology 140 Laboratory Workbook.* The means from two populations are the same, yet the data from each are different.

Table 3. Mean Length of Salmon Fry (cm) from Two Different B.C. Hatcheries

Length of fry from hatchery 1 (cm)	**Length of fry from hatchery 2 (cm)**
1.5	8.5
3.5	10.5
5.5	9.5
7.5	8.5
9.5	8.5
11.5	9.5
13.5	9.5
15.5	10.5
17.5	10.5
9.5	9.5
Mean 9.5	**Mean 9.5**

Note that the means are rounded off to the same number of decimal places as the data. Note also that the data from hatchery 1 are more spread out than those from hatchery two. Two statistics that help us describe these differences are **variance** and **standard deviation**. A third statistic represents the analysis that allows us to better interpret differences between populations: the **95% confidence limit** of the mean.

Calculate the Variance

The **variance (s^2)** measures how much data scatter around the mean. The statistic is calculated by adding together all the squared deviations from the mean. That is, you subtract a given data value from the mean value (that's the deviation), square it (raise to the power of 2) and add it to all the others. Then you divide this number by the sample size (n = number in the population) minus one. Here is the formula:

$$S^2 = \frac{\sum (x - \bar{x})^2}{n-1}$$

Your practice calculation of the salmon fry data should yield these results: 26.6 variance for hatchery 1 and 0.6 variance for hatchery 2. As you calculate, keep all of the decimal

places; however, report variance values to the same number of decimal places as the data points.

Calculate the Standard Deviation

The **standard deviation from the mean (s)** relates to the variance as follows:

$$S = \sqrt{S^2}$$

Normally distributed data result from experiments with a **large number of subjects**, yielding the familiar bell-shaped curve. If that curve is tall and not wide, the data lie more clustered around the mean than if it were short and wide. Tall and not wide would give you small numbers for variance and standard deviation compared to short and wide. In either case, 68% of the data points would fall within one standard deviation on either side of the mean. The example below, from UBC's *Biology 140 Laboratory Workbook*, shows a normal distribution of the length of 55 salmon fry measured prior to release from a hatchery. Note that 68% of the values lie within one standard deviation of the mean (x ±1 s.d.), between the lengths of 9.3 and 9.7 cm.

Figure 3. Number of salmon fry at each length.

Calculate 95% Confidence Intervals

The 55 salmon fry above represent a sample of all the fry released from the hatchery. The mean and standard deviation of this sample represent an **estimate** of the mean and standard deviation of the lengths of this hatchery's entire population of released fry. Would another hatchery's fry be larger or smaller? With similarly derived data, we can compare our hatchery with another and determine whether we can consider the data of the compared hatcheries to come from different populations or from the same population. Here's how to compare: calculate the **95% Confidence Interval (of the mean**.

$$\text{C.I.} = \bar{X} \pm 1.96\ s / \sqrt{n}$$

Remember that s = standard deviation and n = sample size. The two numbers generated (the 95% confidence limits: one plus and one minus the mean) give a 95% chance that the

mean really does lie in this range. With a visual comparison, we can now determine whether or not two populations are statistically different, with no overlap, or the same, with overlap. If they do overlap, even if they *seem* different, they probably are not.

Report means and 95% confidence intervals to the same number of decimal spaces as your collected data. Retain decimal spaces in your intermediate calculations: standard deviation and variance.

95% confident means **5% chance of being wrong!** Statistical analyses yield probabilities, not absolutes. For most biological research, if scientists come up with a 5% chance of being wrong, they are happy enough to say, "There's a difference between these two populations". That means the difference does not come from chance or sampling error. The difference is real: it is statistically significant. Most biologists use the **5% probability level**, commonly expressed as **p = .05**, or 5 chances in 100, as the acceptable risk of being wrong about their conclusions.

In summary, **if the 95% confidence intervals of two samples DO NOT overlap**, you can be 95% confident that the two samples are drawn from different populations. That means that there is a 5% probability, or less, that the difference is due to chance or sampling error. **Reject the null hypothesis**, that there is no difference between the samples. **Support the alternative hypothesis**, that the two samples differ and the populations that they are drawn from differ. The further apart the means and confidence intervals, the greater the difference between the populations, for the characteristic measured.

If the 95% confidence intervals of two samples DO OVERLAP, we can be 95% confident that they are drawn from the same population. It's possible that the difference in the means has a 5% or greater likelihood of occurring due to chance or sampling error. We **fail to reject the null hypothesis**: the evidence does not convince us that there is a difference between the populations that the samples are drawn from.

Compare your samples for each trial or each experiment separately. If you used the same animals for trials 1 and 2, you can not throw them together for analysis, since the samples would no longer be independent.

Apply the 95% Confidence Interval to a Measured-Response Experiment

Your measured-response experiment likely yields data for a treatment control sample and treatment samples. Your analysis will lead you to a conclusion: either your data from the treatments are significantly different from your control or they are not. Let's look at those earthworms again, and see if caloric intake did indeed affect their growth.

H_o: Caloric intake does not affect the growth of earthworms after 14 days.

H_a: Caloric intake does affect the growth of earthworms after 14 days.

Table 1. The Effect of Caloric Intake on Weight Gain of Earthworms in 14 Days. Recorded in mg.

	Caloric Intake	
Replicate	**1 kcal/worm/day**	**2 kcal/worm/day**
1	4	5
2	2	7
3	1	9
4	2	4
5	0	5
6	2	4
Mean Weight Gain	1.8	5.7

We've simplified the analysis here by including the treatment control, 2 kcal/worm/day and one of the treatments, 1 kcal/worm/day. Looking closely at this data, we could *almost* get away without statistical analysis because most data points in the treatment are smaller than those in the treatment control. But… we've got a few ties: replicate one of the treatment has the same value as replicates 4 and 6 of the treatment control. If there were no overlap at all in the values from the two sets of data, we'd be home free: the samples would come from different populations; there would be a statistically significant difference. Because there is some overlap, we need to do the math.

1. We've already calculated the means: 5.7 mg for the treatment control and 1.8 for the treatment. (means with the same number of decimal places as the data.)
2. Calculate the variance.

   Treatment control data:

   $$s^2 = \frac{(5–5.7)^2 + (7–5.7)^2 + (9–5.7)^2 + (4–5.7)^2 + (5–5.7)^2 + (4 –5.7)^2}{6 – 1} = 3.868$$

   $$s = \sqrt{3.868} = 2.0$$

   Treatment data:

   $s^2 = 1.768$

   $s = 1.3$

3. Calculate the 95% confidence interval for each set of data.

   Treatment control data:

   $$\text{C.I.} = 5.7 \pm (1.96 \times 2.0 / \sqrt{6}) = 4.1 – 7.3$$

   Treatment data:

   $$\text{C.I.} = 1.8 \pm (1.96 \times 1.3 / \sqrt{6}) = .8 – 1.8$$

   Remember that means and confidence interval limits are reported to the same number of decimal places as the original data.

4. Data and statistics alone yield no conclusions: **you** must **interpret** what they mean. Is there a **significant difference** between these sample sets? If there is, the samples represent different populations of measurements.

   Our conclusion? There is a significant difference between the treatments: earthworms who were offered a lower caloric value of food gained less weight in 14 days than the treatment control. The confidence limits do not overlap. We reject H_o. We support H_a. **Important:** we did not ***prove*** that the populations were different**.** We **supported** the hypothesis that they were different. There's still a 5% chance that sampling error or chance led us to our tentative conclusion. If lots of repetitions of the experiment by other experimenters continued to support our data, then we become more confident that we're arriving at the truth. Science works that way.

   Your experiment has three treatment levels, one of which serves as the treatment control. You may reject H_o if one or more of your confidence intervals do not overlap. As a standard of comparison, your treatment control may overlap your treatments while the treatments may not overlap. In this case you reject H_o. If all treatments overlap, you will fail to reject H_o. This, by the way, does not mean that your experiment failed!

   Remember to analyze each of your trials or experiments separately. If you kept the procedures for the two trials identical, expect similar results. What if the results are inconsistent? The solution might lie in conducting more trials, but you won't be able to in our class. You will discuss possible reasons for discrepancies. The problem may lie in experimental design or in the inherent variability of your subjects or…? We'll talk about it if this happens.

5. Check your statistical analysis with your instructor or lab demonstrator.

6. Beyond your numerical data and statistical analysis, describe the response of your organism to the factor, the independent variable. If you supported H_a, describe the **specific effect** that the factor had on your organism. In the case of the earthworms above, lowered caloric value of food led to a **significant** decreased wait gain compared to the controls. In your Discussion you will elaborate on the meaning of your results and compare them with your predictions and previous studies.

Introduction to Statistical Analysis of Data for Choice Experiments: the X^2 Test

Read the measured-response experiment section as well as this one.

In your choice experiment, you want your statistical analysis to answer a simple question: did your animals choose or did they not choose between alternatives. Go back to those earthworms. Did the moisture content of soil influence choice? The X^2 test is often called a "goodness of fit" test because it allows us to discern whether or not the data conform to the null hypothesis of "no choice".

Table 2. The Number of Worms Choosing Different Soil Moisture Levels within 5 Minutes in an Arena.

	Soil Moisture Level Selected		
	Level 1 (drier)	Level 2 (medium)	Level 3 (wetter)
Replicate 1	X		
Replicate 2		X	
Replicate 3		X	
Replicate 4		X	
Replicate 5	X		
Replicate 6		X	
Replicate 7	X		
Replicate 8			X
Replicate 9	X		
Replicate 10		X	
Replicate 11		X	
Replicate 12		X	
Replicate 13	X		
Replicate 14		X	
Replicate 15		X	
Total	5	9	1

The numbers that matter here are the totals. These numbers are frequencies: discrete events (the formula does not work if you use percentages). If the worms exhibited no preference for different soil moisture levels, as determined by their movement into an area, then how many would you expect to end up there? Fifteen worms, three choices, so five worms expected in each of the three soil moisture conditions. So how far off from equal frequencies for each choice will represent a rejection of the null hypothesis? Here comes the χ^2 test.

$$\chi^2 = \Sigma \text{ (observed value – expected value)}^2 / \text{expected value}$$

$$\chi^2 = \frac{(5-5)^2}{5} + \frac{(5-9)^2}{5} + \frac{(5-1)^2}{5} = 6.40$$ (retain two decimal spaces for the probability table)

Now we must find out what the χ^2 value means. Turn to page 775 in the Morgan/Carter lab manual. On the left of Table B.2 you will find a column that lists degrees of freedom (df). Basically, degrees of freedom derive from the observation that once you know all of the values for the categories (in our case choice of soil moisture) except for one, you know the value of that remaining one. In our example, given 15 replicates, if you know

the totals for level 1 and level 2, then you know what level 3 must be. So degrees of freedom equal n –1. In our example, 3-1 = 2 df. On Table B.2, find the row with 2 df. Our χ^2 value of 6.4 is between 5.99 and 9.21. This means that the probability that our earthworms exhibited no choice of soil moisture due to chance alone is less than .05 (<.05) or 5/100. We reject the null hypothesis, H_o: Soil moisture level does not affect the habitat choice of earthworms, and support the alternative, H_a: Soil moisture level does affect the habitat choice of earthworms. The results of this analysis do not tell you which of the classes of choices caused the greatest deviation from expected values, but a look at the data tells you that the worms preferred level two and avoided level 3.

Remember that each trial or experiment must be analyzed separately. Check your statistical analysis with your instructor or lab demonstrator. When you report your results and analysis, make sure to describe the relationship between the factor and your animals' choices, specifically describing the preferences. In your discussion, relate your findings to your predictions and previous studies that you consulted.

For more clarification, study Appendix B of Morgan/Carter, pages 773-776.

After Data Analysis

What if you did not reject your null hypothesis? If your experiment was well-designed and well-performed, not to worry: showing no change or no choice provides valuable biological information

Now that you've crunched the numbers, call back the biology. What do your results mean, biologically speaking? Did your animals behave as you predicted? Did biological variation creep in to raise more questions in your mind? Do you have cause to expect experimental error? If you did it again, what would you change? Talk it up with your team and your instructors. This is where scientists have fun (well, one of many places that they have fun)! You will interpret your results, not only from your experiment and thoughts, but also in comparison to other studies.

Presentation of Results

Include graphs, drawings and/or images that work to summarize your data. You must also include written descriptions. Each valid trial or experiment requires a graph. Raw data do not belong in a scientific report, so leave your data tables out. Your presentation of results will differ from the ones that you've seen in journal articles because you will offer **one** complete sample calculation of your statistical analysis.

Graphs and Tables

Determine whether bar graphs or line graphs best suit your data. Usually, discrete data call for a bar graph and continuous data warrant a line graph. Computer generated graphs are acceptable, as are hand-drawn graphs on graph paper. Each team member makes their own.

Model your graphs and tables after those you found in journal articles. Consult Morgan/Carter, *Presenting and Analyzing Results*, pp 14-18, and *Interpreting and Communicating Results* on pp 18-20 and 22-27 for examples and practice. Pechenik warrants a couple of look-throughs of his chapter, *Summarizing Data Using Tables and Graphs*, pp 158-175 and 180-190. Attend to figures 23 and 24 on pp 172-173 to see how to display confidence intervals.

Report about Your Experiment

Reports take time! Make time! Don't wait! Communicate! Schedule meetings with your team to consolidate your results, share your interpretations and refine your English and Biologish. Add in email discussions. Take personal ownership of the deliverables: the oral report and the written report. Teams work best when each individual takes 100% responsibility for the project.

Model your writing after literature that you have read. Find more scientific articles. Attend carefully to directions. Raise questions, advance new hypotheses, suggest further experiments. Acknowledge one another's contributions.

Prepare the Written Report

Each team member will submit a written report of the experiment. Prepare the written report prior to your oral presentation. The final version of the written report will be due after your oral presentation, so that you have opportunity to modify the report subsequent to feedback. **All writing, tables, graphs, illustrations** (with the exception of photographs)**, and citations must be original.** All partners may use photographic images taken by one team member, with proper citation. Although each team member's report is original, the team should discuss and review the written reports. If you wish to include another partner's ideas in your report, cite them. In summary, scientists collaborate, *and* your report is yours. Ensure that you have back-up copies safely dispersed.

Format for the Report

By reading journal articles, you have discovered how scientists communicate their research. Model your report after these. Biology journals often contain "Instructions for Authors" sections that can guide you. Read Appendix A of Morgan and Carter's *Investigating Biology Laboratory Manual.* Use Jan Pechenik's *A Short Guide to Writing About Biology* for excellent advice for crafting an excellent product.

Scientific reports summarize what researchers researched, how they did it, what they found out, what they thought about what they found out, and how they related their study to the rest of the world. Your scientific report will include the following sections:

- **Title/Cover Page**
- **Abstract**
- **Introduction**
- **Methods**
- **Results**
- **Discussion**
- **Conclusion**
- **Acknowledgements**
- **Citations and References**
- **Appendix** (if needed)

Submission Standards

Use all of the above, except Title/Cover Page, as section headers. Do not begin a separate page for each section, except for the Title/Cover Page.

- Write in the active voice (Jones (2001) found this; we discovered that).
- Computer-printed, 10 or 12-point readable, conservative font, with standard margins.
- Double-spaced.
- Pages numbered.
- Stapled, no folders or binders.
- Carefully proofread!
- Submitted on time, with multiple, safely stored back-ups.

Detailed Guidelines and Evaluation (marked out of 100)

Title/Cover Page (2 marks)

A proper **title** includes the scientific name of your organism and the independent and dependent variables of your experiment, as specifically as you can. Also appearing: **your name**, the **names of your team members**, the **date**, and the **course name**.

Abstract (4 marks, up to 200 words)

An abstract is a brief **one-paragraph summary.** Write the abstract after you finish writing the report. Then place it at the beginning, single-spaced. Include the **purpose** of the experiment, a very brief summary of the research **method** used, a brief summary of your **results**, including actual numbers and trends, your **interpretation** of these results, and a **conclusion**, if one can be drawn.

An abstract answers these questions: Why did we do this? What did we do? What did we discover? What does it mean? Any information or opinion in your abstract must appear somewhere in your report.

Introduction (15 marks, up to 450 words)

Present **relevant, specific, cited background information** about your organism, its natural environment, and both the independent variable (the environmental factor that you manipulated) and the dependent variable (the organism's response that you measured). Include reasons for your choice of environmental factor, how it varies in nature, how the organism processes and responds to it, and its relevance to the organism.

Now clearly **state the purpose** of your investigation; keep in mind the question that drove the investigation. State your **hypotheses**, supported with a rationale linked to theory or previous knowledge. State specific **predictions** derived from your hypothesis.

Throughout the introduction you must **cite literature** supporting all the information that you present. This is not a repetition of the literature review assignment. You may use the same references, among others, but they need to be specifically focused.

Methods (10 marks, up to 650 words)

The methods section outlines your procedures with enough clear detail that another Biology 1100 student could repeat your experiment and analysis exactly. Do not describe what each team member did or details of how equipment works. Remember to include descriptions of control preparation or examples of calculation of sample preparation, such as dilutions, as applicable.

Write in the **past tense** ("We diluted the solution."). Do not write a recipe of instructions. Describe the **source** of your subject population. Present **numbers** that characterize the subjects, such as sample size (number of subjects), ages, or sizes. Use at least one **diagram** that helps the reader see how you set up your experiment. State very exactly how you **collected and analyzed** data.

If your methods differed only slightly between trials, describe those differences as modifications to the first procedure. However, if the trials differed substantially, or were altogether different experiments, write two separate procedures.

Results (15 marks, up to 250 words plus graphs and images)

Summarize outcomes clearly in **graphs** and **drawings** or photographic **images**. Guide your reader with **sentences** that describe the trends that graphs/tables/images illustrate. Make sure that your sentences make reference to the appropriate figure (e.g., Fig.1 shows…). You need not verbalize all of your values, only that data important enough to bring to your discussion section.

Do **not** include raw data tables. All graphs, tables, and images must be clearly **titled and labeled**. Number your figures sequentially. Use graphs rather than tables if reasonable, and do not repeat information in both graph and table. If you make graphs by hand rather than computer, use graph paper. Each team member makes their own figures, even though you draw from the same raw data. To make sure that you produce your graphs and tables correctly, see pages157-188 of *A Short Guide to Writing About Biology***.**

Calculate means, standard deviations, 95% confidence intervals or frequency totals and χ^2 values as applicable. **Provide one sample calculation**. Your descriptive sentences point out trends and the amount of variation for each trial separately. Indicate significance of 95% confidence limits: where they overlap and where they don't. If you used the χ^2 test, point out the obvious choices or preferences. Make a clear statement about your null hypothesis: did you reject or fail to reject it? Reserve comments about the alternative hypothesis for the discussion section.

Present **qualitative data**, such as description of behaviours, again without interpretation. Give the facts and nothing but the facts, what, not why, no interpretations, in as few words as possible.

Discussion (30 marks, maximum 800 words)

The discussion is the most creative and important part of your report because here you **interpret** and **explain** your results. Keep the discussion focused on the biology of your organism. **First** discuss whether or not your results support your alternative (experimental) hypothesis, based on your statistical analysis, for each trial. Do not repeat your data report from the results section, but refer to it. **Examine the overall cause and effect relationship** between your independent variable (environmental factor) and your dependent variable (the measured response of your organism). You may explore a number of biologically relevant possibilities to explain your results, whether or not they support your alternative hypothesis. **Relate** your findings to the background information and theory from your introduction. Make sure that you **discuss variability** in your results, and propose explanations for it. Discuss **sources of error** and how they may have affected your results. **Be specific**. Discuss your opinions, ideas, speculations, and questions. If these come from a classmate, acknowledge him or her (Smith 2004: pers. com.). **Propose** ways to improve your study. **Be creative**. Suggest new hypotheses and new experiments. You may come up with a new scientific idea.

You must use and cite references in your discussion. The studies of other biologists help you understand your research, and allow you to compare your findings to theirs. You gain support from common findings, and fuel for discussion from disparities. Examine not only their results, but also their methods, since these affect results, and their explanations. Include some recent (within 10 years) citations, some of which may also appear in your introduction.

Conclusion (2 marks, a few sentences)

Add nothing new here. Simply restate your hypotheses and findings, and the significance of your findings.

Acknowledgements (2 marks, a few sentences)

Formally recognize colleagues, instructors and others who significantly aided you and your project. Keep it brief, but give full names, including your team members, and the specific nature of their contributions.

Citations and References (10 marks)

All information comes from somewhere, so you must cite it properly throughout your report. Do not quote or use footnotes; put information and ideas into your own words and cite correctly. You must cite **at least three journal articles** and **at least one general text** reference other than your own. Encyclopedias are not acceptable for citation in this report.

The reference list or literature cited section at the end of your report must include full and proper citations of all the resource materials referred to in your report. If you did not cite a reference in the text of your report, it doesn't go here. If you did not read a reference, it doesn't go here (or anywhere).

Appendix

This section is optional, for extras that don't fit into the report. Since appended materials must be referred to in your report, make sure that these pages bear titles and numbers.

Style (10 marks)

Believe that proper sentence and paragraph structure, technical terminology, scientific notation, grammar, spelling, scientific attitude and just plain good writing count. The report must be well organized, economically written, and logically presented. Make it look good but don't be cutesy. **The words must be your own**. Plagiarism is against the law; we know that others' writing is for sale, and we know how to check for it. Don't risk your academic future.

Prepare the Oral Report

Your oral report should inform your colleagues about your experiment and stimulate them to wonder further and ask questions. You have **12 minutes** to present, followed by a question period. You want to come off as a team, both in presentation and fielding questions. Strive for clarity. Make it enjoyable for all.

Most commonly, oral scientific reports follow the format of written ones: Introduction, Methods, Results, and Discussion. What was the experiment about (background, question, hypotheses)? How did you do it? What did you find out? What do you think about it? You may choose other presentation formats. Make sure to divide the airtime equitably amongst your team, either in sequence or alternating otherwise. Good timing is essential, and you want to avoid repetition. To make this work, you will need to get together to organize and to practice. A team mark forms part of your personal mark, so do your best to have everyone do their best.

Your audience should become aware of not only your "good" results, but also problems that you encountered and how you would avoid them in the future. That's part of growing science and one another. Following attend to some presentation tips.

- The Stage:
  - Arrange your team in an orderly way.
  - Remove clutter.
  - Come with a plan for placing your props or demonstrations.
- Visual Aids:
  - Yourselves! Dress for success. You interpret.
  - Use at least one visual aid per section or team member. Refer to it. Visual aids include the chalkboard, flip chart, overhead projector transparencies, and PowerPoint™. *Caution: PowerPoint presentations require a trial run on our equipment. We won't pause for technical problems within your control.*
  - Visual aids can help you provide overviews, data summaries, picturing experimental equipment, posing questions, and more. They need to be **simple**.
  - Diagrams and graphs are information rich. Use them on visuals when they can do the job of lots of words. Avoid lots of words on visuals.
  - Scale your visuals appropriately. If you print on acetate, print the letters at least one cm tall, or 16 point for type. Avoid direct photocopies to acetate of text, figures or tables from your written report because they are too small for your audience to see easily. **Minimize the amount of information on each acetate or slide.**
  - Check tables and graphs for clarity. No more than a dozen numbers on a table; title and legends on a graph present and easy to see.
  - Write on acetate with black, blue or purple inks. Red and green don't show up well. Keep PowerPoint slides conservative.
  - Use the visuals to guide your talk, subject to subject. Do not read from them.
- Notes
  - Use 3x5 or 5x8 cards to keep you on track. Best if each team member has the entire set.
  - Avoid sheets of paper.
- Eyes
  - On your audience.

- All of your audience.

- Voice
  - Project
  - Animate
- Questions
  - Anticipate what they might be.
  - Come with a plan for fielding questions, such as an order and a signal to pass. You don't want one team member dominating.

As a member of the audience, give the presenters enthusiastic attention. Make notes about content that requires clarification or further discussion. Pose questions during the question period following the presentation. Good questions and observations score for your participation mark.

Laboratory: Hominid Evolution

***Lab Objectives*:**

1. Using our hominid skull collection, hypothesize a phylogeny that illustrates their history, in the form of a cladogram.
2. Identify historical trends in skull morphology.
3. Propose explanations for observed differences in the skulls.

***Text Reference*:** Campbell and Reece Chapter 34.

***Lab Overview*.**

Apply careful observation along with principles of evolution and speciation to solve a paleontological puzzle.

***Lab Procedure*.**

The entire group needs to work together since we have a limited number of skulls. Observe carefully. Consider these characteristics:

Cranial capacity
Teeth
Eyebrow ridges
Forehead
Cranial crest
Jaws

Your observations must indicate specifics about these, and other, characteristics.

Arrange the skulls in a hypothetical chronological order. Further arrange them as a cladogram (you may now use your textbook)

Next consider how the hominids may have diverged from the pongids, the great apes, a process that occurred between 7 and 5 million years ago.

Laboratory: Plant Diversity

***Lab Objectives*:**

1. Describe and distinguish between the major terrestrial plant groups.
2. Catalogue the historical debuts of the major terrestrial plant groups.
3. Recognize differences between non-vascular and vascular plants.
4. Recognize differences between non-seed and seed plants.
5. Recognize differences between non-flowering and flowering plants.
6. Describe reproductive adaptations of terrestrial plants.
7. Document adaptations of various plants to terrestrial life.

***Lab Reference*:** Morgan/Carter Lab Topics 15 and 16, pp 399-448. This is reference: we don't do all of the exercises! Attend especially to pp 400-401, the tree and Table 15.1, the geological time chart on p 404, and Table 16.6 on p 445. The life cycle diagrams will also assist you: Figs 15.4 (406), 15.6 (415), 16.1 (431), and 16.3 (440). Examine plates 30-49 at the back of the lab manual.

***Text Reference*:** Campbell and Reece Chapters 29 and 30, pp 573-607.

***Lab Overview*.**

This lab introduces you to plant diversity and adaptations. In Biology 1200 you will explore plant growth, physiology and anatomy.

***Lab Procedure*.**

Work in pairs or threes and visit the displays around the room. You will observe live and not-alive specimens, models, microscope preparations, and posters. You and your partners will complete the accompanying form on your journey. You will not submit these forms, although you may check them with the instructor or lab demonstrator. Any information on the completed forms may appear on an exam.

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Plant Group	***Name of representative***
CIRCLE OR HIGHLIGHT: Vascular Non-vascular	
CIRCLE OR HIGHLIGHT: Seeds No seeds	
CIRCLE OR HIGHLIGHT: Flower No flower	
Gametophyte description:	
Sporophyte description:	
Reproductive adaptations:	
Other terrestrial adaptations:	

Laboratory: Conservation Biology

Learning Objectives: during this laboratory, you can expect to

1. identify and describe endangered B.C. vertebrates
2. present above information to classmates
3. gather above information from classmates
4. link your species and its circumstances to the major concepts of Biology 1100

Text Reference: Chapter 55 in Campbell and Reece.

Other References: Wildlife in B.C. at Risk, pamphlets available in the lab.
srmwww.gov.bc.ca/atrisk/
An Outline of Biodiversity Facts for British Columbia

***Session Protocol*:**

After a presentation about selected conservation issues, you will:

- Select a species from our collection of Wildlife in B.C. at Risk pamphlets.
- Use the classroom computers to access the BC government website listed above.
- Prepare and briefly present synthesized information about your species.
- Work on a concept map linking your species and its circumstances to the major concepts of Biology 1100.

An Outline of Biodiversity Facts for British Columbia
with Emphasis on the Georgia Depression Ecoprovince

Setting the scene for BC's biodiversity:

Geological history

Most of BC's rocks immigrated here during the past 190 million years in land masses called **terranes**.

Plate subduction began 100 million years ago, and the last portions of the ocean plate are currently disappearing under the continent. Mountains are in a period of **uplifting**.

The Georgia Depression Ecoprovince, a large basin, recently filled with ice, encompasses the mountains of southeastern Vancouver Island, the Nanaimo lowlands, the Gulf Islands, the Strait of Georgia, and the Georgia and Fraser Lowlands. The Fraser delta was deposited in the last 8000 years.

Glaciers eroded the V-shaped mountain river valleys into U-shaped valleys, and smoothed many mountains (craggy mountain tops stood out above glaciers). The Fraser Glaciation, which ended about 10,000 years ago, lowered the land, which rebounded to its present level about 8000 years ago.

Climatic history

5 continental glaciations occurred in the last 2 million years, at least four in the last 600,000 years. They were interspersed with warm periods; it's getting warmer now. Deglaciation was so recent that relatively complex ecosystems have not yet evolved, except for those that immigrated.

Climate today

BC climates range from subarctic to Mediterranean

The Fraser Lowland ecosection has the longest growing season in BC, and the southern parts have the most moderate climate and the most sun in BC.

Landscape diversity

- **Barrens**: about a third of BC (mostly high alpine and glacier).
- **Mountains**
- **Freshwaters and wetlands:**
  Rivers, streams, underground streams, lakes, ponds, marshes, bogs, fens, swamps
- **Lowlands**
- **Marine shorelines:** 27,500 km of coastline in BC
  The Strait of Georgia is a semi-enclosed estuarine system with these shoreline and surface characteristics:
  1. rocky and steep shorelines (most shorelines)
  2. channels and sounds, which provide a variety of habitats
  3. shallow, nutrient-rich areas
  4. estuaries, rich in nutrients and life. The Fraser estuary is the largest in BC, by far, including 500 km of shoreline.

Ecological succession…the history of evolving ecosystems

- Begins with weathering rock forming soils.
- Continues with the participation of living creatures.
- The importance of soil formation and a healthy soil ecosystem cannot be overemphasized
- **Seral stages** proceed from relatively simple communities of hardy pioneer species, through more complex communities including larger creatures and greater diversity until a self-renewing system establishes itself, the climax community. And sometimes it even happens this way…disturbances alter the textbook story.

Ecosystem diversity:

Ecodomains--areas of broad climatic uniformity, including 3 of the 4 land ecodomains in N.America
- Polar
- Humid Temperate
- Dry
- as well as the Cool Oceanic off our coast
- divided into **Ecoprovinces**--areas of similar climate, topography, and geological history.
  10 in BC, further divided into 30 ecoregions and 68 ecosections

Biogeoclimatic Ecosystem Classification includes 14 zones (developed for BC by the late Vladimir Krajina)

Georgia Depression biogeoclimatic zones

1. **Coastal Western Hemlock Zone (temperate rain forest)**, including the following habitat types: old growth coniferous forest (3% undisturbed), young seral and managed second growth forests, mixed coniferous and deciduous forest, rocky cliffs, talus and sparsely vegetated rocks, avalanche tracks and seepage sites, upland grassy areas, agricultural areas, riparian areas, wetlands, meadows, floodplains, lakes and streams, offshore forested islands, estuaries, shallow bays, intertidal and subtidal marine habitats (Miedinger and Pojar, 1991).
2. **Coastal Douglas Fir Zone**
3. **Mountain Hemlock Zone (subalpine)**
4. **Alpine Zone (alpine tundra)**

GVRD identifies four large, interrelated ecosystems:
- North Shore Systems (40% old growth forests; high biodiversity)
- Coastal/Intertidal Systems
- Fraser River System
- Fraser Lowland System, which includes:
  Burns Bog, one of the largest urban wildernesses in the world, and the largest domed peat bog on the west coast of the Americas.
  the Fraser River Estuary, with its high biodiversity
  twice as productive as the richest farmland
  all the Western Sandpipers in the world stop here twice a year
  agricultural lands
  urban/suburban lands

Forests
- About half of BC is forested.
- Perhaps 85% of forest species are arthropods.
- BC has highly diverse soil fauna, essential to forest ecosystem function.
- Fires, insects, and pathogens contribute to forest biodiversity.
- BC contains almost half of Canada's softwood timber volume.

A managed forest is not the same as an unmanaged forest.
- Sustaining timber yield is not the same as sustaining biological productivity of a forest ecosystem.
- New ecosystems are created if old ones are fragmented, and changes to them maintained.
- Forest management may lead to increased impact of insect pests.
- Clearcut logging (used in 90% of BC forests) removes nest trees for cavity-nesting birds.
- 65% of bird species, about 30% of mammals, and almost 10% or reptiles and amphibians in BC require some structural elements of old growth forests.
- Loss of old growth forests may reduce the populations of neotropical song birds and predacious and parasitoid insects which control insect pests.
- Less than one percent of coastal old growth Douglas fir forest remains.
- Successional stages after clear cuts can be highly productive with as much biodiversity as old growth.
- Forest conversion can perhaps be managed to maintain biodiversity by retaining enough old growth, in the right places, with the right corridors connecting them, and planning reforestation and harvesting on an ecological basis, to mimic old growth forests, including standing snags (wildlife trees).
- Recent provincial forestry regulations are revolutionary and positive. Although more progress is needed, there is hope.

Marine/estuary biodiversity in the Strait of Georgia

Estuaries, fjords, shorelines and benthos (bottom) contribute to high biodiversity. Most pollution is local, and the system is generally healthy. Pulp mills may have a low level impact throughout the strait, but this should diminish with current effluent regulations

There are no shorelines in BC where all the creatures are completely protected. Provincial marine parks and ecological reserves cover 0.06% of BC's marine environment.

We do not have a history of sustainably managing any living marine resources.

Species Diversity:

BC is the most biodiverse province in Canada:

- 1088 vertebrates (including introduced species)
  458 fishes (365 marine, 71 freshwater, 22 both)
  A number of species and populations have declined in recent decades. A few, such as sockeye salmon, have increased.
- 20 amphibians (4 red-listed; 2 blue-listed)
- 19 reptiles (4 red-listed; 5 blue-listed)
- 452 birds, 297 of which breed here, 3/4 of Canadian species (31 red-listed; 52 blue-listed).
  The Georgia depression has the highest diversity of birds of any BC ecoregion: 90% of all BC spp recorded here; 60% of all known to breed in BC
- 143 mammals (24 red-listed; 27 blue-listed; 3 officially endangered) and at least 64 extinct mammalian megafauna
  238 subspecies of 105 terrestrial mammals, 21% endemic, demonstrate the role of our diverse topography and environments
- humans
- 2850 vascular plants (4150 in Canada; 634 red-listed)
- 950 mosses, hornworts and liverworts (3/4 of Canadian spp)
- 1013 lichens (essentially intact…logging the biggest threat: as many as 70% of BC's rare lichens probably occur in forests; potentially threatened by air pollution)
- perhaps more macrofungi than vascular plants
- most of the 645 taxa of marine algae; one of the richest and most diverse in the world
- 4500 marine invertebrates (one of the most biologically diverse marine areas in the world)
  fewer spp than on land, but significantly more diverse based on body architectures
  including the largest chiton in the world, the largest octopus, the largest sea slug, the heaviest sea star, and the biggest barnacle

  68 sea stars
  600 amphipod crustaceans
  100 sea lice
  133 shrimps, crabs, and relatives
  478 polychaete worms
  111 nudibranchs
  55 sea squirts
  15,000 insects found, perhaps 35,000 total (48 rare and threatened)
  174 butterflies (28 of prov. conservation concern) and over 2000 moths
  94 ladybird beetles
  3626 beetles
  other terrestrial invertebrates ? freshwater invertebrates ?
  fungi ?
  bacteria ? 17,000,000,000/cubic cm on the surface of Fraser River Estuary mud

Alien species

682 vascular plants (21%)
248 beetles
14 fishes
2 amphibians
4 reptiles
12 mammals
14 birds

Urban biodiversity

Loss of natural habitats leads to tremendous losses in biodiversity.

In the Lower Mainland there are 55 rare vascular plants, 5 red-listed (two bats, the spotted owl, marbled murrelet, and the sharp-tailed snake) and 18 blue-listed animals
20-30% land surface is paved; most of the rest is covered by buildings.
Further loss due to increase in pollutants, aquifer reductions, ground water diversion to storm drains, pets as predators, competitors, and disease vectors, and introductions of exotic plant species at the expense of native ones.

Urban green areas, collectively, can have a major impact on a city and surrounding wilderness.

Urban biodiversity can be encouraged by using native plants for landscaping and connecting green areas with rows of trees and shrubs.

Genetic Diversity

The diversity of genes in populations of all creatures is the "stuff" on which natural selection works. Populations at the outskirts of their distributions and isolated populations may contain unique combinations of genes.

Fragmentation of landscapes decreases genetic diversity of large animals especially, because small, probably highly related, populations, then share a smaller diversity of genes. Inbreeding may occur.

Futures:

Global climate change

A number of models predict warmer, wetter winters, and warmer, somewhat wetter summers.
Precipitation in Vancouver has been rising over the last four decades.
Sea levels, sea surface temperatures, and ocean currents may change. River hydrology, snowpack depths, and rates of glacial movement are changing.
Climate change may occur more quickly than ecosystems can adapt.
Vegetation may revert to a similarity with BC 7000-10,000 years ago, when it was 2˚ C warmer.
Greatest impact likely in wetlands and alpine.
Sea level rises will affect shorelines and estuaries.

Forests

forest composition will likely change
pests may increase (fewer cold snaps to kill in winter; invasion by southern species)
increased physiological stress on trees due to moisture deficiencies and increased ultraviolet radiation.
present silvicultural plans may be inappropriate for a changed climate.

Marine

Increased toxic algal blooms?
Sockeye salmon are at the southern limit of their range, and may not survive increased river and stream temperatures
There are a minimum of 753 protected areas, 7.37 million hectares, about 7.68% of BC's land and water area. The goal is 12% by the year 2000.

"A primary challenge for everyone is to think fundamentally, to get to the roots of our relationship with the planet, to dig below everyday language and concepts."

Rowe, J.S. 1994. The Importance of Conserving Systems, in Harding, L., and McCullum, E., (eds.), Biodiversity in British Columbia: our changing environment. Ministry of Supplies and Services. p 5

Compiled March 1995; modified for Biology 1100 June 2005