

Department of Earth Sciences  
City College of San Francisco  
*Professor Katryn Wiese*

# Oceanography 1 LAB

## *Spring 2021 Manual*



# **Oceanography 1 Lab Manual**

*Author: Katryn Wiese*

Manual Produced By Katryn Wiese

(send edits/comments to [katryn.wiese@mail.ccsf.edu](mailto:katryn.wiese@mail.ccsf.edu))

Cover image from *Pillar Point Tidepooling Fieldtrip*.

*Unless otherwise stated, all images in this manual were produced and copyright is held by Katryn Wiese.*

**COPYRIGHT FOR COMPLETE MANUAL:**

**Creative Commons Attribution-Noncommercial- Share Alike 3.0**

# Table of Contents

<b>Measurements – Numbers and Angles .....</b>	<b>3</b>
Measurements – Prereading Exercises .....	5
Measurements – Lab Exercises .....	6
Weekly Reflection .....	11
Measurements Review Practice Sheet.....	12
<b>Latitude, Longitude, &amp; Compasses.....</b>	<b>15</b>
Latitude, Longitude, & Compasses – Prereading Exercises.....	20
Latitude, Longitude, & Compasses – Lab Exercises.....	21
Weekly Reflection .....	24
Latitude, Longitude, & Compasses Practice Sheet.....	25
<b>Nautical Charts: Bathymetry.....</b>	<b>29</b>
Nautical Charts: Bathymetry – Prereading Exercises .....	34
Nautical Charts: Bathymetry – Lab Exercises .....	35
Weekly Reflection .....	41
Nautical Charts: Bathymetry Practice Sheet .....	42
<b>Marine Rocks &amp; Sediments.....</b>	<b>47</b>
Marine Rocks & Sediments – Prereading Exercises .....	50
Marine Rocks & Sediments – Lab Exercises .....	53
Weekly Reflection .....	55
Marine Rocks & Sediments Practice Sheet .....	56
<b>San Francisco Bay Seawater Chemistry.....</b>	<b>61</b>
San Francisco Bay & Seawater Chemistry – Prereading Exercises .....	69
San Francisco Bay & Seawater Chemistry – Lab Exercises .....	70
Weekly Reflection .....	89
San Francisco Bay Seawater Chemistry Practice Sheet.....	90
<b>Deep Sea Chemistry.....</b>	<b>93</b>
Deep Sea Chemistry – Prereading Exercises .....	100
Deep Sea Chemistry – Lab Exercises .....	101
OPTIONAL EXTRA: Investigating Vent Microhabitats: Winogradsky Column .....	107
Weekly Reflection .....	108
Deep Sea Chemistry Practice Sheet .....	109
<b>Global Climate Change .....</b>	<b>113</b>
Global Climate Change – Prereading Exercises.....	115
Global Climate Change – Lab Exercises.....	116
Weekly Reflection .....	125
<b>El Nino &amp; Coastal Upwelling .....</b>	<b>127</b>
El Nino & Coastal Upwelling – Prereading Exercises.....	134
El Nino & Coastal Upwelling – Lab Exercises.....	135
Weekly Reflection .....	145
El Nino & Coastal Upwelling Practice Sheet.....	146
<b>Beach Materials.....</b>	<b>151</b>
Beach Materials – Prereading Exercises .....	155
Beach Materials – Lab Exercises .....	156
Weekly Reflection .....	161
Beach Materials Practice Sheet .....	162
<b>San Francisco Bay Coastal Processes Field Trip .....</b>	<b>165</b>
San Francisco Bay Coastal Processes – Prereading Exercises .....	172
San Francisco Coastal Processes Field Trip .....	175

Weekly Reflection .....	177
San Francisco Bay Coastal Processes Practice Sheet .....	178
<b>Taxonomic Classification of A SUBSET OF Marine Organisms .....</b>	<b>181</b>
<b>Plankton .....</b>	<b>185</b>
Plankton – Prereading Exercises .....	196
Plankton – Lab Exercises .....	198
Weekly Reflection .....	202
Plankton Practice Sheet .....	203
<b>Aquarium Field Trip – Prereading Exercises .....</b>	<b>205</b>
Aquarium Field Trip – Lab Exercises.....	208
Weekly Reflection .....	212
Pelagic Organisms (Aquarium) Practice Sheet .....	213
<b>Fouling Organisms – Prereading Exercises .....</b>	<b>215</b>
Fouling Organisms – Lab Exercises.....	218
Weekly Reflection .....	223
Fouling Organisms Practice Sheet.....	224
<b>Tidepooling Field Trip .....</b>	<b>227</b>
Tidepooling Field Trip – Prereading Exercises.....	234
Tidepooling Field Trip – Lab Exercises.....	236
Weekly Reflection .....	243
Tidepooling Practice Sheet .....	244
<b>APPENDIX: Microscope and Grain Size and % Scales.....</b>	<b>247</b>

# Measurements – Numbers and Angles

## NEEDED SUPPLIES:

- Ruler that shows inches AND centimeters
- Protractor to measure angles (often these also come with a ruler on the bottom, so you get 2 in one) – you will need one for the first ½ of the class, so try to buy your own. 😊
- Pencil and eraser
- Calculator

These exercises cover measurement skills that you will be using in future labs. Since these skills often cause big time issues in future labs, because of varied math skill levels, we use the first lab of the semester to get everyone up to speed. If you are already strong in these areas, you should finish today's lab quickly. If, however, you are weaker, you may need more time and might need to work on it outside class time over the next week. If you're struggling, reach out for help. Come to office hours or make an appointment with the instructor. But just be sure you take the time now to master this material before proceeding further in this class. If you do not think your math skills are up to this task, consider re-enrolling in this course another semester after you've built up your math skills. *Discuss with instructor if any concerns!*

## Metric system

The metric system is the only system used by scientists globally and hence will be the system we use throughout this course.

- 1 km = 1 kilometer = 1000 meters (m) *(1 km = 0.614 miles)*
- 1 m = 1 meter = 100 centimeters (cm) = 1000 millimeters (mm) *(1 m = 1.09 yards)*
- 1 cm = 1 centimeter = 10 millimeters (mm) *(1 cm = 0.394 inches)*

## Inequalities

< is a **Less than** sign. Example:  $6 < 7$  means 6 is less than 7.  $X < 7$  means any number less than 7.

> is a **Greater than** sign. Example:  $7 > 6$  means 7 is greater than 6.  $X > 7$  means any number greater than 7.

In science we use inequalities regularly to describe error of measured numbers and to provide estimates that sit within a range of numbers. As such, you will need to be able to read an inequality correctly.

*(The mouth of the alligator opens towards the larger meal!)*

- **6 meters > 2 meters** means 6 meters is greater than 2 meters.
- **4 meters < 10 meters** means that 4 meters is less than 10 meters.
- **2 meters < X ≤ 4 meters** means X is a number greater than 2 meters and less than or equal to 4 meters.

## Precision

How many times have you completed a calculation on your calculator and wondered how to round your answer? For example, take 10 and divide it by 3. Your calculator will read 3.3333333. What does that mean? Are all those 3s after the decimal necessary? Meaningful? To help us understand the answer to this question, we first have to be sure we correctly and consistently describe the precision of a number – the depth of information provided in terms of scale or depth. The number **1.2 cm is precise to 1 decimal place**

- The number **1.22 is precise to 2 decimal places**. It is MORE precise than 1.2 cm.
- The number **1 cm is precise to the ones place**. It is LESS precise than 1.2 cm or 1.22 cm.
- The number **320 cm is precise to the tens place** because the 0 with no decimal means it could have been rounded, meaning not 310 cm and not 330 cm. It is the LEAST precise of all the numbers in this list. *What do we do then when the measurement really is 320 cm NOT 321 or 319? We have to add a range to it: 320 cm +/- 0.5 cm. Otherwise, there's no way for our audience to distinguish the differences, and we must assume the least precision.*
- The number **320.000 cm is precise to three decimal places**. It is the MOST precise of all the numbers in this list.

## Precision and Measurements

When we take measurements, our instruments have a limit to their precision and thus our answers are rounded to the smallest graduation of measurement. *(HINT: Want to know what's been measured? There should be a unit attached! Examples: 10 kg or 6 meters.)* We call the smallest graduation of measurement for an instrument its **PRECISION**.

- A thermometer that we use at home to take our body temperature can indicate 98.6°F or 98.7°F, but no more precise than 1 decimal place.

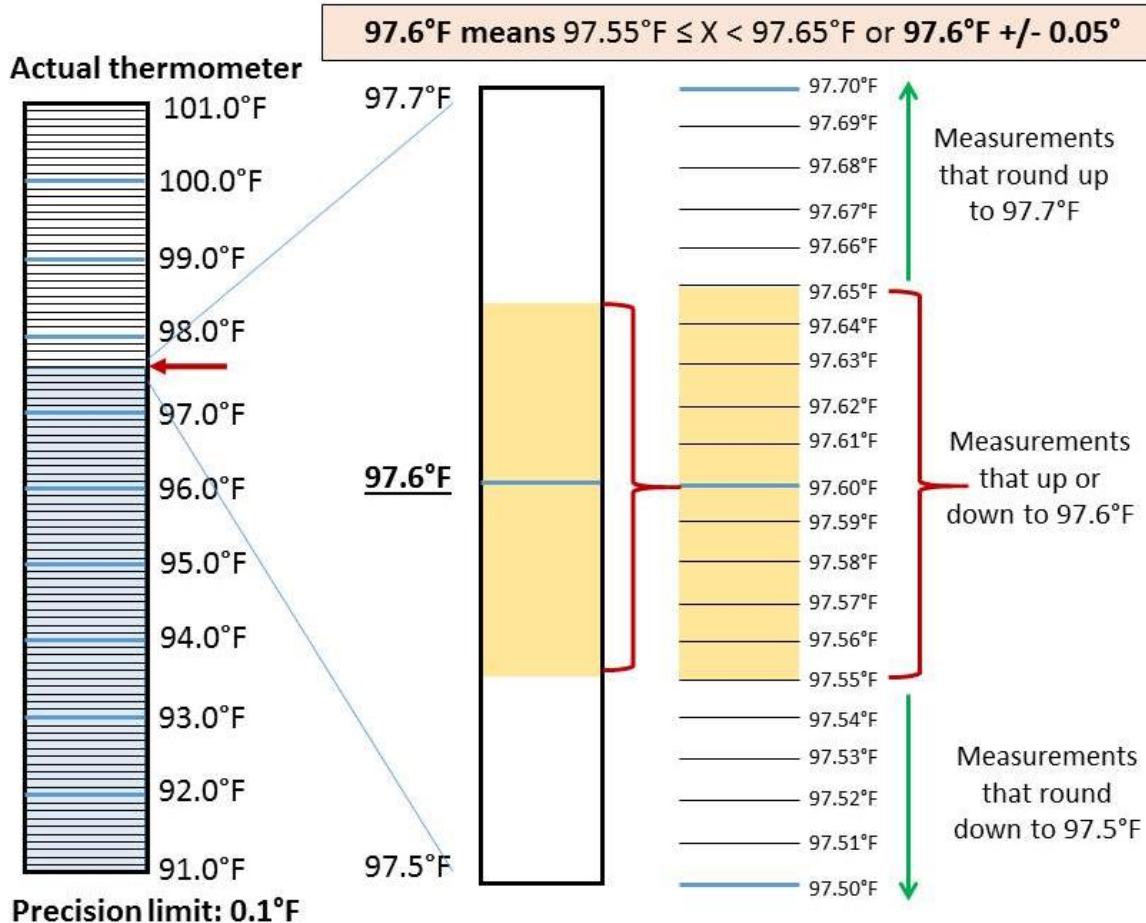
- A meter stick that we use in the classroom has millimeters as the smallest graduation. So we can use it measure to the nearest millimeter (0.001 m), but no more.

Since all measuring devices have a limit to their precision, there will always be a **range** (or error) to our measurements, dependent on that precision.

**Example:** 98.6°F means NOT 98.7°F and NOT 98.5°F. If our measurement lands between graduations on the thermometer, we'll round up or down as is most appropriate. Values between 98.6°F and 98.7°F are rounded up to 98.7°F if  $\geq 98.65^\circ\text{F}$  or down if  $< 98.65^\circ\text{F}$ .

- 98.64°F rounds down to 98.6°F. As does 98.63°F, 98.62°F, 98.61°F, and 98.60°F.
- 98.55°F rounds up to 98.6°F, as does 98.56°F, 98.57°F, 98.58°F, and 98.59°F.

SO, 98.6°F really means everything from 98.55°F to 98.64°F. Although it is not exactly equivalent, it is also similar to saying 98.6°F  $\pm 0.05^\circ\text{F}$ . (See following image for visual of this concept.)



More error will be added to a measurements when an instrument is difficult to read or hold. If you can't align it precisely, for example, then you can't be sure you are reading the correct measurements. In that case, the user adds additional error to the measurements to reflect that situation.

**Example:** 98.6°F  $\pm 0.3^\circ\text{F}$  means I wasn't sure I could read it as precisely as the instrument allowed or it fluctuated during measurement between a range of numbers, so it could have been as high as 98.9°F or as low as 98.3°F.

**ALL MEASURED NUMBERS (UNITS ATTACHED) SHOULD COME WITH AN ERROR. IF NONE IS GIVEN, THEN YOU ASSUME THE ERROR TO BE  $\pm \frac{1}{2}$  THE MEASUREMENT OF THE NEXT NUMBER PLACE).**

- 12.3 cm with no error attached is really 12.3  $\pm 0.05$  cm
- 12.3 cm  $\pm 0.1$  cm has additional error than the measurement tool maximum precision, which means the user of the instrument felt their own limitations in using the instrument were higher

## Measurements – Prereading Exercises

1. Circle which of the numbers here is the MOST precise. 100 m   110 m   111 m   111.1 m	2. Circle which of the numbers here is the LEAST precise. 1000 m   79 m   1 m   0.1 m
3. Find a meter stick or metric ruler that shows inches and centimeters. Insert correct symbol: <span style="float: right;">1 cm _____ 1 inch</span>	
4. Use symbols and variable X to describe a measurement between 6 meters and 18 meters.	
5. Use symbols and variable X to describe a measurement that is less than or equal to 2.5 meters.	
6. Translate the following math symbols into English: $10 < X < 90$ cm	
7. Look again carefully at your ruler and indicate its maximum precision (on metric side). (What is the smallest gradation of measurement visible on the tool?)	
8. Use this meter stick or metric ruler to measure the width of this page in cm. Give the measurement below and its range or error. <i>(Incorporate the error that you experience as the user/holder of your instrument.)</i>	9. Pick another object in the room. Describe the object, and give the measurement below and its range or error. <i>(Incorporate the error that you experience as the user/holder of your instrument.)</i>
10. If your error is greater than the precision of the instrument, explain why. What prevented you from getting as precise as the instrument could get?	
11. The measured number, 2.9 cm, has what precision and represents what range or error?	12. The measured number, 3200 cm, has what precision and represents what range or error?
13. If one person measures a sample of chemical powder to weigh 1 g $\pm$ 0.5 g (range is 0.5 g to 1.5 g), and another person measures a second sample that weighs 1.3 g $\pm$ 0.05 g – more precise (range is 1.25 g to 1.35 g), and we add these two samples together for an experiment, what is the result? CIRCLE: 2.3 g (range 2.25 g to 2.35 g) or 2 g (range 1.5 g to 2.5 g) <b>Why did you pick the answer you did?</b>	

## Measurements – Lab Exercises

### Rounding

Let's return now to the calculator problem. If I measure an object to be 2.8 cm long, and then I divide that into 3 equal pieces, how long is each piece? Using a calculator, 2.8 cm divided by 3 is 0.93333333 cm. Does it make sense to keep all those decimals when I know the original measurement only to one decimal place? We can't make a measurement more precise just by breaking it into 3 pieces, so we have to round it to match the precision of our original number. To round, determine first the place you'll round to. That's the limit of precision you're allowed. Call that number MAX. Now look at the number to the right of MAX. If it is  $\geq 5$ , round MAX up, meaning add 1 to it. If the number to the right is  $< 5$ , no change!

- \$32.5 rounded to the **ones place** is \$33 | \$32.4 rounded to the **ones place** is \$32.
- \$56,712 rounded to the **tens place** is \$56,710 | \$56,712 rounded to the **hundreds place** is \$56,700
- \$56,712 rounded to the **thousands place** is \$57,000 | \$56,712 rounded to the **ten thousands place** is \$60,000

14. Round \$45,325 to the thousands	15. Round \$3.6258 to two decimal places	16. Round \$5.56 to the ones place
-------------------------------------	--	------------------------------------

### Rounding and maintaining precision during mathematical calculations

**Basic rule:** if your calculation involves any measured numbers (recognizable because they come with a unit!), and those numbers all have the same unit, and your result also has the same unit, then round your answer so it is as precise as the **least precise of any of your starting measurements.**

- $12.6 \text{ cm} + 3 \text{ cm} = 15.6 \text{ cm}$  rounded to answer: 16 cm (precise to same as 3 cm, the least precise).
- $12.6 \text{ cm} \times 1.3 = 16.38 \text{ cm}$  rounded to answer: 16.4 cm (precise to same as 12.6 cm, the only measurement).

Calculate the following and round answer to the correct precision. (Show original answer and rounded one.)

17. $12.7 \text{ cm} + 6.43689 \text{ cm} =$	18. $12.7 \text{ cm} - 3 \text{ cm} =$
19. Take your page width measurement from Q7 and divide it by 3, to figure out the width of 1/3 of this page. <i>Remember to keep your error in your final answer!</i>	20. Take your object measurement from Q8 and divide it by 3, to figure out the height of 1/3 of the table. <i>Remember to keep your error in your final answer!</i>

### Unit conversion

Whenever you want to convert units from one into another, follow this simple technique that ALWAYS works:

1. Turn your original number into a fraction over 1.
2. Multiply this fraction by another fraction, one that equals 1: the conversion factor. Put the number with the units you want to cancel out on the bottom and the number with the units you want to end with on the top. (So the original unit cancels, and the new unit remains).

For example, to convert 3605 cm to inches:

$$\frac{3605 \text{ cm}}{1} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = ? \text{ in} \rightarrow \frac{3605 \cancel{\text{cm}}}{1} \times \frac{1 \text{ in}}{2.54 \cancel{\text{cm}}} = \frac{3605 \text{ in}}{2.54} = 1419 \text{ in}$$

**How do we round our answer?** When converting units, if the starting unit and ending units are comparable, like inches and centimeters or miles and kilometers, then we can just keep the initial precision. Make them match. **NOTE:** we should use conversion factors that are more precise than our actual measured numbers so we can ignore their precision when rounding.

21. Convert 34.2 km to miles. Conversion factor: 1 km = 0.6214 mi. ( <i>km and miles are similar, so keep original precision</i> ) <b>Show ALL work, with units.</b>
---

22. Convert 12 cm to inches. Conversion factor: 1 in = 2.54 cm. (*cm and in are similar, so keep original precision*)  
**Show ALL work, with units.**

What do we do when our mathematical calculation changes the units considerably, so we no longer know what precision to maintain? Answer: we have to carry our range/error along and then use it to round our final answer. How? We run the computation 3 times:

1. The first time with the original numbers
2. The second time with range/error end members that would produce the largest answer.
3. The third time with range/error end members that would produce the smallest answer.

We then compare the range end member calculations and see at what precision they start to vary. That's the maximum precision we keep for our original calculation, so we return to that original calculation and round accordingly.

**Example:** Convert 2111 m to km

$$\frac{2111\text{m}}{1} \times \frac{\quad}{\quad} = ? \text{ km} \quad \rightarrow \quad \frac{2111\cancel{\text{m}}}{1} \times \frac{\quad \text{km}}{\cancel{\text{m}}} = ? \text{ km} \quad \rightarrow \quad \frac{2111\cancel{\text{m}}}{1} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} = \frac{2111 \text{ km}}{1000} = 2.111 \text{ km}$$

How to round? 2111 m could be as big as 2111.4 m or as low as 2110.5 m. Now we solve the problem for the range/error limits, – 2111.4 m and 2110.5 m. Comparing where these values start to vary from each other tells us our precision.

$$\text{RANGE: } \frac{2111.4 \cancel{\text{m}}}{1} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} = 2.1114 \text{ km} \quad \frac{2110.5 \cancel{\text{m}}}{1} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} = 2.1105 \text{ km}$$

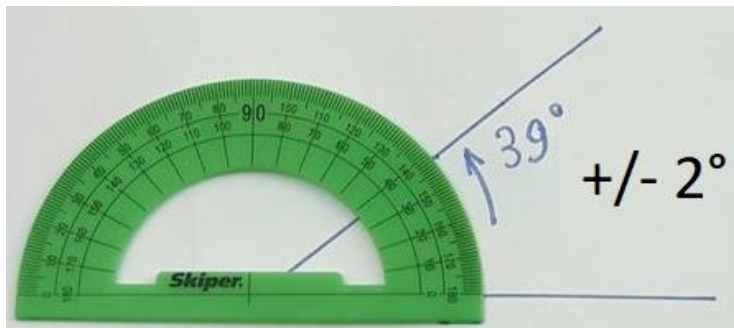
Range is 2.1105 to 2.1114 km (the first place to change is the third decimal place; so we round original to this place).

**ANSWER: 2.111 km**

23. Convert 6310 ft to miles. Conversion factor: 5,280 ft = 1 mi. (It could be as big as 6314 feet or as low as 6305 feet.) (*Unit change is considerable, so use the 3-calculation rounding/precision technique described above.*) **Show ALL work, with units.**

### Measuring angles

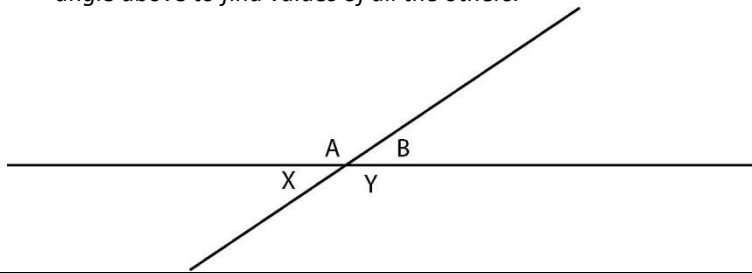
We use a protractor to measure angles made between two nonparallel lines. To ensure you're using the protractor correctly, first ask yourself, where is 0° in your diagram. Once you find that, line the protractor up so the 0 line along the bottom of the protractor points at or lines up along the 0° line on your diagram. The T in the center of your protractor zero line should be placed at the intersection of your angle lines. Then read from 0° up. Notice that all protractors have two sets of measurements on the outside, 0° to 180° in one direction and the opposite for the other direction. Be sure you're reading the angles that start at 0° at your 0° line.



*Image: wikiHow website on how to use a protractor.  
 Link on lab website.*

*Notice how the center of the protractor goes through the middle of where your two lines intersect, so it can measure the angle between them. Error of 2° is limit of tool and eye/hand used to measure!*

24. For the image on the below, use a protractor to measure all angles. Remember, since you're using an instrument to make a measurement there SHOULD be some error. Include that! *HINT: Notice that you need to measure only one angle above to find values of all the others.*



A: \_\_\_\_\_

B: \_\_\_\_\_

X: \_\_\_\_\_

Y: \_\_\_\_\_

### Adding and subtracting angles

1 degree (1°) can be broken into 60 equal pieces, each called 1 minute (1'); each minute is further divided into 60 equal pieces, each called 1 second (1"). When adding or subtracting angles, line up like units and add or subtract those as needed, then borrow or carry as needed so you don't end up with more than 60 seconds or 60 minutes in your answers. *Examples:*

$\begin{array}{r} 36' \\ + 45' \\ \hline = 81' \text{ or } 1^\circ + 21' \end{array}$	$\begin{array}{r} 23^\circ 11' 45'' \\ - 7^\circ 44' 59'' \\ \hline \end{array} \rightarrow \begin{array}{r} 22^\circ 70' 105'' \\ - 7^\circ 44' 59'' \\ \hline = 15^\circ 26' 46'' \end{array}$	$45'' - 59''$ would give a negative number, as would $11' - 44'$ , so we borrow before we subtract. Subtract $1^\circ$ from $23^\circ$ to get $22^\circ + 60'$ ; add $60'$ to $11'$ to get $71'$ ; borrow $1'$ from $71'$ to get $70' + 60''$ ; add the $60''$ to $45''$ to become $105''$ .
---	--	--

25. 
$$\begin{array}{r} 32^\circ 45' 36'' \\ + 3^\circ 25' 52'' \\ \hline = \end{array}$$

26. 
$$\begin{array}{r} 32^\circ 45' 36'' \\ - 3^\circ 25' 52'' \\ \hline = \end{array}$$

When converting degrees, minutes, or seconds, treat similarly to the unit conversion problems above. **Examples:**

$42.5^\circ = 42^\circ 30' \quad \left( \frac{0.5^\circ \times 60'}{1} = 30' \right)$	$42.125^\circ = 42^\circ 7' 30'' \quad \left( \frac{0.125^\circ \times 60'}{1} = 7.5' \right) \quad \left( \frac{0.5' \times 60''}{1} = 30'' \right)$
---	---

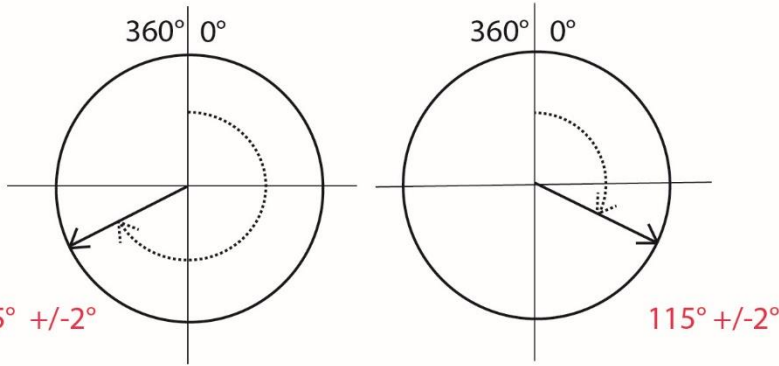
27.  $3 \frac{1}{4}^\circ = \underline{\hspace{1cm}}^\circ \underline{\hspace{1cm}}' \underline{\hspace{1cm}}''$

28.  $45.825^\circ = \underline{\hspace{1cm}}^\circ \underline{\hspace{1cm}}' \underline{\hspace{1cm}}''$

### Orientation & Bearing

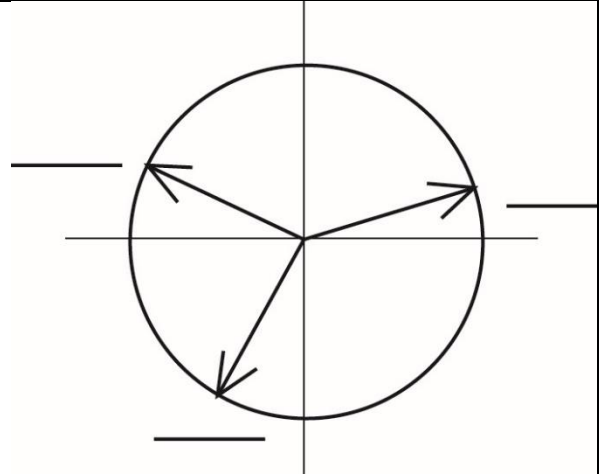
Orientation or bearing or heading are angle measurements that describe the direction relative to north that someone is moving or looking. An oceanographer measures the angle always as a number from 0 to 360°, measured clockwise from north. Example: 75° means "face north and rotate 75° to your right." That's the format an oceanographer uses to describe the orientation of a line or arrow or direction you're facing (bearing) or direction you're traveling (heading) on a map. The last two pages of your Measurements lab describe this process AND include the way that geologists describe and format that orientation as well. Both are provided because you'll see different formats depending on what tool you're using. Geologist format: example: N15°W means "face north and rotate 15° toward the west." S75°E means "face south and rotate 75° toward the East.

IN THIS CLASS, please always use oceanographer format, so that means you'll have to convert other formats to the oceanographer format.

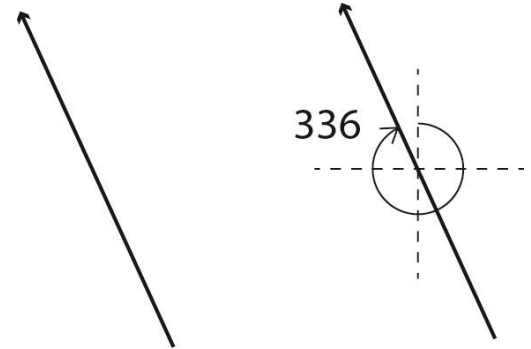


A circle encompasses 360° of arc. Starting with 0° at the top (OR NORTH) of the circle, and moving clockwise, indicate the degrees of arc encompassed by each of the four divisions indicated in the graphic. (Example: 270° means starting at the top of the circle, rotate 270° clockwise.)

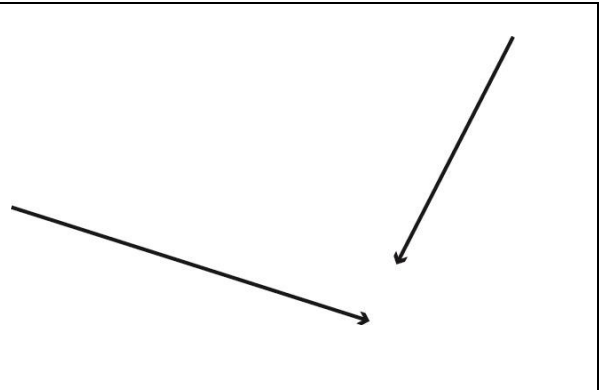
29. How would an oceanographer give the bearings of the lines in this image? (See examples above to help.) Give error/range.



EXAMPLE: What is the bearing of these lines, according to oceanographers? (First draw your own N-S-E-W cross-hairs across the line.)



30. What is the orientation of these lines, according to oceanographers? (You can draw your own circle if helpful.) (See example.) Give error/range.



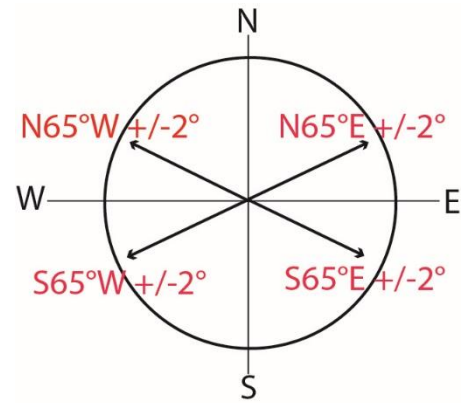
### Bearings for Geologists

Final note: Compasses, which we'll use next week, often show angles using two methods – the one we learned above – the Oceanographer's method – and the one that's described here for Geologists. **Geologists** measure bearing of an arrow or sightline as a number of degrees east or west of North or east or west of South, depending on whether the arrow points towards the northern hemisphere or southern hemisphere. Examples:

- N15°W means face north, then rotate 15° towards the west.
- S45°E means start facing south and then rotate 45° towards the east.

Note: your angle of rotation must always be  $\leq 90^\circ$ .

(See examples to right.)



Be sure you know which compass reading you're using when you pick up a compass.

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Evaluate instrument precision for rulers and protractors	A   B   C   D   F	
Evaluate error on given measurements and propagate those correctly through a calculation	A   B   C   D   F	
Use a protractor to accurately measure angles and associated error	A   B   C   D   F	
Apply angle measurements to the geographic coordinate system to describe, in a geologist format, the orientation of a line on Earth's surface relative to north or south	A   B   C   D   F	
Convert units for distance, time, and angles while maintaining correct precision.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

## Measurements Review Practice Sheet

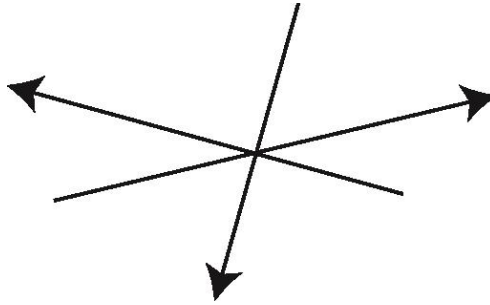
Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

1. Use symbols and variable X to describe a measurement between 1 and 7 cm.	2. Use symbols and variable X to describe a measurement that is greater than 4 m.
3. Round 45,325 to the tens precision	4. Round 3.6258 to three decimal places precision
5. The measured number, 1.7 cm, is precise to one decimal place and represents what range?	6. The measured number, 3220 cm, is precise to the tens and represents what range?
7. $1.7 \text{ cm} \div 3 =$	8. $3220 \text{ cm} \div 3 =$
9. $6.555 \text{ cm} + 1.12 \text{ cm} =$	10. $56.5 \text{ cm} - 1 \text{ cm} =$
11. $10 \text{ cm} + 1 \text{ cm} =$	12. $12.7 \text{ cm} \times 8 =$

1 mi = 5280 ft	1 in = 2.54 cm	1 km = 1000 m	1 g = 0.035 oz	1 cm/yr = 10 km/my
1 ft = 12 in	1 km = 0.6214 mi	1 m = 100 cm	1 kg = 2.205 lbs	1 km/hr = 0.2778 m/s

13. Convert 12.6 lbs to kg. ( <b>Show ALL work, with units – like one of the examples above</b> )	
14. Convert 12 inches to centimeters. ( <b>Show ALL work, with units – like one of the examples above</b> )	
15. Convert 6.72 miles to feet. (Use ranges to determine rounding.) <b>Careful with rounding here!</b>	
16. Convert 129 km/my to cm/yr. (Use ranges to determine rounding.) <b>Careful with rounding here!</b>	
17. $42.125^\circ = \underline{\hspace{1cm}}^\circ \underline{\hspace{1cm}}' \underline{\hspace{1cm}}''$	18. $21^\circ 53' 39'' - 1^\circ 15' 49'' =$

19. What is the bearing of these arrows, according to **oceanographers**? (You can draw your own circle if helpful.) (See example.)



### KEY

1. Use symbols and variable X to describe a measurement between 1 and 7 cm. <b><math>1 &lt; X &lt; 7 \text{ cm}</math></b>	2. Use symbols and variable X to describe a measurement that is greater than 4 m. <b><math>X &gt; 4 \text{ m}</math></b>
3. Round 45,325 to the tens precision <b>45,330</b>	4. Round 3.6258 to three decimal places precision <b>3.626</b>
5. The measured number, 1.7 cm, is precise to one decimal place and represents what range? 6. <b>1.65 to 1.74 cm</b>	7. The measured number, 3220 cm, is precise to the tens and represents what range? <b>3215 to 3224 cm</b>
8. $1.7 \text{ cm} \div 3 = 0.6 \text{ cm}$	9. $3220 \text{ cm} \div 3 = 1073.3 = 1070 \text{ cm}$
10. $6.555 \text{ cm} + 1.12 \text{ cm} = 7.68 \text{ cm}$	11. $56.5 \text{ cm} - 1 \text{ cm} = 55.5 = 56 \text{ cm}$
12. $10 \text{ cm} + 1 \text{ cm} = 11 \text{ cm} = 10 \text{ cm}$	13. $12.7 \text{ cm} \times 8 = 101.6 \text{ cm}$
14. Convert 12.6 lbs to kg. ( <b>Show ALL work, with units – like one of the examples above</b> ) <b><math>12.6 \text{ lbs} \times 1 \text{ kg} / 2.205 \text{ lbs} = 5.7 \text{ kg}</math></b>	
15. Convert 12 inches to centimeters. ( <b>Show ALL work, with units – like one of the examples above</b> ) <b><math>12 \text{ inches} \times 2.54 \text{ cm} / 1 \text{ inch} = 30 \text{ cm}</math></b>	
16. Convert 6.72 miles to feet. (Use ranges to determine rounding.) <b>Careful with rounding here!</b> <b><math>6.72 \text{ miles} \times 5280 \text{ ft/mile} = 35,481.6 \text{ ft}</math>   <math>6.715 \text{ miles} \times 5280 \text{ ft/mile} = 35,455.2 \text{ ft}</math>   <math>6.724 \text{ miles} \times 5280 \text{ ft/mile} = 35,502.72 \text{ ft}</math></b> <b>So the range is between 35,455.2 and 35,502.72 (the hundreds place is the first to change; round to this):</b> <b>ANSWER 35,500 ft</b>	
17. Convert 129 km/my to cm/yr. (Use ranges to determine rounding.) <b>Careful with rounding here!</b> <b><math>129 \text{ km/my} \times 1 \text{ cm/yr} / 10 \text{ km/my} = 12.9 \text{ cm/yr}</math></b> <b><math>129.4 \text{ km/my} \times 1 \text{ cm/yr} / 10 \text{ km/my} = 12.94 \text{ cm/yr}</math></b> <b><math>128.5 \text{ km/my} \times 1 \text{ cm/yr} / 10 \text{ km/my} = 12.85 \text{ cm/yr}</math>      ANSWER: 12.9 cm/yr</b>	
18. $42.125^\circ = 42^\circ 7' 30''$	19. $21^\circ 53' 39'' - 1^\circ 15' 49'' = 20^\circ 37' 50''$
20. What is the bearing of these arrows, according to oceanographers? (You can draw your own circle if helpful.) (See example.) <b><math>75+/-2^\circ, 195+/-2^\circ, 290+/-2^\circ</math></b>	



# Latitude, Longitude, & Compasses

## NEEDED SUPPLIES:

- Desktop version of Google Earth Pro
- Protractor to measure angles
- Compass (from hardware store – physical, OR phone app)
- Blank paper to use as a paper ruler
- Clear plastic surface like a page protector with a pen to write on it
- Pencil and eraser
- Calculator

## Latitude and longitude

By international agreement the earth's surface is divided by a series of east-west and north-south lines to form a grid. If the earth's surface were flat, it would be easy to set up a global grid system. Simply designate some point as the starting place (origin) and measure your distance east or west (right or left on a map) and north or south (up or down on a map) relative to the origin. But the earth's surface is circular, so we must do something slightly more complicated. Instead of measuring miles or inches up and down and right and left from the origin, we measure angles (degrees). There are 360 degrees ( $^{\circ}$ ) in a full circle, 60 minutes ( $'$ ) in one degree, and 60 seconds ( $''$ ) in one minute. These minutes and seconds are units of angle and have nothing to do with time. We use the intersection of the **equator** (imaginary line running around the center of the planet) and **prime meridian** (imaginary line connecting the poles and intersecting Greenwich, England) as the origin. So we can describe each surface position in degrees north or south of the equator ( $90^{\circ}$  north and south are the maximums) and degrees east or west of the prime meridian ( $180^{\circ}$  east and west are the maximums).

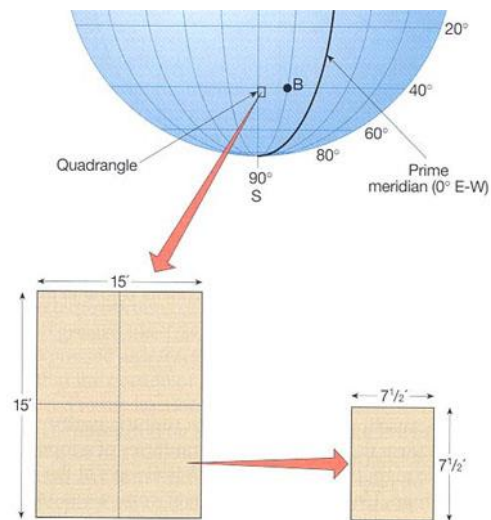
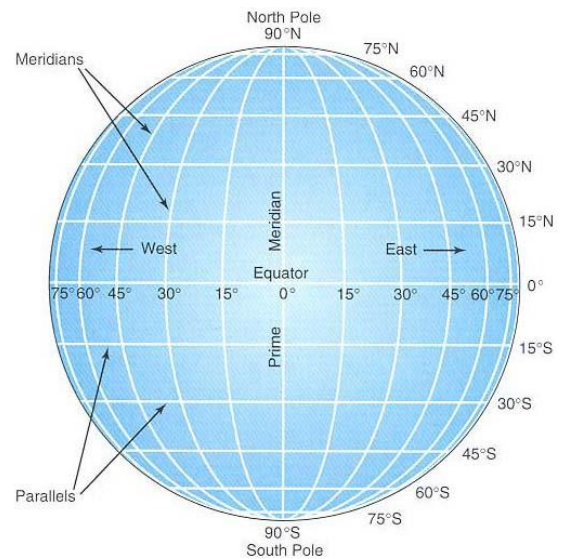
- **Parallels** (lines of **latitude**) circle the globe parallel to the equator. Latitude is measured from the equator to  $90^{\circ}$  N at the North Pole and  $90^{\circ}$  S at the South Pole.
- **Meridians** (lines of **longitude**) are north-south lines that run from pole to pole. Meridians are measured east and west of the prime meridian to  $180^{\circ}$ , which is the **International Date Line**.

Most maps are based on latitude and longitude: their east and west boundaries are meridians and their north and south boundaries are parallels. The United States Geological Survey (USGS) currently produces only 7.5-minute ( $1/8^{\circ}$ ) quadrangles, which means that there are  $7\frac{1}{2}$  minutes of latitude between the north and south boundaries and  $7\frac{1}{2}$  minutes of longitude between the east and west boundaries. When near the poles, such maps are significantly narrower than they are tall: the east-west distance across the map is less than the north-south distance even though the map encompasses the same amount of latitude and longitude. When near the equator, they are squarer.

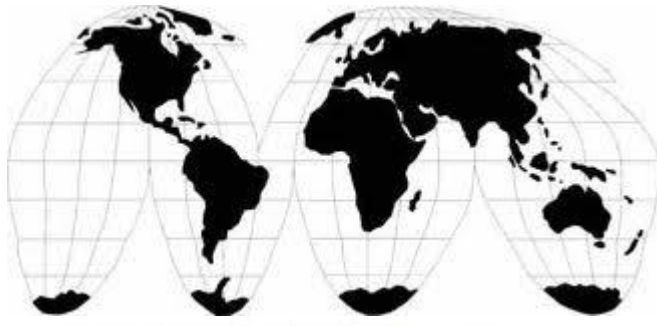
{One 15' quad is  $15'$  of latitude by  $15'$  of longitude. There are four 7.5' quadrangle maps in each 15' quadrangle map.}

**MAPS IN GENERAL** (*maps in this section are from public domain, USGS, or unknown source*)

Map making on a global scale is a series of clever compromises to do a good job showing a spherical surface on flat paper. The only truly accurate map is a globe. All other maps have inherent distortions.

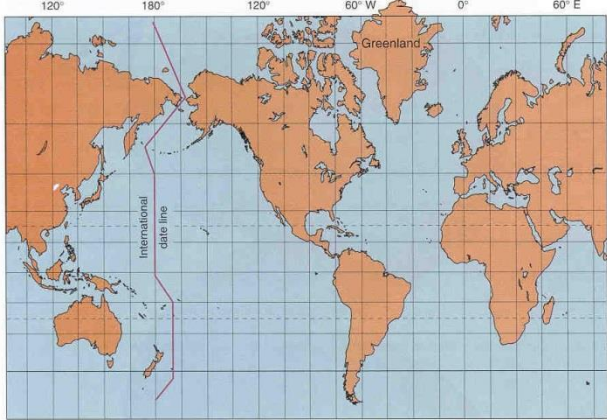


Images: Top: Unknown source. Bottom: USGS

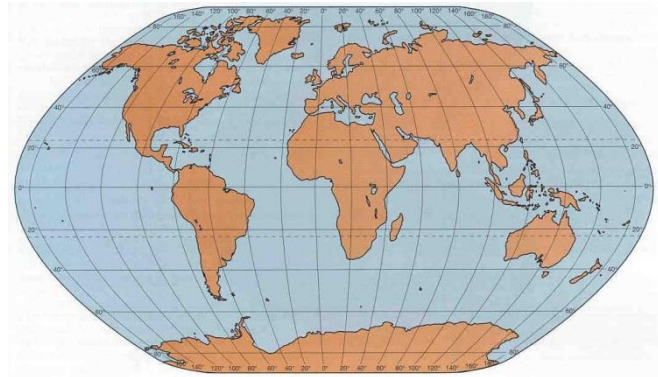


**Goode's homolosine projection.**

The obvious problem with this projection is that adjacent areas in some parts of the world are depicted as being widely separated. The Goode's projection in particular cuts the continents and so shows the three oceans to best advantage. Note that the meridians of longitude converge to points, thus not distorting the shapes and sizes of high-latitude areas. Areas on this map are equal.



**Mercator projection.** Shapes are similar to globe, but areas are distorted, appearing wider as you move away from the equator. South America is really 9x bigger than Greenland. Does it look that way here?



**Hoelzel projection.** Note that the meridians of longitude converge to a line shorter than the equator but still not a point. Thus polar areas are more distorted than equatorial areas, but not as much as in Mercator projections.

*Below map from 1980s USGS*

**Orientation**

All U.S.G.S topographic maps and most other maps are made with north at the top of the sheet. True north is the direction to the north geographic pole (true north – designated as TN or \*). The north-seeking end of a compass needle is attracted to Earth's north geomagnetic pole, which in 2017 was at **86° 30' N and 172° 36' W** (86.5, 172.6). Each topographic map has two north arrows in the lower margin, indicating the directions of both true north and magnetic north. The angular difference between these two directions is called the **magnetic declination**. In the image above, the magnetic declination at Upheaval Dome, Utah in the 1980s was **15°**.

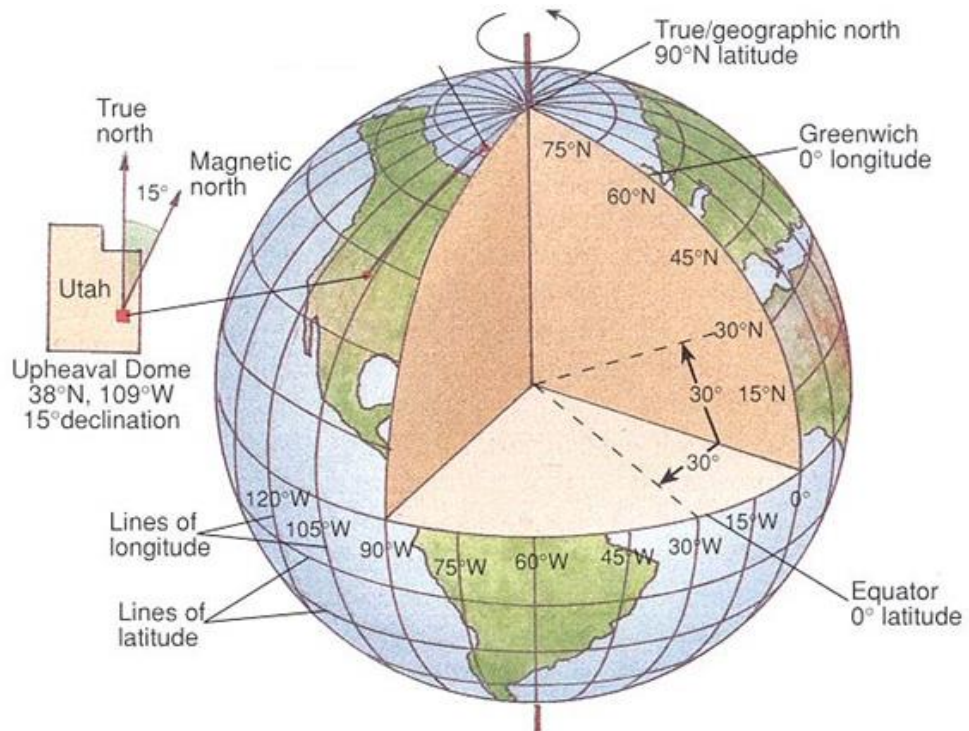


Image credit: NOAA

Nautical charts use compass roses to indicate magnetic declination. This compass rose is for an area of the oceans where magnetic north is 355°45' (a counterclockwise rotation). If navigators do not modify their compasses accordingly, they will not be traveling in the right direction. Also, magnetic north wanders regularly. Compass roses always explain how magnetic north varies in an area each year. (This compass rose indicates that magnetic north is moving closer to the true north at a rate of 8' each year since 1985, the year the chart was made.) These rates of change are estimates and can also change. As a result, people who use maps for navigating waterways or orienteering on land must update maps and update their local declination yearly. In 2011, Earth's north magnetic pole was moving toward Russia at almost 40 miles (64 kilometers) a year.

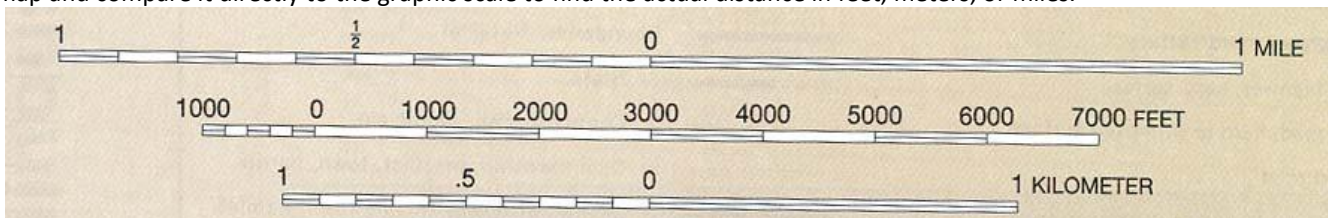
**Scale**

The scale of a map is the ratio of a given distance on the map to the corresponding distance on the ground.

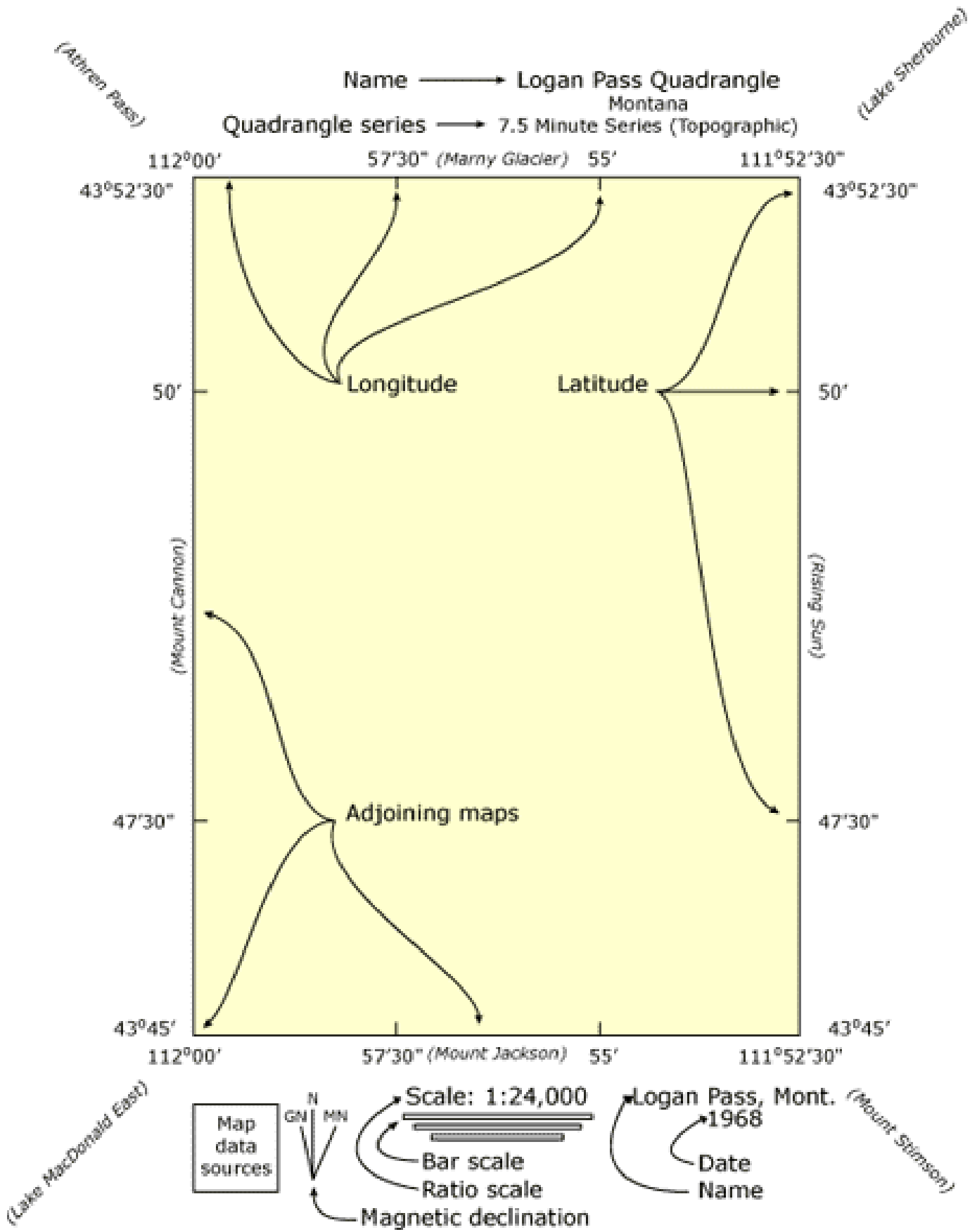
It may be expressed fractionally, verbally, or graphically. Fractional and graphical scales can be found in the center of the lower margin on all standard U.S.G.S. quadrangles. The fractional scale is a ratio of equal units (inches, feet, yards, meters, etc.). One commonly used scale is 1:62,500. This means that one inch on the map represents 62,500 inches on the ground, or one centimeter on the map represents 62,500 centimeters on the ground. Verbal scales appear as words at the bottom of the map. Commonly used fractional scales and the corresponding verbal scales are given in the following table. *Note: Larger-scale maps show a smaller area, but in greater detail. Small-scale maps show little detail, but a large area.*

	Fractional scale	Verbal scale	Examples of maps using each scale
Largest scale	1:24,000	Approximately 2000 feet per inch	7.5-minute quadrangles
	1:62,500	Approximately 1 miles per inch	15-minute quadrangles
	1:125,000	Approximately 2 miles per inch	30-minute quadrangles
	1:250,000	Approximately 4 miles per inch	60-minute quadrangles
	1:500,000	Approximately 8 miles per inch	Many state maps
Smallest Scale	1:1,000,000	Approximately 16 miles per inch	
	1:2,500,000	Approximately 40 miles per inch	Geologic map of the United States

The bar that looks like a ruler in the center of the lower margin is the graphic scale. It is easy to pick a distance from the map and compare it directly to the graphic scale to find the actual distance in feet, meters, or miles.



Scale bar. Notice that the ZERO mark is in the center, and the left side includes detailed subdivisions. Image: USGS



Sample USGS Quadrangle. Note: MN = Magnetic North | N = True North | GN = Grid North (military use)

# NAUTICAL CHARTS

## Plotting a course

A ship's **course**, expressed in degrees clockwise of North, is the intended direction of travel. For example, a course of  $180^\circ$  is due south, and one of  $90^\circ$  is due east. However, winds, currents, and pilot error may prevent the ship from adhering to a particular course. A ship's **heading** or track is the direction in which the ship is actually traveling, regardless of its prescribed course. A **bearing** is the direction you face when looking at a distant point. Both heading and bearing are angles measured from North. Example: if you're in a boat pointing due north (course is north), and you are observing a lighthouse through the fog immediately east of you, the lighthouse's bearing is  $90^\circ$ . Courses, headings, and bearings are expressed as angles measured clockwise from north. ( $0^\circ$  is north;  $90^\circ$  is east;  $180^\circ$  is south;  $270^\circ$  is west.)

## Determining location using a compass or sextant

Even out of sight of land, sailors have navigated for centuries by measuring apparent positions of stars at night and of the sun during daylight. When sailing in a bay or in sight of the coastline, you use a **compass** to get bearings on two prominent landmarks. Lines drawn on the map from the landmarks and with the measured bearings intersect at the point from which the readings were taken. You can do the same thing, without a compass, by measuring two horizontal angles between three landmarks: the angle between point A and point B and the angle between point B and point C. The device traditionally used to do this is the **sextant** – essentially a fancy protractor that allows you to sight on distant points.

## GPS

The development of satellites and digital electronic devices has made it possible to keep continuous track of your position on the earth with a precision of a few centimeters (using the best equipment available) or a few meters (using hand-held equipment that costs well under \$1,000). Satellite-based electronic positioning, the **Global Positioning System (GPS)**, was established by the U.S. military, but is available for use in nonmilitary applications. A ground-based receiver picks up signals simultaneously from three or more satellites, and the distance from each satellite to the receiver is automatically computed. With four satellites involved, there is only one point in the universe at those four distances. Your location is displayed as latitude, longitude, and elevation.

## Using Google Earth/Oceans – The Basics

To go to a particular location within Google Earth, enter latitude and longitude as follows:

- Latitude first, Longitude second.
- Put spaces between degrees, seconds, minutes (and don't include the units)
- Positive latitudes are North, Negative are South
- Positive longitudes are East, Negative are West
- Example:  $46^\circ 23' 15''$  N,  $122^\circ 22' 15''$  W is entered as: 46 23 15 -122 22 15
- If you enter decimals, Google Earth/Oceans interprets it as a fraction of a degree. Example: 23.5 =  $23^\circ 30' 00''$

To find the latitude and longitude of a particular location in Google Earth/Oceans, you can drop a pin and look at its properties, or you can hold the cursor over the location.

Google Earth provides all latitudes and longitudes with the letter/direction first. Please convert those to correct format before recording in lab. Example: N  $20^\circ 15' 43''$  should be written as  $20^\circ 15' 43''$  N.

To measure distance and orientation in Google Earth/Oceans, use the ruler tool as follows:

- Locate the ruler icon at top of map
- Use the drop-down menu to choose your units (kilometers is preferred!)
- Click on your starting location and then click on your end location.
- Read answers for distance and orientation of that line (note that it's important you start on right side for orientation).

Google Earth provides all orientations as "heading" in the ruler tool and provides the answer in a modified Oceanographer format. It adds a letter afterwards. Be sure you convert those numbers to the correct format. Example:  $220^\circ$ W should first just be  $220^\circ$  (Oceanographers) or  $S40^\circ$ W (Geologist's format). For a review on formats, return to Measurements Lab.

## Latitude, Longitude, & Compasses – Prereading Exercises

Use your own words in your answers – NOT verbatim from the prereading material.

1. How many minutes in a degree? ( ' in a ° )	2. How many seconds in a minute? ( " in a ' )
3. What is wrong with maps that don't show longitude lines converging at the poles? (Be specific.)	
4. How does a 7.5' map get its name? (Be specific – what does the map name mean?)	
5. Latitude and longitude: which runs North-South? (Circle correct answer.)	
6. Latitude and longitude: which runs East-West? (Circle correct answer.)	
7. Latitude and longitude: which indicates location North-South? (Circle correct answer.)	
8. Latitude and longitude: which indicates location East-West? (Circle correct answer.)	
9. What is the <b>latitude</b> of each of the following? The equator                      The north pole                      The south pole	
10. What is the <b>longitude</b> of each of the following? The prime meridian                      The international date line	

### Compasses

11. Looking at the website link to NOAA's <b>Magnetic Pole Wandering</b> , find and provide below the latitude and longitude of magnetic north pole, then enter that into Google Earth (browser version or downloaded desktop version) and describe that location (is it on an island or continent? In the ocean?)
12. Looking at the website link to NOAA's <b>Magnetic Declination Estimated Anywhere</b> website, what is the magnetic declination (magnetic north's variation from true north) for San Francisco today? For Perth, Australia? Give in the Oceanographer's format for bearing. How does the Perth value today compare to that shown in the prereading for 1985?
13. What is the difference between heading and bearing? (Use your own words!)

# Latitude, Longitude, & Compasses – Lab Exercises

## Google Earth & Google Oceans

Log on to the department laptops. Launch Google Earth & Oceans (desktop version – browser version can be used in a pinch, but need to have access to ruler tool). Explore a bit. You'll be using this software throughout the semester. But you'll be learning it from each other and from the software itself. Be patient. If you have questions, ask.

- **Latitude & Longitude:**
  - To determine latitude and longitude:
    - Turn on grid lines (these are latitudes and longitudes).
    - Or click on a point and look at the lat/long shown in the lower right corner.
  - Google Earth can search on latitudes and longitudes, but you must enter them like this: 37 30 15, 122 45 13 (where the first set of numbers are latitude in degrees, minutes, and seconds, and the second set of numbers is longitude in degrees, minutes, and seconds; positive latitudes are N of the equator; negative latitudes are S of the equator; positive longitudes are east of the prime meridian; negative longitudes are west of the prime meridian.)
- **Distance and Orientation:** use the ruler to measure distance and orientation—from first click toward second click; orientation will be given using the Oceanographer's standard: 0-360 measured clockwise from north.

### Latitude and Longitude estimates using Google Earth

	Grid Lines	Click on point
1. What is the latitude and longitude of <b>San Francisco</b> ? <i>(Be sure to provide direction and the error range based on the precision of you and your instrument.)</i>		
2. What is the latitude and longitude of <b>Sydney, Australia</b> ? <i>(Be sure to provide direction and the error range based on the precision of you and your instrument.)</i>		
3. All of the above measurements have an error associated with them. What factors were involved in calculating your error for each?		

### Distance and Orientation

4. What is the distance between New York and London <b>in kilometers</b> ? (Don't forget units!) <i>(Be sure to provide the error range based on the precision of you and your instrument.)</i>
5. What is the orientation of the line drawn FROM New York TO London? (Don't forget to use proper formatting!) <i>(Be sure to provide the error range based on the precision of you and your instrument.)</i>
6. List two small, unique places that the International dateline passes through.
7. List two small, unique places that the Prime Meridian passes through.
8. List two small, unique places that the Equator passes through.

**San Francisco South Quadrangle** (*paper copy or digital version linked on class website*)

Look at the San Francisco South quadrangle topographic map. Note that there are two sets of numbers on the edges of the chart. The black numbers that appear most frequently are kilometers away from a grid origin used by the military. Ignore those. Instead, look for the longitude and latitude measurements. You can find them on all corners, and usually 2-4 more evenly spread across each map edge.

9. What are the latitudes of the north and south boundaries of the map respectively?
10. What are the longitudes of the west and east boundaries of the map respectively?
11. How much angle of latitude is covered by this map?
12. How much angle of longitude is covered by this map?
13. What size map is this (in minutes)?
14. What is the fractional scale of this map?
15. What is the verbal scale of this map? (This information is not usually on the map. See table in prereading for answer.)
16. What was the magnetic declination in this quadrangle when it was made (and when was that)? (Format answer correctly for orientations!)
17. Comparing the above answer to the one you got in the prereading, how much has magnetic declination changed in San Francisco since this map was made?
18. Locate City College Ocean Avenue Campus and using the map only <i>estimate</i> its present latitude and longitude to the nearest second with error.
19. What is your answer to the above from Google Earth (with error)? (Is your Google Earth measurement within the error of your estimate from the map (previous question)?)
20. Notice that the above map is longer from bottom to top than from right to left, even though the area encompasses the same number of degrees of latitude (north-south) and longitude (east-west). Also note that the east and west boundaries of the map should not be parallel to each other. Explain why.

**Bolinas Quadrangle** (*paper copy or digital version linked on class website*)

21. What is the quadrangle size in minutes?	22. What was the magnetic declination in this area when the map was made and when was that?
---	---

	ANSWER USING MAP	ANSWER USING GOOGLE EARTH
23. Highway 1 intersects the road to Bolinas just west of the center of the map area. How far, <b>in km</b> , is it from that intersection to the tip of Duxbury Point? Provide error range.		
24. What is the bearing of Duxbury Point from that intersection? Provide error range		
25. If you were to move along Highway 1 north from the intersection, what would your heading be? Provide error range.		
26. A couple of tourists in a boat offshore are in trouble. They need immediate rescue. They have a cell phone with built-in compass and are in contact with the Coast Guard, who has asked them to take bearings on objects on land that they can see. They supplied the Coast Guard with bearings on Duxbury Point (250°) and on the southern end of the beach in front of the town of Stinson Beach (95°). Plot these bearings, along with a north arrow on a sheet of transparent material. Use the transparency as an overlay on the map to determine the point from which the compass readings were taken. Find that location on Google Earth and give its longitude and latitude. Be as precise as you can. (Include seconds.) Provide error range. (Sample transparency available on website.)		

### Orientation & Compasses

The **Brunton compass** has a two rings on the outside. The outer one goes from 0 to 360 and represents oceanographic standards for determining bearings and directional orientations (where 0 is north, 90 is E, 180 is S, 270 is W). The inner ring indicates N, S, E, W and has angle measurements from 0 to 90 and represents geologic standards for determining orientations (as learned in the last lab). The markings on the compass appear reversed from what you would think, so that the compass will give you the correct reading when you face one direction and the internal magnet continues to point north. The inside of the compass (the face) is used for measuring dip, which we will do later in this class. Whether you use a Brunton compass or a more traditional mariner's compass, you have to correct it for the magnetic declination in your area. *(If you're doing this exercise at home, use a downloaded compass app on your phone or a compass you have purchased at a sporting goods store. (If you use a compass app on your phone, you can go into settings to set it to point to True North instead of Magnetic North. Otherwise, you should assume it's pointing at the magnetic north pole NOT the true north pole.)*

27. Get a compass and ensure it is corrected for the magnetic declination that you calculated in the prereading (or be aware it's not corrected, and make adjustments as needed). Go outside behind the lab (the metal in the lab tables make this exercise impossible to do in class), or outside your house if you're at home. Stand just a few feet outside the door. Orient yourself by finding North, East, South, and West. What buildings or objects do you see in each of those directions?

North	East	South	West
-------	------	-------	------

28. <b>Estimate first with no compass</b> , your bearing if you are facing the door you exited from the building. Indicate value using an oceanographer's standard. Then use compass to take more precise measurement. Provide error range. How good was your estimation?	29. <b>Turn your back to the door, and estimate first with no compass</b> , your bearing if you are facing away from the door you exited from the building. Indicate value using an oceanographer's standard. Then use compass to take more precise measurement. Provide error range. How good was your estimation?
---	---

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

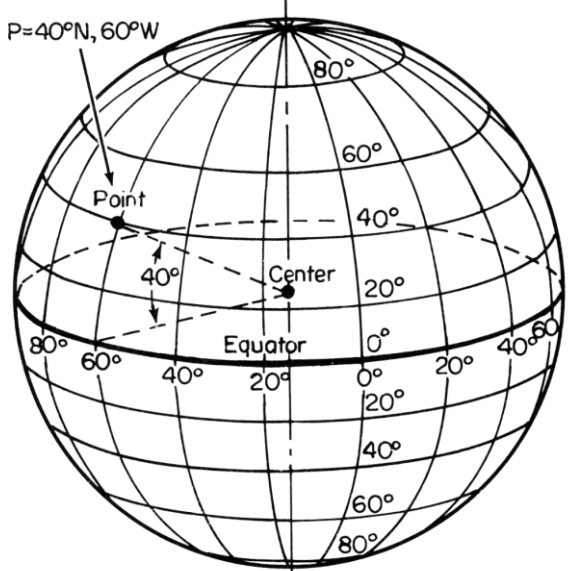
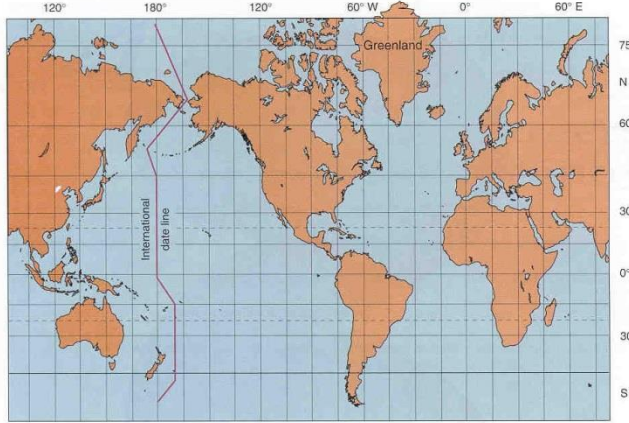
Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Use latitude and longitude to accurately describe with associated error (depending on instrument) a particular location on Earth's surface (using both maps and Google Earth)	A   B   C   D   F	
Use map information to evaluate magnetic declination in a particular region and how it will impact compass measurements	A   B   C   D   F	
Use a hand-held compass to accurately measure orientation of a line between two points on Earth's surface	A   B   C   D   F	
Measure distances and orientation angles between two objects on maps and provide accurate answer with appropriate error (using both maps and Google Earth)	A   B   C   D   F	
Use angles between objects and north to triangulate your position and locate yourself on a map.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

# Latitude, Longitude, & Compasses Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

<p>1. Use this globe to define a 15' quad and to explain how a 15' quad's shape differs at the equator and at the poles.</p>	 <p style="text-align: center;"><i>Image from US Department of Energy</i></p>
<p>2. Use the above globe and the Mercator projection to the right to explain what is wrong with flat maps of the world.</p>	 <p style="text-align: right;"><i>Image: Unknown source</i></p>
<p>1. Earth's north geomagnetic pole in 2017 was at <b>86° 30' N and 172° 36' W</b> (86.5, 172.6). Open Google Earth and mark this location. Then enter the coordinates of location X = 89° 50'N and 82°E. I also recommend you find the North Rotational pole (90, any number for longitude). Put markers on all those locations. Use the ruler to draw a line from location X to the magnetic north pole. What is the orientation of this line (magnetic declination)?</p>	
<p>3. What is the latitude and longitude of the southern tip of Africa?</p>	<p>4. What would magnetic declination be in Barrow, Alaska (again use Google Earth)?</p>
<p>5. Be sure you can use a compass to determine directions and orientations.</p>	

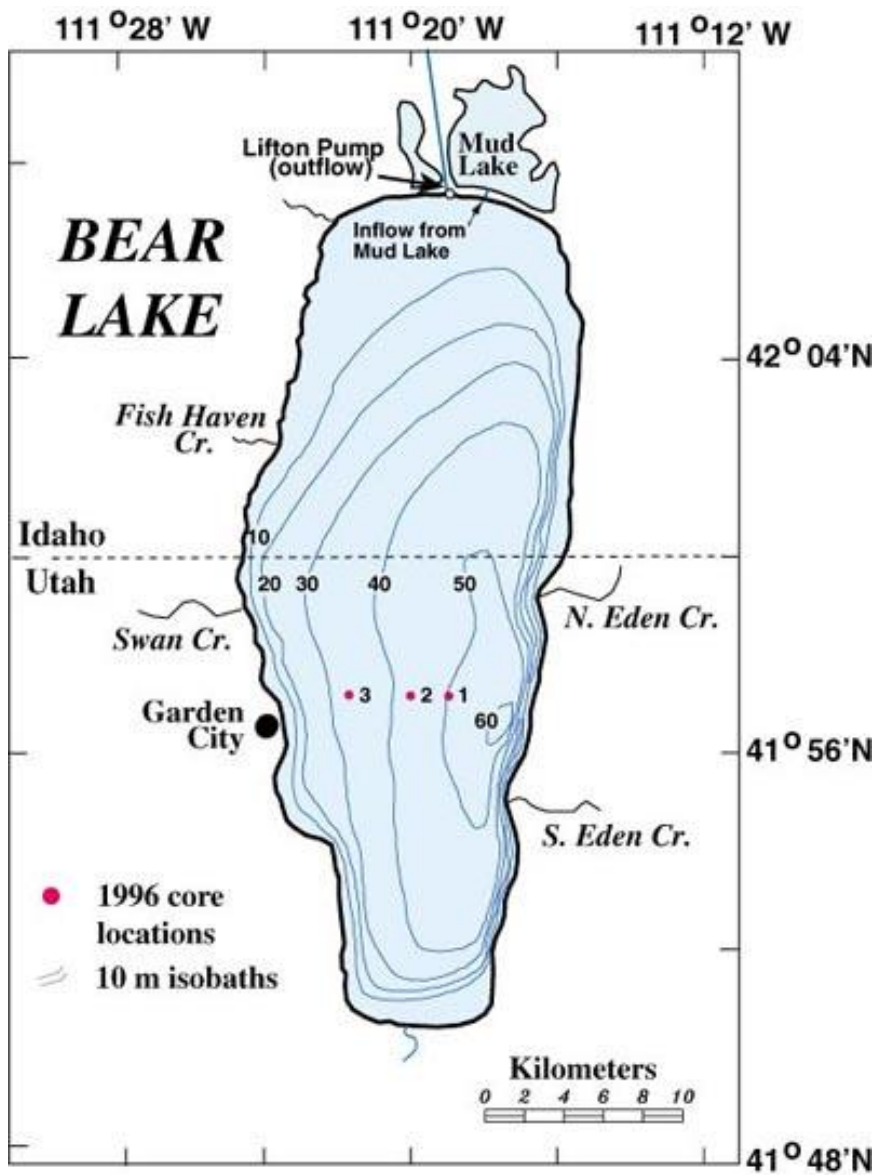


Image based on USGS map. Modified by unknown author.

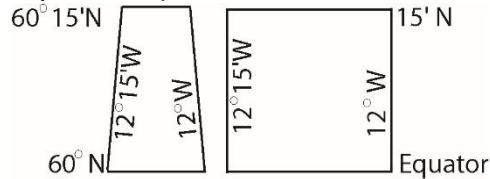
**USGS Bear Lake Bathymetric Map**

6. What is the latitude and longitude of Garden City?
7. What is the latitude and longitude of the Lifton Pump Outflow?
8. Using the scale bar, what is the distance from Garden City to Lifton Pump Outflow?

## KEY

1. Use this globe to define a 15' quad and to explain how a 15' quad's shape differs at the equator and at the poles.

*A 15' quad has 15' of latitude between the north and south boundaries and 15' of longitude between east and west boundaries. On the globe, that shape is square at the equator (where latitude and longitude cover equal distances). But since longitude lines converge at the poles, there will be progressively less and less distance between them as you move north and south of the equator, while latitude still maintains the same distance. Maps towards the poles thus get narrower and are rectangles, as tall as the equator maps, but skinnier, and with right and left margins converging a bit – not parallel (exaggerated in picture below)*



2. Use the above globe and the Mercator projection to the right to explain what is wrong with flat maps of the world.

*When the longitude lines are spread out at the north and south poles to make a flat map like this one, it stretches everything out – including the North POINT which is now a broad swath. As a result, all objects are stretched, to an increasing degree the further north and south you move from the equator.*

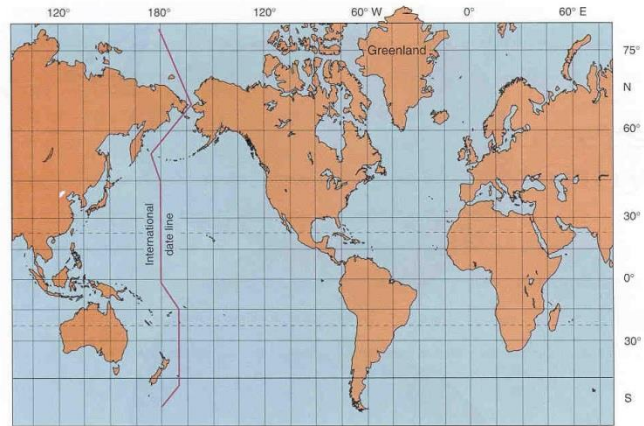


Image: source unknown

3. Earth's north geomagnetic pole in 2017 was at **86° 30' N and 172° 36' W** (86.5, 172.6). Open Google Earth and mark this location. Then enter the coordinates of location X = 89° 50' N and 82° E. I also recommend you find the North Rotational pole (90, any number for longitude). Put markers on all those locations. Use the ruler to draw a line from location X to the magnetic north pole. What is the orientation of this line (magnetic declination)?  
**~89° +/- 10°**

4. What is the latitude and longitude of the southern tip of Africa? **35+/-1°S 20+/-1°E**

5. What would magnetic declination be in Barrow, Alaska (again use Google Earth)? **353.5 +/- 0.5°**

6. Be sure you can use a compass to determine directions and orientations.

### USGS Bear Lake Bathymetric Map

7. What is the latitude and longitude of Garden City?  
**41° 56' 30" N +/-30" and 111° 24' 0" W +/-30"**

8. What is the latitude and longitude of the Lifton Pump Outflow?  
**42° 08' 00" N +/-30" and 111° 18' 30" W +/-30"**

9. Using the scale bar, what is the distance from Garden City to Lifton Pump Outflow?  
**28 km +/- 1km**



# Nautical Charts: Bathymetry

## NEEDED SUPPLIES:

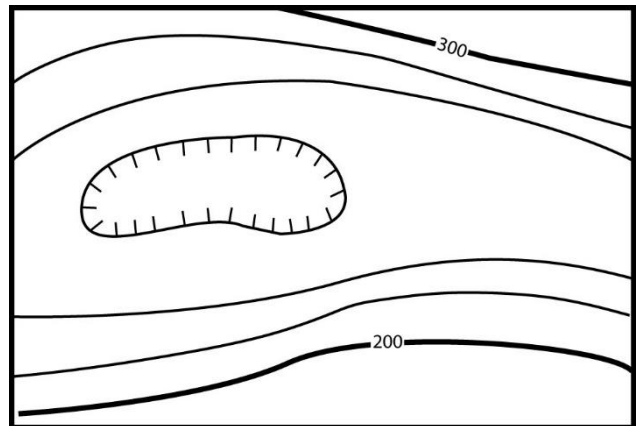
- Desktop version of Google Earth Pro
- Protractor to measure angles
- Blank paper to use as a paper ruler
- Pencil and eraser

## Bathymetric Charts

Bathymetric charts show depth to the ocean floor, so readers can visualize the shape of the seafloor in three dimensions. **Isobaths** (also called contours, when above sea level) connect points of the same depth. Because the sea surface is (nearly) horizontal, isobaths are shorelines that would exist if sea level dropped and exposed increasing amounts of seafloor. The **isobath interval** is the difference in depth between one isobath and the next. A common chart interval is 300 feet, but it can be more or less, depending on scale and terrain steepness.

These miscellaneous facts should help you interpret isobath patterns:

- All isobaths close somewhere, although the closure point may not appear on a map sheet.
- Isobaths never divide or split, although they may appear to do so when they represent a vertical cliff. In this case they overlap one another.
- Isobaths are farther apart on gentle slopes and closer together on steep slopes.
- Isobaths bend (or V points) upslope for valleys or canyons and cross valley or canyon floors perpendicularly, making a V pointing upslope.
- Isobaths bend (or V points) downslope for ridges, which are linear sloping landforms that sit between two valleys or canyons as they cut through a mountain.
- Closed isobaths represent hilltops or mountain tops.
- Closed depressions (without outlets) are represented by closed isobaths with hachures (tick marks) on the inside, pointing down slope. (See image at right.)
- Every fourth or fifth isobath line (depending on the isobaths interval) is called an **Index** isobath and is printed heavier than the other lines. The elevation of the index isobath is printed somewhere along the line.
- Every chart has the scale and the isobath interval given in the center of the bottom margin.



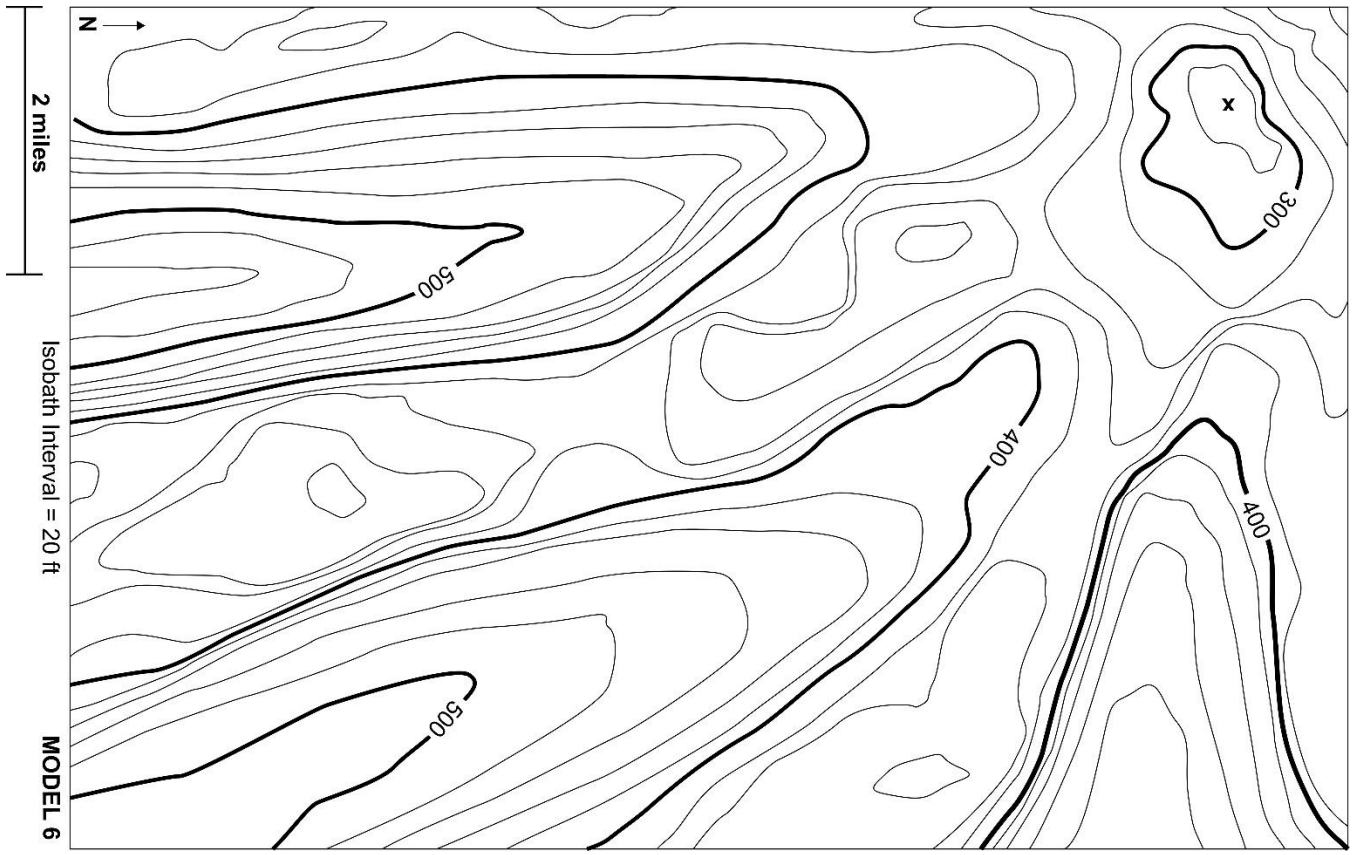
Isobath Interval: 20 feet; Note closed isobath (isobath lines joins itself) with hachures indicating depression. Image: D. DeVecchio –BY-NC-SA 3.0

The **depth of a point** is its vertical distance below sea level. Specific depths are commonly given for hilltops, bottoms of depressions, and index isobaths. **Depths between isobaths should NOT be interpolated. For example, depth of a point midway between the 1240 and 1260-ft isobaths should be given as  $1240 < X < 1260$  ft.** Approximations assume that slopes are straight between isobaths. This assumption is rarely the case.

The **height of a feature** is the vertical distance above its surroundings. Example: if the top of a seamount is at an elevation of 1000 ft, and surrounding area is 1555 ft deep, the seamount is 555 ft high.

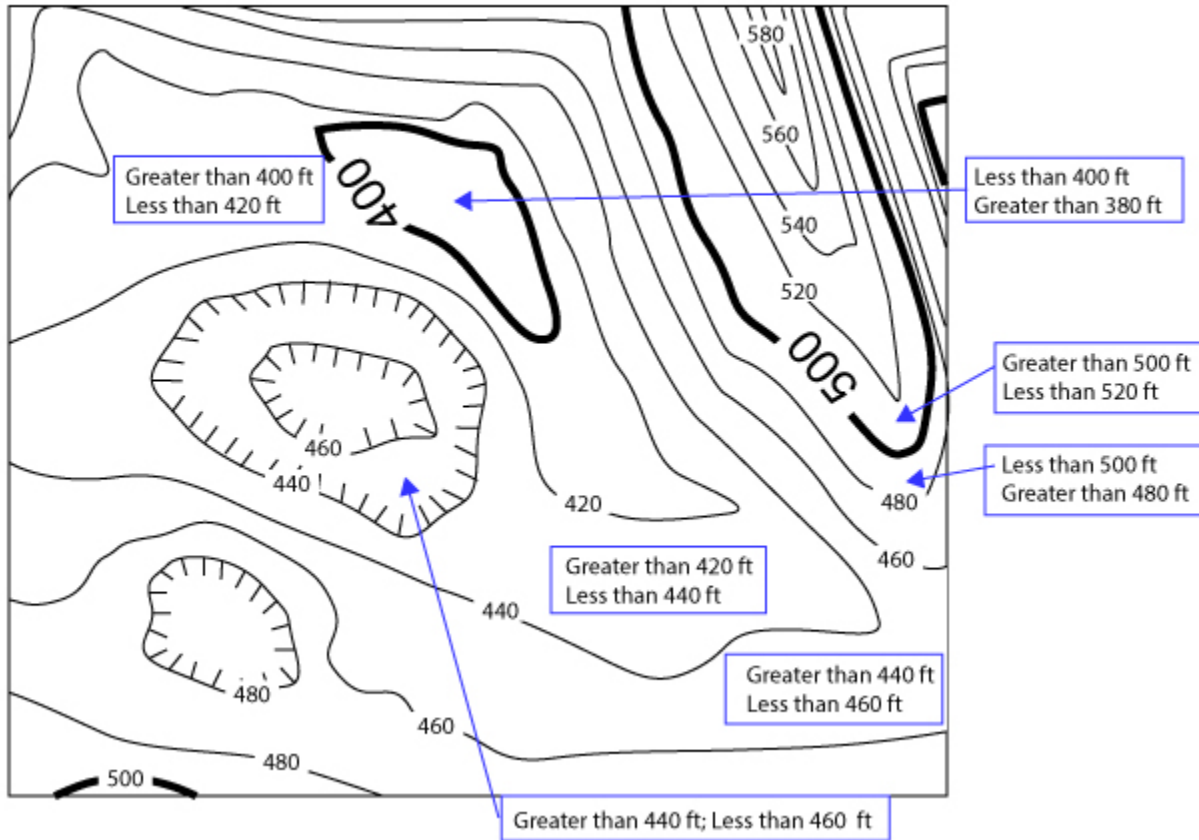


# Canyons & Hilltops



Isobaths interval is 20m

## Isobath Interval = 20 ft



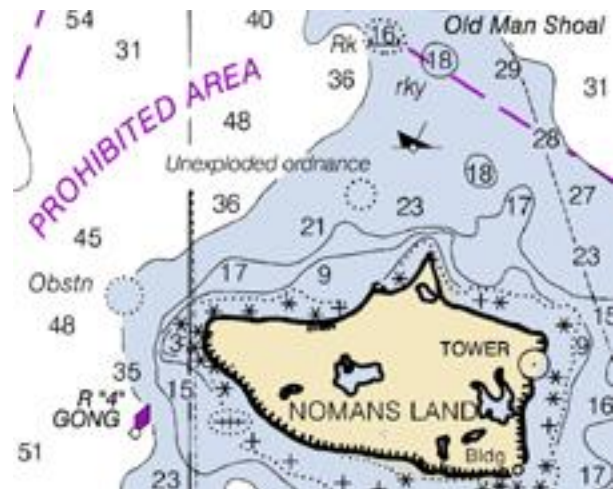
### Units of distance and speed

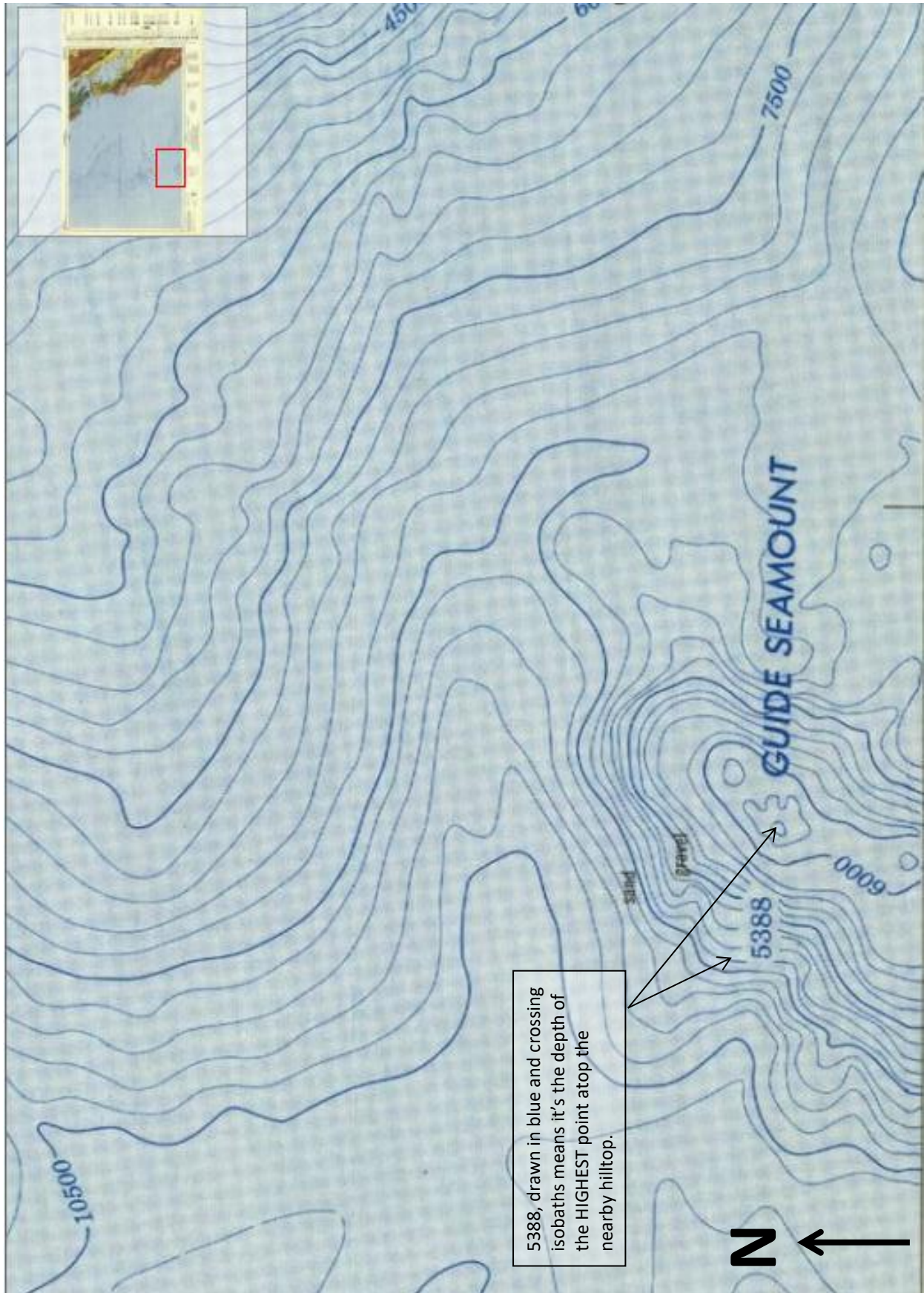
On land, distances are expressed in kilometers or statute miles, whereas at sea they are in **nautical miles**, one of which = 1' of longitude at the equator. 1 nautical mile is about equal to 1.15 statute miles or 1.85 kilometers. Most charts have bar scales that show distance in nautical miles or yards. Depths are measured in **fathoms** (1 fathom = 6 feet). Speed is measured in **knots** (1 knot = 1 nautical mile/hour).

### Navigational Charts of the Seafloor

The navigational chart of San Francisco Bay contains bathymetric information. There are isobaths, and also hundreds of individual **soundings**, or depth measurements. Before the development of electronic depth sounders, a weighted line was lowered overboard, and the length of submerged line when the weight touched bottom was measured. A small sample of bottom material would be taken along with the depth measurement. This bottom material is recorded as "M" for mud, "S" for sand and "Sh" for shells.

(Charts from NOAA.)





Geologic map of California: San Francisco sheet, Author(s): Jennings, C.W., and Burnett, J.L.  
Publishing Organization: California Division of Mines and Geology 1961 (ISOBATH interval – 300 feet)

## Nautical Charts: Bathymetry – Prereading Exercises

1. What is an <b>index isobath</b> , and how do you recognize it?	
2. What is the isobath <b>index interval</b> for the chart on the preceding page (Guide Seamount)?	
3. In the figure in the prereading, what is the height of the Guide Seamount from the west? <i>(Look for slope change to indicate edge.)</i>	
4. What is the height of the Guide Seamount from the east? <i>(Look for slope change to indicate edge.)</i>	
5. From the prereading figure labelled Canyons & Hilltops, what is the depth (not height) of the highest hilltop?	
6. From the same figure labelled Canyons & Hilltops, describe the terrain at point X (steep hill, gentle hill, flat plain, valley or canyon (like a river valley if on land), hilltop, saddle between hilltops, cliff, etc.).	
7. From the same figure, determine the depth below sea level of point X. <i>(Be specific. If letter is NOT on an isobath, then you only know for certain that the point is between two values. Indicate such in your answer.)</i>	
8. From the same figure, describe the terrain at point Y.	
9. From the same figure, determine the depth below sea level of point Y.	
10. From the same figure, describe the terrain at point Z.	
11. From the same figure, determine the depth below sea level of point Z.	
12. What is a <i>sounding</i> ?	
13. How are <i>nautical miles</i> related to land or <i>statute miles</i> ? (Be specific.)	
14. What is a <i>fathom</i> ?	15. What is a <i>knot</i> ?

## Nautical Charts: Bathymetry – Lab Exercises

**MODELS** (At home, review the video on the website showing the different models.)

Each of the six models is approximately 8 in x 11 in. Each is accompanied by a corresponding bathymetric map (*digital versions on website*). Sit at a table that contains one of each of the models. Use the models as references, to learn and confirm general rules, as you answer the following questions.

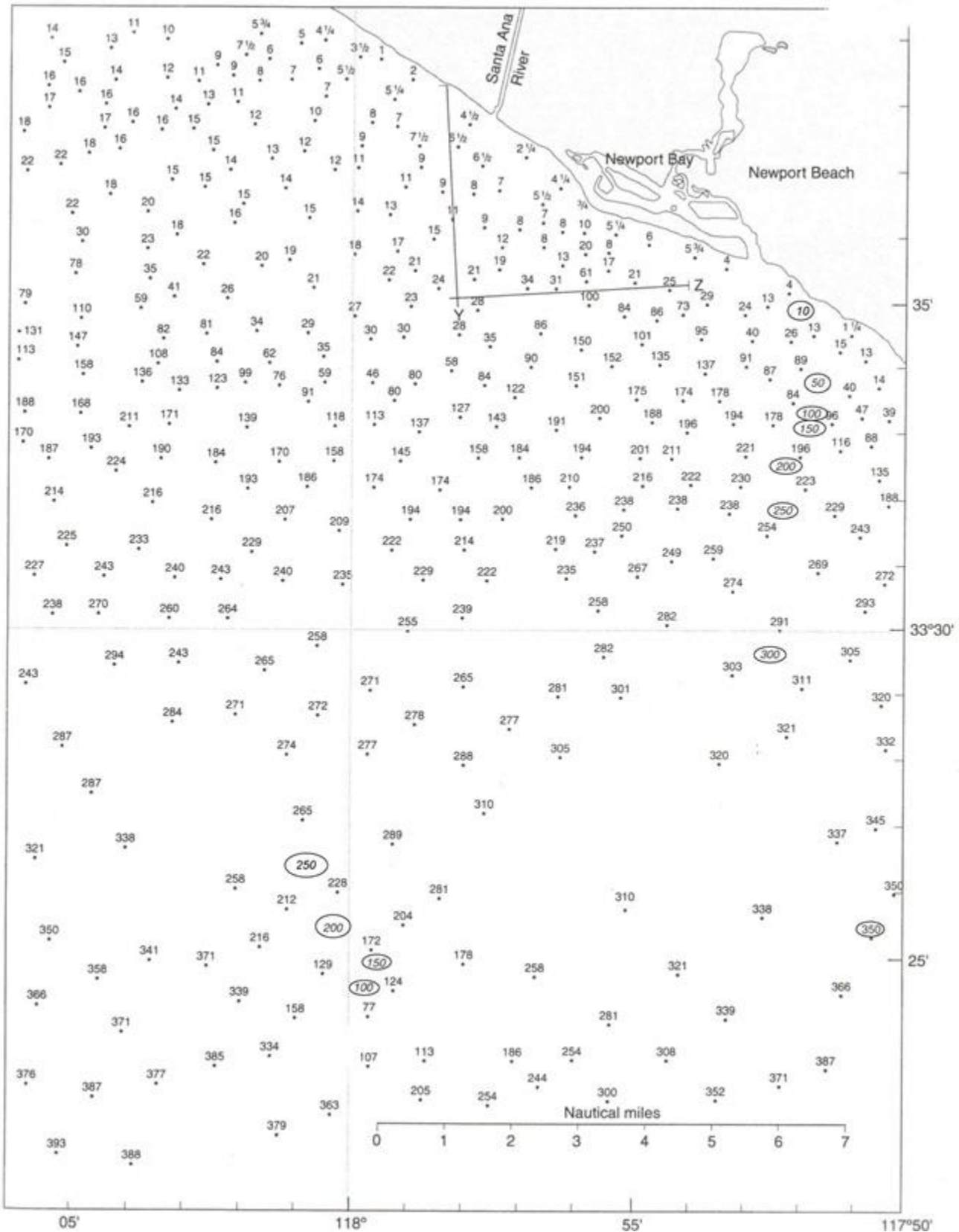
<p>1. Review the <b>hilltops</b> shown in the models. Notice what they all have in common – the common shape of a HILLTOP. In this space, draw isobaths in the shape of a generic hilltop – <b>very steep on the west, gentle on the east.</b> <b>Add north arrow to your drawing.</b> <i>Do not draw a copy of what is on the models – just use them as a guide.</i></p>	
<p>2. Basic isobath rules: <b>Steep slopes</b> are recognized how?</p>	
<p>3. Review the <b>valleys or canyons</b> shown in the models. Notice what they all have in common – the common shape of a valley or canyon. In this space, draw isobaths in the shape of a <b>generic valley or canyon moving downhill from east (right side of paper) to the west (left side of paper).</b> <b>Add north arrow to your drawing.</b> <i>Do not draw a copy of what is on the models – just use them as a guide.</i></p>	
<p>4. Basic isobath rules: How can you determine the <b>downhill direction of a canyon?</b></p>	

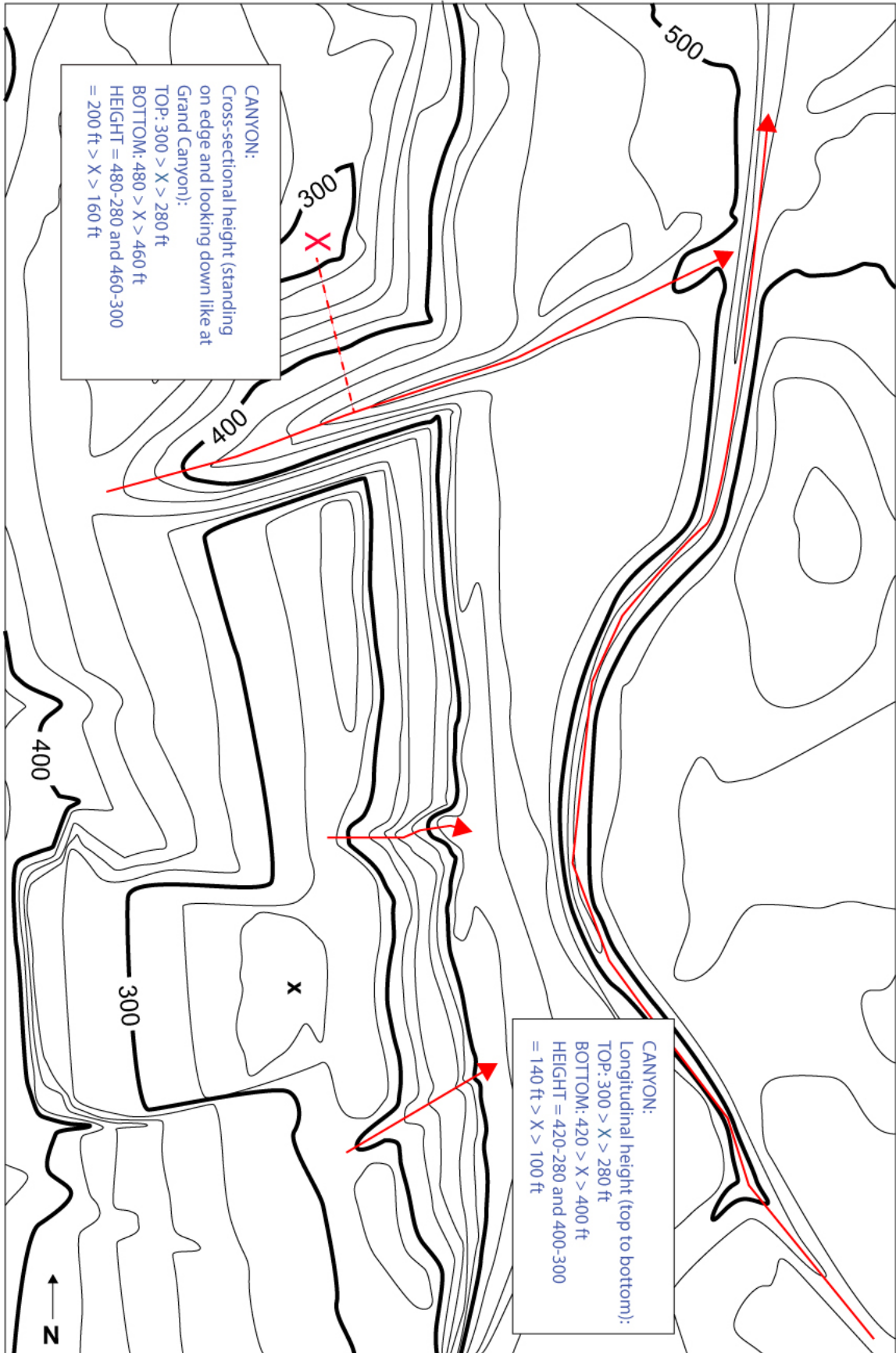
**Nautical Chart of Entrance to San Francisco Bay** (*on front bulletin board or found in digital form on website*)

<p>5. <b>Review the flyover seafloor video on the lab website.</b> Where is the deepest point in San Francisco Bay (describe)?</p>
<p>6. Find the above location on the nautical chart of San Francisco Bay. What is the depth?</p>
<p>7. What is the latitude and longitude (to nearest minute). <i>*Give error range (precision).</i> Check answer in Google Earth &amp; Oceans by entering it and zooming to that location.</p>
<p>8. Note the area outside of the Golden Gate that is marked "Four Fathom Bank." The term "Bank" means shallow area. Why is this bank called "Four Fathom ...?"</p>
<p>9. The part of Four Fathom Bank called "Potato Patch Shoal" is an area of rough water. Find that location on the nautical chart. The waves in this area are often higher and more unpredictable than in surrounding areas. Ships have been wrecked in this area. Study the isobaths to see if you can determine why Potato Patch shoal is so rough.</p>

**NOAA Chart 18746, San Pedro Channel, Newport Beach, CA**

10. The attached chart is 1:160,000 scale, which means 1 inch on the chart = 160,000 inches in real life (or ~2.5 statute miles). Soundings are in fathoms. Create isobaths lines for the soundings using a 50-fathom isobath. Also, draw in the 10-fathom isobath. Start closest to shore and work outwards.





**CANYON:**  
 Cross-sectional height (standing  
 on edge and looking down like at  
 Grand Canyon):  
 TOP: 300 > X > 280 ft  
 BOTTOM: 480 > X > 460 ft  
 HEIGHT = 480-280 and 460-300  
 = 200 ft > X > 160 ft

**CANYON:**  
 Longitudinal height (top to bottom):  
 TOP: 300 > X > 280 ft  
 BOTTOM: 420 > X > 400 ft  
 HEIGHT = 420-280 and 400-300  
 = 140 ft > X > 100 ft

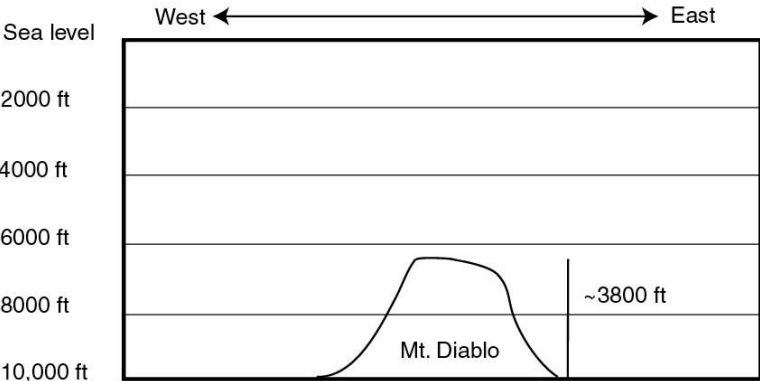
2 miles

Isobath Interval = 20 ft

MODEL 3

### San Francisco Geologic Map

Look at the San Francisco State Geologic topographic map. Its fractional size is 1:250,000. This means that 1 inch on the map = 250,000 inches in reality (~ 4 miles). Locate the feature called Pioneer Seamount. Notice from the isobaths that the **western base of Pioneer Seamount is at a depth of about 10,000 ft** and that on the **east side its base is about 6,000 ft deep**. Notice also that blue numbers across isobaths represent high and low points.

<p>11. What is the <b>isobath interval</b> of this map? (Don't forget units! And be careful to look for submarine isobaths, not land contours.)</p>	
<p>12. What is the <b>depth of the highest (shallowest) point</b> on Pioneer Seamount? (There should be a special benchmark there. Look carefully!)</p>	
<p>13. About <b>how tall is the seamount</b>, from its western base to its top? (Reference the isobaths markers mentioned above in the intro text.)</p>	
<p>14. Review this vertically exaggerated profile of 3800-ft Mount Diablo (the Bay Area's highest mountain). In this same image, sketch the west-to east profile of Pioneer Seamount so you can compare the two mountains. Be precise! Which Bay Area mountain is really the highest?</p>	
<p>15. In Google Earth &amp; Oceans, from the View menu, uncheck "water surface" to make sure ocean surface disappears. Find the Pioneer seamount and get the latitude and longitude at the highest point. Use the path or ruler tool to determine the distance in kilometers from City College to the seamount. Provide that distance (as the crow flies) and heading here <i>and provide error (range)</i>:</p>	

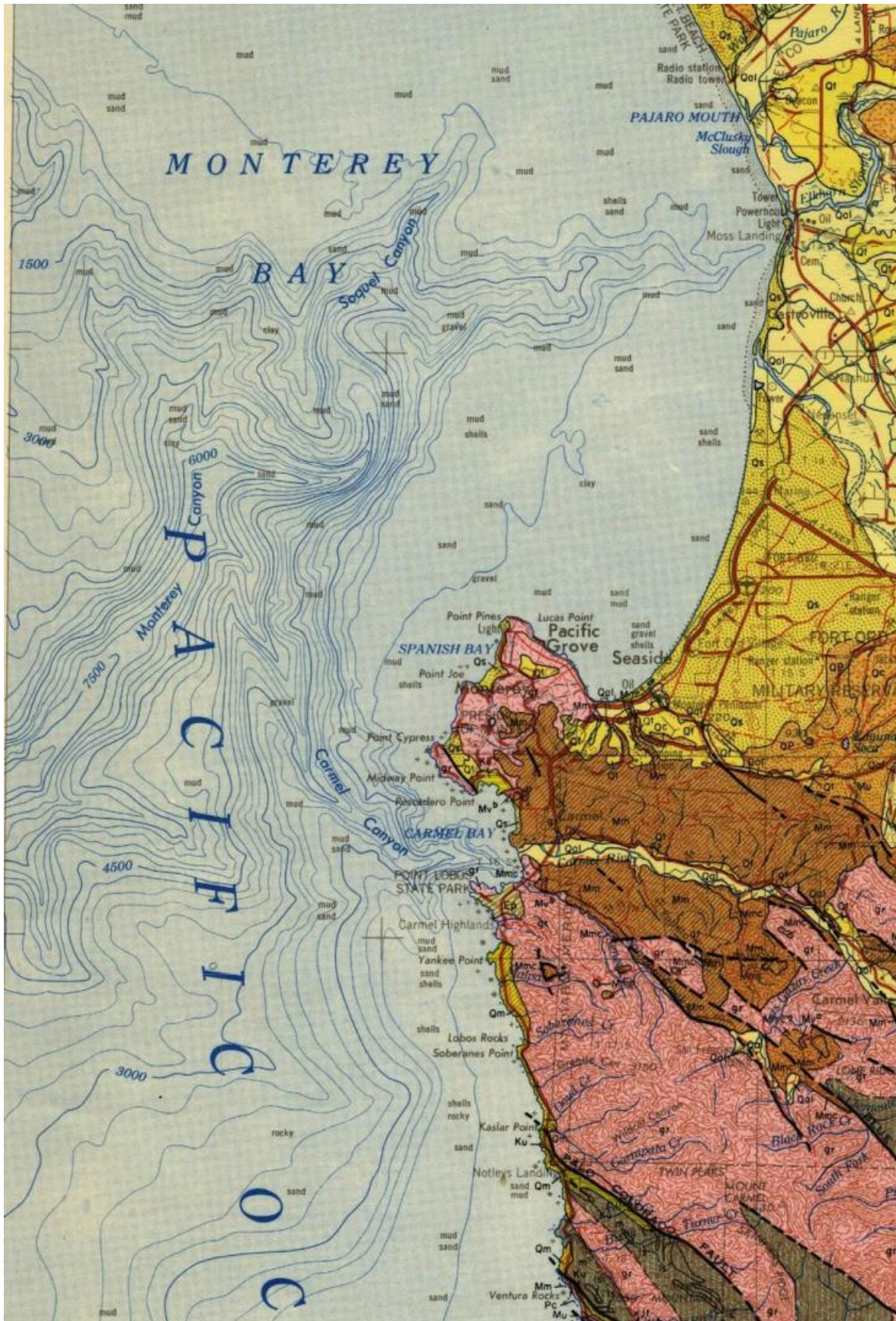
**Pioneer Canyon** lies just south of Pioneer Seamount. Pioneer Canyon is San Francisco's closest submarine canyon. It is not very large compared to Monterey Canyon to the south.

<p>16. To get an idea of the size of Pioneer Canyon, count isobaths down to the bottom of the canyon along a line from the top. What is the total elevation change of the canyon from top to bottom <i>and error (range)</i>? <i>Hint: move upslope to where V shape first begins and do same downslope.</i></p>	
<p>17. How deep is the steepest part of Pioneer canyon (if you could stand on the top of the cliffs that mark the edges of the canyon and look down into the steepest section) <i>error (range)</i>? (The closer the isobaths, the steeper the gradient. Draw an imaginary line perpendicular to the canyon bottom where the side isobaths are steepest. Measure the elevation of the top of the cliff edge and the bottom of the canyon, and subtract.)</p>	
<p>18. How does the Pioneer Canyon depth at the steepest point compare with the Grand Canyon (at the visitor center, the depth straight down to the river bottom is about 5000 feet or 1524 meters)?</p>	
<p>19. Use Google Earth &amp; Oceans to locate the Pioneer Canyon. What is the distance, in km, as the crow flies from top to bottom <i>with error (range)</i>?</p>	
<p>20. Using Google Earth &amp; Oceans find the steepest part and determine its latitude and longitude <i>with error (range)</i>:</p>	

### Bathymetric Chart of Monterey Bay

Notice the sinuous shape of the Monterey Bay Canyon, one of the largest canyons on Earth.

- |  |
|--|
| 21. Use Google Earth & Oceans to locate the Monterey Bay Canyon. What is the distance, in km, as the crow flies from top to bottom <i>with error (range)</i> ?   |
| 22. Using Google Earth & Oceans find the steepest part and determine its latitude and longitude <i>with error (range)</i> :  |
| 23. Using Google Earth & Oceans orient yourself to look up the canyon. As you move up the canyon, note the relief and features throughout the canyon. You can use the PATH tool to see an elevation profile at any point across the canyon. Try it! Click on the Ruler icon. Check the elevation profile box. Then click on one spot and another. See elevation profile at base. Go to the Monterey Canyon (MBARI) link on class website and watch the 1-minute video there. Review the page for useful information. Describe below any notes of things you noticed during this journey through the Monterey Canyon? |
| 24. Using the attached map, determine how deep is the steepest part of Monterey Bay canyon (if you could stand on the top of the cliffs that mark the edges of the canyon and look down into the steepest section)? (The closer the isobaths, the steeper the gradient. Draw an imaginary line perpendicular to the canyon bottom where the side isobaths are steepest. Measure the elevation of the top of the cliff edge and the bottom of the canyon, and subtract.) <i>Include error (range)</i> . SHOW WORK.  |
| 25. How does the Monterey Bay Canyon depth at the steepest point compare with the Grand Canyon (at the visitor center, the depth straight down to the river bottom is about 5000 feet or 1524 meters)? SHOW WORK.  |



Isobath interval: 300 feet (USGS – Geologic Map – Jennings, C.W., and Strand, R.G., 1958, Geologic map of California: Santa Cruz sheet: California Division of Mines and Geology, scale 1:250,000

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Generate a nautical chart with isobaths based on depth measurements taken in a particular water basin.	A   B   C   D   F	
Read a bathymetric map and interpret what it looks like in 3D (including identifying steep vs. gentle hills, plains, mountain tops, depressions, valleys, saddles, and ridges).	A   B   C   D   F	
Determine the elevation range of any point on a bathymetric map.	A   B   C   D   F	
Compare and contrast the relief of mountains and valleys on the seafloor with those on land.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

## Nautical Charts: Bathymetry Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

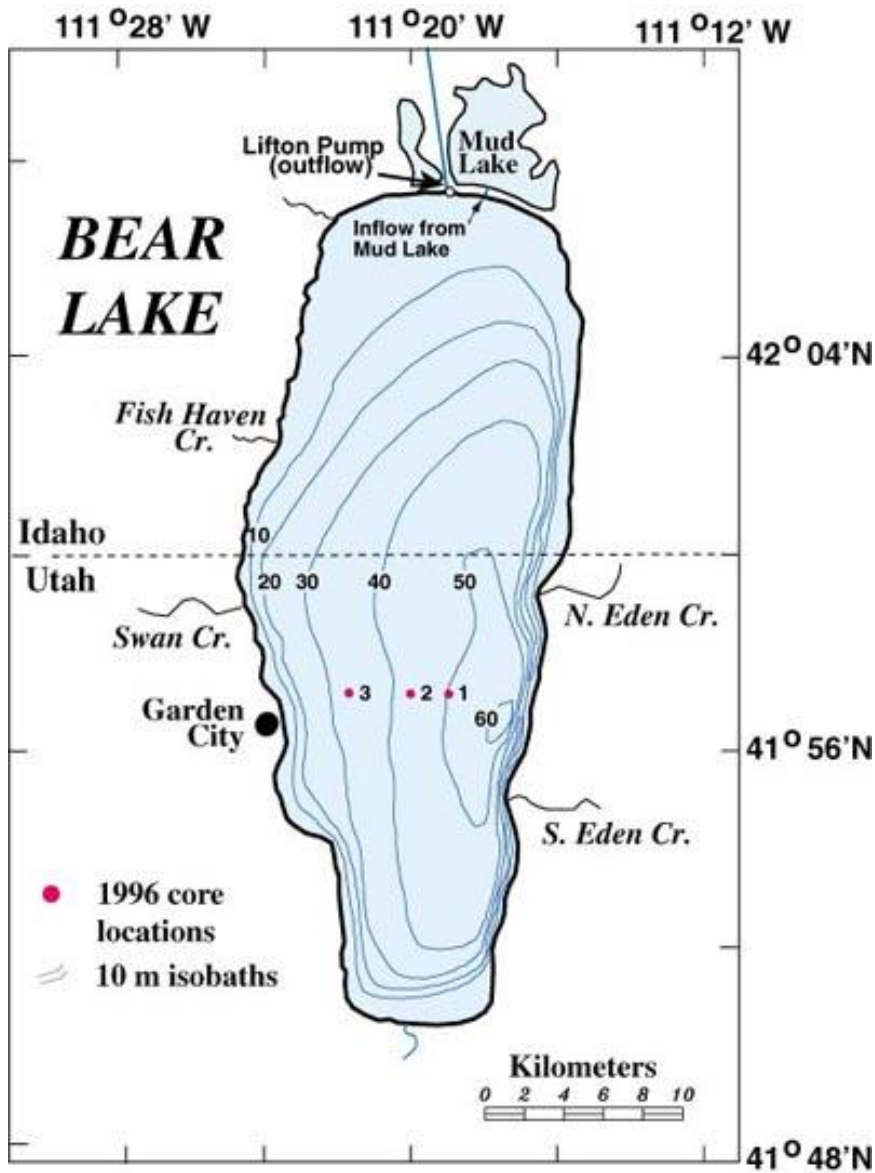
1. From your study of San Francisco Bay and its nautical chart, where was the deepest point in San Francisco Bay and how deep was it? (general location OK)	
2. What is a <i>fathom</i> ?	3. What is a <i>knot</i> ?

### Pacific Coast from San Francisco to Monterey Bay (soundings in fathoms) – access through lab website resources

4. What is the isobath interval on this map?
5. What is the latitude and longitude of the top of Gumdrop Seamount?
6. What is the depth at the top of Gumdrop Seamount?
7. What is the deepest depth east of this seamount?
8. What is height of this seamount measured from the eastern edge?
9. What's the bearing on the Gumdrop Seamount FROM the SE Farallon Islands?
10. Imagine you are in a boat above the Gumdrop Seamount. Your heading is 45°. Where would you eventually end up if you maintained this heading?
11. What side of the Pioneer Seamount is the steepest?

*NOAA Ocean Explorer: Image courtesy of Islands in the Stream 2001, NOAA/OER.*

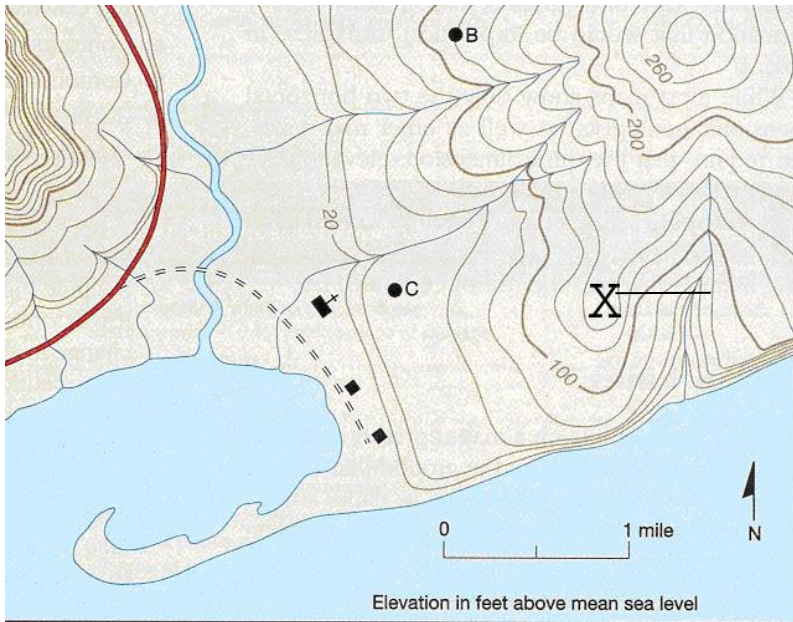
12. In this space, sketch isobaths (at least four) to show the shape of two hills with a saddle between them. <b>Add north arrow to your drawing.</b>	
13. In this space, sketch isobaths (at least four) to show the shape of <b>a generic river moving downstream from north to south. Add north arrow to your drawing.</b>	



**USGS Bear Lake Bathymetric Map**

14. What is the isobath interval on this map?
15. There are no index isobaths on the figure to the left. Using an index interval of 30 m and a pencil, darken the index isobaths in this image. (Start at 30.)
16. What is the latitude and longitude of the deepest spot in the above picture?
17. How deep is the deepest spot?
18. Which side of the map has the steepest slope?

USGS Open-File Report 2005-1124



(image from USGS)

**Contour Map (Note: these contours are ABOVE sea level)**

19. What is the total depth or elevation change of the river valley on the far most right of the map (just south of the hilltop)?
20. How deep is the aforementioned valley at point X (if you could stand on the top of the cliffs that mark the edges of the canyon and look down into the steepest section)?

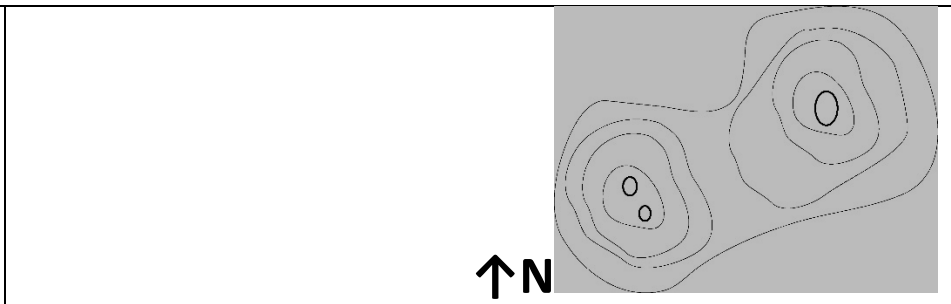
**KEY**

1. From your study of San Francisco Bay and its nautical chart, where was the deepest point in San Francisco Bay and how deep was it? (general location OK) <b>351 ft deep just west (1/4 mile?) from the Golden Gate Bridge</b>	
2. What is a fathom? <b>6 feet</b>	3. What is a knot? <b>1 nautical mile/hour</b>

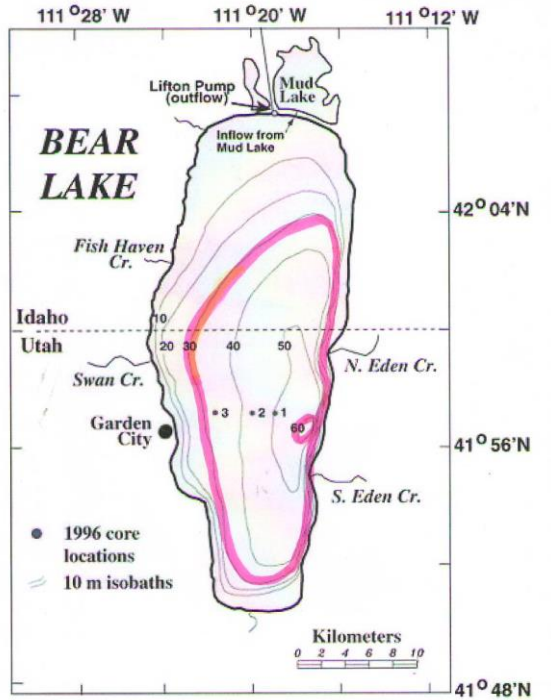
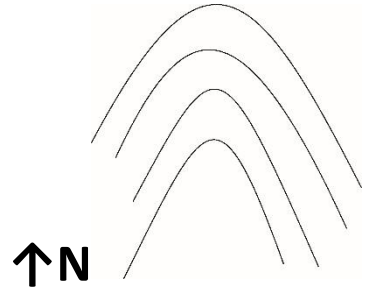
**Pacific Coast from San Francisco to Monterey Bay (soundings in fathoms) – access through lab website resources**

4. What is the isobath interval on this map? <b>100 fathoms (600 feet)</b>
5. What is the latitude and longitude of the top of Gumdrops Seamount? <b>37°42' 00" +/- 30" N 123°25'10"W +/-30"</b>
6. What is the depth at the top of Gumdrops Seamount? <b>400 fathoms &lt; X &lt; 500 fathoms</b>
7. What is the deepest depth east of this seamount? <b>1100 fathoms &lt; X &lt; 1200 fathoms</b>
8. What is height of this seamount measured from the eastern edge? <b>(1200 to 1100 fathoms) - (500 to 400 fathoms) = 800 to 600 fathoms</b>
9. What's the bearing on the Gumdrops Seamount FROM the SE Farallon Islands? <b>237° +/- 5°</b>
10. Imagine you are in a boat above the Gumdrops Seamount. Your heading is 45°. Where would you eventually end up if you maintained this heading? <b>Through Farallon islands to south of Drakes Bay on mainland: near Double Pt.</b>
11. What side of the Pioneer Seamount is the steepest? <b>Southeast</b>

12. In this space, sketch isobaths (at least four) to show the shape of two hills with a saddle between them. **Add north arrow to your drawing.**



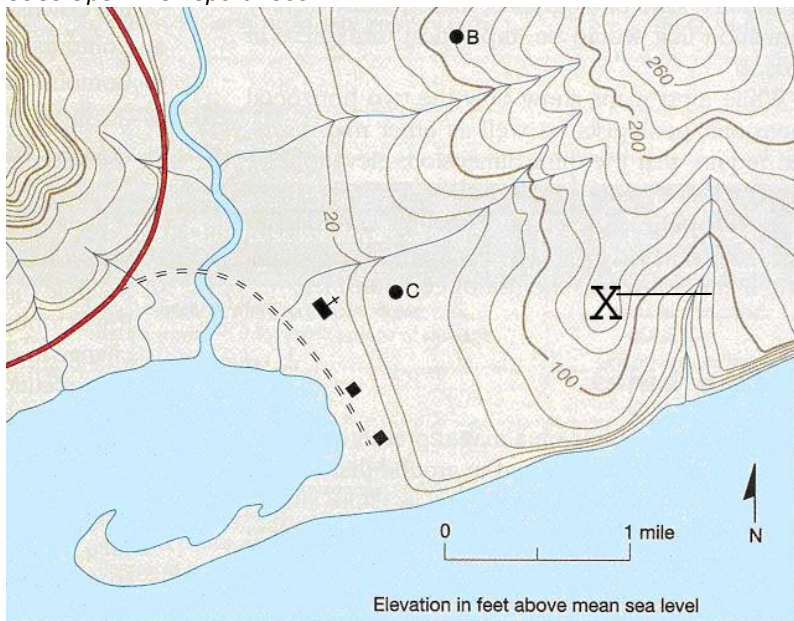
13. In this space, sketch isobaths (at least four) to show the shape of **a generic river moving downstream from north to south**. Add north arrow to your drawing.



**USGS Bear Lake Bathymetric Map**

- 14. What is the isobath interval on this map?  
**10m**
- 15. There are no index isobaths on the figure to the left. Using an index interval of 30 m and a pencil, darken the index isobaths in this image. (Start at 30.)
- 16. What is the latitude and longitude of the deepest spot in the above picture?  
**41°56'30"N 111°17'00"W +/- 1'**
- 17. How deep is the deepest spot?  
**60 m < X < 70m**
- 18. Which side of the map has the steepest slope?  
**. East side**

USGS Open-File Report 2005-1124



(Image from USGS)

**Contour Map (Note: these contours are ABOVE sea level)**

- 19. What is the total depth or elevation change of the river valley on the far most right of the map (just south of the hilltop)?  
**240 ft – 0 ft = 240 Feet**
- 20. How deep is the aforementioned valley at point X (if you could stand on the top of the cliffs that mark the edges of the canyon and look down into the steepest section)?  
**140 feet-160 feet = top**  
**Base = 20-40 feet**  
**Total depth at steepest point = 140 to 100 feet**



# Marine Rocks & Sediments

## Sedimentary Rocks

Sedimentary rocks form through the precipitation of minerals directly from water (example: salt flats that form when seawater evaporates) or through the lithification of sediment – small particles of rocks, minerals, and organic material, broken up, transported, and deposited in piles. Two lithification processes are:

- **Cementation** of sediments usually by aqueous solutions that percolate through sediments and deposit calcite, quartz, or iron oxide glues that then cement the sediments together). Example: sandstones that used to be sand dunes.
- **Compaction** of sediments (usually by being buried under progressively more and more layers of other rocks and sediments). Example: Mudstone or shale that used to be layers of ooze.

Grain size is important for sedimentary rocks. We use grain size (if grains are present) to help determine the formation environment and rock type:

- Gravel (>2 mm) – Associated with high-energy waters, like headlands or the base of cliffs.
- Sand (< 2 mm, > 1/16 mm) – Associated with moderate-energy waters, like beaches or rivers.
- Mud (<1/16 mm) – Associated with low-energy waters, like lagoons and the deep sea.

Rock name	Description	Possible formation environment
<b>Sandstone</b>	Sand-sized particles. Well to fairly well sorted. Dominantly quartz; may also contain rock fragments if sands are immature.	Along beaches, in sand dune regions, along inner continental shelves, submarine canyons, and in trenches where there are subduction zones – all places where sand-sized grains accumulate, carried by wind, water, or turbidity currents.
<b>Mudstone or shale: special case: kaolinite mudstone</b>	Mud-sized particles only. Usually clay minerals, like kaolinite. Because of mud-sized particles, often can't see grains at all unless they rub off. Surface looks dull, and usually has a rougher appearance than say, a chemical rock, with which it's commonly confused.	Areas of still water where mud-sized grains can settle out: tidal flats, lagoons, and the deep sea. Collections of clay occur in the deep sea where airborne clay (off deserts) or suspended clay from river runoff (off major rivers) settles to the abyssal plains. Chemical weathering of many common minerals on Earth's surface produces the clay. <b>Shale is a more compacted variety of mudstone.</b>
<b>Kaolinite mudstone</b> – Chalky white. Denser than chalk and diatomite. Gets sticky when wet.		
<b>Conglomerate or breccia</b> 2 samples	Mud to gravel-sized grains. Very poorly sorted. Usually composed of rock fragments.	Areas where grains of all sizes drop out of glaciers, water, or gravity (landslides): headlands or the base of cliffs. When grains are angular, we call the rock <i>breccia</i> ; when rounded, <i>conglomerate</i>
<b>Chert</b>	Green, yellow, red, white, opaque, smooth, dense, microcrystalline silica (can't see crystals). Hard (can't scratch with steel). Chemical rock, so plastic-like luster (shiny).	On the deep ocean floor, through the lithification of siliceous oozes (muds comprised primarily of quartz (SiO <sub>2</sub> ) plankton shells that settle out of the water). More rarely: in hydrothermal areas where quartz (SiO <sub>2</sub> ) precipitates from water.
<b>Diatomite</b>	White, loosely-consolidated mud-sized (like flour) silica shells.	Deep ocean floor, where muds are composed primarily of quartz (SiO <sub>2</sub> ) planktonic shells that rain down in the deep sea; these rocks haven't hardened as much as required to form chert.
<b>Limestone</b>	Grey, yellow, brown, or white, opaque, smooth, dense, microcrystalline calcium carbonate (can't see crystals). Soft (can scratch with nail). Reacts with acid. Chemical rock, so plastic-like luster (shiny).	On the ocean floor, through the lithification of calcareous oozes (muds comprised primarily of calcite (CaCO <sub>3</sub> ) plankton shells that settle out of water). In lagoons, through the lithification of calcareous muds. More rarely in coastal areas where calcite (CaCO <sub>3</sub> ) precipitates from water. Also can be the hardened form of coquina – coming from reefs.

Rock name	Description	Possible formation environment
<b>Chalk</b>	White, loosely-consolidated mud-sized grains (like flour) of calcium carbonate shells. Reacts with acid.	Deep ocean floor, where muds are composed primarily of calcite (CaCO <sub>3</sub> ) planktonic shells that rain down in the deep sea; these rocks haven't hardened as much as required to form limestone.
<b>Coquina</b>	Consists entirely of sand- to gravel-sized CaCO <sub>3</sub> shell fragments. Reacts with acid.	Continental shelves which are large biologically productive regions, including coral reefs.
<b>Mn nodules</b>	Dark, dense, rough spherical nodules of primarily Mn (Manganese). Crusty.	Deep ocean floor, where Mn-rich waters precipitate Mn-oxide crusts around local small sediment grains. Crusts accumulate around these nodules over thousands of years.
<b>Tektites</b>	Dark, smooth, aerodynamically shaped particles, each around 1 inch or less long. (Tear-dropped shaped.)	Found in biogenic sediment and ice, where it stands out from surroundings. Forms after meteorite impacts, when melted crustal rocks fly into the air, cooling in droplets as they fall.
<b>Evaporites</b>	Crystalline, layered, varying colors. Some layers may react with acid (because they contain CaCO <sub>3</sub> ).	Shallow inland waterways where seawater evaporates, leaving behind interlocking crystals of <b><i>salt, gypsum, and calcite.</i></b>

**Diagnostic key:**

*Is the texture Chemical (glassy – microcrystalline – precipitated from water and thus impossible to dig pieces out) or Crystalline (layers of intergrown crystals big enough to see) or Clastic (made of fragments that could be removed)?*

Chemical – *Does the rock react to acid and hence it's made of CaCO<sub>3</sub>?*

Yes – Limestone

No – Chert (made from SiO<sub>2</sub>)

Chemical Layers of Crystals – Evaporite

Clastic – *Is the rock mostly of shells or rock and mineral fragments?*

Shells – *Are the shells gravel sized?*

Yes – Coquina

No – The shells should be mud sized and white. *Do they react to acid?*

Yes – Chalk (made from CaCO<sub>3</sub>)

No – Diatomite (made from SiO<sub>2</sub> and should NOT be sticky when wet – instead absorbs water)

Rock and Mineral fragments – *What is the grain size?*

Gravel size with rounded particles – Conglomerate

Gravel size with angular particles – Breccia

Sand size – Sandstone

Mud size – Mudstone – *Are muds white and do they get sticky when wet?*

Yes – Kaolinite (clay mudstone)

No – likely a clastic shell rock either chalk for diatomite (see above)

If the rock is nodular – with black crusts and concentric spheres of precipitate – Mn Nodule

If the rock is glassy, aerodynamic, and pitted – Tektite

**Igneous rocks**

Igneous rocks form from the solidification of magmas (molten rock). Magmas form at depth when the Earth’s mantle melts. Hot, fluid magmas are lower density than the rocks within which they form. Magmas rise toward Earth’s surface, where they cool to become igneous rocks. If magmas erupt on the Earth’s surface, they cool very quickly and form crystals that are too small to see with the eye or no crystals at all (glass). We call such igneous rocks **extrusive or volcanic**. If magmas cool slowly under the surface, they can form large crystals. We call such igneous rocks **intrusive or plutonic**. All igneous rocks are either volcanic or plutonic.

Igneous rocks that you can find in oceanic settings are primarily **basalt** and **gabbro**: high-density, dark-colored rocks. Basalt is the extrusive form; gabbro the intrusive form. These rocks form when magma supply is large and consistent and doesn’t have to travel through thick crust (remember: oceanic crust is very thin – 5 km). Such settings include spreading centers, ocean-ocean subduction zones, and oceanic hotspots. Wherever basalt erupts, underneath the surface some of that same magma is trapped and cools slowly to form the intrusive equivalent of basalt, called gabbro. Continental igneous rocks, on the other hand, are primarily granites – lower density than basalt, and light colored. Granites form when magmas have a long transit time through the crust – that’s why they’re associated with continents, whose crust is very thick – up to 100 km in some places. Remember: basalts are denser than granites. This difference leads to oceanic crust being much more dense than continental crust, which is why oceanic crust (thin and dense) subducts, while continental crust (thick and buoyant) doesn’t.

Rock name	Description	Possible formation environment
<b>Basalt</b>	Black, microcrystalline, dense. Can show weathering (rust) on exposed surfaces.	Oceanic volcanoes – spreading centers, island arcs associated with subduction zone volcanism, and hotspots. The pillow basalt variety forms when oceanic volcanism occurs under water, chilling the lava quickly as it erupts from cracks or vents on the seafloor.
<b>Gabbro</b>	Macrocrystalline. Minerals visible with eye – olivine (green), pyroxene (black), and plagioclase (grey).	Underneath oceanic volcanoes (where basalts form at the surface). Forms when basaltic magmas cool slowly under the surface.
<b>Granite</b>	Macrocrystalline. Minerals visible with eye – quartz (clear to grey), feldspar (white or pink), and biotite or hornblende (black).	Underneath continental volcanoes where long-travelled magmas cool slowly under the surface.

**Diagnostic key:**

Are the crystals all big enough to see? (all surface reflect light well?)

No – Basalt (should be black);

Yes – Gabbro OR Granite. *Is the rock mostly light colored?*

No – Gabbro (dark colored)

Yes – Granite (light colored)

**Metamorphic rocks**

Metamorphic rocks form from the alteration of other igneous or sedimentary rocks. Such alteration occurs from increases in pressure, increases in temperature, and/or addition of chemically active fluids.

Rock name	Description	Possible formation environment
<b>Serpentinite</b>	Green (any shade), mottled, massive. Smooth, rounded slippery surfaces. Usually displays slickened grooves on outside surfaces.	Mantle rocks that are exposed to hydrothermal solutions under seafloor spreading centers. Minerals in rocks hydrate to form low density serpentine, eventually pockets of which squeeze upward along subduction zones towards the surface (like watermelon seeds squeezed between your fingers).

## Marine Rocks & Sediments – Prereading Exercises

For the first 3 questions, read lecture textbook chapter that covers *Marine Sediments*.

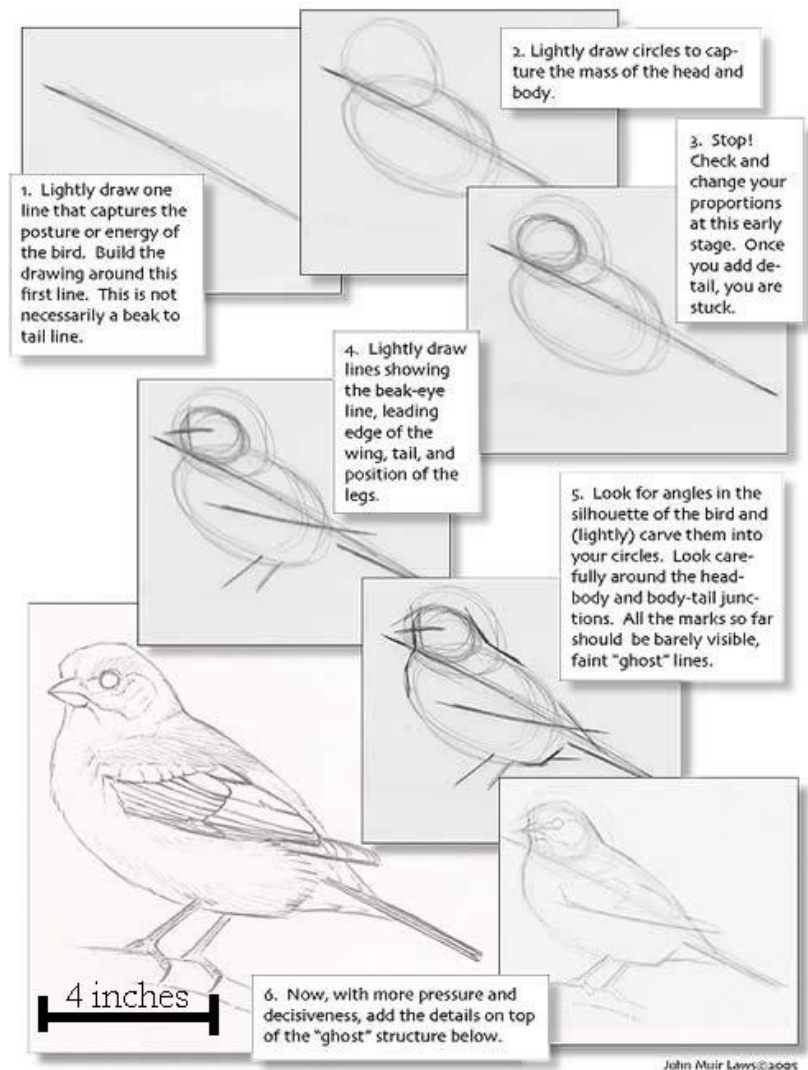
Organisms	Shell material ( $CaCO_3$ or $SiO_2$ )	Heterotroph or Autotroph
1. Diatoms		
2. Radiolaria		
3. Foraminifera		
4. Which rock does reef material turn into?		
5. List all sedimentary rocks composed primarily of $CaCO_3$ .		
6. List all sedimentary rocks composed primarily of $SiO_2$ .		
7. What is the primary difference between mudstone, sandstone, and conglomerates?		
8. Complete this table, based on preceding tables:		
Rock name	Original formation setting explanation of formation process	
Pillow basalt		
Serpentinite		
Chert		
Sandstone		

\*\*Question 9, the last question on this lab, is on the next 2 pages – the drawing. Be sure to continue!

## Drawing – Scientific Observation

Drawing a sketch is one of the most important tools a scientist has in observing the natural world and in documenting it. You don't have to be an artist to make a good scientific drawing, but you do have to be a good observer, and that takes practice. A few tips:

- Try to make your sketch as large as your paper – the larger you make it, the more detail you can show. You will use a scale to indicate size, so don't just make the picture small, because the object is small.
- Start by sketching an outline of your object. Notice the overall dimensions, including width, height, and depth, and make sure your outline sketch is proportioned correctly (so the head of your organisms, for example, is the correct height AND width).
- Once you have an outline, look for patterns in the object and symmetry. Block in the pattern and symmetry next.
- Sketches are best, if you recognize the features of the organism, such as eyes, legs, or shells. Make sure you know what's you're looking at and for, BEFORE you draw your picture. Study, carefully, your object!
- Next, take time to enter detail into the patterns you've already sketched.
- In this class, all sketches will be done in pencil, though you can add color with colored pencils afterwards if you'd like.
- Label key features in your drawing.
- Add a scale. (A scale bar of a known dimension.)
- For the drawings you will be doing in this class, you should be able to complete your sketch in 5 minutes.



Permission to reproduce image for use in this manual granted by John Muir Laws.

© 2005

9. In the space below, draw a 5-minute sketch of one of the organisms whose shells you will be reviewing in this lab: a diatom, radiolarian, or foraminifera. Copy a drawing that's accessible in any Oceanography textbook in the library or as an image on Google when searching on any of the three aforementioned organisms. **You can also review images in *Plankton* Chapter of this Lab Manual.**
- INCLUDE scale as best you can – Label parts as best you can.
  - NAME creature.

Autotroph	Size	Heterotroph	Size
Diatoms	0.005 to 1 mm	Foraminiferans	0.1 to 1 mm
		Radiolarians	0.1 to 1 mm

## Marine Rocks & Sediments – Lab Exercises

**MICROSCOPE SCALES AND GRAIN SIZE AND % CHARTS ARE FOUND IN APPENDIX.**

### Sedimentary Rocks

1. For Box B, match the sedimentary rock samples that you can find in oceanographic settings to their names. **PUT SAMPLE NUMBER UNDER CORRECT ROCK NAME**

Circle and make notes on rock characteristics sheet that helped you make the identification.

Goal: to identify these rocks during exams and upcoming field trips.

Rock name	Sample # that matches	Rock name	Sample # that matches
Sandstone		Limestone	
Mudstone or shale ( <i>generic</i> )		Chalk	
Kaolinite mudstone		Coquina	
Conglomerate		Mn nodules	
Breccia		Tektites	
Chert		Evaporites	
Diatomite			

### Igneous and Metamorphic rocks

2. For Box C, match the igneous rock samples that you can find in oceanographic settings to their names. **PUT SAMPLE NUMBER UNDER CORRECT ROCK NAME**

Circle and make notes on rock characteristics sheet that helped you make the identification.

Goal: to identify these rocks during exams and upcoming field trips.

Rock name	Sample # that matches	Rock name	Sample # that matches
Basalt		Granite	
Serpentinite		Gabbro	

### Rock Review

3. For Box E, match the white rock samples that you can find in oceanographic settings to their names. **PUT SAMPLE NUMBER UNDER CORRECT ROCK NAME**

Circle and make notes on rock characteristics sheet that helped you make the identification.

Goal: to identify these rocks during exams and upcoming field trips.

Rock	Sample #	Rock	Sample #	Rock	Sample #
Chalk		Kaolinite		Diatomite	

4. Review slides under microscopes to review biogenous oozes components. Review images in <i>Plankton</i> Chapter of this Lab Manual for reference.		
Organism type	Organism sketch (include <u>scale</u> for each unique picture; make pictures BIG)	Rock(s) produced from this ooze
<b>Diatom</b>	(3 drawings: include 1 chain, centric, and pillow-shaped species) <i>Note: Recent Marine slides = pillow-shaped species; Strew = chains and centric species.</i>	
<b>Radiolaria</b>	(2 drawings: pick any two, as long as they have different shapes)	
<b>Foraminifera</b>	(3 drawings: include 1 snail-like, 1 globigerina (bulbous), and 1 cornucopia-like shells)	

To determine scale, which you need to include for each picture, determine what fraction of the diameter of the field of view a single organism covers. Then use the given field of view diameters to calculate. For example, if at 40X magnification, the organism takes up 1/5 the field of view, you multiply 1/5 times the 40X diameter, which is 5.0 mm.  $5.0 \text{ mm} \times 1/5 = 5.0 \text{ mm} \div 5 = 1.0 \text{ mm}$ .

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week’s objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Observe and describe textures and composition of common rocks found or created in the marine environment	A   B   C   D   F	
Identify and name above rocks by hand sample and explain their formation environment	A   B   C   D   F	
Observe and describe textures and composition of diatom, radiolarian, and foraminiferan shells commonly found in marine sediments	A   B   C   D   F	
Identify and name above shells by microscope sample and provide an accurate scale of any given sample studied under the microscope	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week’s content? Did anything in particular help you understand something you’ve always wondered about, or made you think about the world with new eyes?

## Marine Rocks & Sediments Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

**Review class amples or go to the course website and review flashcards. Be sure you're able to identify the different rock types.** Be sure you also know how and where each is formed in the ocean.

Rock name	Original formation setting explanation of formation process
Basalt	
Gabbro	
Granite	
Serpentinite	
Diatomite and Chert	
Chalk and Limestone	
Coquina	
Sandstone	
Mudstone	
Conglomerate or breccia	
Mn nodules	
Tektites	
Evaporites	

Trait	Circle correct answer(s)
White	Chalk, Diatomite, or Kaolinite
Absorbs water	Chalk, Diatomite, or Kaolinite
Gets slick/slimy when wet	Chalk, Diatomite, or Kaolinite
Reacts to acid	Chalk, Diatomite, or Kaolinite

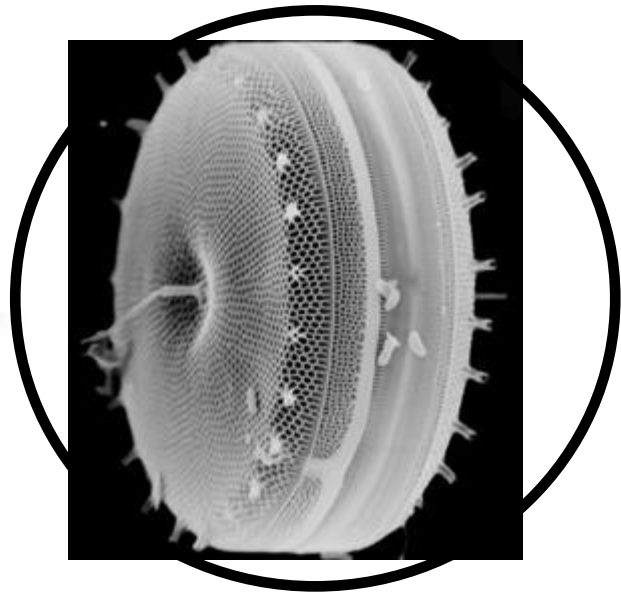
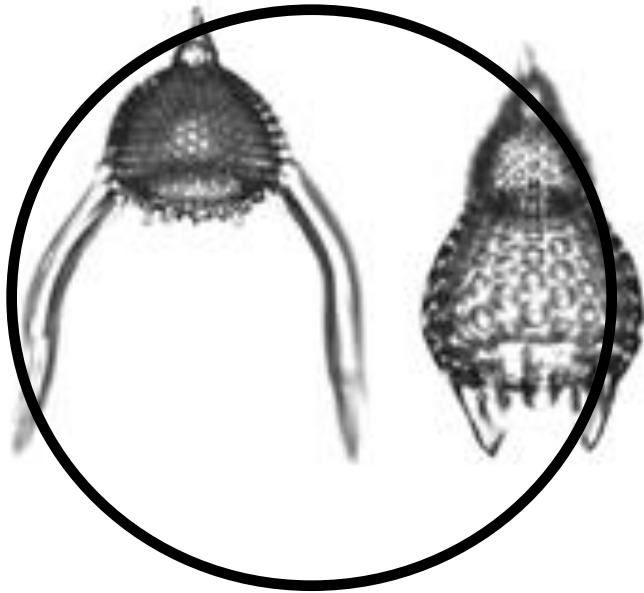
**Go to the course website and review and be able to identify the different OOZE creatures:**

Be sure you can distinguish among foraminifera, diatoms, and radiolarian:

For the following pictures, give the scale of the creature in the picture.

Creature's width: \_\_\_\_\_  
 PICTURE A: field of view diameter is 0.42 mm

Creature's width: \_\_\_\_\_  
 PICTURE B: field of view diameter is 0.11 mm



NBII Image Gallery, Public Domain

Image: Monterey Bay Aquarium

**\*\*Be able to identify the following three organisms if shown an image of their shell.**

Organisms	Shell material ( $CaCO_3$ or $SiO_2$ )	Heterotroph or Autotroph	Rocks produced
Foraminifera			
Radiolaria			
Diatoms			

## KEY

Rock name	Original formation setting explanation of formation process
<b>Basalt</b>	<i>Mid ocean ridge or any other oceanic volcanism (hotpots or subduction zone island arcs). The pillow basalt variety forms when oceanic volcanism occurs under water, chilling the lava quickly as it erupts from cracks or vents on the seafloor.</i>
<b>Gabbro</b>	<i>Underneath oceanic volcanoes (where basalts form at the surface). Forms when basaltic magmas cool slowly under the surface.</i>
<b>Granite</b>	<i>Underneath continental volcanoes where long-travelled magmas cool slowly under the surface.</i>
<b>Serpentinite</b>	<i>Under mid-ocean ridges as mantle rock hydrothermally metamorphoses</i>
<b>Diatomite and Chert</b>	<i>Deep ocean floor, where SiO<sub>2</sub> planktonic shells rain down to the seafloor and are buried and turned to rock. When these rocks harden completely and the shells recrystallize under pressure, the rock becomes chert.</i>
<b>Chalk and Limestone</b>	<i>Deep ocean floor, where CaCO<sub>3</sub> planktonic shells rain down to the seafloor and are buried and turned to rock. When these rocks harden completely and the shells recrystallize under pressure, the rock becomes limestone. NOTE: Limestone can also be the hardened form of coquina – coming from reefs.</i>
<b>Coquina</b>	<i>The hardened debris from coral reefs.</i>
<b>Sandstone</b>	<i>Accretionary wedge or the base of a submarine canyon or the beach.</i>
<b>Mudstone</b>	<i>Bottom of the seafloor where clay particles rain down, get buried, and turn to rock. Or in backwater lagoons or other still-water spots in the coastal area.</i>
<b>Conglomerate or breccia</b>	<i>Base of a cliff or rocky headlands, near an actively eroding rocky area. When water continually flows over it, you get conglomerate. When freshly eroded, breccia.</i>
<b>Mn nodules</b>	<i>Deep ocean floor, where Mn-rich waters precipitate Mn-oxide crusts around local small sediment grains. Crusts accumulate around these nodules over thousands of years.</i>
<b>Tektites</b>	<i>Found in biogenic sediment and ice, where it stands out from surroundings. Forms after meteorite impacts, when melted crustal rocks fly into the air, cooling in droplets as they fall.</i>
<b>Evaporites</b>	<i>Shallow inland waterways where seawater evaporates, leaving behind interlocking crystals of <u>salt</u>, <u>gypsum</u>, and <u>calcite</u>.</i>

Trait	Circle correct answer(s)
<b>White</b>	Chalk, Diatomite, or Kaolinite <i>ALL</i>
<b>Absorbs water</b>	Chalk, Diatomite, or Kaolinite <i>Diatomite &amp; Chalk</i>
<b>Gets slick/slimy when wet</b>	Chalk, Diatomite, or Kaolinite <i>Kaolinite</i>
<b>Reacts to acid</b>	Chalk, Diatomite, or Kaolinite <i>Chalk</i>

For the following pictures, give the scale of the creature in the picture.

Creature's width: 0.3 mm

PICTURE A: field of view diameter is 0.42 mm

Creature's width: 0.09 mm

PICTURE B: field of view diameter is 0.11 mm



NBII Image Gallery, Public Domain

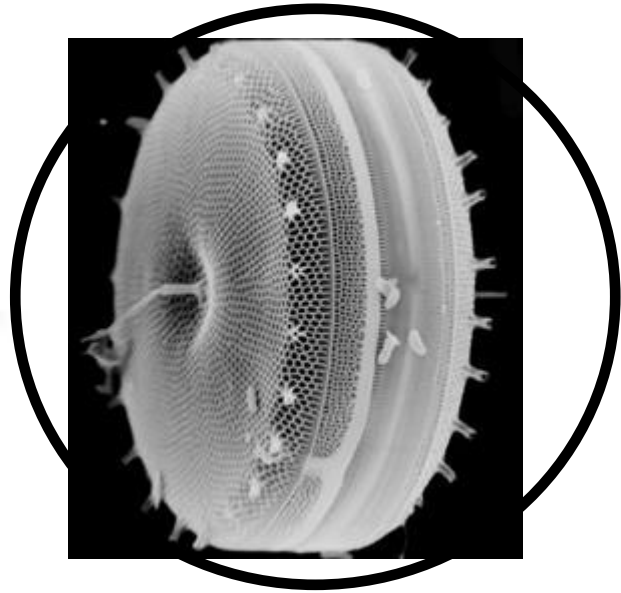


Image: Monterey Bay Aquarium

Organisms	Shell material ( $CaCO_3$ or $SiO_2$ )	Heterotroph or Autotroph	Rocks produced
Foraminifera	$CaCO_3$	Heterotroph	Chalk or Limestone
Radiolaria	$SiO_2$	Heterotroph	Diatomite or Chert
Diatoms	$SiO_2$	Autotroph	Diatomite or Chert



## San Francisco Bay Seawater Chemistry

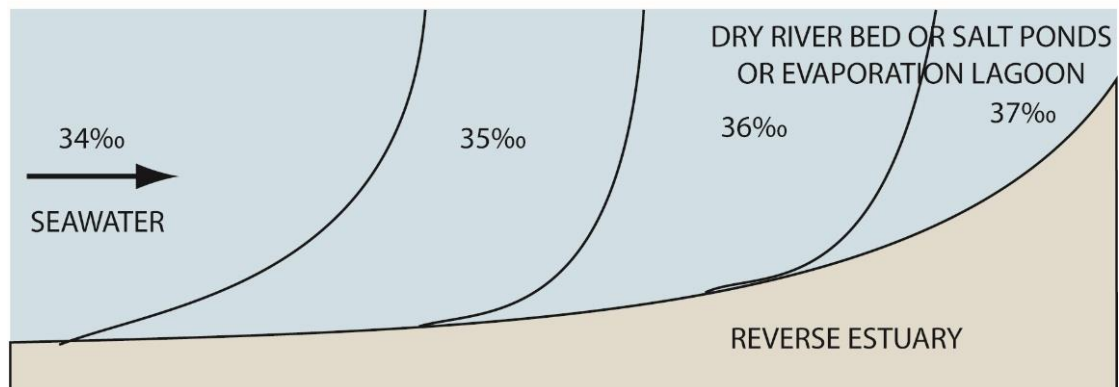
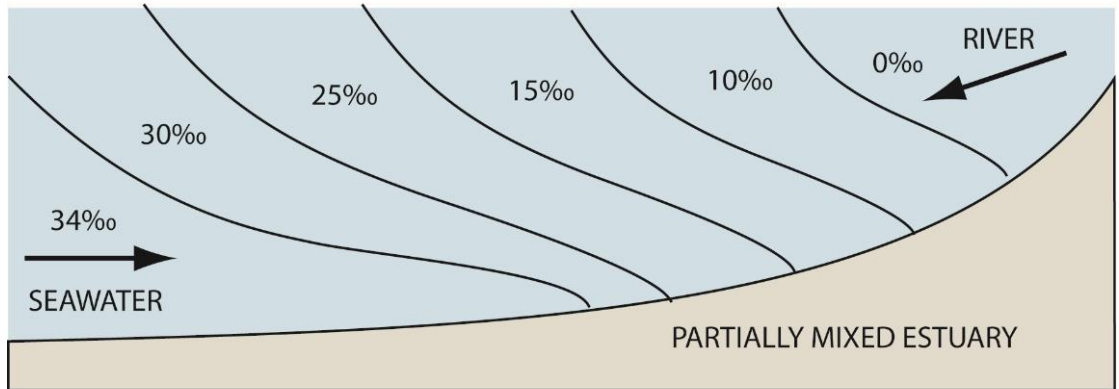
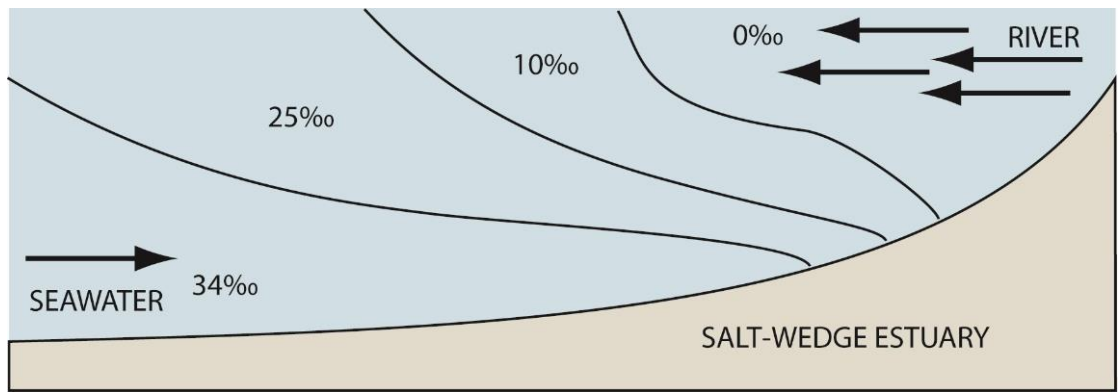
### NEEDED SUPPLIES:

- Sea salt
- Water
- Beakers and scales (at home use kitchen scale and measuring cups and spoons)

### SAN FRANCISCO BAY

San Francisco Bay, located at the confluence of the Sacramento and San Joaquin Rivers and bounded by upraised and faulted crustal blocks on its westward and eastward sides, owes its origin (*in part – just the South Bay*) to tectonic processes associated with strike-slip motion along the San Andreas Fault Zone, a transform plate boundary that runs through southern California. In addition, during the Pleistocene when sea level was low, the Sacramento River eroded a system of channels in the bay although there was no San Francisco Bay as such during glacial times, the shoreline being located tens of kilometers to the west on what is now the continental shelf. At present, San Francisco Bay is best characterized as a partially mixed estuary, but a very complex one.





- Salt-wedge estuary:** Deep, high-volume river; Strong halocline
- Well-mixed estuary:** Weak, low-volume river; No halocline
- Partially mixed estuary:** Medium-volume river, Weak halocline
- Reverse estuary:** High evaporite content along dry river bed

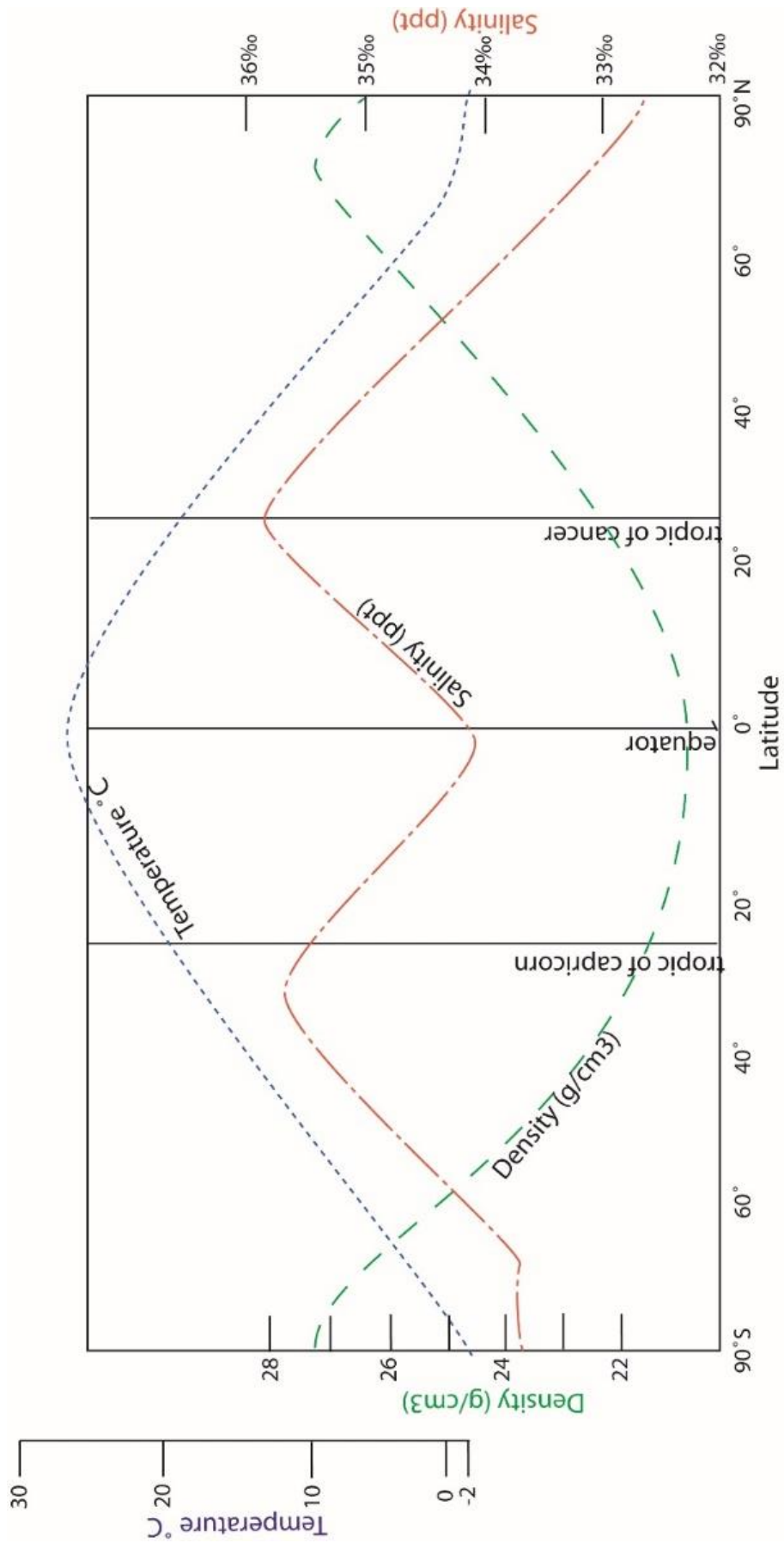
## Salinity

Salinity mostly affects organisms because of a process called osmosis. Biological cell membranes allow water to pass through, but not salts. A membrane with a more saline solution on one side and a less saline solution on the other will experience a net flow of water from the fresher side to the saline side to try to bring the two fluids' salinity to equilibrium values. For this reason, humans shouldn't drink saltwater. If we do, the cells that come in contact with the salt water will actually expel water. Net result: by drinking seawater, we actually lose more water – we dehydrate.

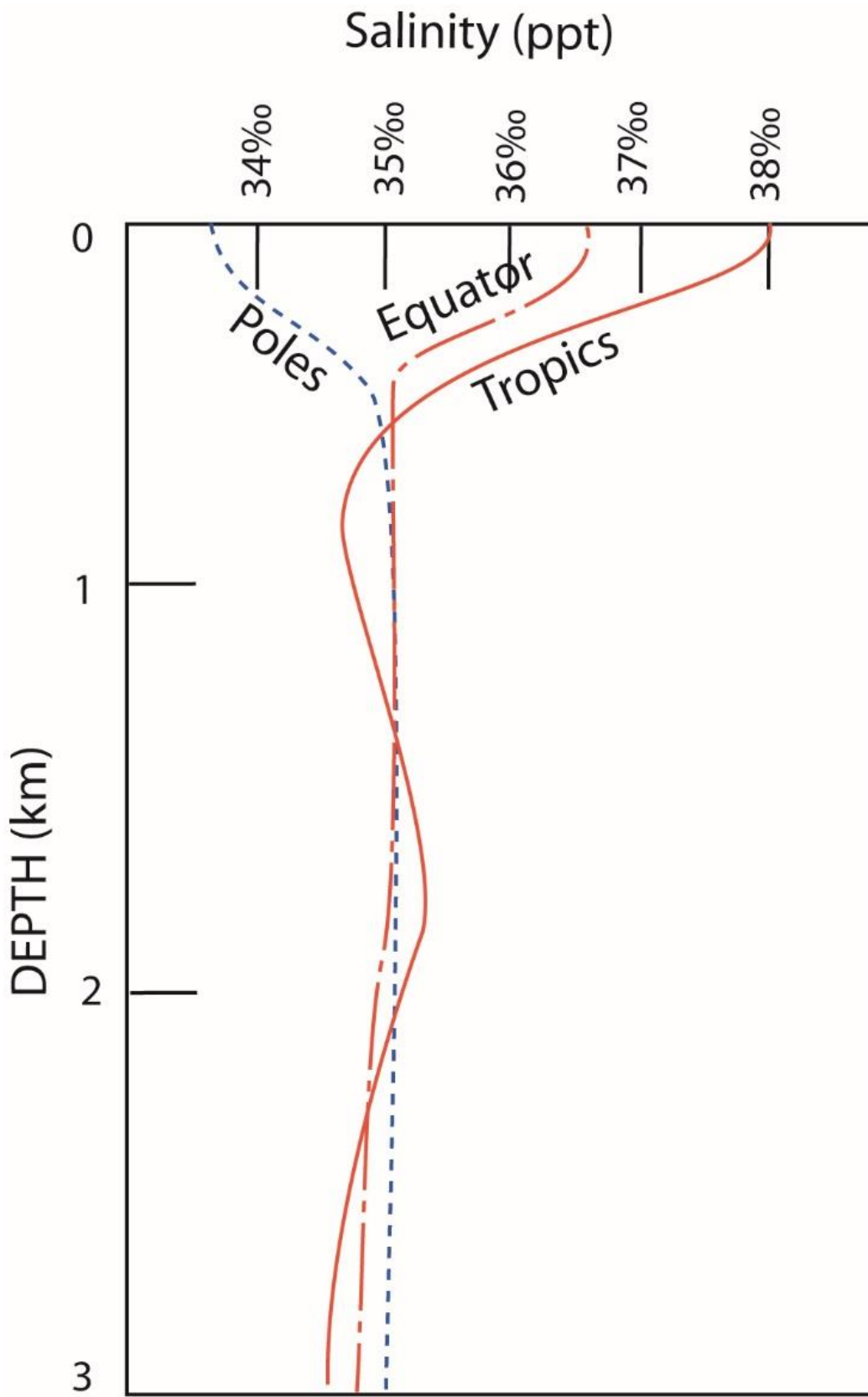
Most marine algae, invertebrates, and sharks maintain the salinity of their internal fluids at the same level as that of the surrounding seawater. Most organisms that apply this strategy live in ocean habitats whose salinities don't change very much, if at all. Therefore these organisms are never challenged by major shifts and swings in the salinity of the water under ordinary circumstances. If such an organisms' environment changed drastically, they could die from loss of water or by gaining too much water.

Marine fishes drink salt water and absorb most of the salt and water from their intestines into their bloodstreams. Their gills extract salt from the blood and excrete it into the water passing over the gills. Freshwater organisms experience the reverse of the osmotic problem encountered by marine fishes. Because the internal fluids of these organisms is more saline than freshwater, water constantly diffuses into their bodies. For freshwater fishes, the kidneys extract water from the blood, leaving the salts. Organisms that can survive changing salinities are common in estuaries or along coasts, where rainfall and river runoff create changing salinities.

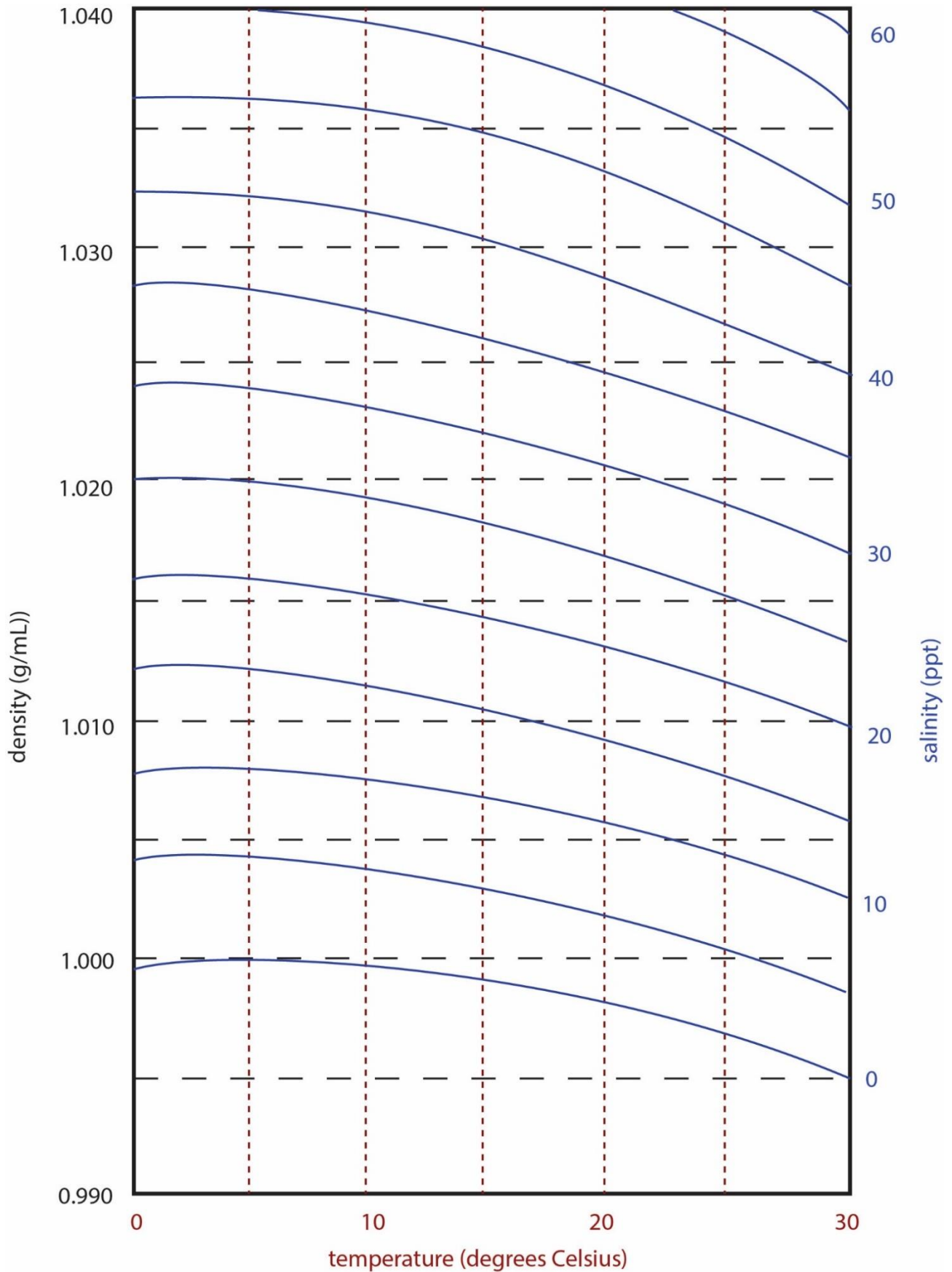
Sea or Ocean	Salinity (ppt)	Main processes affecting salinity
<b>SURFACE WATER</b>		
Arctic Ocean	28-33	River runoff, ice formation
Caribbean Sea	35-36	Evaporation
Mediterranean Sea	38	Evaporation, winter cooling
Baltic Sea	2-10	River runoff, ice formation
Red Sea	39-41	Evaporation
Gulf of California	35	Evaporation
Sea of Japan	33-34	River dilution, current from Pacific
South China Sea	34	River dilution, current from Pacific
Southern Ocean	34	Mixing of all ocean waters, ice formation
Gulf of Mexico	25-36	Evaporation, discharge of Mississippi River
Black Sea	16	Dilution by rivers
<b>AVERAGE OF SURFACE AND DEEP WATER, WHOLE OCEAN</b>		
Pacific Ocean	34.62	More rainfall and river runoff than evaporation
Atlantic Ocean	34.90	Less rainfall and river runoff than evaporation
Indian Ocean	34.76	Less rainfall and river runoff than evaporation
<b>World Average</b>	<b>34.70</b>	<b>All process balance</b>



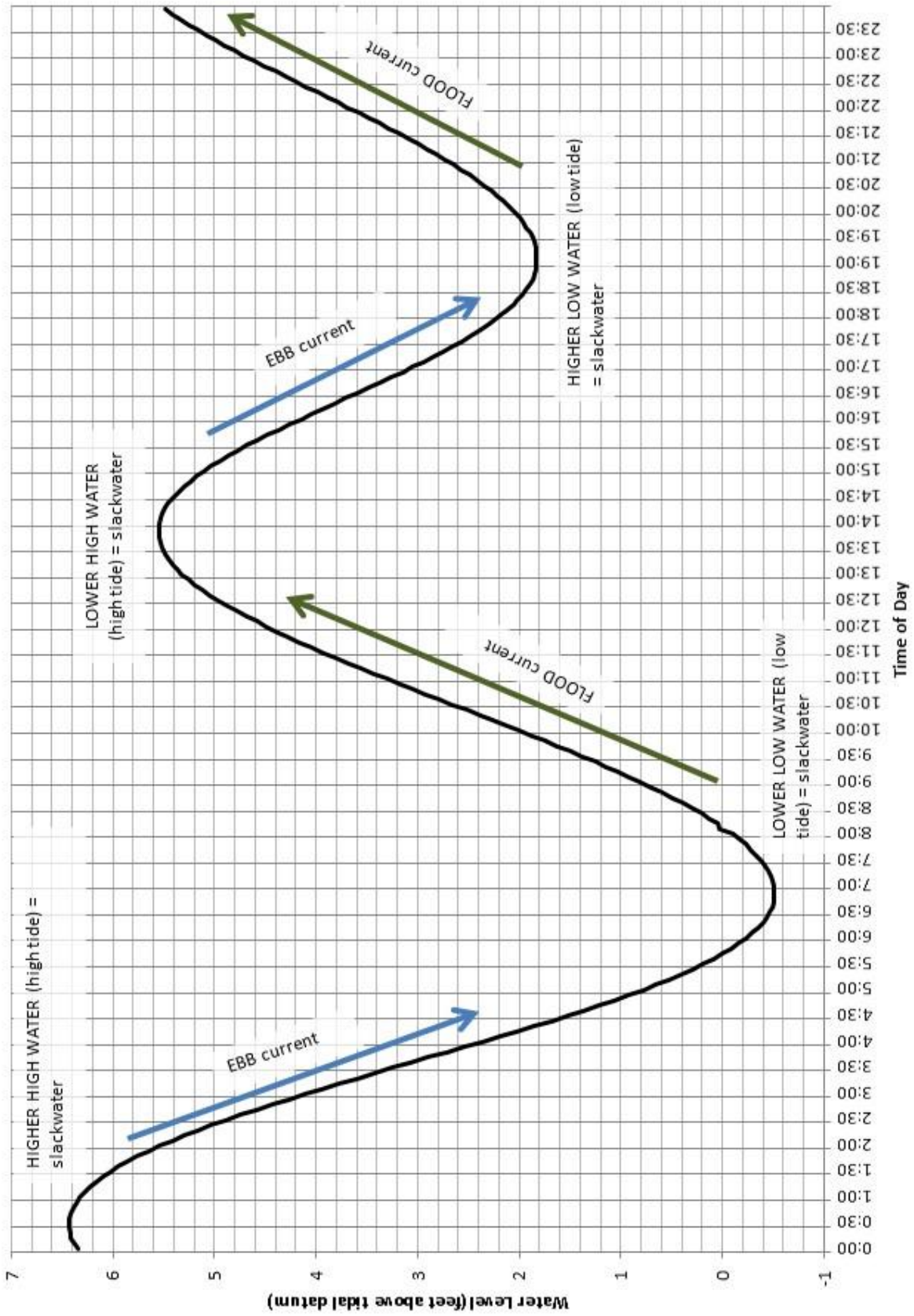
Average temperature, salinity, and density of surface seawater by latitude

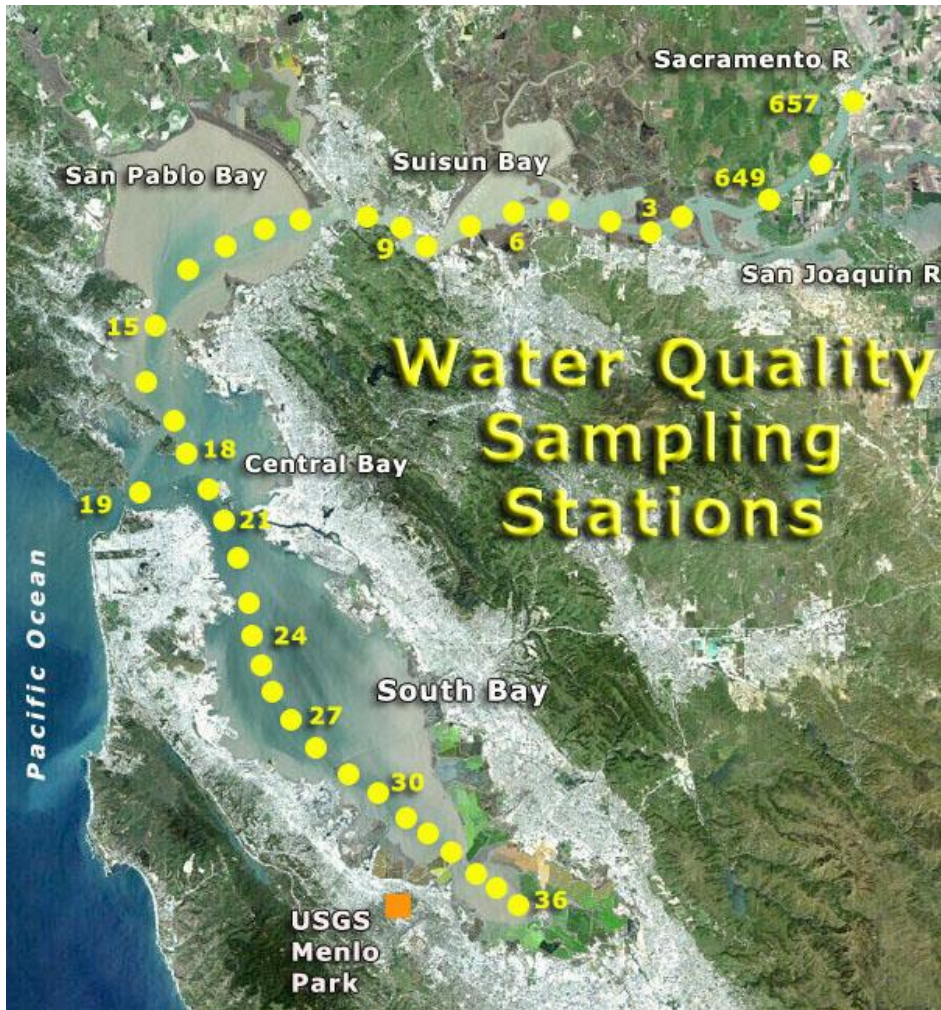


Haloclines with latitude



Temperature (vertical short-dashed lines), density (horizontal long-dashed lines), and salinity (curved solid lines). Example: If a water sample is 20°C and has a density of 1.010 g/mL (measured by hydrometer), then salinity is 16 ppt +/- 0.5 ppt.





Data from the USGS Water Resources Division for San Francisco Bay. Yellow dots represent the Water Quality Sampling Stations. Data source: <http://sfbay.wr.usgs.gov/access/wqdata/index.html>

### FULL BAY

TIDAL DATUM	VOLUME (10 <sup>6</sup> m <sup>3</sup> )	SURFACE AREA (10 <sup>6</sup> m <sup>2</sup> )	AVG. DEPTH VOL/AREA (m)	MEDIAN DEPTH (m)
MLLW	7142	1138	6.3	2.8
MSL	8446	1219	6.9	3.6
MHHW	9570	1244	7.7	4.4

\*MLLW = Mean Lower Low Water (low tides); MSL = Mean Sea Level; MHHW = Mean Higher High Water (high tides)

### Properties based on the Mean Sea Level grid

PROPERTY	SOUTH BAY	CENTRAL BAY	SAN PABLO BAY	SUISUN BAY	FULL BAY
Area (Mm <sup>2</sup> )	426.8	326.3	273.4	169.6	1219
Volume (Mm <sup>3</sup> )	1971	4388	1016	990	8446
Average depth (m)	4.6	13.4	3.7	5.8	6.9
Median depth (m)	3.2	10.9	2.5	3.6	3.6
% Area < 5 m	69	32	82	57	59

## San Francisco Bay & Seawater Chemistry – Prereading Exercises

\*Answer in space below or on back. If need addition paper, add extra pages.

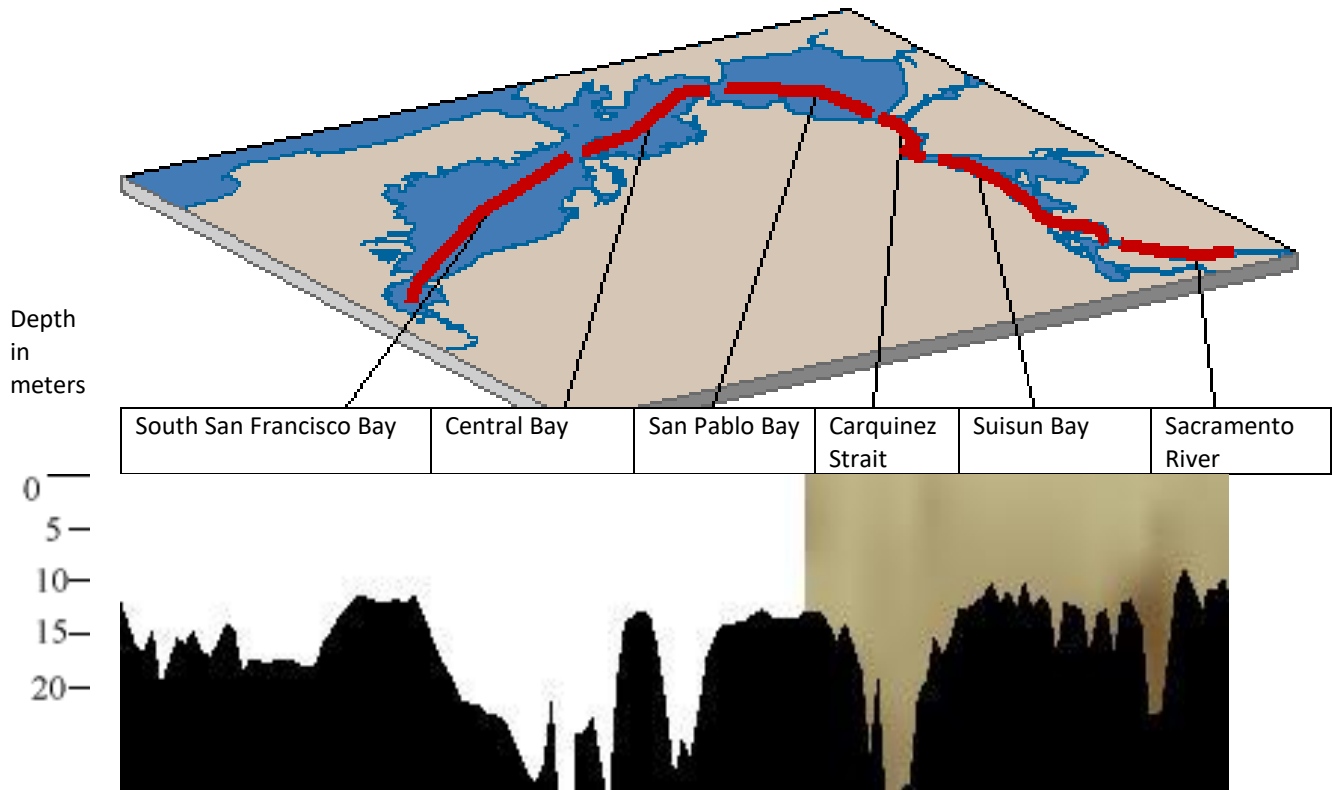
1. What is the origin of the San Francisco North Bay estuary? CIRCLE: (bar-built, tectonic, drowned river mouth, or fjord)
2. What is the origin of the San Francisco South Bay estuary? CIRCLE: (bar-built, tectonic, drowned river mouth, or fjord)
3. <b>North San Francisco Bay is a slightly stratified (or partially mixed) estuary.</b> What does that mean about its river (freshwater) input? CIRCLE: (River is high volume, ; River is medium volume; River is low volume)
4. What does it mean about its halocline? CIRCLE: (Strong halocline, Weak halocline; No halocline)
5. <b>South San Francisco Bay is a well-mixed estuary.</b> What does that mean about its river (freshwater) input? CIRCLE: (River is high volume, ; River is medium volume; River is low volume)
6. What does it mean about its halocline? CIRCLE: (Strong halocline, Weak halocline; No halocline)
7. Using the attached salinity-density graph, what would the seawater salinity be if water temperature was 15°C and Density was 1.022 g/cm <sup>3</sup> ?
8. What is the average depth of San Francisco Bay at mean sea level? Median depth? What's the difference?

QUESTION	OBSERVATIONS ( <i>what – real data!</i> )	INTERPRETATION ( <i>Why? Explanations</i> )
9. How does <b>ocean water salinity</b> change with <b>latitude</b> in the world ocean (in general)? Where is it highest and lowest?		
10. How does <b>ocean water salinity</b> change with <b>depth</b> in the world ocean (in general)? Where is it highest and lowest?		
11. Summarize, briefly, the main effects of <b>changing</b> salinity on marine organisms.		

## San Francisco Bay & Seawater Chemistry – Lab Exercises

All data, graphs, and images come from the USGS Water Quality Website at <http://sfbay.wr.usgs.gov/access/wqdata>.

**San Francisco Bay – Depth data** – Distances are measured northward from the southernmost portion of the South Bay, thus progressing through the South Bay, into the Central Bay, San Pablo Bay, Carquinez Strait, Suisun Bay, and the lower Sacramento River West of Rio Vista.



**The major sources of fresh water to San Francisco Bay** are through the Sacramento and San Joaquin Rivers. There are also some minor rivers dumping into San Pablo Bay, including the Napa and Petaluma Rivers. In the South Bay, there are only minor creeks and thus no real fresh water source.

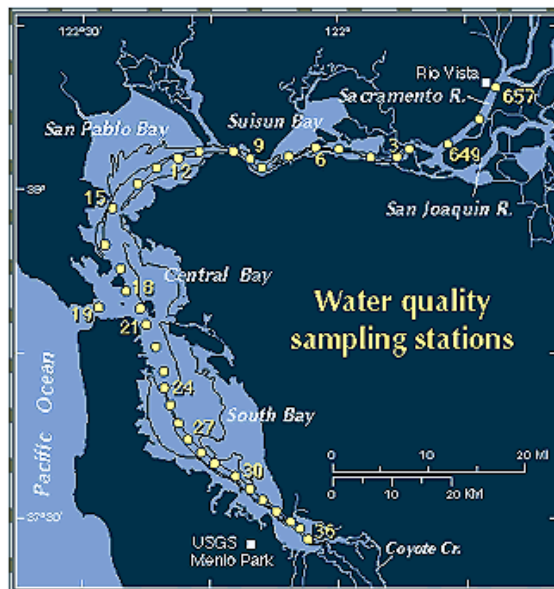


**San Francisco Bay – Full Bay Data** Distances are measured northward from station 36 in the southernmost portion of the South Bay, thus progressing through the South Bay, into the Central Bay, San Pablo Bay, Carquinez Strait, Suisun Bay, and the lower Sacramento River West of Rio Vista.

*Note: On graphs below, Central Bay/Golden Gate Bridge area lie approximately 55 km north of the south most portion of the Bay.*

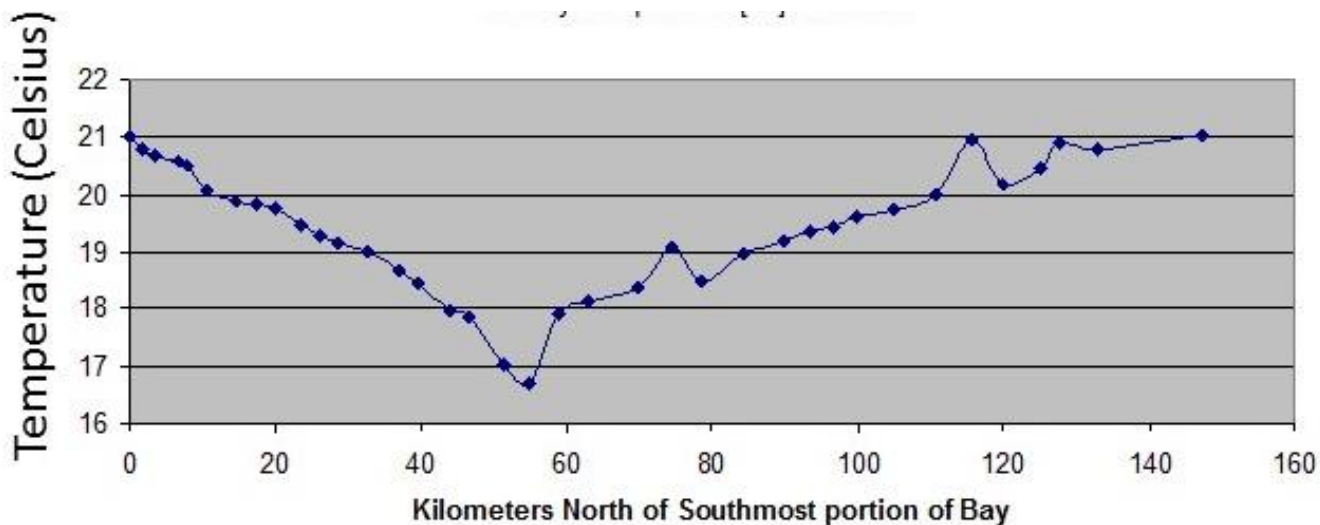
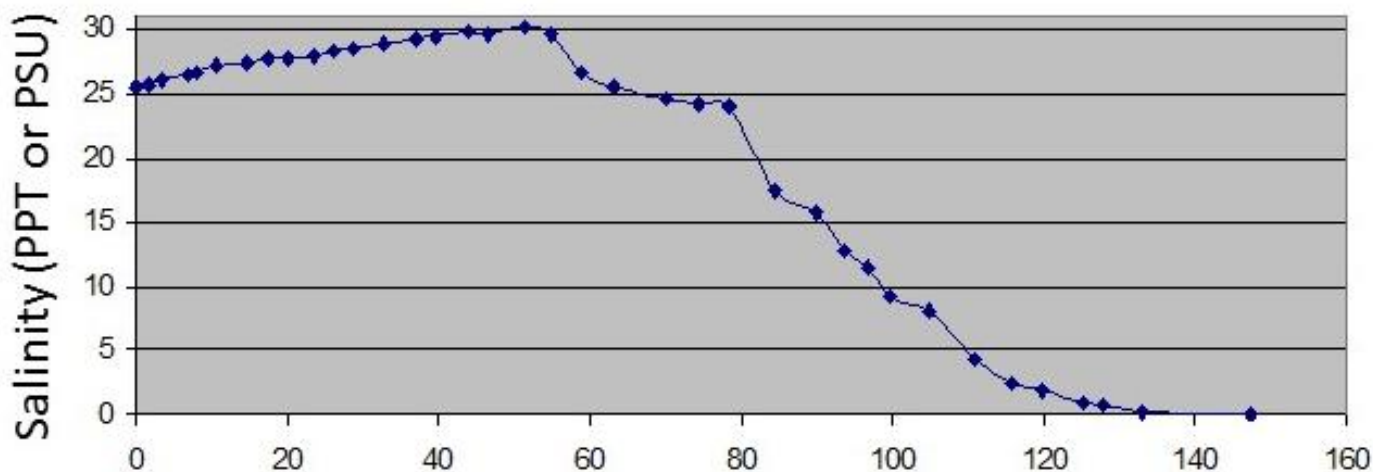
For all remaining graphs, use these month numbers to correspond to the seasons:

Winter (12, 1, 2)      Spring (3, 4, 5)  
 Summer (6, 7, 8)      Fall (9, 10, 11)



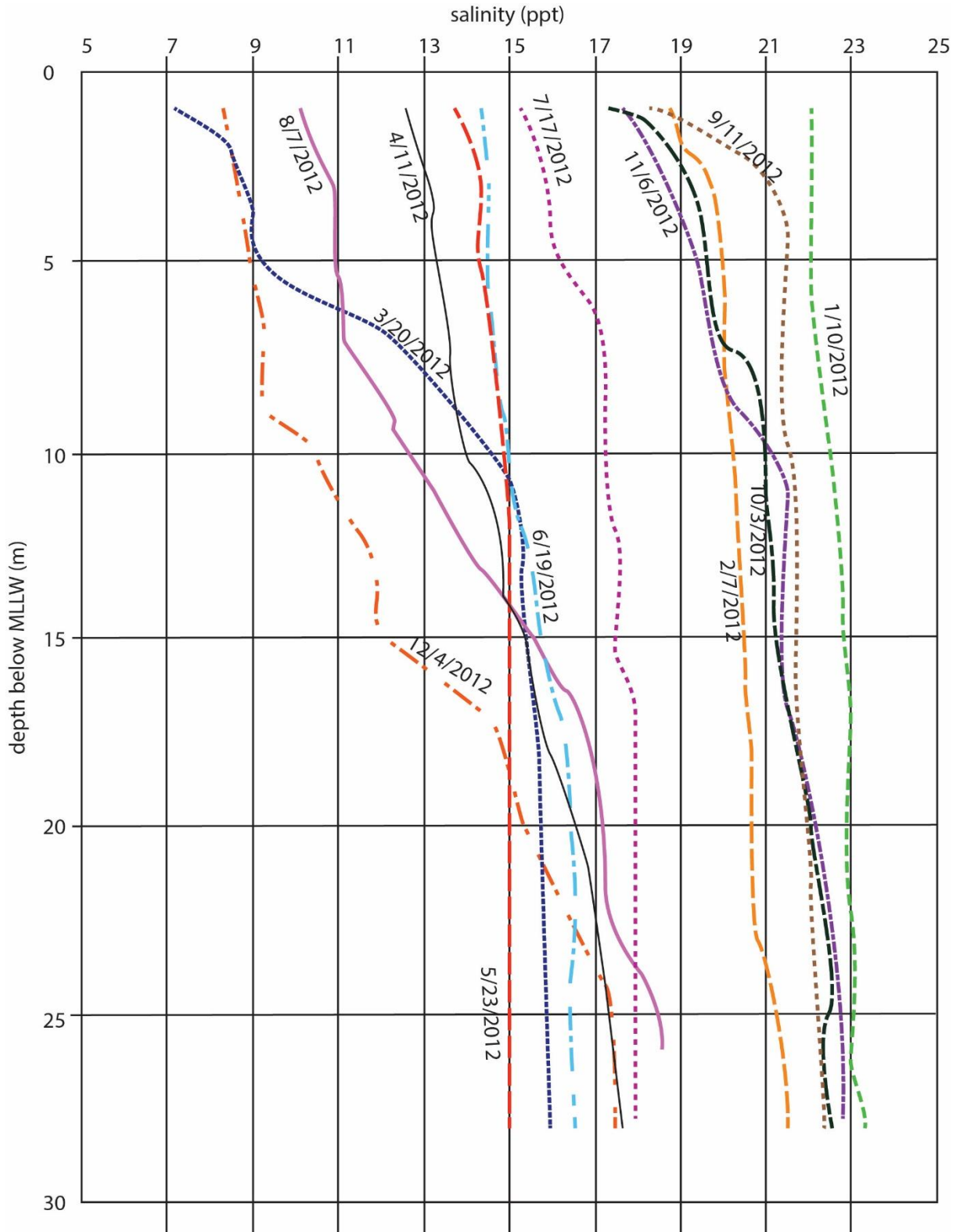
Data and maps: USGS Water Resources

SF Bay 9/12/2006



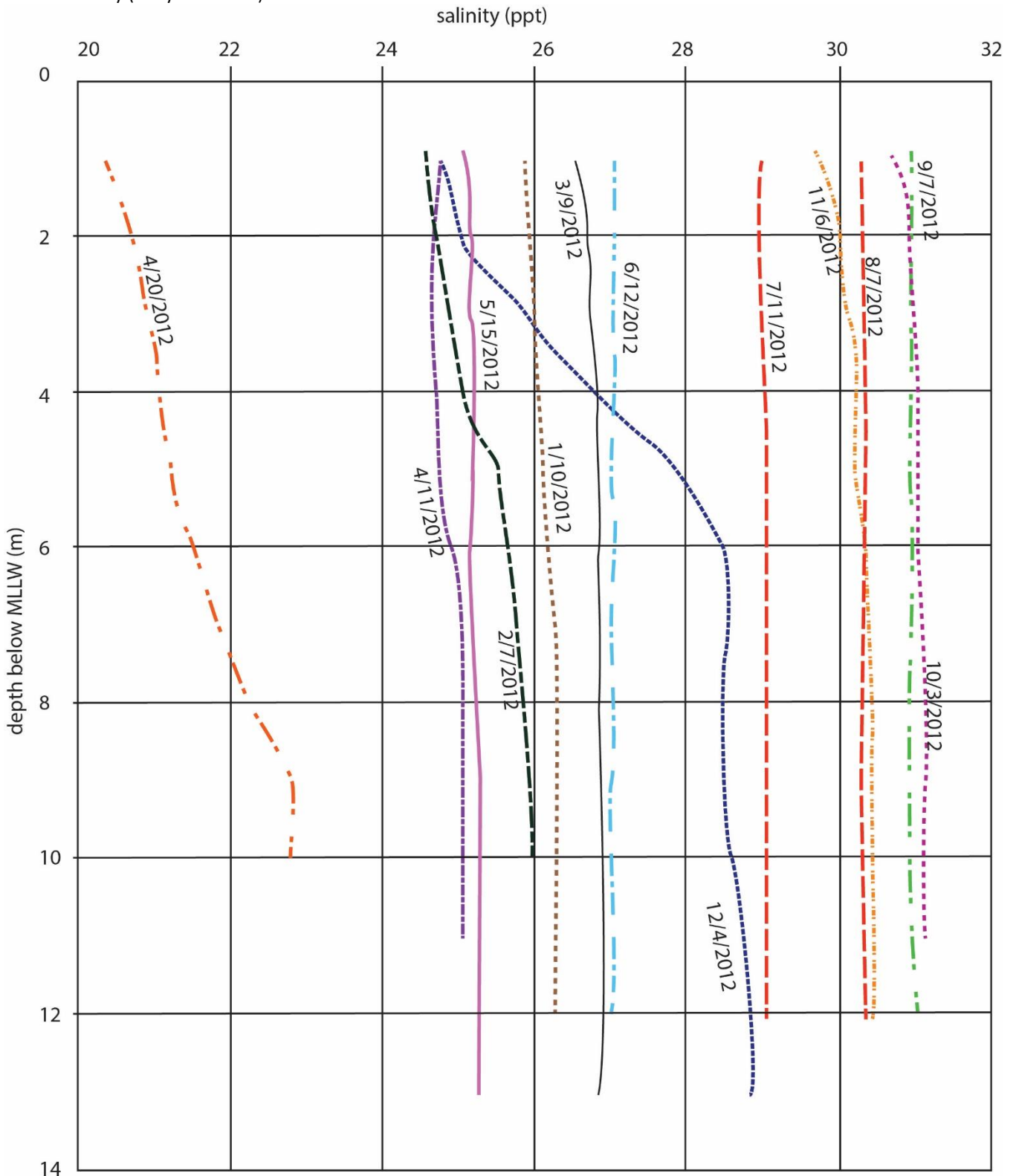
### STATION 9 – (North San Francisco Bay)

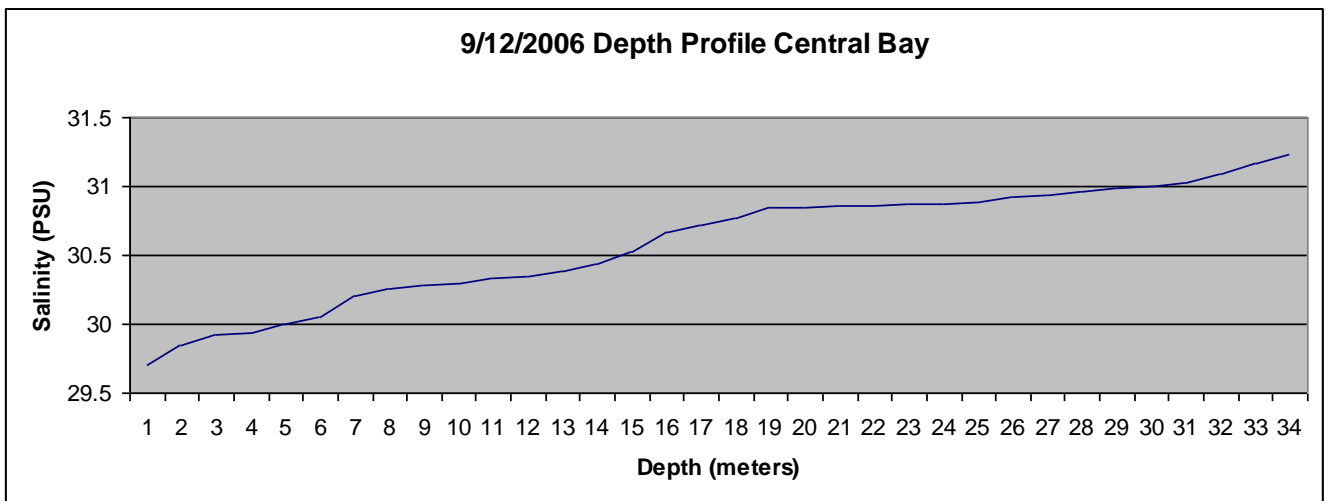
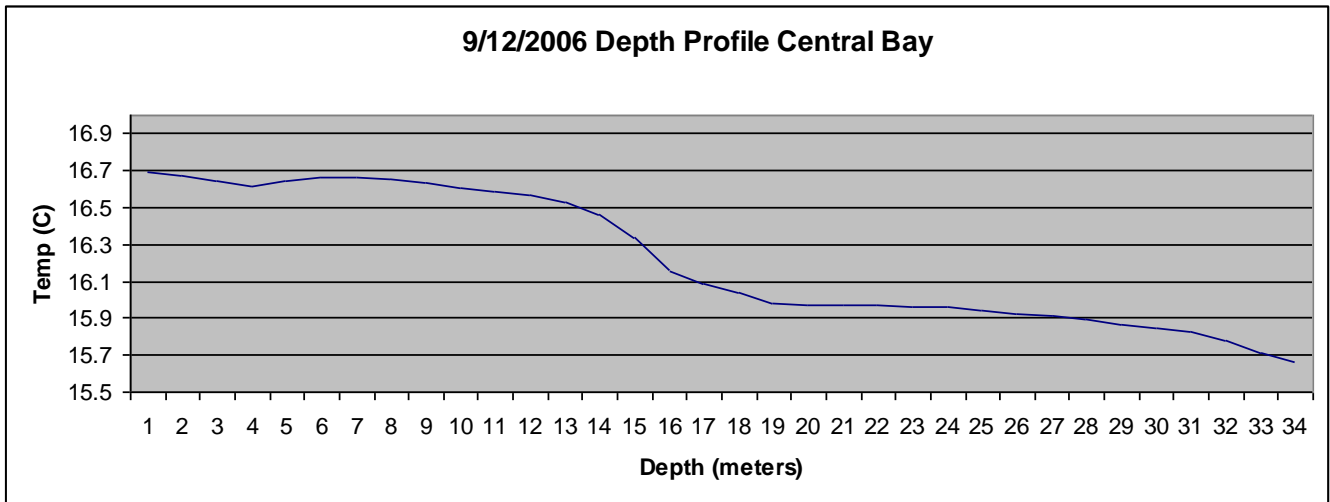
Graphs below represent depth profiles (salinity as one descends from surface to bay floor) at different times of the year. Each sampling date is noted with a different color and pattern and labeled with the date of the sampling. These samples were taken aboard the Polaris – a research vessel run by the USGS out of Menlo Park, at each station shown in the first map for this activity (the yellow dots).



**STATION 33 – (South San Francisco Bay)**

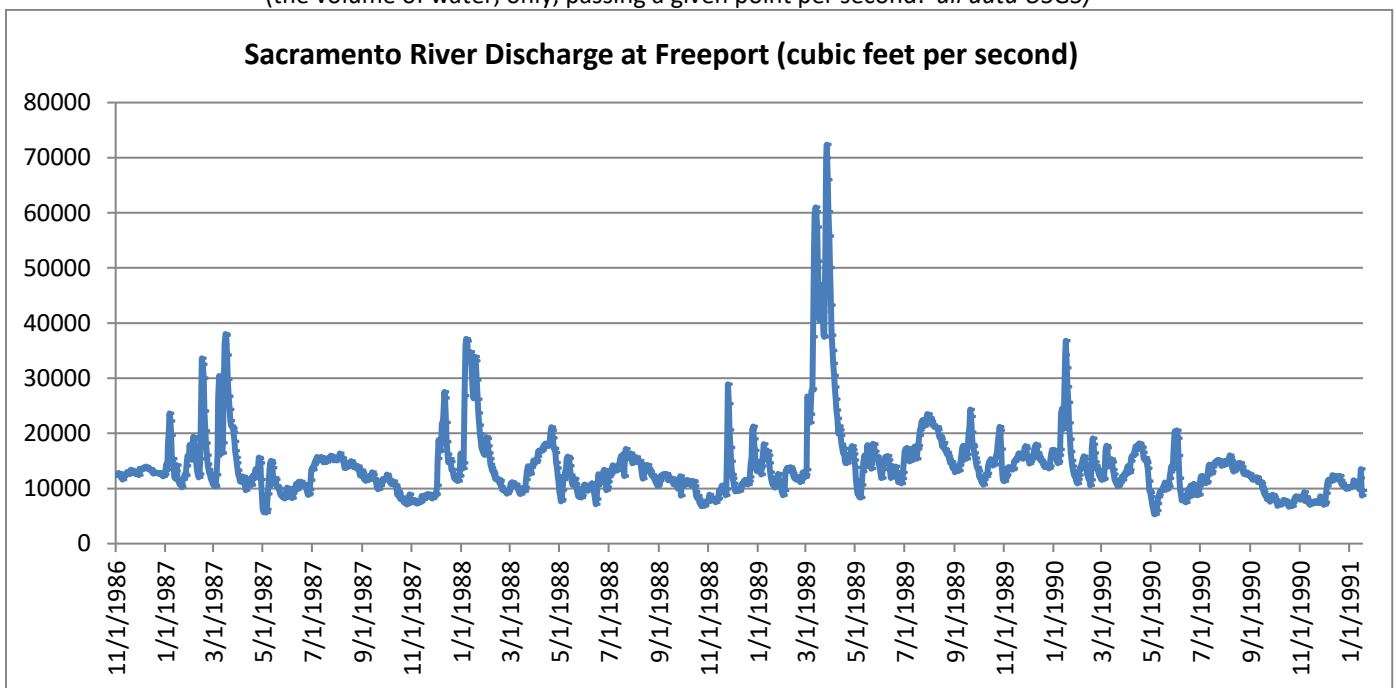
Graphs below represent depth profiles (salinity as one descends from surface to bay floor) at different times of the year. Each sampling date is noted with a different color and pattern and labeled with the date of the sampling. These samples were taken aboard the Polaris – a research vessel run by the USGS out of Menlo Park, at each station shown in the first map for this activity (the yellow dots).



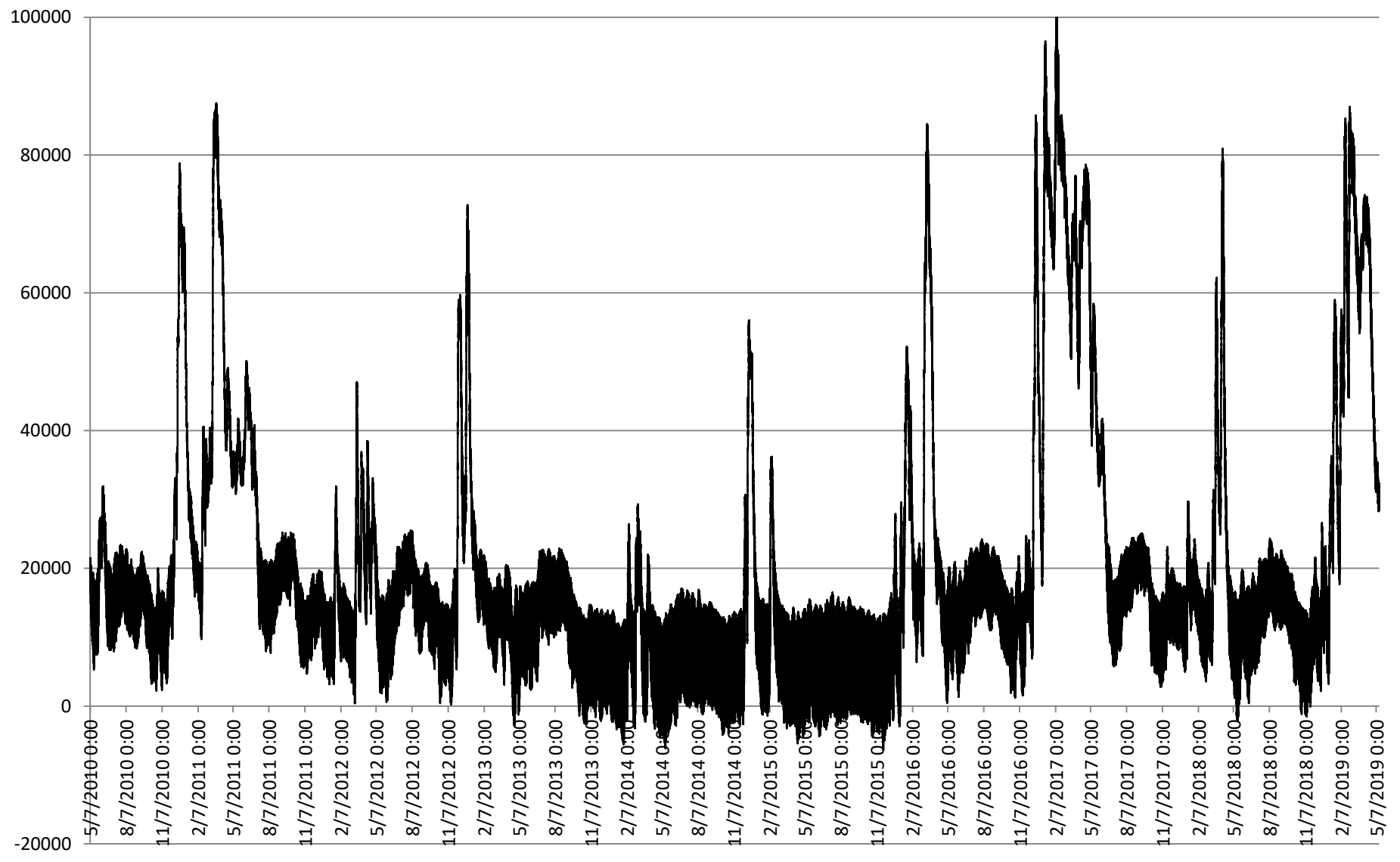


PSU = PPT

**Discharge from the Sacramento River**  
(the volume of water, only, passing a given point per second: *all data USGS*)

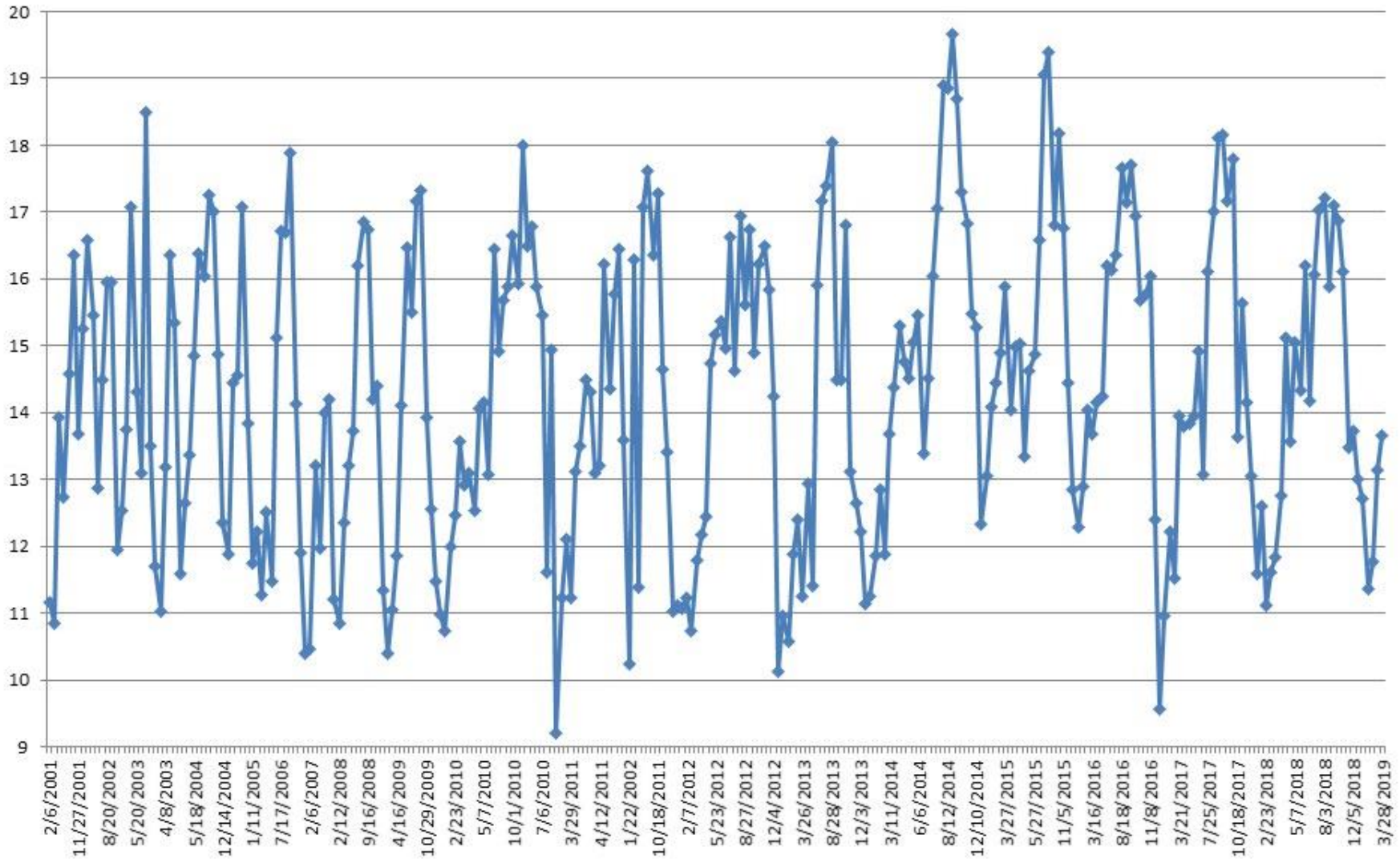


# Discharge (cfs) at Freeport, Sacramento Rv



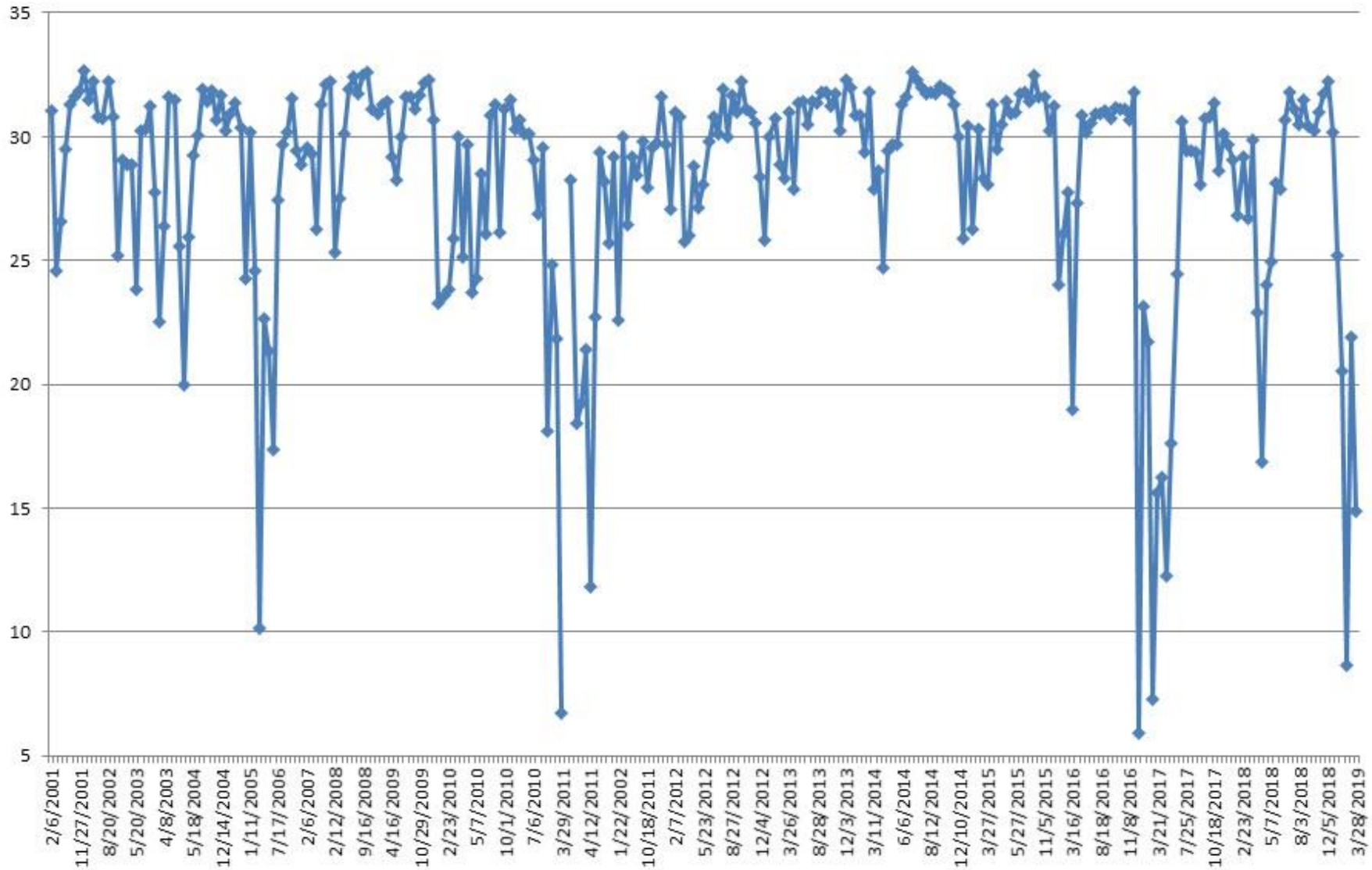
Data: USGS Water Resource

### Central Bay Temperature from 2/6/2001 through 3/28/2019 [°C]



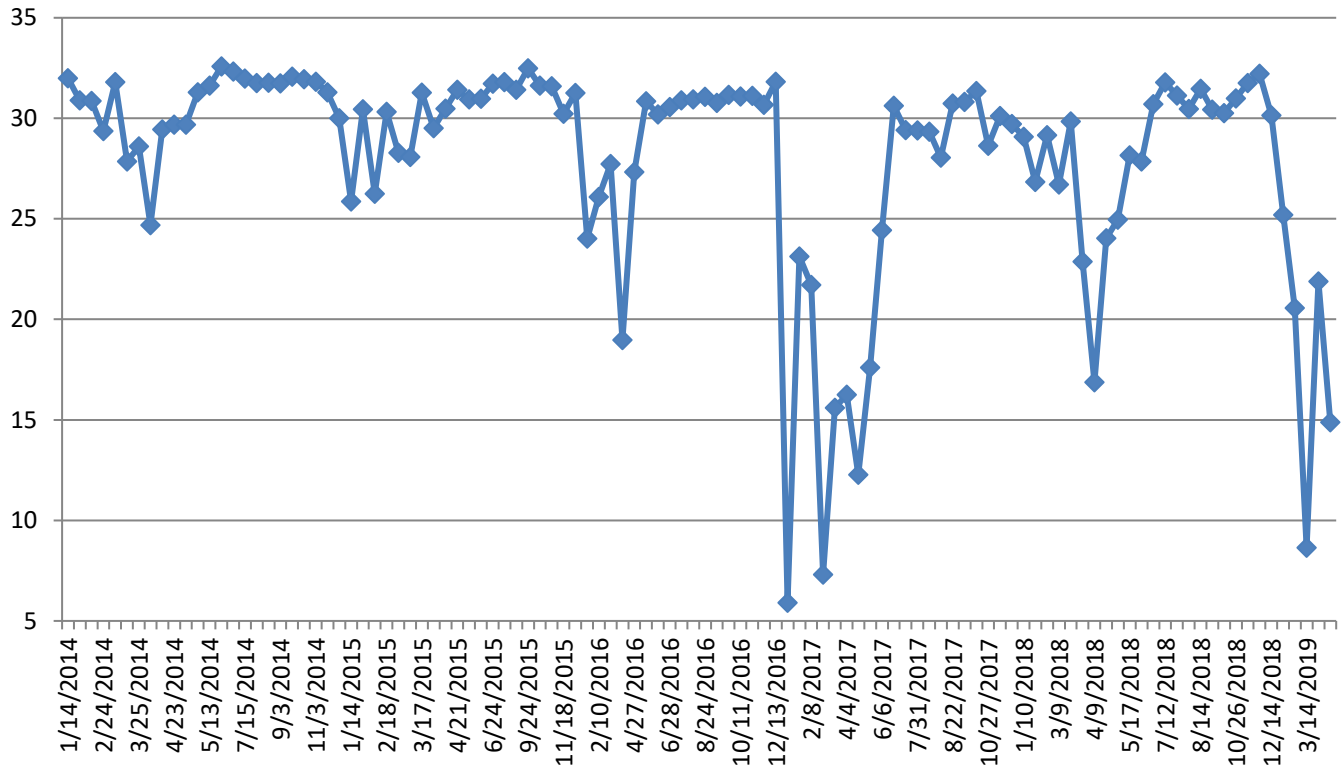
Data: USGS Water Resource – Station 18 (Central Bay) – Depth: 1 ft

### Central Bay Salinity from 2/6/2001 through 3/28/2019 [ppt]

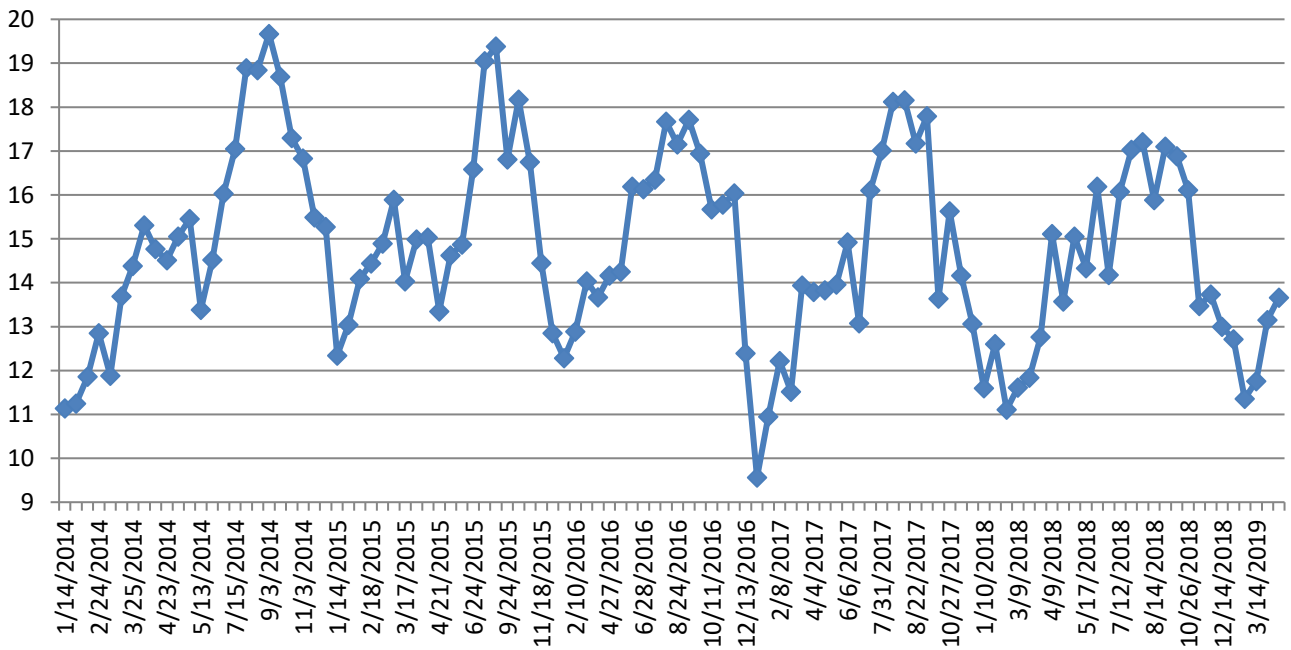


Data: USGS Water Resource – Station 18 (Central Bay) – Depth: 1 ft

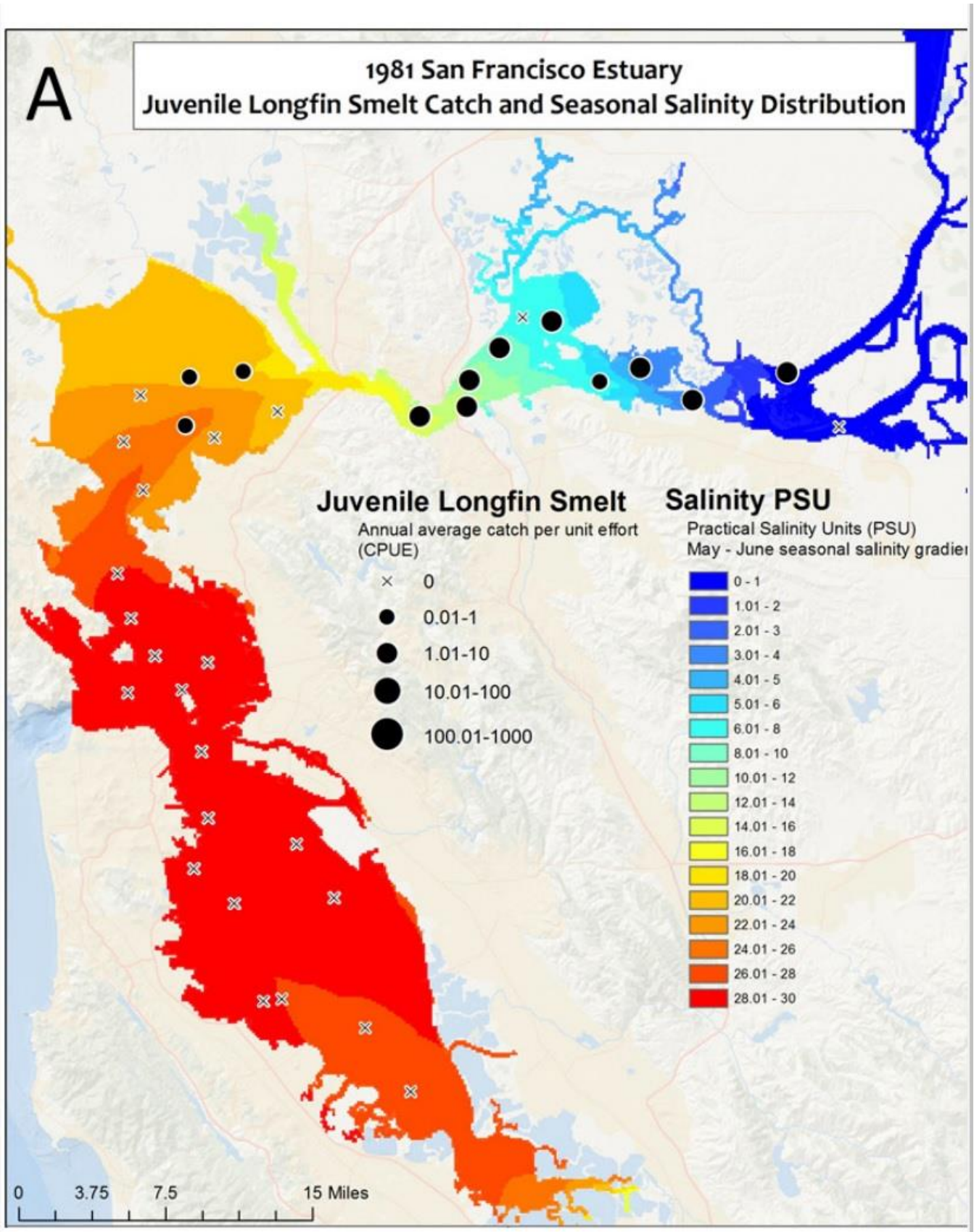
### Central Bay Salinity CLOSE UP from 2014 through 2019 [ppt]



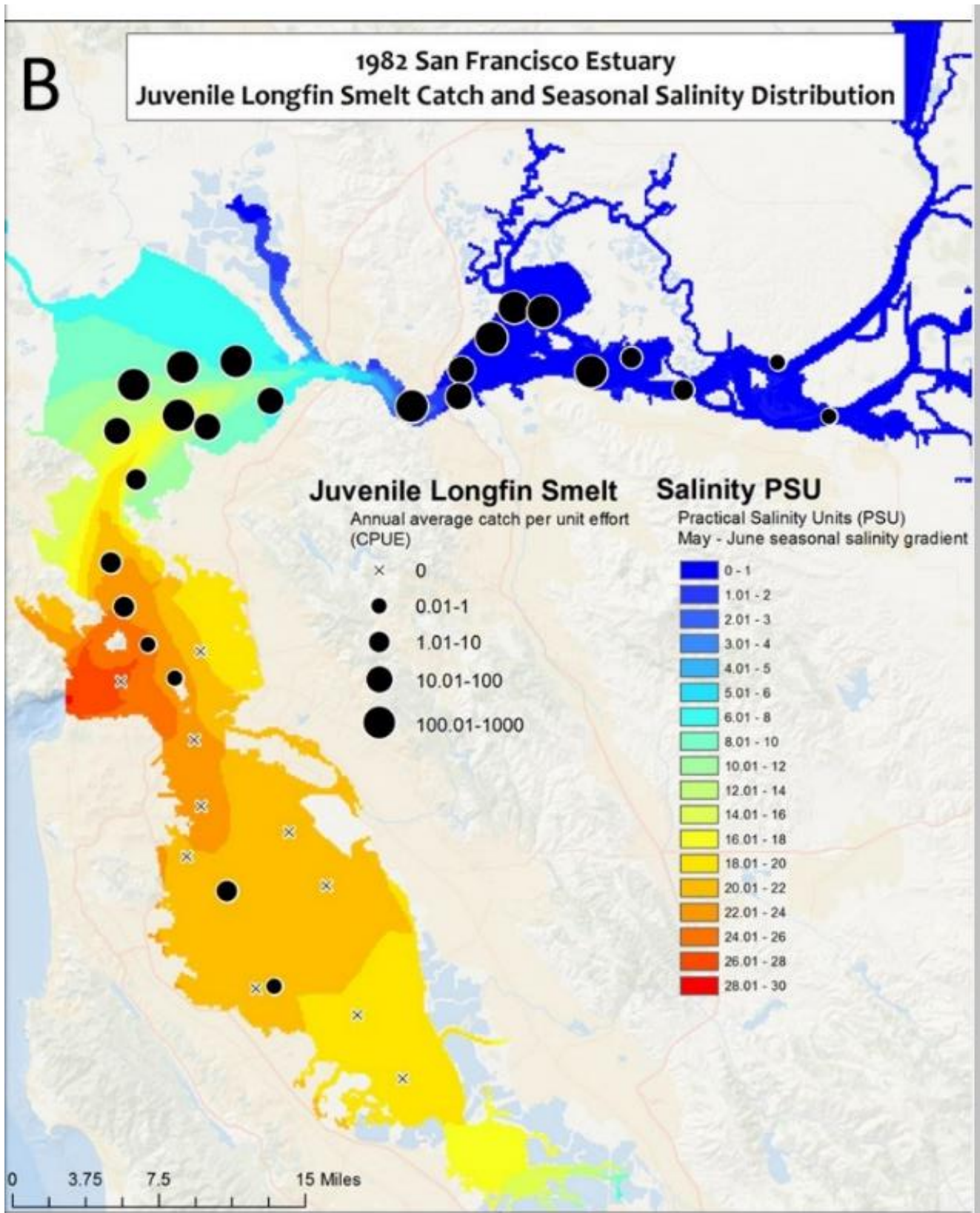
### Central Bay Temperature CLOSE UP from 2014 through 2019 [°C]



Data: USGS Water Resource – Station 18 (Central Bay) – Depth: 1 ft

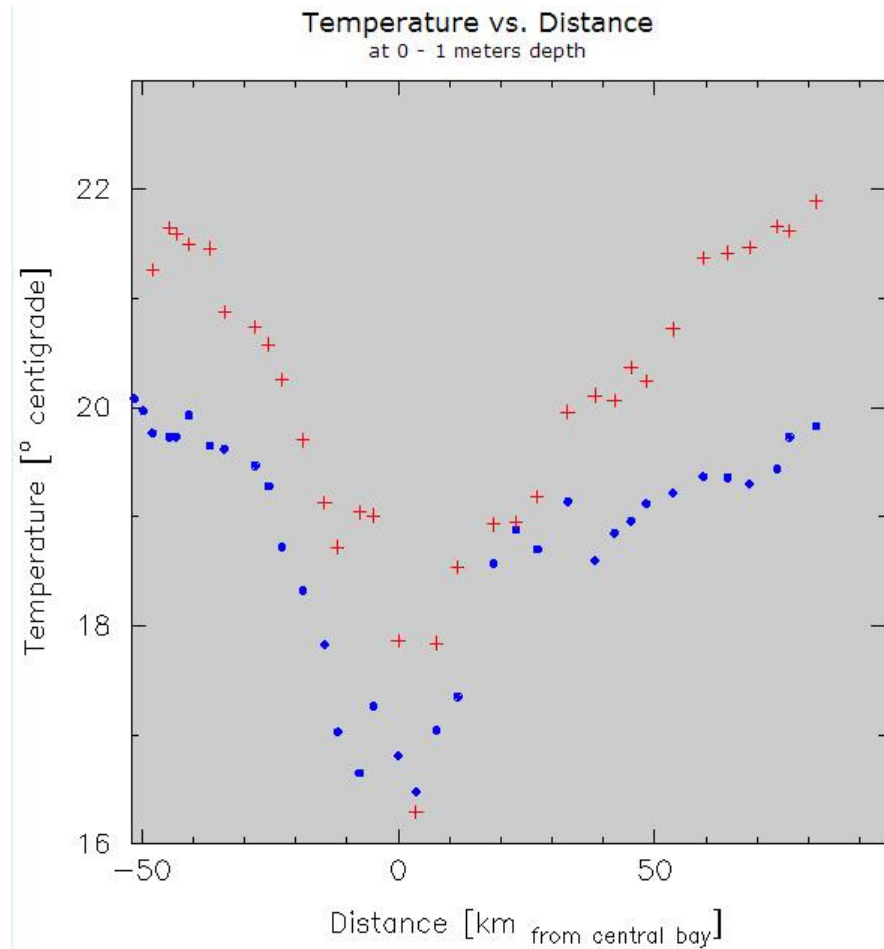
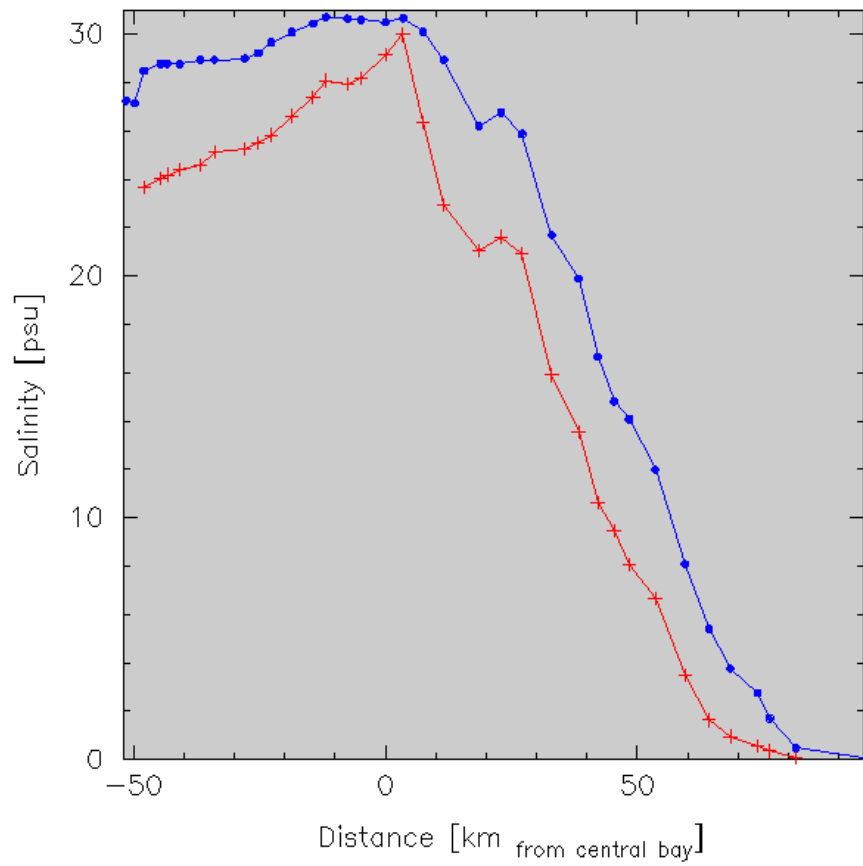


Predicted average salinity (PSU or PPT) between May 1 and June 30 1981 with annual average catch per unit effort (CPUE) of Juvenile Longfin Smelt. From MacWilliams, Bever, and Foresman, 2016. CC-BY 4.0



Predicted average salinity (PSU or PPT) between May 1 and June 30 1982 with annual average catch per unit effort (CPUE) of Juvenile Longfin Smelt. From MacWilliams, Bever, and Foresman, 2016

**San Francisco Bay – sea surface salinity (psu = ppt) and temperature data (°C) from August 2010 (circles) and 2011 (plus signs)**  
Distances are measured southward and northward from the central bay. *Data: USGS Water Resources*



## OBSERVATIONS AND ANALYSIS OF SAN FRANCISCO BAY CHEMISTRY

Use the previous charts of water chemistry in San Francisco Bay and classroom maps and photos of San Francisco Bay to review the data.

First describe the data! Then use your knowledge of weather and ocean dynamics to analyze the data and explain why it is what it is.

**These month numbers to correspond to the seasons: Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)**

QUESTION	OBSERVATIONS <i>(review charts and record what the data says – no interpretation yet!)</i> :	INTERPRETATION <i>(Analyze the data – what makes these characteristics the way they are? Pull ideas from knowledge of estuarine dynamics and weather systems from your class to date and your life experiences in SF Bay)</i>
1. <b>Deepest locations</b> in SF Bay (two general places)	<b>CIRCLE BEST ANSWERS:</b> South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
2. <b>Shallowest locations</b> in SF Bay (two general places)	<b>CIRCLE BEST ANSWERS:</b> South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
3. <b>Location of highest surface salinity</b> in SF Bay (two general places)	<b>CIRCLE BEST ANSWERS:</b> South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
4. <b>Location of lowest surface salinity</b> in SF Bay (one place)	<b>CIRCLE BEST ANSWERS:</b> South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
5. <b>Location of highest surface temperature</b> in SF Bay (two general places)	<b>CIRCLE BEST ANSWERS:</b> South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
6. <b>Location of lowest surface temp</b> in SF Bay (one place)	<b>CIRCLE BEST ANSWER:</b> South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
7. <b>Depth of highest salinity and lowest temperature</b> <i>(general answer)</i>	<b>CIRCLE BEST ANSWER:</b> Shallow Deep	

QUESTION	OBSERVATIONS <i>(review charts and record what the data says – no interpretation yet!)</i> :	INTERPRETATION <i>(Now analyze the data – what makes these characteristics the way they are? Pull ideas from knowledge of estuarine dynamics and weather systems from your class to date and your life experiences in SF Bay)</i>
8. <b>When during a given year is discharge</b> (total volume of water) from the Sacramento and San Joaquin rivers <b>greatest?</b>	<b>CIRCLE BEST ANSWER:</b> <i>Numbers refer to months</i> Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
9. <b>When during a given year is discharge</b> (total volume of water) from the Sacramento and San Joaquin rivers <b>least?</b>	<b>CIRCLE BEST ANSWER:</b> <i>Numbers refer to months</i> Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
10. <b>When during a given year</b> in San Francisco Bay would you find the <b>highest salinity?</b>	<b>CIRCLE BEST ANSWER:</b> <i>Numbers refer to months</i> Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
11. <b>When during a given year</b> in San Francisco Bay would you find the <b>lowest salinity?</b>	<b>CIRCLE BEST ANSWER:</b> <i>Numbers refer to months</i> Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
12. <b>When during a given year</b> in San Francisco Bay would you find the <b>highest temperature?</b>	<b>CIRCLE BEST ANSWER:</b> <i>Numbers refer to months</i> Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
13. <b>When during a given year</b> in San Francisco Bay would you find the <b>lowest temperature?</b>	<b>CIRCLE BEST ANSWER:</b> <i>Numbers refer to months</i> Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	

	<b>STATION 9 – North San Francisco Bay</b>	<b>STATION 33 – South San Francisco Bay</b>
14. Study the depth profiles across the year for each station. What <b>MOSTLY</b> happens to salinity with depth?	(circle best answer) Increases with depth Decreases with depth Stays the same with depth	(circle best answer) Increases with depth Decreases with depth Stays the same with depth
15. For each station, when is surface salinity <b>highest</b> ? How high? Why?	<b>HIGHEST SURFACE VALUE:</b>  <b>WHEN:</b>  <b>WHY:</b>	<b>HIGHEST SURFACE VALUE:</b>  <b>WHEN:</b>  <b>WHY:</b>
16. For each station, when is surface salinity <b>lowest</b> ? How low? Why?	<b>LOWEST SURFACE VALUE:</b>  <b>WHEN:</b>  <b>WHY:</b>	<b>LOWEST SURFACE VALUE:</b>  <b>WHEN:</b>  <b>WHY:</b>
17. For each station, what is the highest salinity difference experienced during the year (difference between salinity at surface and salinity at depth at a single location one a single date)? When? Why?	<b>HIGHEST DIFFERENCE:</b>  <b>WHEN:</b>  <b>WHY:</b>	<b>HIGHEST DIFFERENCE:</b>  <b>WHEN:</b>  <b>WHY:</b>
18. What is the lowest surface-depth salinity difference that occurred? When? Why?	<b>LOWEST DIFFERENCE:</b>  <b>WHEN:</b>  <b>WHY:</b>	<b>LOWEST DIFFERENCE:</b>  <b>WHEN:</b>  <b>WHY:</b>
19. What kind of pycnocline <b>dominated</b> for each station?	(circle best answer) Strong pycnocline Weak pycnocline No pycnocline	(circle best answer) Strong pycnocline Weak pycnocline No pycnocline
20. Referencing the <i>Longfin Smelt maps</i> , describe the general distribution of salinity for <b>May and June 1981</b> in San Francisco Bay. Be thorough and provide <b>ONLY</b> observations, not evaluations or explanations.	21. Referencing the <b>Longfin Smelt maps</b> , describe the general distribution of salinity for <b>May and June 1982</b> in San Francisco Bay. Be thorough and provide <b>ONLY</b> observations, not evaluations or explanations.	

## SEAWATER CHEMISTRY

### 22. Complete table below:

<b>Sample Location</b>	Princeton Harbor (Pillar Point)	Fort or North Point (Central SF Bay)	Oyster Point (South SF Bay)
<b>Date and Time of Day Sample was taken</b>			
<b>Tide Level at sample location at that time</b>			
<b>Current type at location at sample time (circle)</b>	Ebb   Flood   Slack water	Ebb   Flood   Slack water	Ebb   Flood   Slack water

### 23. REFRACTOMETER AND SALINITY

#### Purpose

A refractometer measures how much light bends as it travels through a drop of water. The more saline the water (the denser the water), the more light bends as it travels through it. Since density is dependent on both salinity and temperature, this device has been calibrated for average seawater in the range of 10-30C, to give you the accurate density and salinity of the sample.

#### Materials

Eye dropper and cup of seawater                      Refractometer                      Distilled water and Kim Wipes

#### Method

1. BE CAREFUL with this instrument. It is expensive and fragile. Carefully lift up the plastic cover on the end of the instrument and ensure that surface is clean (visual inspection ok).
2. Place two drops of seawater on the glass, in the center.
3. Carefully close plastic cover. Drop should cover entire glass. If it doesn't, clean surface gently with distilled water and a Kim Wipe and do over.
4. When drop coverage is complete, hold instrument to your eye and read the density and salinity from the screen. (Move outer objective out or in to focus.)
5. CLEANING: With distilled water and a Kim Wipe, gently clean the glass surface and put instrument back in its box.

	<b>Density in g/cm<sup>3</sup> (+/- error range due to precision of instrument)</b>	<b>Salinity (from device) in ppt (+/- error range due to precision of instrument)</b>
<b>Princeton Harbor (Pillar Point)</b>		
<b>Fort or North Point</b>		
<b>Oyster Point</b>		

### 24. DENSITY AND SALINITY

#### Purpose

Density is the measurement of how much more a substance weighs than an equal volume of pure water. Example: Gold has a density of 20. That means that if you have equal volumes of water and gold, the gold will weight 20 times more than the water! When we measure the density of seawater, therefore, we are comparing it to the weight of an equal amount of pure fresh water. If our measurement was exactly 1.00, then the densities would be identical, and we could bet that our sample was really freshwater! The salinity of normal seawater is about 34 parts of salt per thousand parts of seawater. Bay water can be more or less, depending on evaporation and runoff. Note: Since density is dependent on what ions are dissolved in seawater and in what proportions (mass), the graph you use to calculate salinity has been calibrated for average seawater in the range of 10-30C.

#### Materials

100 ml graduated cylinder filled with seawater                      Hydrometer                      Salinity-Temperature graph (*in prereading!*)

#### Method

1. Ensure that cylinder is filled with enough seawater so hydrometer floats freely: doesn't touch insides.
2. Use thermometer to measure temperature of water sample and record below.
3. Record the density of the water sample below. (Value is a number that represents how many times denser your sample is than pure, fresh water. 1.000 is the value for fresh water.)

4. Use temperature – density chart to determine salinity.
5. **DISPOSAL/CLEANING:** Other lab groups will reuse this sample, so do not dump it down the drain.

	<b>Water temperature °C (+/- error range due to precision of instrument)</b>	<b>Density g/cm<sup>3</sup> (+/- error range due to precision of instrument)</b>	<b>Salinity (from graph) ppt (+/- error range due to precision of instrument)</b>
<b>Princeton Harbor (Pillar Point)</b>			
<b>Fort or North Point</b>			
<b>Oyster Point</b>			

### SALINITY COMPARISONS

Salinity is the total of all the different kinds of salts and minerals dissolved in seawater. We have used two different methods to measure it: using a refractometer to measure light refraction and from that determine salinity (because increased salinity increases the refraction or bending of light); using a hydrometer to measure density and temperature (because increased salinity and decreased temperatures increases the density of water).

<b>25. Why did your different water samples have different salinities (why vary from the average of seawater)?</b>
<b>26. How much difference exists between the two salinity measurements for each location?</b>
<b>27. Which location(s) had the most variation Between the two methods?</b>
<b>28. Which location(s) had the least variation Between the two methods?</b>
<b>29. Provide ideas as to why the same water sample might show two different salinity values, for two different measurement types (be specific).</b>

**30. Make a 35 ppt solution with distilled water and salt. Measure 17.5 grams of salt and add to 500 gram (0.5 kg) of water. Note: 1 kg of water is equivalent to 1 Liter. (Or 3.5 grams of salt per 100 grams of water).**

**Measure this new solution with a refractometer and hydrometer. Record readings below:**

#### HYDROMETER WITH 35 ppt distilled water/salt

<b>Water temperature °C (+/- error range due to precision of instrument)</b>	<b>Density g/cm<sup>3</sup> (+/- error range due to precision of instrument)</b>	<b>Salinity (from graph in prereading) ppt (+/- error range due to precision of instrument)</b>

#### REFRACTOMETER WITH 35 ppt distilled water/salt

<b>Density g/cm<sup>3</sup> (+/- error range due to precision of instrument)</b>	<b>Salinity (from DEVICE) ppt (+/- error range due to precision of instrument)</b>

**31. How do these measurements (with error) compare with the 35 ppt that you know this solution was measured to be? If different, why?**

**32. Measuring Salinity by TASTE**

1. Fill 5 of the same type of cup/glass with the same amount of tap water (use measuring cup to be sure the amount of water is the same.
2. Make 5 small labels (1, 2, 3, 4, 5) and place labels in front of glasses.
3. Add 1/4 tsp of salt to the the glass labeled 1, 1./2 tsp to the glass labeled 2, and so on.
4. Mix each glass until salt is fully dissolved.
5. Fold labels and tape them to the glasses.
6. Mix up samples and use taste to order them again 1-5. (Find someone in your household to share the experience and see if they can also order these correctly.)

**Describe below how well you ordered your samples and how good your taste buds are as a measurement tool for salinity. In what ways is it good? In what ways is it lacking?**

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week’s objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Characterize the normal distributions of surface bay water temperature and salinity, geographically and seasonally.	A   B   C   D   F	
Characterize the normal distributions of bay water temperature and salinity changes with depth, geographically and seasonally.	A   B   C   D   F	
Characterize the tidal fluctuations in water volume and depth in San Francisco Bay, geographically.	A   B   C   D   F	
Compare and contrast the hydrometer and refractometer and taste as methods of measuring water salinity, including the methods of calibration, associated human user error, and ease of use.	A   B   C   D   F	
Characterize the spatial and salinity distribution between Pillar point, Fort Point, and Oyster Point in San Francisco Bay.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week’s content? Did anything in particular help you understand something you’ve always wondered about, or made you think about the world with new eyes?

## San Francisco Bay Seawater Chemistry Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

### SALINITY

<i>Where is <b>surface water salinity</b> highest in the world? And why? (Circle appropriate answer)</i>	<b>Poles</b> <b>Mid-latitudes</b> <b>Tropics</b> <b>Equator</b>	
<i>Where in the water column (with depth) is <b>water salinity</b> highest? And why? (Circle appropriate answer)</i>	<b>Surface</b> <b>Mid ocean</b> <b>Deep ocean</b>	

In San Francisco Bay, salinity and alkalinity values vary from expected seawater values. How and Why?	
---	--

<i>What are the two <b>deepest locations</b> in SF Bay? Why?</i>	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
<i>What is the <b>shallowest location</b> in SF Bay? Why?</i>	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
<i>Where is the <b>highest surface salinity</b> in SF Bay? Why?</i>	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
<i>Where is the <b>location of lowest surface salinity</b> in SF Bay (one place)? Why?</i>	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
<i>Where is the <b>location of highest surface temperature</b> in SF Bay (two general places)? Why?</i>	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
<i>Where is the <b>location of lowest surface temp</b> in SF Bay (one place)? Why?</i>	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	
<i>Where is the <b>depth of highest salinity and lowest temperature</b>? Why?</i>	Shallow Deep	

<i><b>When during a given year is discharge</b> (total volume of water) from the Sacramento and San Joaquin rivers <b>greatest</b>? Why?</i>	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
<i><b>When during a given year is discharge</b> (total volume of water) from the Sacramento and San Joaquin rivers <b>least</b>? Why?</i>	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	

<b><u>When during a given year</u></b> is in San Francisco Bay would you find the <b><u>highest salinity</u></b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
<b><u>When during a given year</u></b> is in San Francisco Bay would you find the <b><u>lowest salinity</u></b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
<b><u>When during a given year</u></b> is in San Francisco Bay would you find the <b><u>highest temperature</u></b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	
<b><u>When during a given year</u></b> is in San Francisco Bay would you find the <b><u>lowest temperature</u></b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	

**QUESTIONS BELOW REQUIRE LAB EQUIPMENT AND SAMPLE WATER**

Determine salinity (using the graph in your other lab) for a sample of water whose <b>Temperature</b> 15C <b>Density</b> 1.016 g/cc. <b>Salinity</b>	Use the <b>refractometer</b> to measure salinity of a sample of seawater. <b>Salinity:</b>
---	---

**KEY**

**SALINITY**

Where is <b><u>surface water salinity</u></b> highest in the world? And why? (Circle appropriate answer)	<b>Poles</b> <b>Mid-latitudes</b> <b>Tropics XXX</b> <b>Equator</b>	Generally in the tropics, because here evaporation rates are high, while precipitation rates are low.
Where in the water column (with depth) is <b><u>water salinity</u></b> highest? And why? (Circle appropriate answer)	<b>Surface</b> <b>Mid ocean</b> <b>Deep ocean XXX</b>	Generally in the deep ocean, water is saltiest, because salty water is denser and sinks. Exceptions exist, however, especially where water is HOT and salty, like with Med or Red Sea water.

In San Francisco Bay, salinity and alkalinity values vary from expected seawater values. How and Why?	Values were all low. The sample we studied contained a combination of seawater and freshwater, because it was taken from the mouth of San Francisco Bay, where freshwater from the Sacramento River mixes with ocean water.
---	---

What are the two <b><u>deepest locations</u></b> in SF Bay? Why?	South Bay Central Bay/GG BridgeX San Pablo Bay Carquinez StraitX Suisun Bay Sacramento River	because river and/or tidal influx through narrow opening. Both = increased power of current, therefore increased erosion.
What is the <b><u>shallowest location</u></b> in SF Bay? Why?	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento RiverX	where sediments are deposited, because of still water or delta formation.
Where is the <b><u>highest surface salinity</u></b> in SF Bay? Why?	South BayX Central Bay/GG BridgeX San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	because highest seawater component; because little freshwater input + high evaporation rates due to shallow water and warm weather.

Where is the <b>location of lowest surface salinity</b> in SF Bay (one place)? Why?	South Bay Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun Bay Sacramento RiverX	because freshwater discharge is so high.
Where is the <b>location of highest surface temperature</b> in SF Bay (two general places)? Why?	South BayX Central Bay/GG Bridge San Pablo Bay Carquinez Strait Suisun BayX Sacramento RiverX	because shallower area so warms from sun faster. Furthest from the cold ocean water.
Where is the <b>location of lowest surface temp</b> in SF Bay (one place)? Why?	South Bay Central Bay/GG BridgeX San Pablo Bay Carquinez Strait Suisun Bay Sacramento River	because largest open ocean component and deep (sunlight can't access).
Where is the <b>depth of highest salinity and lowest temperature</b> ? Why?	Shallow DeepX	because increased salinity usually means increased density, so it sinks. Also, there is a partial salt wedge in the estuary, bringing increased salinity seawater in at depth. Also, no direct sunlight?

<b>When during a given year is discharge</b> (total volume of water) from the Sacramento and San Joaquin rivers <b>greatest</b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) X Summer (6, 7, 8) Fall (9, 10, 11)	Snow in Sierras melts and rainfall levels are highest.
<b>When during a given year is discharge</b> (total volume of water) from the Sacramento and San Joaquin rivers <b>least</b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11) X	No more snow melt and long time since rains.
<b>When during a given year</b> is in San Francisco Bay would you find the <b>highest salinity</b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11) X	Evaporation levels were high all summer and discharge is at its lowest.
<b>When during a given year</b> is in San Francisco Bay would you find the <b>lowest salinity</b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5)X Summer (6, 7, 8) Fall (9, 10, 11)	Discharge is at its highest.
<b>When during a given year</b> is in San Francisco Bay would you find the <b>highest temperature</b> ? Why?	Winter (12, 1, 2) Spring (3, 4, 5) Summer (6, 7, 8) Fall (9X, 10, 11)	The sunlight has had all summer to transfer heat to Bay water.
<b>When during a given year</b> is in San Francisco Bay would you find the <b>lowest temperature</b> ? Why?	Winter (12, 1, 2) Spring (3X, 4, 5) Summer (6, 7, 8) Fall (9, 10, 11)	The sunlight has been at its lowest levels all winter.

**QUESTIONS BELOW REQUIRE LAB EQUIPMENT AND SAMPLE WATER**

Determine salinity (using the graph in your other lab) for a sample of water whose <b>Temperature</b> 15C <b>Density</b> 1.016 g/cc. <b>Salinity</b> X ppt	Use the <b>refractometer</b> to measure salinity of a sample of seawater. <b>Salinity: X ppt</b>
---	---

# Deep Sea Chemistry

## NEEDED SUPPLIES:

In lab all will be provided; at home you'll have to gather these – see notes below:

- Red cabbage
- pH color chart (see below)
- Seawater sample (at home: collect one sample – if no ocean nearby, use lake water or river water)
- Straw
- Sea Salt – fine ground (Goya is a good example)
- Sugar
- $\text{CaCl}_2$  (pick up at hardware store or any store where pickling/mason jars are found )
- Baking soda ( $\text{NaHCO}_3$ )
- Vinegar (Acetic acid:  $\text{CH}_3\text{COOH}$ )
- Bleach ( $\text{NaClO}$ )
- Seltzer water
- Beakers and spoons (at home: use glasses, measuring cups, and spoons)
- Ice
- Toothpick
- Pen and paper for labels
- Kettle for boiling water

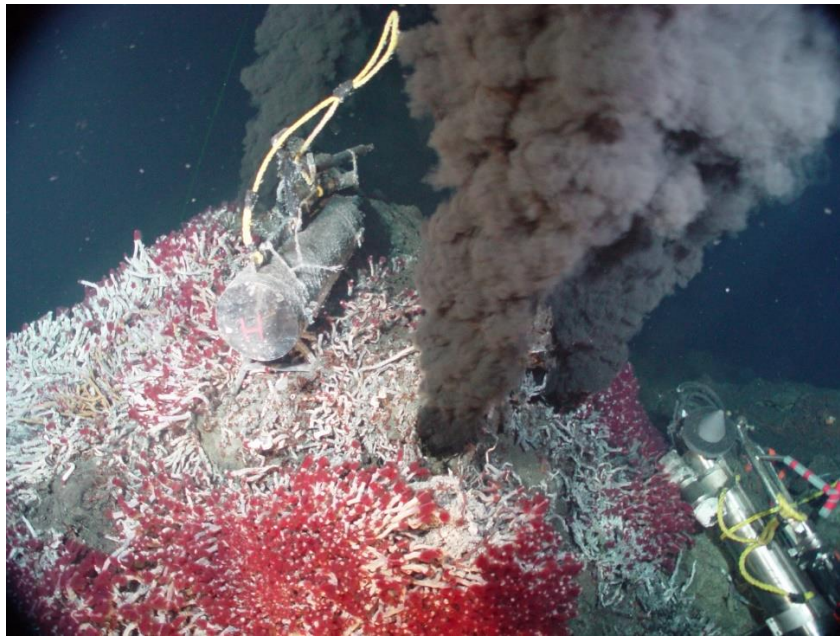
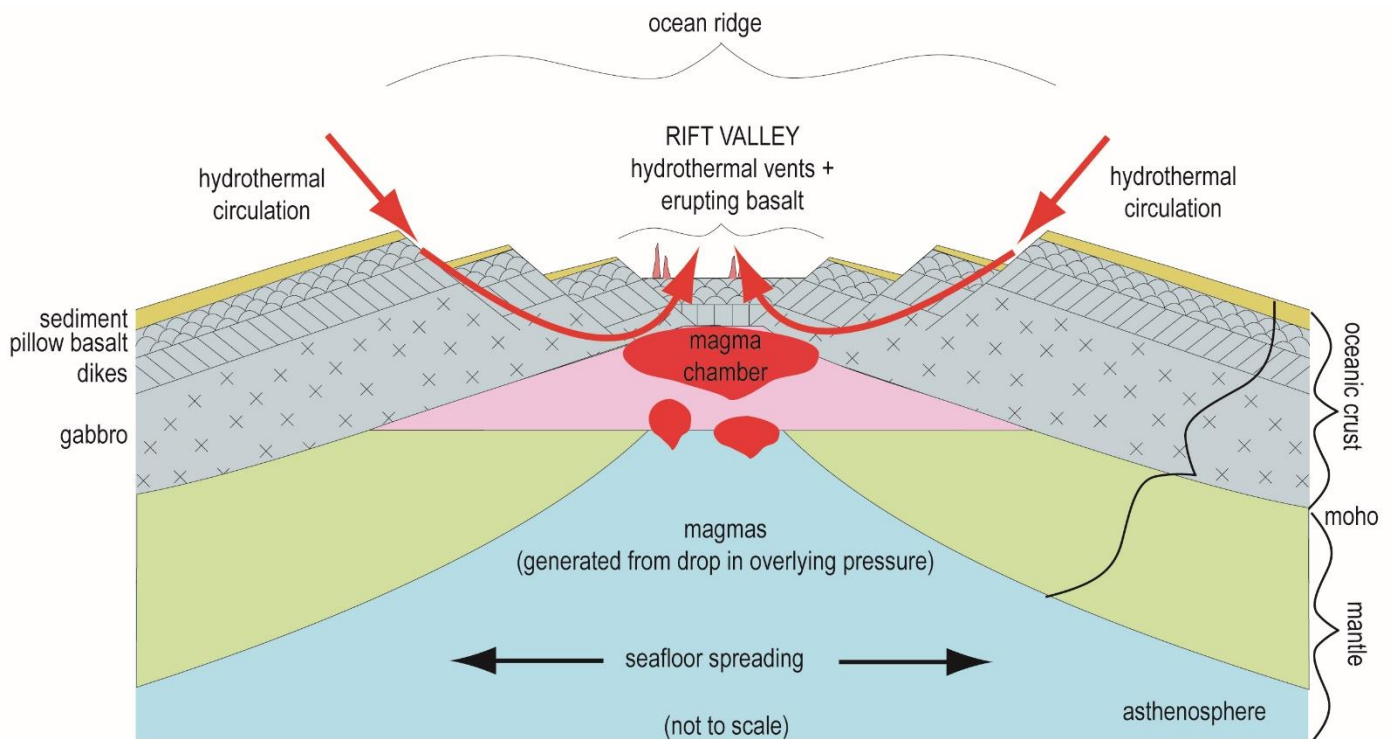
## Hydrothermal Vents

*Adapted from materials produced by Allison Beauregard*

**Hydrothermal vents** are tiny vents (1-5 feet in diameter) in the ocean floor from which hot water emanates (hence the name – “hydro” and “thermal”). Many important oceanic crustal processes occur at these vents and tell us a lot of about the inner workings of the planet. The hot water was originally seawater that flowed down cracks in the crust toward magma chambers about 2 to 3 km under the surface. The water was heated up due to its proximity to the magma chamber (temperatures of close to 1500C), expanded in response, became less dense, and then rose back up to the crustal surface (bottom of the oceans), where it escaped through the hydrothermal vents.

During the water's journey through the crust, it releases some of its **dissolved** ions (like salts), dissolves some of the existing minerals, and leaches out metals from the rocks it encounters. As the liquid becomes hot, when it nears the magma chamber, its dissolution power increases so as the water rises from the magma chamber back to the surface, it continues to pick up more and more dissolved ions, especially iron and sulfur. However, it also begins to slowly cool down, decreasing its dissolving power.

Upon exit from the vent, the temperature of the water is between 350 to 400°C. *Note: the reason that the water temperature can get to such high temperatures without boiling is because of the high pressure at the bottom of the ocean, which increases the boiling point of water.* The temperature of deep ocean water is 0 C. The immediate cooling of the hydrothermal vent fluids as they hit the cold ocean water means that certain ions are no longer stable in the dissolved state. The water can no longer hold them in dissolution. The ions get together with each other and form bonds in solids (typically sulfide minerals), which then precipitate out of the fluid. In this fashion, **chimneys** are formed around the vent. The largest found to date have been ~150 ft tall, while most are between 10 and 20 ft tall (the largest ones eventually fall over because they're so skinny and unstable). Growth rates are up to 6 meters (18 feet) in a year. Chimneys have many internal layers created from successive vent **precipitation**. A similar process happens in your plumbing pipes in your home, where mineral deposits successively line the interior of the pipes over time. The composition of vent fluid is extremely rich in metal-sulfides, which is in contrast to the composition of deep ocean water. It is these chemicals that give hydrothermal vent fluid the characteristic black color that you see in photographs. Because of the black color, these vents are sometimes referred to as a "black smokers". *(Image below by K.Wiese)*



*Sully Vent in the Main Endeavour Vent Field, NE Pacific. A bed of tube worms cover the base of the black smoker. An acoustic hydrophone and resistivity-temperature-hydrogen (RTH) probe surround the vent during ROV ROPOS dive number 852, 2004. (NOAA)*

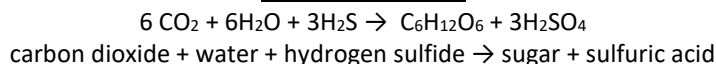
- **Dissolution** is the process where a solid material's atoms are separated from one another (usually pulled apart by the power of other liquid molecules, such as water). During dissolution by water, the dissolved (pulled-apart) ions are now surrounded by attached water molecules (think of a shirt covered by static-cling socks), which prevent them from finding their original bonded solid partners. Note: **Soluble** materials are those that are easily dissolved. **Insoluble** materials will not dissolve. All solids have a specific **solubility**, which is a measurement of how easily they can be dissolved at a given temperature.
- **Precipitation** is the reverse process, where the water molecules release the dissolved ions, allowing them to find their bonding partners, bond, and then create solid crystals that can grow bigger over time and eventually settle out of the fluid.

The other major process that occurs at hydrothermal vents is **chemosynthesis**. Most autotrophs on our planet capture energy from the sun to power the synthesis of sugar from water and carbon dioxide, a process known as **photosynthesis**. In chemosynthesis, sugar is synthesized using energy captured from gases, such as methane or hydrogen sulfide.

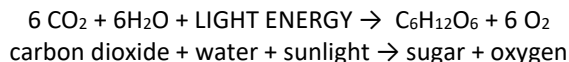
These processes are similar to how the earliest life forms on our planet most likely survived – making their own food (sugars) from energy stored in hydrogen sulfide gases that come out with the hot water in hydrothermal vents. The organisms that developed the ability to survive in these environments can not only capture energy from gases, but also withstand the high temperatures associated with the vents. We call these organisms thermophiles (“thermo” for heat, “phile” for loving that heat). The chemosynthetic thermophiles that thrive around hydrothermal vents today are single-celled archaea bacteria that are likely the same ones that first existed on our planet 3.8 billion years ago (because hydrothermal vents have likely existed on our planet since its first ocean crust solidified). The heterotrophs that feed on these bacteria and on each other are a unique set of organisms that also can withstand high heat. Some of them, such as the large Pompeii tube worms, harvest bacteria that live symbiotically within their tissues. Another big difference between photosynthesis and chemosynthesis is that photosynthesis produces oxygen and chemosynthesis happens without oxygen.

**Respiration** is the opposite of photosynthesis or chemosynthesis. It is the process of splitting up the sugar molecule and releasing the energy stored within, that now becomes available for reproduction, movement, cell growth, etc. All organisms perform respiration. Most do it by burning the sugar in the presence of oxygen, called **aerobic respiration**. Some organisms have developed the ability to break down sugar without oxygen present – **anaerobic respiration**. In most cases, aerobic respiration is more efficient and preferred.

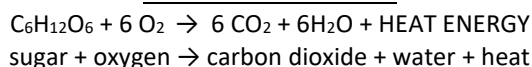
#### **CHEMOSYNTHESIS**



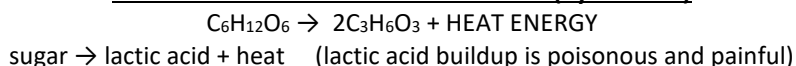
#### **PHOTOSYNTHESIS**



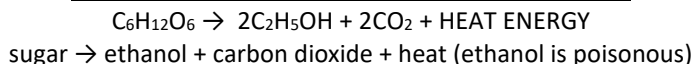
#### **AEROBIC RESPIRATION**



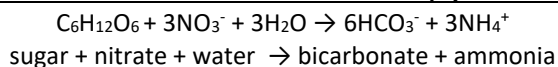
#### **EXAMPLE OF ANAEROBIC RESPIRATION (by humans)**



#### **EXAMPLE OF ANAEROBIC RESPIRATION (by YEAST)**



#### **EXAMPLE OF ANAEROBIC RESPIRATION (by microbes)**



The huge chemical and temperature gradients that occur in hydrothermal vent communities as a result of the mixing of these two fluids tends to sort vent organisms into clearly defined zones. These distinct habitat zones are much like those observed in other habitats, such as the colored zones of different bacterial species that occur around thermal hot springs or in the characteristic zones of rocky tidal habitats. What's interesting about studying the zones of different bacteria present around hydrothermal vents is that doing so allows scientists to investigate a range of life "strategies" for dealing with the very different habitat traits present in each zone.

Hydrothermal vents last for a few years only before their heat source disappears. Old vents die out and with them their biological communities. New vents form miles away. How do organisms get to these new vent locations? Bacteria and larval

organisms are carried in the water column and distributed by currents to new sites. Bacteria are adept at lying dormant until the right conditions come around for their survival. As such, the muds around hydrothermal vents are likely filled with a variety of them.

The main way that scientists study bacterial colonies is to grow large populations in the lab from a few organisms found in soils or rocks (**cultivation**). Often there are many bacteria that lie dormant in soil and rocks waiting for the right conditions to thrive. Scientists take samples of these soils or rocks into the lab and try to recreate natural conditions so they can see the different bacterial colonies grow. Changes to environmental conditions can also be tested to see how various bacterial populations react. One of the big limitations with cultivation is that it is very difficult to culture bacteria from real environmental samples. It is likely that less than 1% of microbes from the marine environment have been successfully cultured. Such difficulty in cultivation means that those scientific data is biased towards the hardy organisms that survive and thus make it even harder to get to the more fragile species.

## **HISTORY**

In the 1950s and 1960s, Wegner's idea of continental drift and Holme's mechanism of convection cells causing plates to move were pulled together. In 1962, Hess combined the two theories to create our modern theory of plate tectonics, incorporating additional evidence showing the mid-ocean ridges as scars created by the splitting apart of plates at divergent boundaries. Hess' idea of seafloor spreading at mid ocean ridges:

- Oceanic crust and upper mantle spread due to convection cells
- Crust forms at mid ocean ridges, moves away from ridges, and forces nearby attached continents apart as the ocean floor grows

Hess has no way to test this idea, so he called it an "essay" rather than a hypothesis and it was pretty well disregarded by the geologic community. During the mid/late 1960s, Vine, Matthews, and Morley discovered magnetic stripes that are symmetrical across mid ocean ridges, explained perfectly by Hess' seafloor spreading hypothesis.

In 1964, British oceanographers found elevated temperatures at the bottom of the Red Sea (~55°C), where it was believed that a divergent boundary existed. In 1965, Woods Hole oceanographers found metal-rich sediment in the same location. These sediments were very different from other deep water sediments that had been discovered at that time. In the late 1960s, Degens and Ross predicted hydrothermal vents would form along mid-ocean ridges due to extrusion of new, warm oceanic crust at spreading centers and the warming of ocean water, thus causing elevated temperatures and metal-rich sediment.

In 1972, the Southtow expedition to the Galapagos rift found elevated temperatures, lots of small earthquakes, and topography that further supported presence of hydrothermal vents. But they still hadn't retrieved or seen any part of a hydrothermal vent. From 1973 to 1976, several cruises in the area, including a few of the first deep Alvin dives, brought scientists to the mid ocean ridge, but didn't find any hydrothermal vents. In 1977, during an Alvin dive in a Galapagos rift, scientists finally found hydrothermal vents! We now know that hydrothermal vents do occur along mid ocean ridges, just as scientists in the 1960s and 70s predicted. The global mid ocean ridge is 55,000-60,000 km (30,000-35,000 mi) long, most of which is unexplored. However, nearly every explored place on the global mid ocean ridge has shown hydrothermal vents and their associated ecosystems!

Hydrothermal vents were not only a very important geological feature on Earth, but also perhaps THE most important biological discovery on Earth. In general, the deep ocean floor is relatively devoid of life—it is very cold and dark and food is scarce. Because of this, they didn't expect there to be much going on in terms of biology at the vent, if they found it, and so they didn't even have a biologist on board the ship. They were shocked to find a previously unknown ecosystem teeming with life!

Life surrounding hydrothermal vents illustrates that life can exist in very harsh conditions. At the vent sites, organisms have to deal with huge pressures that would quickly crush a human. And they have to deal with not only extremely hot temperatures (of up to 400 °C), but highly variable temperatures, since the vent fluid quickly mixes with the surrounding seawater that is just above freezing temperatures. Scientists now refer to organisms that live under such harsh conditions "**extremophiles**".

Perhaps even more striking was the surprising discovery that these ecosystems are completely independent from the sun -- they live in total darkness and thus cannot be photosynthetic. Since the limited food supplies "raining" down from the surface ocean are not sufficient to support the large vent ecosystems discovered, the bottom of the food chain in these areas must be supported by chemosynthesis. Before hydrothermal vents were discovered, scientists believed that ALL life on earth was supported by photosynthesis.

## **EXPLORATION**

Why weren't hydrothermal vents discovered earlier? It is difficult to get to the bottom of the ocean. The deep ocean is so "foreign" or so different from the conditions that we are exposed to on land, that deep ocean exploration is often compared to space exploration.

One of the big challenges that both space explorers and deep-sea explorers must overcome is the low level of oxygen -- levels that are too low for human survival. The oxygen that is present in the deep ocean is dissolved in water, so even though it is present, it is not accessible to humans. Another obstacle that must be overcome in the deep ocean is the buoyancy in the deep ocean, which makes it difficult to travel to a desired location and to securely hold your position. In the deep ocean, the enormous pressure of the ocean water would crush a human very quickly and cause death and the temperature can vary from 0-4°C in most of the deep ocean, to temperatures as high as 350 or 400°C in vent fluid.

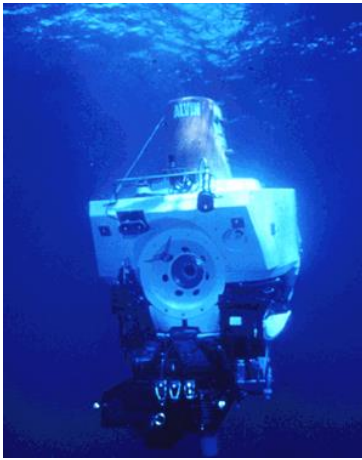
In the 1950s and 60s, deep ocean explorers experimented with sending tethered cameras and probes to record temperature data into the deep ocean, which allowed for some exploration while keeping humans safely at the ocean's surface. However, cameras could be sent down for twelve hours, taking thousands of photographs that scientists had to look through -- a very labor-intensive process.

In the 1960s and 70s, scientists started using mini submarines, called HOVs "human operated vehicles" to explore the deep ocean. The most famous HOV is the Alvin, out of Woods Hole Institute of Oceanography in Massachusetts. The advantage of using Alvin is that humans actually get to go down to the deep ocean and see what is there. Alvin is also outfitted with various arms and probes for manipulating experiments, taking measurements, and collecting samples to bring back to the surface.

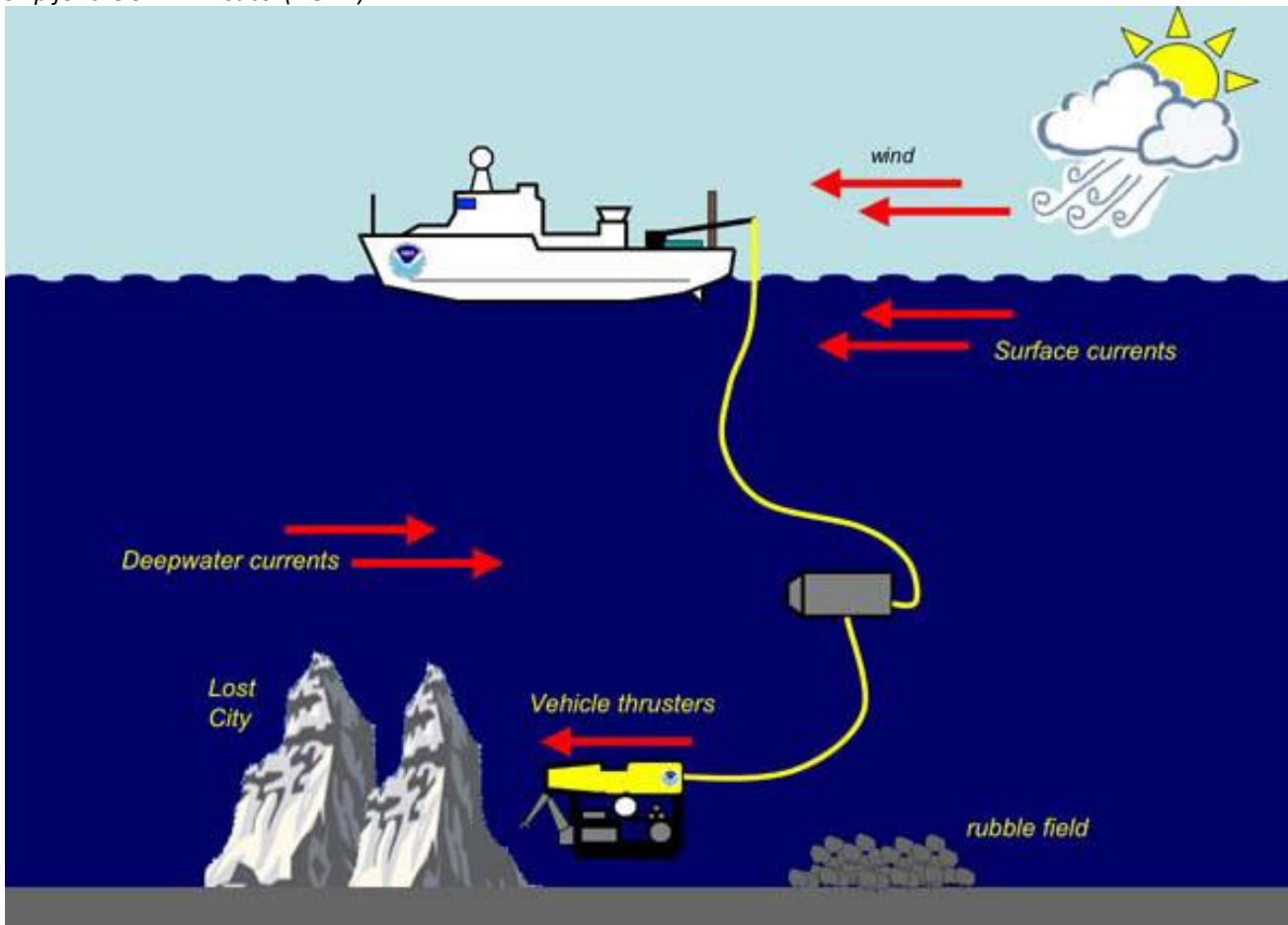
There is an inherent risk involved with humans traveling to such an extreme environment. Thus there are also now some more advanced vehicles that remove this human risk -- remotely operated vehicles (ROVs) or autonomous underwater vehicles (AUVs). An example of a remotely operated vehicle is Jason. ROVs are usually outfitted with lots of cameras (both video and still), probes, and sampling arms -- much like the Alvin that we just discussed -- but ROVs do not carry humans. ROVs have reduced mobility (compared to HOVs), as they are tethered to the ship, but they can send real time images and data to scientists aboard the main vessel. ROVs also allow for a longer period of time that the instruments are actually on the seafloor collecting samples. Jason can be on the bottom indefinitely, with average bottom times of approximately 21 hours, whereas Alvin is limited to only a few hours of bottom time.

Engineers have also developed AUVs or autonomous underwater vehicles that are not attached to the ship. Like ROVs, AUV pilots are safely on the ship. An example of an autonomous underwater vehicle is Sentry. Typically AUVs have limited sampling gear compared to ROVs. They are also set up for a pre-determined task (it's harder to change their mission en route). AUVs and ROVs are often used together for hydrothermal vent investigations: the AUV will do larger scale sampling of an area and then the ROV will follow up with more fine-scaled or detailed sampling of one particular area, based on the data collected by the AUV.

Recently, engineers have developed some hybrid vehicles that can function as either an autonomous underwater vehicle or as a remotely operated vehicle. An example of a hybrid vehicle is the Nereus, which can operate in the autonomous mode for surveying large areas or can operate in the ROV-mode for more detailed sampling of a small area.



LEFT: The Alvin submarine deployed from the R/V Atlantis II below water after the launch and en route to the deep seafloor. (Photograph courtesy of the Woods Hole Oceanographic Institution and USGS). RIGHT: R/V Natsushima, Japan's support ship for the SHINKAI subs. (NOAA)



Three vehicles have to stay in alignment in order to navigate the towers of Lost City. The NOAA ship Ronald H. Brown is tethered by a cable to IFE's ROV Argus, which is tethered to IFE's ROV Hercules. Wind pushes the ship one direction, deep currents push both the Argus and the Hercules in various directions, and all three vehicles are powered to move independently. The coordination is a difficult dance of sophisticated machinery. Image courtesy of Dr. Peter Girguis, Lost City science party vis NOAA Ocean Explorer.

### Synergistic Effects of pH

Synergy is the process whereby two or more substances combine and produce effects greater than their sum. When acid waters (waters with low pH values) come into contact with certain chemicals and metals, the chemicals and metals often make the acid waters more toxic than normal. As an example, fish that usually withstand pH values as low as 4.8 will die at pH 5.5 if the water contains 0.9 mg/L of iron. Mix an acid water environment with small amounts of aluminum, lead, or mercury, and you have a similar problem—one far exceeding the usual dangers of these substances.

The pH of sea (salt) water is not as vulnerable as fresh water's pH to acid wastes. This is because the  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$  (carbonate and bicarbonate) in seawater tend to buffer the water. Many shellfish and algae are more sensitive than fish to large changes in pH, so they need the sea's relatively stable pH environment to survive.

pH is a measure of the balance between the hydrogen ion ( $\text{H}^+$ ) and the  $\text{OH}^-$  ion (both form when the water molecule dissociates). A pH value of 7 is **neutral**:  $\text{H}^+$  and  $\text{OH}^-$  are present in equal amounts. pH above 7 indicates that there is more  $\text{OH}^-$  than  $\text{H}^+$ ; such solutions are called **basic**. The higher the pH (14 maximum), the more  $\text{OH}^-$  is present. pH values below 7 indicate more  $\text{H}^+$  than  $\text{OH}^-$ ; such solutions are called **acidic**. The lower the pH, the more  $\text{H}^+$  is present. Natural fresh water and marine environments are normally between 7.5 and 8.5 (slightly alkaline). Your blood is 7.14 (almost neutral); your stomach is 1.5 (strongly acidic); and lemon juice is 3.5 (mildly acidic). The legal value for San Francisco Bay is between 7.0 and 8.5.

Normal pH values in seawater are about 8.1 at the surface and decrease to about 7.7 in deep water. The reason for the lower pH at depth is because pH changes most readily with the concentration of dissolved  $\text{CO}_2$  gas. The more such gas exists, the more  $\text{H}^+$  ion in the water, and hence, the more acidic it is (the lower the pH). And vice versa. More gas is dissolved at depth, because decreased temperatures and increased pressures increase the solubility of gases.

### Alkalinity

Alkalinity is a measure of the amount of ions dissolved in seawater than can combine with  $\text{H}^+$  or release  $\text{H}^+$  thereby enabling an equilibrium point for seawater pH (also known as buffering pH). In seawater, the most abundant ions available to perform this action are carbonates. Thus total alkalinity is usually equal to the total concentration of carbonate and bicarbonate. Alkalinity is not a pollutant. When concentrations are low, it becomes easier to change pH in that area (by adding acids or bases to water, like in coastal regions). When concentrations are high, buffering capacity is high, so excess acids or bases are neutralized quickly.

**The buffer equation for pH in water:**  $\text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{HCO}_3^- + \text{H}^+ \rightleftharpoons \text{CO}_3^{2-} + 2\text{H}^+$

Water + carbon dioxide  $\rightleftharpoons$  carbonic acid  $\rightleftharpoons$  bicarbonate + hydrogen ion  $\rightleftharpoons$  carbonate + hydrogen ion

Add acid to water and the above reaction will move to the left to remove the acid and neutralize the water. Add base to the water, and the reaction will move to the right to produce more  $\text{H}^+$  to neutralize the  $\text{OH}^-$ . To illustrate, we will compare two samples of pure water and buffered water. Absolutely pure water has a pH of exactly 7.0. It contains no acids, no bases, and no (zero) alkalinity. A sample of buffered water might have a pH of 6.0, but high alkalinity. If we add a small amount of weak acid to both water samples, the pH of the pure water will change instantly (become more acid). But the buffered water's pH won't change easily because the buffers absorb the acid and keep it from expressing itself.

Buffering pH in the oceans is important for aquatic life because many sensitive biological processes such as brain function depend on a stable pH. Buffered seawater also makes water less vulnerable to acid rain. The main sources of natural alkalinity in the oceans is dissolved  $\text{CO}_2$  gas produced during respiration and decomposition, and dissolved from atmospheric gases.

### Chemical testing—Volumetric tests (Titration)

The chemical test for alkalinity is volumetric: we measure concentration by volume of reactant added. For example, suppose that molecule X and molecule Y combine to form molecule XY. If we want to know how much of molecule X is in a test sample, we add measured amounts of molecule Y until the two stop combining. If we keep track of the amount of Y added (measured in terms of its volume), we know how much X was in the sample. To tell when enough Y has been added, we use an indicator – something that changes color when all of the X in our sample has been used up. For example, in the alkalinity test, the indicator turns color when all of the carbonate ions (X) in the sample have reacted with the reagent (Y) that we add to the sample.

## Deep Sea Chemistry – Prereading Exercises

1. What happens to temperature as you move outward from a hydrothermal vent? (Include actual temperature values)
2. What happens to abundance of sulfides and hydrogen sulfide gas as you move outward from a hydrothermal vent?
3. <b>What type of ecological zonation would you expect as a result?</b> (What are the physical, chemical, and biological changes/zones you'll see as you move outward from the vent – what kinds of organisms will you see living in each of these zones?)
4. Where would photosynthesizing organisms be found in this zonation? Why?
5. Where do bacteria that live in hydrothermal vents come from (how did they get there)?
6. How many bacterial species have scientists been able to culture to date?
7. When were hydrothermal vents first discovered?
8. What are chimneys made of? How?
9. What is the original source of waters that emanate out of hydrothermal vents?
10. What process happens to salt and sugar crystals when you put them in water?
11. How can one get dissolved salt out of water?
12. Write the buffering equation below and circle the components that are part of what we call the <b>alkalinity</b> of a sample?
13. What does it mean for a sample of water to have high alkalinity? Low?
14. How does <b>pH</b> change with <b>depth</b> in the world ocean (average)? Where is it highest and lowest? Why?

## Deep Sea Chemistry – Lab Exercises

### How Do Vents Form? Precipitation of Insoluble Material

- **Soluble** = a description of a solid substance that dissolves when added to a liquid. Example, salt is soluble in water.
- **Insoluble** = a description of a solid substance that remains solid when in a liquid solution. Example, once you reach the maximum amount of salt that can be dissolved in a glass of water (it's now **saturated**), no more salt can be dissolved, and any additional salt that is added will be insoluble (remain a solid).

The chimney-like structure of hydrothermal vents forms as a result of chemical solids precipitating out of solution when chemicals in the vent fluid react with chemicals in ocean water. Over time, layers of precipitated material settle out of the water column and eventually create the characteristic smoke stack structure of hydrothermal vents. The rapid decrease in temperature that occurs as hot vent fluid mixes with cold ocean water causes some chemicals to be less soluble in water and therefore to precipitate, or come out of solution. Additionally, chemicals that are dissolved in the vent fluid can react with chemicals dissolved in the ocean water so that the resulting chemical product is insoluble; the product would precipitate out of solution as a solid. During this exercise, students will investigate both of these reasons that chemicals precipitate out of solution at vents.

Some chemicals are soluble in water, while others are not. Think about how reactions between chemicals in ocean water and those in hydrothermal vent fluid would create both soluble products as well as insoluble products and discuss how this might contribute to the idea that hydrothermal vents can be a "source" for some chemicals dissolved in seawater and can be a "sink" for other chemicals dissolved in seawater.

#### 1. Temperature and Solubility

In this section, we will investigate how the solubility of solids changes with water temperature. Before you begin, write out your hypothesis on how you believe the solubility of sugar will change as the temperature of the water changes.

Hypothesis:

#### Procedure:

*Needed: 3 glasses, 3 spoons, ice, granulated sugar, 1 extra cup, kitchen or phone timer, toothpick, paper and pen for labels.*

1. Locate 3 glasses (preferably similar in size and transparent). Set them alongside each other on a flat surface in your kitchen (preferably by sink).
2. Create 3 labels and set each in front of one of your 3 glasses: "cold", "room temp," and "warm".
3. Fill the cold-labeled glass with 1 cup of tap water, fill it with ice, and put in freezer (it should be in there for at least 5 minutes before you remove it – see below where you'll do that).
4. Fill the room-temp-labeled glass with ½ cup of room temperature tap water and set down in front of its label.
5. Put 1 cup of hot water into a kettle or microwave and boil it.
6. After the water has boiled pour ½ cup of it into the warm-labeled glass.
7. Measure 2 tsp of sugar into the warm-labeled glass and start a timer.
8. Record below the initial amount of dissolution (instantly upon dropping into the water).
9. Begin stirring, and after 30 seconds, note how much has dissolved.
10. Continue until all is gone. Record notes in table.
11. Repeat the above procedure for the room-temp-labeled water. Restart time and begin as soon as you add 2 tsp of sugar to the water. Record notes in table.
12. Take the cold-labeled glass out of the freezer, dump its contents into an extra cup and then pour ½ cup of that water (no ice) back into the cold-labeled glass.
13. Repeat the above procedure for the cold-labeled water. Restart time and begin as soon as you add 2 tsp of sugar to the water. Record notes in table. *(Add all sugar solutions together into one glass, add toothpick, and set aside for a week.)*

	COLD	ROOM TEMP	HOT
% of your 2 tsp that appears to dissolve instantly upon meeting the water.			
How much sugar has dissolved at time = 30 seconds? (enter a percentage from 0 to 100)			
How much sugar has dissolved at time =1 minute? (enter a percentage from 0 to 100)			
How much sugar has dissolved at time =1.5 minutes? (enter a percentage from 0 to 100)			
How much sugar has dissolved at time =2 minutes? (enter a percentage from 0 to 100)			
RECORD ADDITIONAL NOTES FOR EACH SAMPLE			

2. For any of your samples that has fully dissolved, continue to add sugar and stir, until you can dissolve no more (your solution is saturated). Keep track of that amount and record it below.

	COLD	ROOM TEMP	HOT
Tsp of sugar added (in addition to original 2 tsp) to reach saturation (sugar is no longer dissolving).			

3. Provide two different hypotheses for how you could you get these saturated sugar solutions to precipitate out their sugar. *(Observe the sugar solution mixture in the glass over the next week to see what happens – and post a photo on the class website student photos album of what it looks like one week from today. Go to site to see other student photos from previous semesters.)*

4. Based on your observations, list the water (cold, room temp, and hot) in order from least soluble to most soluble, in terms of its ability to dissolve sugar.

5. In one sentence, what is the relationship between water temperature and solubility of sugar crystals?

6. Do your findings support your original hypothesis?

7. Based on the results of this experiment, explain one mechanism by which the chimney-like structure of hydrothermal vents forms.

### 8. Chemical Reactions Between Soluble Compounds

In this section, you are going to investigate chemical reactions between two soluble compounds. Before you begin, answer:

Do you think chemical reactions between two compounds that are soluble in water will always produce products that are soluble in water? Or can some soluble compounds react to form insoluble products?

**Procedure:**

Needed: 2 glasses, 2 spoons, Baking soda ( $\text{NaHCO}_3$ ),  $\text{CaCl}_2$  (pickle crisp)

1. In one glass, add 1 tsp of **baking soda ( $\text{NaHCO}_3$ )** to  $\frac{1}{2}$  cup of room temperature tap water. Mix with spoon to dissolve all solid. **(If all solid doesn't dissolve, keep adding small amounts of water until it does).**
2. In second glass, add 1 tsp of  **$\text{CaCl}_2$  (pickle crisp)** to  $\frac{1}{2}$  cup of room temperature tap water. Mix with spoon to dissolve all solid. **(If all solid doesn't dissolve, keep adding small amounts of water until it does).**
3. Record observations. Are both substances equally soluble?
4. Pour one glass contents into the other (mix your two samples).
5. Record observations. *(Dispose of all water down drain and clean and dry for next procedure.)*

	What does solution look like?	Is this compound soluble in water?
<b><math>\text{CaCl}_2</math> solution (pickle crisp + water)</b>		
<b><math>\text{NaHCO}_3</math> solution (baking soda + water)</b>		

	What do products of reaction look like?	Are products water soluble?
<b>Reaction of <math>\text{CaCl}_2 + \text{NaHCO}_3</math></b>		

**\*Take photo and add to class photo album (see link on website).**

9. Do your findings support your original hypothesis?

10. Based on the results of this experiment, explain a second mechanism by which the chimney-like structure of hydrothermal vents forms?

**pH AND ALKALINITY**

**11. Making your own pH indicator**

**Procedure:** *Needed: 1 large glass or pitcher, ¼ of a red cabbage, filter, separate container to hold indicator*

1. Cut a red cabbage into 4 parts – we'll use just ¼ -- cut that ¼ into small pieces (by hand or using food processor).
2. Add tiny cut pieces into large pitcher or glass and fill with with about 2 cupts of boiling water.
3. Let soak for 15 minutes.
4. Filter liquid into another glass (to remove cabbage pieces).
5. Fill a separate glass with 2 cups of tap water and add about ¼ cup of indicator -- enough to turn it from purple to blue. This is now our diluted pH indicator. You will be adding small amounts of this to other items as described in lab below. So repeat 3 times to make at least 6 cups worth!

**12. pH**

**Procedure:**

*Needed: pH indicator made above, 1 seawater sample, sea salt, Baking soda (NaHCO3), Vinegar (Acetic acid: CH3COOH), Bleach (NaClO), 5 glasses*

<b>Seawater sample location and date/time:</b>	
--	--

1. Place 5 glasses on counter near sink. Create 5 labels and set them in front of each: vinegar, seltzer water, tap water, baking soda solution (1 tsp of baking soda + ½ cup of water), bleach
2. Measure out exactly 1 cup of red cabbage indicator and place in each glass. *(note: you'll also need 1 cup for final procedure, so don't use it all. If not enough, just add equal amounts to each glass and leave 1 extra unit for later.)*
3. Pour about ¼ cup of vinegar into the vinegar-labeled glass (or less – just pour until there's a color change)
4. Repeat step 3 for remaining solutions (add about ¼ cup of tap water to its labeled glass with the indicator; ¼ cup of seltzer water to its labeled glass with the indicator, ¼ cup of the baking soda mixture to its labeled glass with the indicator; for each glass, stop when there is a color change).
5. Compare colors with pH color chart below. Arrange in the same order and then record color and pH estimate in table.



pH color chart for red cabbage pH indicator. Red to light pink ranges from 1-4, Purple and dark blue: 5-6, Medium to light blue around 7, Green-blue: 8-12, Yellows: 14. image by V. Belkhir

6. Determine and record pH of samples in time = 0 row in table below. Include error range based on instrument precision. Keep these samples out for comparison with the next set of procedures below (do not dump them yet!).

	Vinegar	Seltzer Water	Tap Water	Baking soda solution	Bleach
<b>Color and estimated pH</b>					

**\*Take photo and add to class photo album (see link on website).**

### 13. pH and alkalinity

In this section, you are going to investigate how alkalinity affects pH changes (buffering). Before you begin, answer:

List the following substances in order from highest anticipated alkalinity (and buffering capability) on the left and least on the right: baking soda solution, seltzer water, tap water. Explain why you chose this order.

When you add acid to the above substances, how will you anticipate each will respond?

#### Procedure:

*Needed: seawater and tap water and baking soda samples from previous procedure, vinegar, small measuring glass, measuring spoons*

1. Pull the seawater and tapwater and baking soda solution samples forward, with their labels.
2. Add about 1/8 cup of vinegar to a small glass (or leave in measuring cup).
3. Use a 1/8 teaspoon (or if you don't have one, use a ¼ tsp) to add vinegar from this small glass, 1/8 tsp at a time, to the tap water sample. Mix after each addition. Stop after the addition has change the pH (color of the pH indicator). Record below.
4. Repeat for seawater sample. Record below.
5. Repeat for baking soda solution. Record below.
6. Discard these solutions when done, but keep your original Vinegar and Seltzer water pH samples for comparison in next procedure.

	Baking soda solution	Seawater	Tap Water
<b>Color of pH indicator and estimated pH (give error range)</b>			
<b>Starting point</b>			
<b>Final point</b>			
<b># tsp of vinegar added to reach final point</b>			

Describe results for adding vinegar. Did pH change for all in same amount and at same rate? Why or why not?

Do your findings support your original hypothesis?

#### 14. pH and CO<sub>2</sub>

In this section, you are going to investigate how CO<sub>2</sub> affects pH. Before you begin, answer:

What do you expect to happen to pH of a liquid when CO<sub>2</sub> is added to it? Why?

#### Procedure:

*Needed: tap water, straw, glass, pH indicator from above*

1. Add 1 cup of pH indicator to a glass. Add enough tap water to create a light blue color (might already start this way, in which case, just leave as is). Note color of starting position below.
2. Use a straw to blow bubbles (your breath will be mostly CO<sub>2</sub>) into the sample for 2 minutes or until color changes to a new pH (take breaks and be sure you don't drink/inhale any of the sample).

Time	Color of tap water solution	Estimated pH
0		
30 seconds		
1 minute		
1.5 minutes		
2 minutes		

Do your findings support your original hypothesis?

Propose an experiment or procedure to return the sample to its original pH. Describe it below.

If possible, complete that experiment and describe results below:

What is the difference between these last two procedures (buffering/alkalinity and pH/CO<sub>2</sub>)?

## OPTIONAL EXTRA: Investigating Vent Microhabitats: Winogradsky Column

The physical and chemical environment of hydrothermal vent systems varies tremendously to create a large number of zones of different habitats. These habitat zones will vary in terms of vastly different temperatures and chemical properties. Organisms that are adapted to the very specific conditions in each habitat zone will therefore also be present in different zones, or bands, around the vent system. Bacteria are the base of the hydrothermal vent ecosystem and therefore represent an important "player" in these communities – thus, they are an interesting group to focus on during an investigation of these species bands. Additionally, different species of bacteria are often different colors, so it can be easy to visually see bands of different bacterial species in culture. We obviously can't easily get to a hydrothermal vent to observe the habitat zones that occur there, so we will use local aquatic bacteria to observe how spatial differences in the physical environment can explain the general distribution of life and will use this as a proxy for analogous biological bands in hydrothermal vent systems.

In this exercise, we look at Winogradsky Columns: model systems in which spatial gradients in physical parameters (i.e., oxygen and sulfur concentration) are created. There are bacteria within all muds – many of them lying dormant until the right conditions appear for their success. By creating a closed system of sediment, we can watch various bacterial colonies grow and thrive in different zones of the column – where oxygen and sulfur and nutrients are varying. Much the same thing happens to bacteria in muds on the bottom of the seafloor – especially around hydrothermal vents, where conditions are especially challenging. The resulting habitat bands lead to the formation of bands of different species of bacteria. Because the different bacterial species are different colors, we can easily see these bands when they form.

*To make your own Winogradsky Column, you need the following materials:*

- A clear plastic bottle within which to make a Winogradsky Column (must have an airtight seal and ideally a wide mouth). Example: discarded Gatorade bottles
- Enough wet sediment to fill the columns 80% (you can collect sediment from any shoreline or lake near your house)
- Extra water from this sediment location (store in bottle)
- 1 raw egg per column
- Shredded newspaper (1/2 of a full sheet per column)
- Electrical or duct tape to really seal the top closure
- one wooden dowel or plastic knife
- a small bucket
- Egg shell (crushed)

*Procedure:*

- 1) Shred a piece of newspaper into very small pieces and add them to the bottom of your empty column, along with one raw egg (no shell).
- 2) Put a few cups of wet sediment in your bucket (enough to fill columns 80%).
- 3) Carefully sift through the sediment with your hands and remove any sticks, rocks, leaves, etc.
- 4) While stirring, slowly add water from the site where your sediment was collected until the mixture is the consistency of a milkshake. Also add the eggshell (after you've crushed it). Be careful not to add too much water.
- 5) Slowly add your sediment to the column – adding in 4-6 cm increments. If you need to, gently tap the column on the desk so that the sediment settles to the bottom of the column.
- 6) After each increment, work the wooden dowel or plastic knife slowly into and out of the sediment layer to remove any air bubbles.
- 7) Continue to work in batches to add a small layer of sediment to the column and then remove air bubbles with the dowel/knife until the sediment layer reaches 2-4 centimeters from the top of the column (or until it is about 80% full).
- 8) Gently add or remove enough pond or stream water on the top of the column so that you have a layer of water approximately 2 centimeters deep over the sediment. If your sediment is more mud-like, you should wait approximately 30 minutes for the mud and water to settle before you add or remove any water.
- 9) Clean the inside and outside of the top so you can see into water from the outside of the column. Cover the column with the top. Ensure it is airtight. (Use tape to secure it closed.)
- 10) Set column in a spot where it gets partial sunlight (not too hot!) and watch it evolve over the next few months as varying bacterial colonies grown.

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Explain the formation process of chimneys at hydrothermal vents.	A   B   C   D   F	
Describe the symbiotic relationships among extremophiles that live at hydrothermal vents.	A   B   C   D   F	
Measure the pH of a substance	A   B   C   D   F	
Explain buffering and evaluate the buffering capability of a substance.	A   B   C   D   F	
Describe the causes and consequences to changing the amount of carbon dioxide dissolved in the oceans.	A   B   C   D   F	

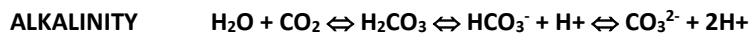
## INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

## Deep Sea Chemistry Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

1. What would you expect to happen over time to the oxygen concentration in sediment that is buried or otherwise removed from interaction with open air and water (closed)?	
2. Where in the Winogradsky column would anaerobic respiration most likely occur? Why?	
3. Where in the Winogradsky column would sulfides most likely form? Why?	
4. Do chemical reactions between two compounds that are soluble in water always produce products that are soluble in water?	
5. What are hydrothermal vent chimneys made of?	
6. Where does the water come from that pours out of hydrothermal vents?	
7. Describe two mechanisms by which the chimney-like structure of hydrothermal vents form.	
8. What happens to the solubility of material as temperature cools? (Would these materials more likely dissolve or precipitate?)	
9. What happens to temperature as you move outward from a hydrothermal vent? (Include the actual temperature values)	
10. Where do bacteria that live in hydrothermal vents come from (how did they get there)?	
11. What process forms the base of the food chain in hydrothermal vents? Where does the energy come from that feeds the ecosystem?	
12. When were hydrothermal vents first discovered?	



Circle, in the above equation, the components you measured in the lab (and that comprise alkalinity of seawater).		
Where does CO <sub>2</sub> come from in the oceans?		
If more CO <sub>2</sub> is added to the oceans, what direction does this equation move and what happens to pH as a result?		
If the alkalinity is high, what happens when acids (H <sup>+</sup> ) are added to the oceans (what direction does the above equation move?)		
What happens to the pH?		
What is this process called?		
If the alkalinity is low, what does it mean for your sample of seawater?		
<i>Where in the water column (with depth) is <b>CO<sub>2</sub> content highest (and hence pH lowest)</b>? And why? (Circle appropriate answer)</i>	Surface Mid ocean Deep ocean	

**KEY**

1. What would you expect to happen over time to the oxygen concentration in sediment that is buried or otherwise removed from interaction with open air and water (closed)?	<b><i>Used up by respiration and decomposition.</i></b>
2. Where in the Winogradsky column would anaerobic respiration most likely occur? Why?	<b><i>Furthest from surface and light because furthest from oxygen source.</i></b>
3. Where in the Winogradsky column would sulfides most likely form? Why?	<b><i>Furthest from light, where chemosynthesis likely to happen.</i></b>
4. Do chemical reactions between two compounds that are soluble in water always produce products that are soluble in water?	<b><i>No</i></b>
5. What are hydrothermal vent chimneys made of?	<b><i>Sulfides</i></b>
6. Where does the water come from that pours out of hydrothermal vents?	<b><i>Seawater that penetrated ocean crust, was heated up by magma chambers, and rose up through center of ridge.</i></b>
7. Describe two mechanisms by which the chimney-like structure of hydrothermal vents form.	<b><i>Precipitation due to chemical reactions that create insoluble compounds. Precipitation due to drop in temperature.</i></b>
8. What happens to the solubility of material as temperature cools? (Would these materials more likely dissolve or precipitate?)	<b><i>Less soluble as temperature drops. Thus precipitate.</i></b>
9. What happens to temperature as you move outward from a hydrothermal vent? (Include the actual temperature values)	<b><i>Gets cooler (goes from 400C to 0C)</i></b>
10. Where do bacteria that live in hydrothermal vents come from (how did they get there)?	<b><i>Dormant – distributed through currents as larvae and lie dormant until conditions are right.</i></b>

11. What process forms the base of the food chain in hydrothermal vents? Where does the energy come from that feeds the ecosystem?	<b>Chemosynthesis: production of sugars from H<sub>2</sub>S gas.</b>
12. When were hydrothermal vents first discovered?	<b>1977.</b>

**ALKALINITY**       $\text{H}_2\text{O} + \text{CO}_2 \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+ \leftrightarrow \text{CO}_3^{2-} + 2\text{H}^+$

Circle, in the above equation, the components you measured in the lab (and that comprise alkalinity of seawater). <b>HCO<sub>3</sub><sup>-</sup> CO<sub>3</sub><sup>2-</sup></b>		
Where does CO <sub>2</sub> come from in the oceans?	<i>Atmosphere, respiration, shell dissolution.</i>	
If more CO <sub>2</sub> is added to the oceans, what direction does this equation move and what happens to pH as a result?	<i>Moves to right, producing more H<sup>+</sup> and hence lower pH (more acidic)</i>	
If the alkalinity is high, what happens when acids (H <sup>+</sup> ) are added to the oceans (what direction does the above equation move?)	<i>Equation moves to left. The acid (H<sup>+</sup>) is removed</i>	
What happens to the pH?	<i>The pH DOES NOT change.</i>	
What is this process called?	<i>This process is called BUFFERING.</i>	
If the alkalinity is low, what does it mean for your sample of seawater?	<i>Its pH can change easily by adding or removing acid.</i>	
<i>Where in the water column (with depth) is <b>CO<sub>2</sub> content highest (and hence pH lowest)</b>? And why? (Circle appropriate answer)</i>	<b>Surface</b> <b>Mid ocean</b> <b>Deep ocean XXX</b>	<i>CO<sub>2</sub> higher at depth because of increased pressures increasing solubility.</i>



# Global Climate Change

Modified from Kathryn Hoppe, Green River Community College

## The Global Carbon Cycle:

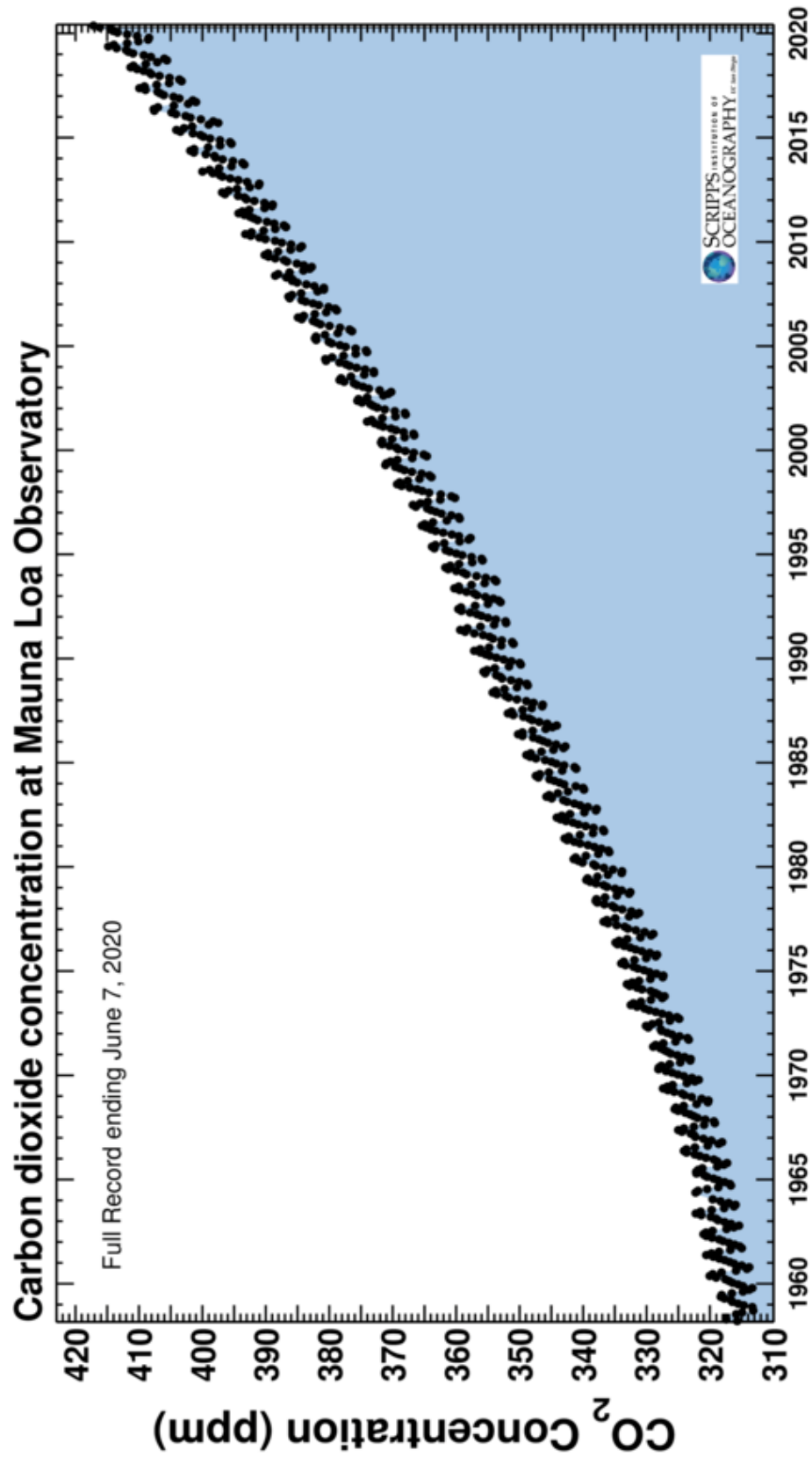
"One hundred and fifty years ago humans started a grand, uncontrolled experiment with carbon on earth. We don't know exactly how the experiment will turn out, but it will certainly change our climate and our lives." -George Kling

Nitrogen and oxygen are the major gases in the Earth's atmosphere. All the remaining gases are "trace gases," including carbon dioxide and the other "greenhouse gases." Greenhouse gases prevent heat from escaping into space from the Earth's surface, thus they cause the temperature of the atmosphere to slowly rise over time. Some greenhouse gases occur naturally in the atmosphere, while others result from human activities. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Certain human activities (such as the burning of fossil fuel) add to the levels of most of these naturally occurring gases.

Global warming is the observed increase in the average temperature of the Earth's atmosphere and oceans over the last 150 years. The prevailing scientific opinion is that most of this warming is due to human activities, which have resulted in an increase in greenhouse gasses in the Earth's atmosphere. Global warming has long been predicted to result from increasing greenhouse gases in the atmosphere. Global surface air temperature has indeed increased in the past century, but at a rate less than 0.1°C/decade. Record global temperatures have been achieved several times in the last several decades, but a new record often exceeds the old record by only a few hundredths of a degree. What relevance, if any, do such small temperature changes have to most people? In the following exercises you will look at temperature records from a variety of location and examine the significance of these changes yourself.

## Carbon Dioxide (CO<sub>2</sub>) Levels in our Atmosphere over Time

The more carbon dioxide and the other greenhouse gases in the atmosphere, the more heat from the sun is trapped in the atmosphere. This graph is from measurements of carbon dioxide in the atmosphere from March, 1958 Mauna Loa observatory on Hawai'i. This site is thought to be the least polluted air on the Earth because there is no source of air pollution upwind for thousands of miles from Mauna Loa.



Atmospheric carbon dioxide concentration at Mauna Loa, Hawaii since 1957. Source: Scripps College of Oceanography

## Global Climate Change – Prereading Exercises

1. Describe how much the amount of CO<sub>2</sub> varies over the course of one year. (Just the observations.) and what the pattern of this variation is (Hint: for close up of one year follow links on class website)

2. What advantages are there to measuring CO<sub>2</sub> content in the atmosphere in Hawaii rather than on the continental United States?

3. Fill in the blanks below to calculate the total change in **Total Change in Average** CO<sub>2</sub> concentrations:

Ave. CO<sub>2</sub> Levels today \_\_\_\_\_ Date: \_\_\_\_\_ - Ave CO<sub>2</sub> in 1957 \_\_\_\_\_ = Total Change in CO<sub>2</sub> \_\_\_\_\_  
*\*Get today's value from links on class website*

4. What is the **Average Annual Change** in CO<sub>2</sub> concentration since 1957?

Total change \_\_\_\_\_ ÷ Number of years of data collection \_\_\_\_\_ = Ave. Rate of Change \_\_\_\_\_

5. The wiggles seen on the graph result from seasonal changes in CO<sub>2</sub> concentration. The primary seasonal driver is the winter season of the Earth's Northern Hemisphere (which has more land mass and a higher population than the Southern Hemisphere). Suggest 2 reasons why CO<sub>2</sub> concentration would increase when it is winter in the Northern Hemisphere. (Hint: consider what happens to plants in the winter time and how this would affect CO<sub>2</sub> levels in the atmosphere and consider how the behavior of humans changes in the winter time.)

## Global Climate Change – Lab Exercises

### Global Emissions by Greenhouse Gas

From EPA.gov:

“At the global scale, the key greenhouse gases emitted by human activities are:

- Carbon dioxide (CO<sub>2</sub>): Fossil fuel use is the primary source of CO<sub>2</sub>. CO<sub>2</sub> can also be emitted from direct human-induced impacts on forestry and other land use, such as through deforestation, land clearing for agriculture, and degradation of soils. Likewise, land can also remove CO<sub>2</sub> from the atmosphere through reforestation, improvement of soils, and other activities.
- Methane (CH<sub>4</sub>): Agricultural activities (rice paddies), waste management, energy use, and biomass burning all contribute to CH<sub>4</sub> emissions.
- Nitrous oxide (N<sub>2</sub>O): Agricultural activities, such as fertilizer use, are the primary source of N<sub>2</sub>O emissions. Fossil fuel combustion also generates N<sub>2</sub>O.
- Fluorinated gases (F-gases): Industrial processes, refrigeration, and the use of a variety of consumer products contribute to emissions of F-gases, which include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>).”

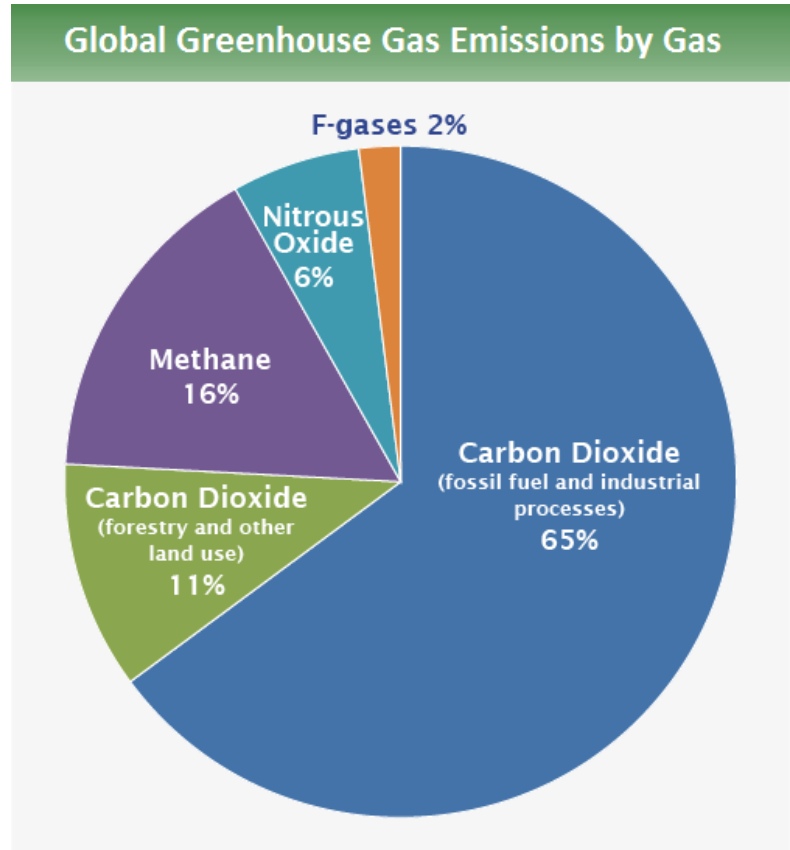
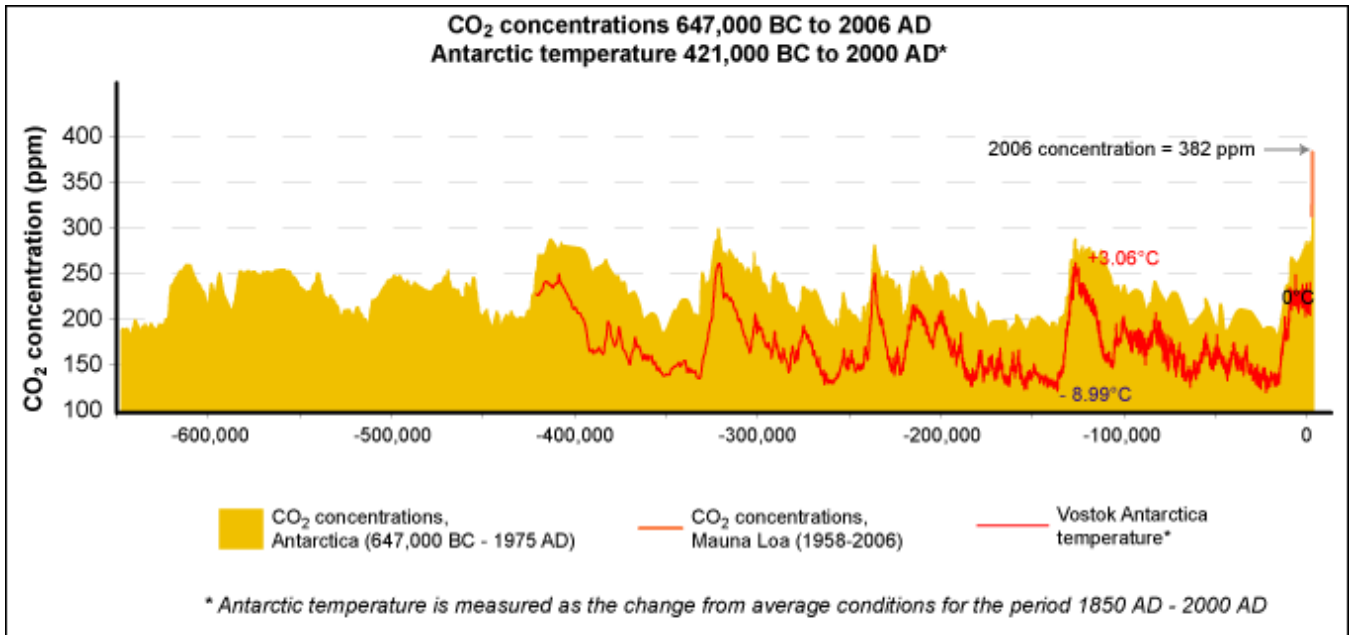


Image: Global GHG emissions by gas: 65% is from carbon dioxide fossil fuel use and industrial processes. 11% is from carbon dioxide deforestation, decay of biomass, etc. 16% is from methane. 6% is from nitrous oxide and 2% is from fluorinated gases.

Source: IPCC (2014) <https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>

Most scientists have said that the increase in CO<sub>2</sub> is due to human emissions and the destruction of the rain forests. It is possible that some of the variation could be due to natural variations in carbon dioxide. To fully understand the issues related to greenhouse gases and global change, we need to examine the past to see if CO<sub>2</sub> levels have changed over time and if so, to what extent. We can use ice cores for Antarctica to understand past variations in trace gases. As snow falls it traps small amounts of air in the spaces between the snowflakes. Some of this gas forms small bubbles as the snow metamorphoses into glacial ice. These bubbles become fossil atmospheres providing us with a means to examine the gas content of the atmosphere thousands of years in the past. Of primary interest to those studying global change and our present atmosphere, is the abundance of carbon dioxide and methane, the primary natural greenhouse gases.

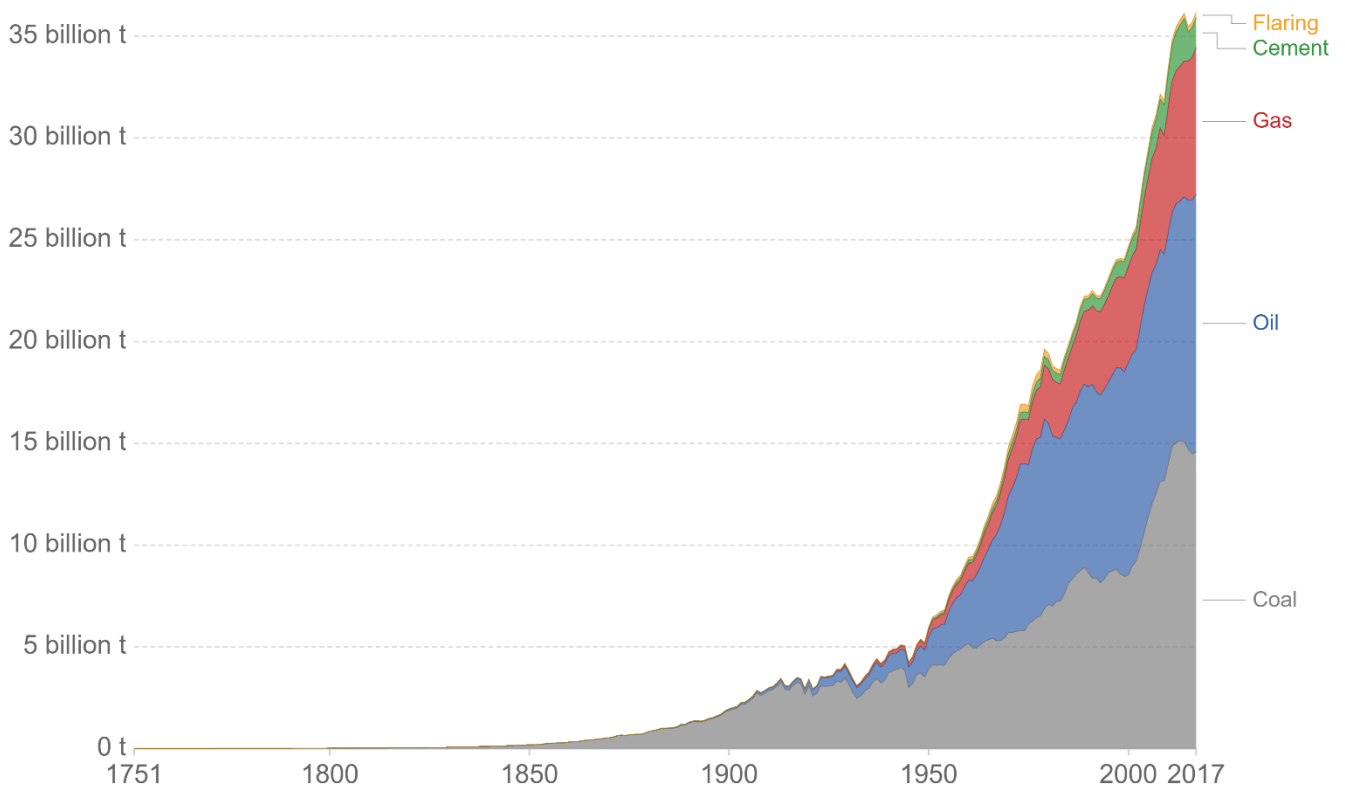


Fluctuations in temperature (red line) and in the atmospheric concentration of carbon dioxide (yellow area) over the past 647,000 years. The vertical bar at the end is the increase in atmospheric carbon dioxide levels over the past two centuries and before 2007. Vertical Axis Units: ppm = parts per million (by volume). Horizontal axis = years.

## CO<sub>2</sub> emissions by fuel type, World, 1751 to 2017

Our World in Data

Annual carbon dioxide (CO<sub>2</sub>) emissions from different fuel types, measured in tonnes per year.



Source: Global Carbon Project (GCP); CDIAC

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Annual carbon dioxide (CO<sub>2</sub>) emissions from different fuel types, measured in tonnes per year.  
 Global Carbon Project (GCP) and Carbon Dioxide Information Analysis Center (CDIAC)

1. What are the maximum and minimum CO<sub>2</sub> levels over the last 650,000 years up until 1800 AD (0 in the Fluctuations chart on preceding page). As this variation happened BEFORE the industrial revolution, it represents a natural variation produced by geologic processes at work with the end of an ice age. What is that natural range (difference between max and min) in CO<sub>2</sub>? \*Use graph on preceding page (or 800,000-year time interval on Keeling Curve online).

Maximum \_\_\_\_\_ | Minimum \_\_\_\_\_ | Natural range \_\_\_\_\_

2. Referring to same graph (last 800,000 years), what is the minimum number of years it takes for the natural system to change from a high CO<sub>2</sub> level to a low for CO<sub>2</sub> level? (= What is the fastest time in which this has occurred naturally?).

3. What were the CO<sub>2</sub> values in 2020 and how much higher is this value than the maximum level of CO<sub>2</sub> before the year "0" (your maximum value answer from Q1)?

3b. Where did the data on CO<sub>2</sub> come from for this chart of the last 650,000 years?

4. The burning of different fossil fuels is a major cause of rising CO<sub>2</sub> levels. What was the major source of carbon emissions between 1850 and 1900?

5. How did this change after 1950?

6. What other cause of increasing CO<sub>2</sub> levels is shown on this graph besides the burning of fossil fuels?

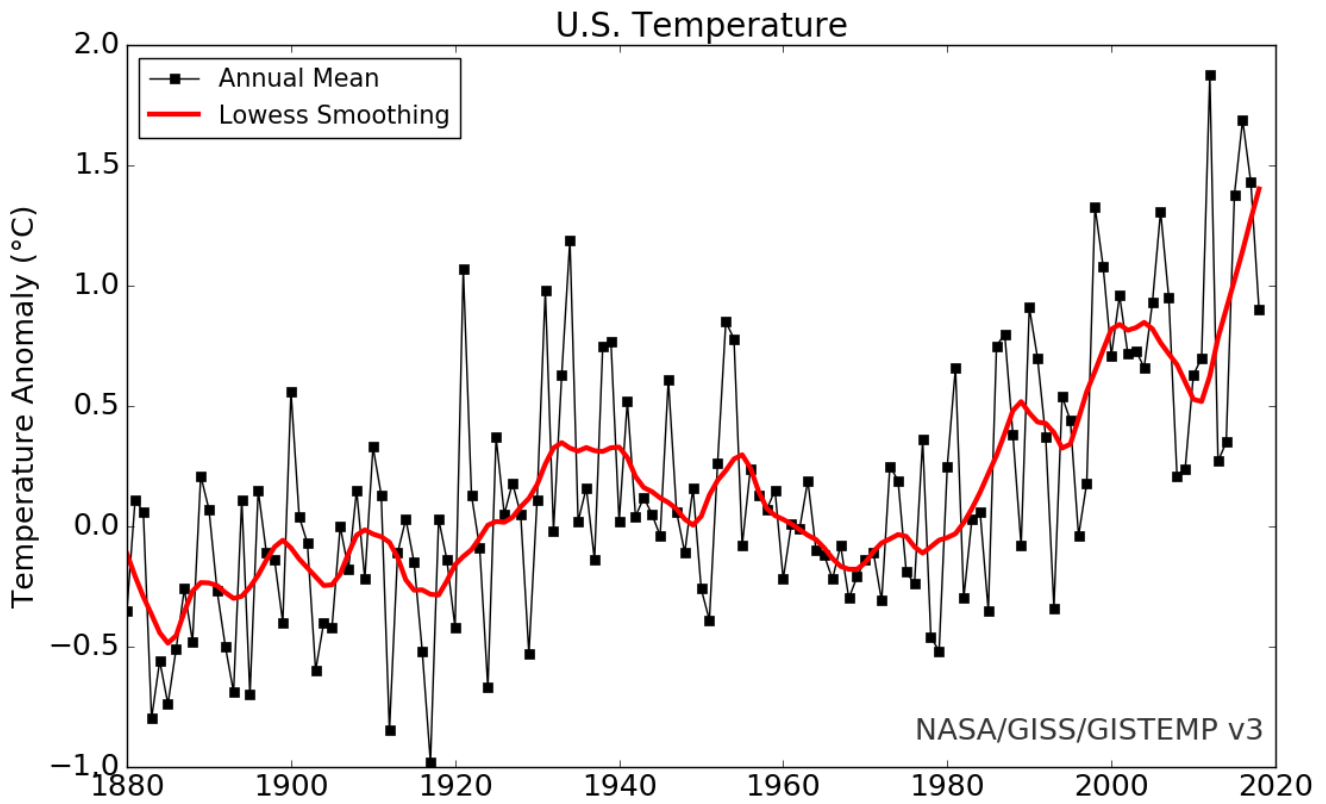
6b: List all the human-introduced sources for greenhouse gases not mentioned above:

There have been natural variations in carbon dioxide through time as reported from this ice core and these changes reflect changes in global temperature. However, just because carbon dioxide goes up during a warm period, that does not mean that carbon dioxide necessarily caused the warming (although it is consistent with our model). Let's look at some additional information and some recent climate data to further consider the relationship between CO<sub>2</sub> and temperature.

**Regional Temperature Records (the United States):**

On the next page is a figure showing the annual running mean surface air temperature in the contiguous 48 United States (= 1.6% of the Earth's surface) since 1880 compared to the mean (average) temperatures from 1951-1980. This is kind of an odd way to show the data, but it allows us to look for see how average temperatures have changed over the last century. Each square represents the average temperature for one year. The wiggly line represents the average temperatures over a 5-year period. Although this kind of graph does not show the actual temperatures, it allows you to look for potential long-term changes in temperature over time. You can find the actual data for this figure and a color version of the graph on the web at: [http://data.giss.nasa.gov/gistemp/graphs\\_v3/](http://data.giss.nasa.gov/gistemp/graphs_v3/).

7. Examine the graph on the next page, or check out interactive graph at link above and fill in the tables that follow. Then determine whether or not temperature shows a trend over time (is there a definite change?). *NOTE: The online graphs will allow you to more precisely see data points (hover mouse over point to see exact year and temperature of each point.).*



Annual Mean Temperature Change in US

Source: NASA [https://data.giss.nasa.gov/gistemp/graphs\\_v3/](https://data.giss.nasa.gov/gistemp/graphs_v3/)

Time period	Number of years with mean Temp. hotter than normal (between 0° and +1° above normal)	Number of years with mean Temp. much hotter than normal (more than +1° above normal)	Number of years with mean Temp. colder than normal (less than 0°)
1880-1899			
1900-1919			
1920-1939			
1940-1959			
1960-1979			
1980-1999			
2000-2019			
Trend over time? (circle one)	Warming / Cooling, No-trend	Warming / Cooling, No-trend	Warming / Cooling, No-trend

#### Summary for Regional Temperature Records (the United States)

\*Note: the black dots are individual years. The red line represents 5 year averages.

	Date/Temp Anomaly		Date/Temp Anomaly
Hottest year		Coldest year	
Hottest 5-year period		Coldest 5-year period	

\*Temperature Anomaly is the difference between average temperature in a given year and the average temperature between 1951 and 1980. So an anomaly of +1°C means that average temperatures are 1° above the 1951-1980 average.

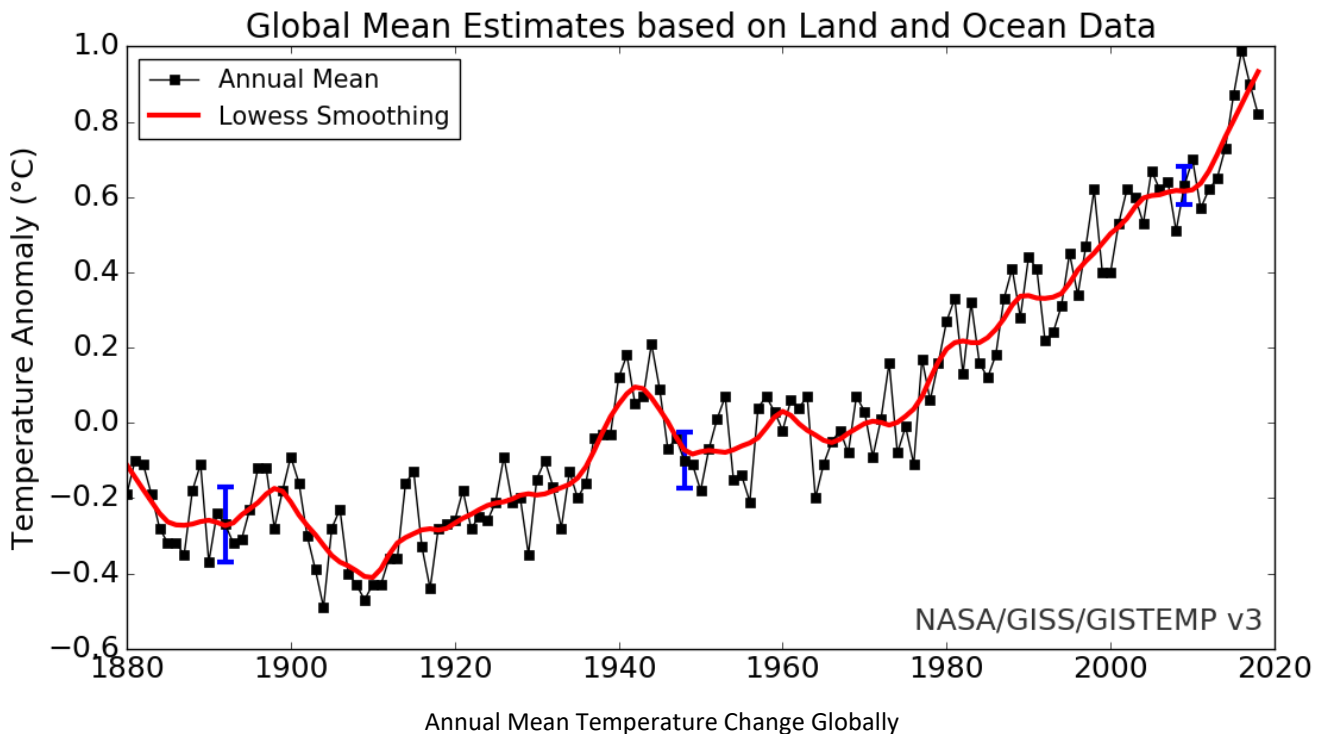
8. How do the dates of the coldest year compare to date of the coldest 5-year period (are the dates the same)?
9. How do the dates of the hottest year compare to date of the hottest 5-year period.
10. If you are looking for trend through time is it easier to identify changes in yearly mean temperatures or the 5-year mean temperature?
11. Overall, do your conclusions on whether there's a trend in mean temperature change depending on which time-frame you examine? Explain your answer.

12. On average have temperatures risen or fallen since 1900 in the US? After looking at this data set, how confident are you that there is an overall change in temperature? Explain your answer.

13. We must be careful not to use one example to try and explain global temperatures. Consider what other factors beyond global climate change may be influencing temperatures in USA. How has the amount of paved streets and parking lots changed in USA since 1900? How would this affect temperatures that were measured in the middle of large cities (Hint: What is like to walk across a parking lot barefoot in summertime?)

### Part 3: Global Temperature Record

On the next page is a figure showing variations in GLOBAL annual since 1880 compared to the mean (average) temperatures from 1951-1980 average. The dotted black line is the annual mean and the solid red line is the five-year mean. The green bars show uncertainty estimates due to incomplete spatial sampling of data. Compare this graph to the one for USA and answer the questions below. You can find the actual data for this figure and a color version of the graph on the web at: [http://data.giss.nasa.gov/gistemp/graphs\\_v3/](http://data.giss.nasa.gov/gistemp/graphs_v3/).



Source: NASA [https://data.giss.nasa.gov/gistemp/graphs\\_v3/](https://data.giss.nasa.gov/gistemp/graphs_v3/)

14. Examine the graph above, or check out interactive graph at link above and fill in the tables that follow. Then determine whether or not temperature shows a trend over time (is there a definite change?). *NOTE: The online graphs will allow you to more precisely see data points (hover mouse over point to see exact year and temperature of each point.).*

Time period	Number of years with mean Temp. hotter than normal (between 0° and +1° above normal)	Number of years with mean Temp. much hotter than normal (more than +1° above normal)	Number of years with mean Temp. colder than normal (less than 0°)
1880-1899			
1900-1919			
1920-1939			
1940-1959			
1960-1979			
1980-1999			
2000-2019			
Trend over time? (circle one)	Warming / Cooling, No-trend	Warming / Cooling, No-trend	Warming / Cooling, No-trend

**Summary for Global Temperature Records**

\*Note: the black dots are individual years. The red line represents 5 year averages.

	Date/Temp Anomaly		Date/Temp Anomaly
Hottest year		Coldest year	
Hottest 5-year period		Coldest 5-year period	

\*Temperature Anomaly is the difference between average temperature in a given year and the average temperature between 1951 and 1980. So an anomaly of +1°C means that average temperatures are 1° above the 1951-1980 average.

15. Predict how many years will be > 0° above normal for the time period from 2020-2039:
16. Compared to the US temperature data, are the trends shown by the global data set: stronger/weaker/the same strength (circle one). Describe the trends:
17. Have global temperatures risen or fallen since 1900, and how much have they changed?
18. What is the **size** of the overall temperature changes in the US, and how does this compare to the size of the global temperature change?

19. Are the **years** with the highest and lowest annual temperatures the same on both graphs? If not how much do they differ?

20. Are the **5-year periods** with the highest and lowest average temperatures the same on both graphs (US and Global)? If not how much to they differ (i.e. how much time is there between them)?

21. Suggest a reason why temperature in USA differs from the average global temperatures:

22. How does the direction and variability of global temperatures compare with the direction and variability of atmospheric CO<sub>2</sub> levels? Explain your answer and suggest a reason for any difference you observe.

### Summary

23. What new things about global temperature changes did you learn in this lab?

24. What questions do you still have?

25. What experiments or research can you propose to do (yourself or others) to help you answer the questions you list above?

26. What are some of the consequences of rising temperatures on our planet? (Be specific! Go online to find some if you don't already know some important ones!)

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Characterize the levels of CO <sub>2</sub> in our atmosphere seasonally and historically.	A   B   C   D   F	
Describe the primary sources of CO <sub>2</sub> to our atmosphere and oceans.	A   B   C   D   F	
Describe the correlation between CO <sub>2</sub> and atmospheric temperature.	A   B   C   D   F	
Characterize the global average atmospheric temperature seasonally and historically.	A   B   C   D   F	
Access active data portals to locate and evaluate current data trends and their implications.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?



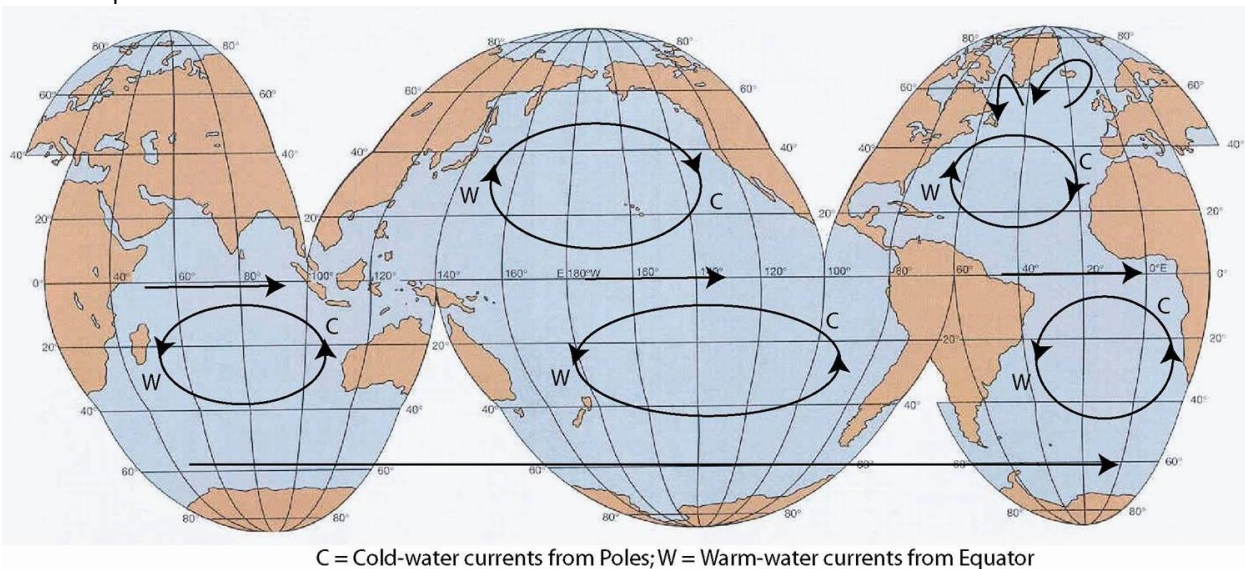
# El Nino & Coastal Upwelling

## NEEDED SUPPLIES: Colored Pencils

Read the sections on El Nino and ENSO in your textbook. PLEASE BRING COLORED PENCILS TO CLASS. The following text and graphics are modified from *NOAA Lab Materials* written by Steve Clark, Monterey Academy of Oceanographic Science (MAOS).

**Coastal upwelling** is the upward movement of water along a coast. This rising water is usually cooler and more nutrient rich than the surface water it replaces: it is originally supplied by deep thermohaline currents coming from the poles and cannot be warmed up by sunlight due to its depth; and nutrients, released from the decay of detritus, accumulate on the bottom where there is a thermocline (no mixing with surface waters). The upwelling of nutrient rich water has made Monterey Bay, on the central coast of California, a favorite with fishermen.

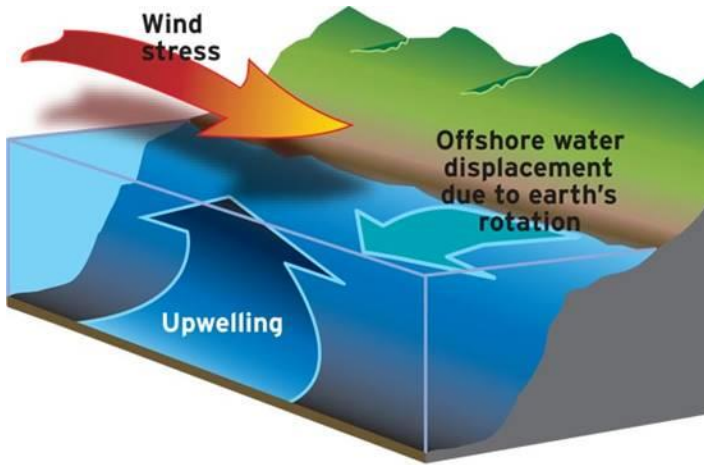
Coastal upwelling can occur only if the winds are in the correct direction relative to the coastline. For the California coastline, upwelling-producing winds are those that come from the northwest. As they drag against the coastal waters, **the Coriolis Effect and Ekman Transport** cause the waters to move 90 degrees to the right of the winds. Based on the geometry of the coastline (see graphic below), such movement causes surface waters to move offshore; deeper waters well up to take their place.



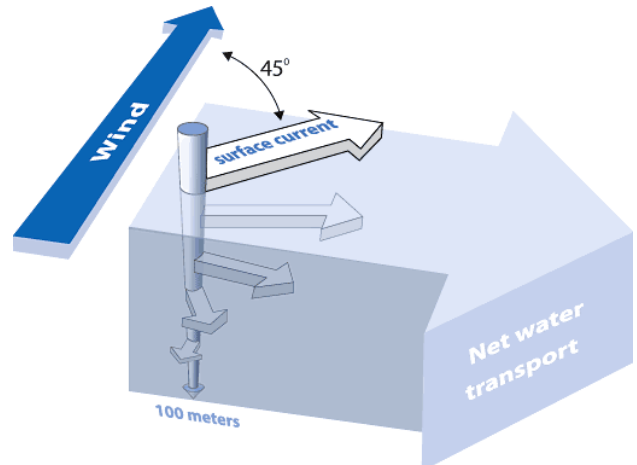
If California were in the Southern Hemisphere, these same winds from the northwest would cause the water to move 90 degrees to the left; water would pile up along the coastline, and downwelling would result. When California's northwest winds are weak or replaced by winds from the south, the upwelling tends to stop. The very large **California Current** travels southward along the California coast from the North Pacific. Usually it mixes with and pushes southward the upwelled water. When coastal upwelling ceases, the waters of the California current (cold, but not as cold as the upwelling waters) are the most dominant coastal waters.

Observations of sea surface temperature from satellites show that upwelling is not uniform along the central California coast, but is strongest at the major **headlands**. This makes sense if you imagine the headland blocking the progress of the California Current. Downcurrent of the headland, water is sucked away, and deeper water wells up to take its place. The cold water of Monterey Bay comes primarily from the upwelling in the Point Año Nuevo area, and then progresses south across the mouth of Monterey Bay toward the Monterey Peninsula. When cool upwelled water rises to the surface at the headlands it departs in two directions.

The upwelled water that flows westward, away from the coast, is immediately influenced by the Coriolis Effect. The portion of the upwelled water that is traveling south is influenced by the California current. The upwelling water can be tracked by measuring its cool temperature, high nutrient content, high salinity and high density. The nutrients brought to the surface encourage the high plankton productivity of the Monterey Bay area which is why it is an excellent fishing locality.



Northern Hemisphere Ekman Transport-induced Coastal Upwelling (NOAA)



Ekman Transport in the Northern Hemisphere (NOAA)

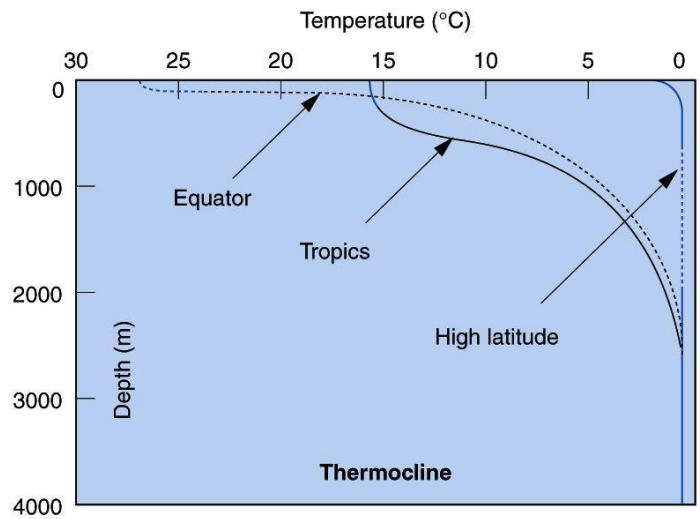
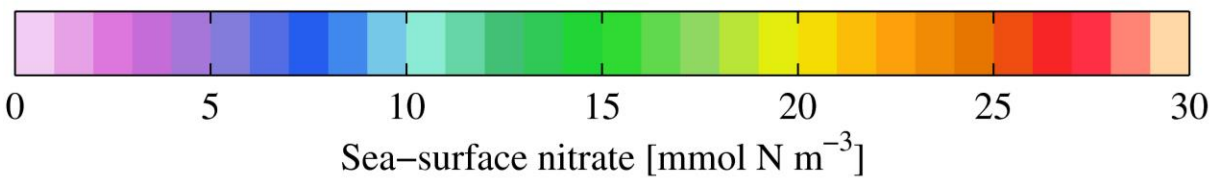
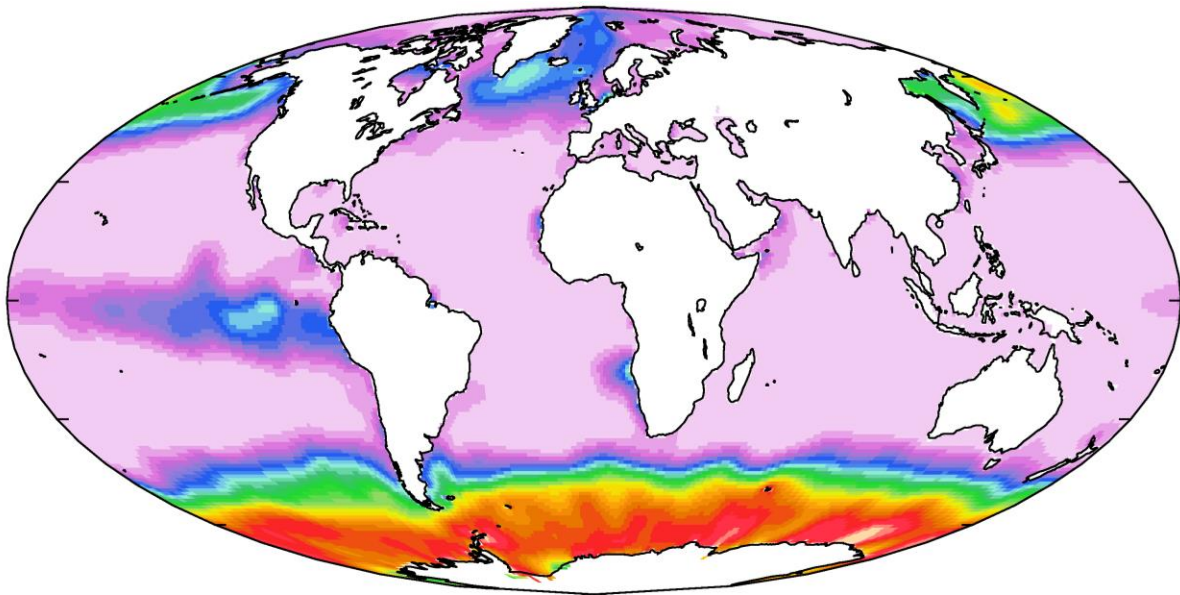
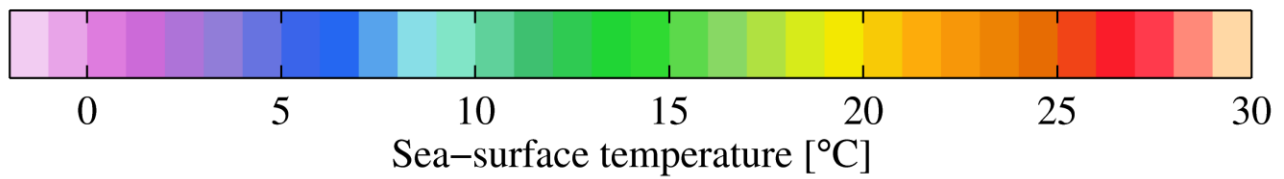
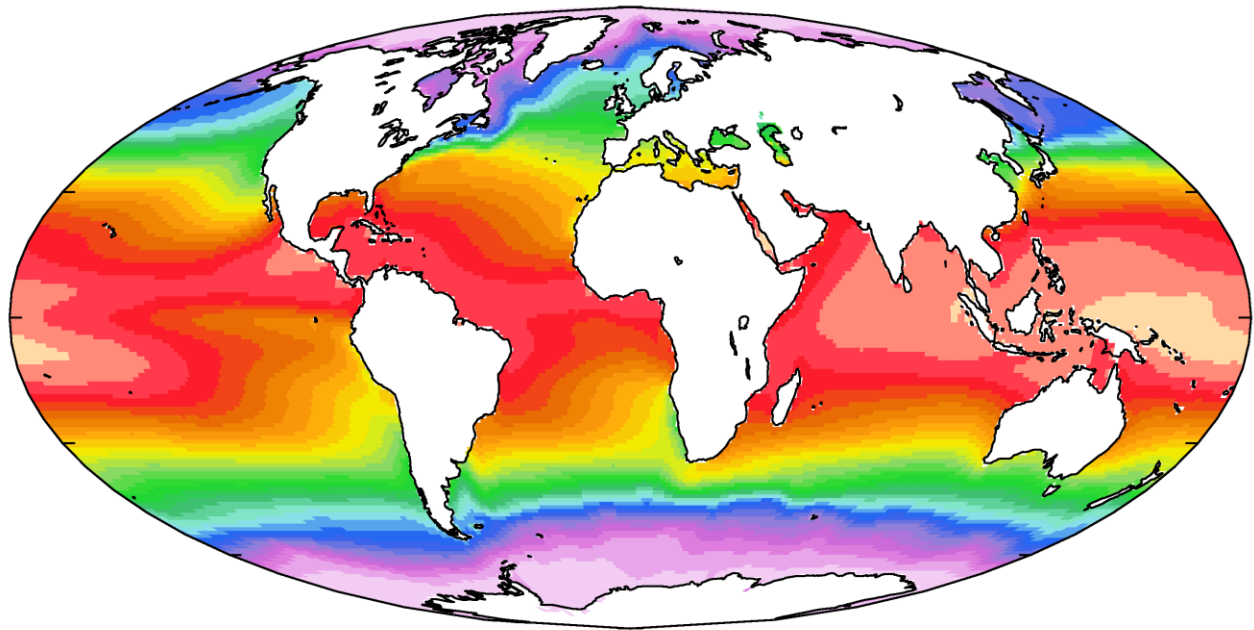


Image source: Steve Hovan, Indiana University of Pennsylvania



Both of the above world maps were produced by Plumbago (CC BY-SA 3.0), Wikipedia, based on data from World Ocean Atlas 2009

## Temperature

Most aquatic organisms are cold-blooded. Consequently, their metabolism increases as the water warms and decreases as it cools. Each species has its own optimum water temperature. If the water temperature shifts too far from the optimum, the organism suffers. Cold-blooded animals can't survive temperatures below 0 °C (32 °F), and only fish like carp can tolerate temperatures much warmer than about 36 °C (97 °F).

Fish can regulate their environment somewhat by swimming into water where temperatures are close to their requirements. Fish can sense very slight temperature differences. When temperatures exceed what they prefer by 1-3 °C, they move elsewhere.

Fish migration often is linked to water temperature. In early spring, rising water temperatures may cue fish to migrate to a new location or to begin their spawning runs. The autumn drop in temperature spurs baby marine fish and shrimp to move from their nursery grounds in the estuaries out into the ocean, or into rivers.

Fish are not the only organisms requiring specific temperatures. Diatoms (phytoplankton – single celled photosynthesizing Protista) seem to grow best at a temperature of 15-25 °C, green algae (like sea lettuce and sea moss) at 25-35 °C, and blue-green algae (stromatolites) at 30-40 °C. Warm water also makes some substances, such as cyanides, phenol, xylene and zinc, more toxic for aquatic animals. If high water temperatures are combined with low dissolved oxygen levels, the toxicity is further increased. High water temperatures can also trigger spawning and make organisms burn energy faster (speed up metabolism).

Water temperature is usually controlled by direct sunlight and currents – western boundary currents pick up warm water along the equators and distribute it northward along the western margins of oceans. Eastern boundary currents pick up cold water in the Polar Regions and distribute it southward along the eastern margins of oceans. In addition, shallow seas in lower latitudes can warm more quickly than deeper oceans.

## Nutrients

Phosphorous and Nitrogen are the predominant nutrients needed by marine organisms.

Phosphate ( $\text{PO}_4^{3-}$ ) is the only form of Phosphorous and Nitrate ( $\text{NO}_3^{2-}$ ) is the primary form of nitrogen used by living organisms. Nitrates are produced naturally as part of the nitrogen cycle, when a bacteria production line breaks down toxic ammonia wastes first into nitrite, and then into nitrate. If there are too few nutrients available in water, growth organisms is impeded. Nutrients enter oceans mainly through rivers and rain. Organisms that live near the ocean's surface use nutrients and then release them only after death and decomposition (which usually happens on the bottom of the seafloor). Dead matter that does not decompose can thus be trapped in ocean sediment. If a well-developed thermocline exists to separate surface waters from bottom waters, recycled nutrients cannot get back up into the surface waters to be used by the phytoplankton. Polar seas do not ever have a thermocline, so they have good nutrient mixing from depth back into surface waters. Equatorial and tropical seas, on the other hand, always have a strong thermocline, so their nutrients are trapped on the bottom and these seas rarely have enough nutrients to support large ecosystems. Temperate seas have no thermocline during the winter, but do have one in the summer. Finally, areas around coastlines will receive a new influx of nutrients from runoff and rivers, and areas of upwelling will see deeper nutrients carried back into the surface waters.

Nearly all fertilizers contain nutrients. When it rains, varying amounts wash from farm soils into nearby waterways. These nutrients stimulate the growth of plankton and water plants that provide food for fish. Added nutrients to the oceans might increase the food for the fish and hence increase the fish population and improve the waterway's quality of life. If too many nutrients are present, however, algae and water weeds grow wildly, choke the waterway, and use up large amounts of oxygen when they decompose. Many fish and aquatic organisms may die. (Such a situation is called **eutrophication**.)

Nutrients also enter waterways from human and animal wastes, phosphate-rich rocks, wastes from laundries, cleaning and industrial processes, lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, and discharges from car exhausts. Phosphates also are used widely in power plant boilers to prevent corrosion

## ENSO – (El Niño Southern Oscillation)

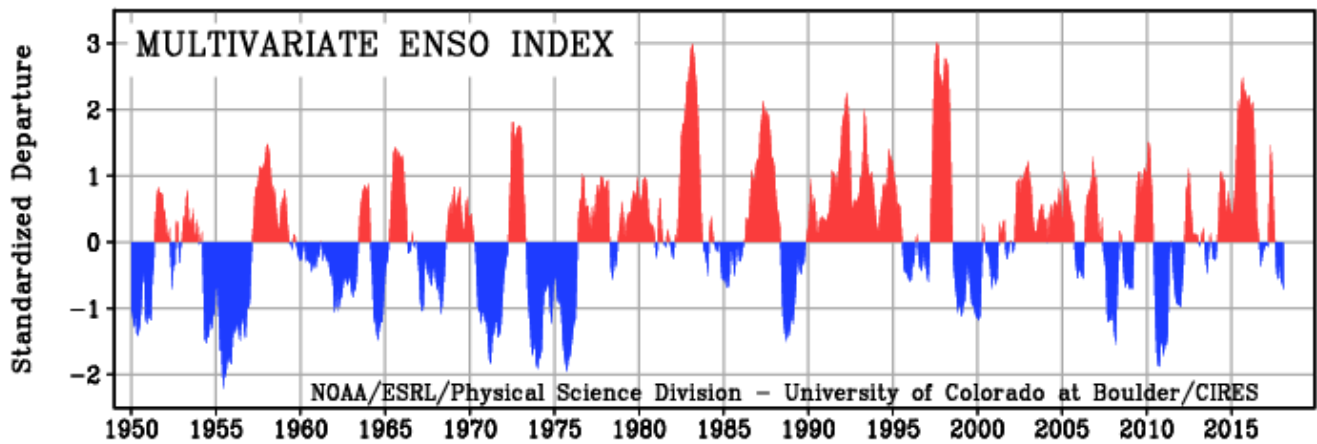
ENSO – (El Niño Southern Oscillation) is the term for the shift in winds, ocean currents, sea surface temperatures, and surface air pressure patterns in the Pacific Ocean. Most commonly observed and reported aspect of ENSO is the change in sea surface temperature in the central and east Pacific Ocean. ENSO changes lead to major shifts in global weather patterns

which effect the weather in several locations around the world. The maps below show where significant changes occur, relative to normal, due to the influence of ENSO. (NOAA)

**El Nino Characteristics:**

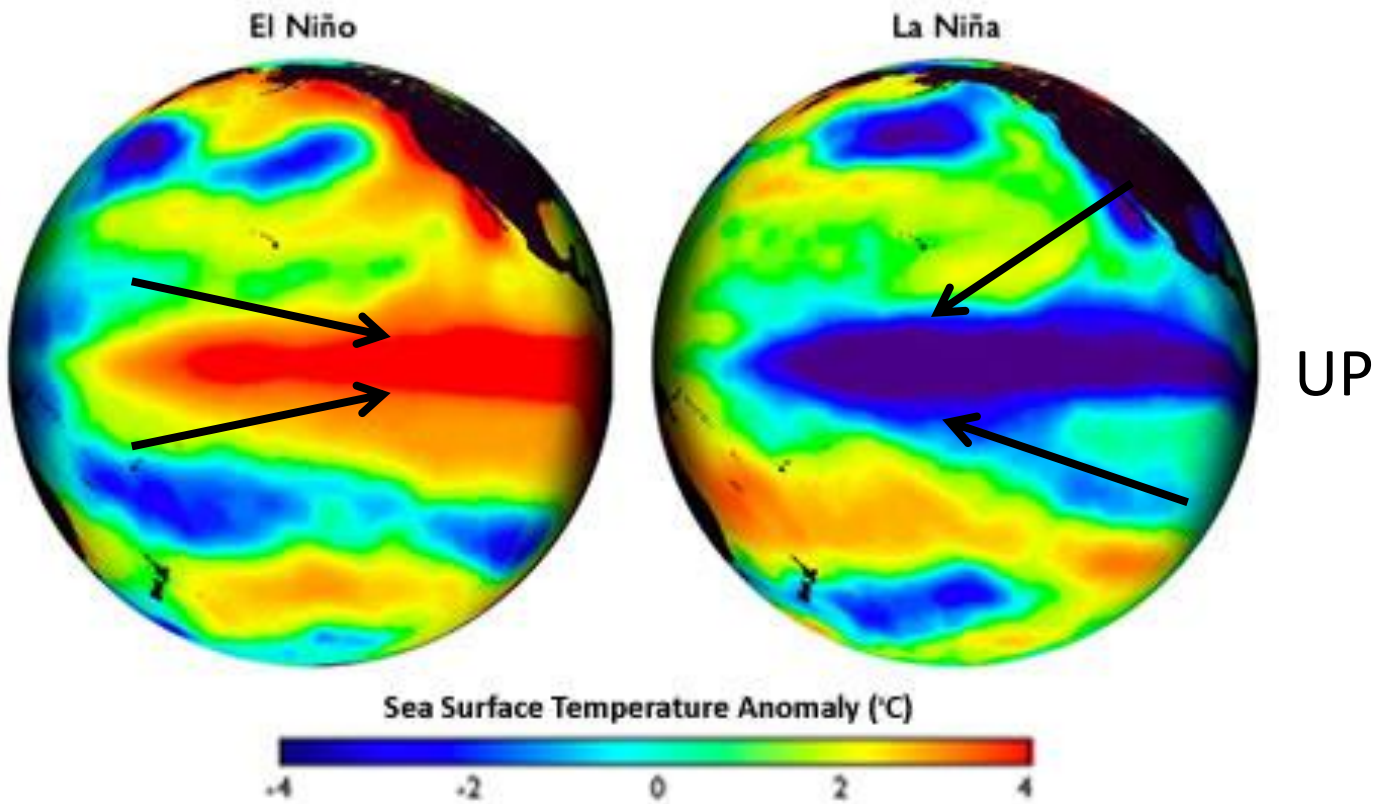
- Reversing or weakening of trade winds (Walker Cell convection shifts eastward in equatorial Pacific): Weather patterns reverse: water-laden air masses reach North America’s west coast (hurricanes and storms – causing flooding – *where normally deserts*); dry air reaches Australia and Asia’s east coasts (causing fires and droughts – *where normally rainforest*)
- Thermocline along the equator flattens:
  - Equatorial currents weaken (*normally strongest*) while equatorial countercurrents strengthen (*normally weakest*) – *cold tongue of upwelled water disappears and is replaced by warm tongue*
  - Upwelling off Eastern Equatorial Pacific stops; hence low nutrients and warmer waters; low nutrients causes biological productivity to drop; combined with warmer waters, many organisms migrate or die.
  - Downwelling off Western Equatorial Pacific stops; water gets slightly colder, sea level drops; destroying reefs.

**El Nino Frequency**



**Multivariate ENSO index, 1950s to presents.** ENSO index values are calculated using 6-7 different atmospheric and oceanic indicators. Values greater than zero (red areas) indicate El Nino while those less than zero (blue areas) indicate La Nina. The greater the value is from zero, the stronger the event.

For updates, see: <https://www.esrl.noaa.gov/psd/enso/mei/>



UP

These global maps centered on the Pacific Ocean show patterns of sea surface temperature during El Niño and La Niña episodes. The colors along the equator show areas that are warmer or cooler than the long-term average. Images courtesy of Steve Albers, NOAA and modified by K. Wiese. Arrows represent trade wind direction. UP = upwelling.

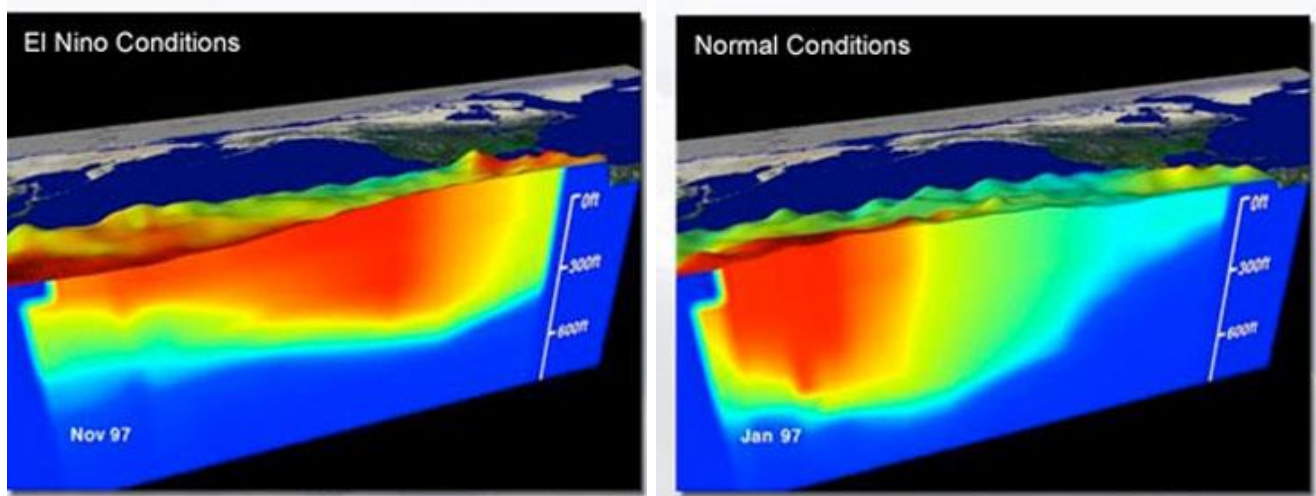
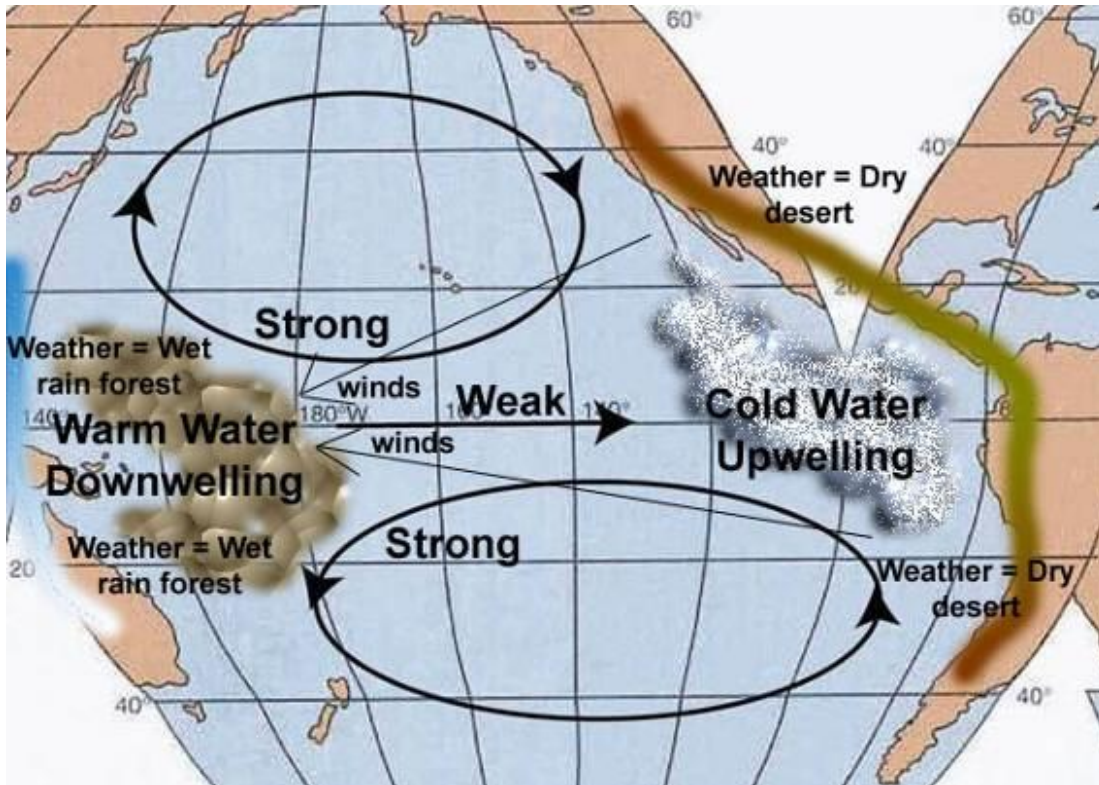
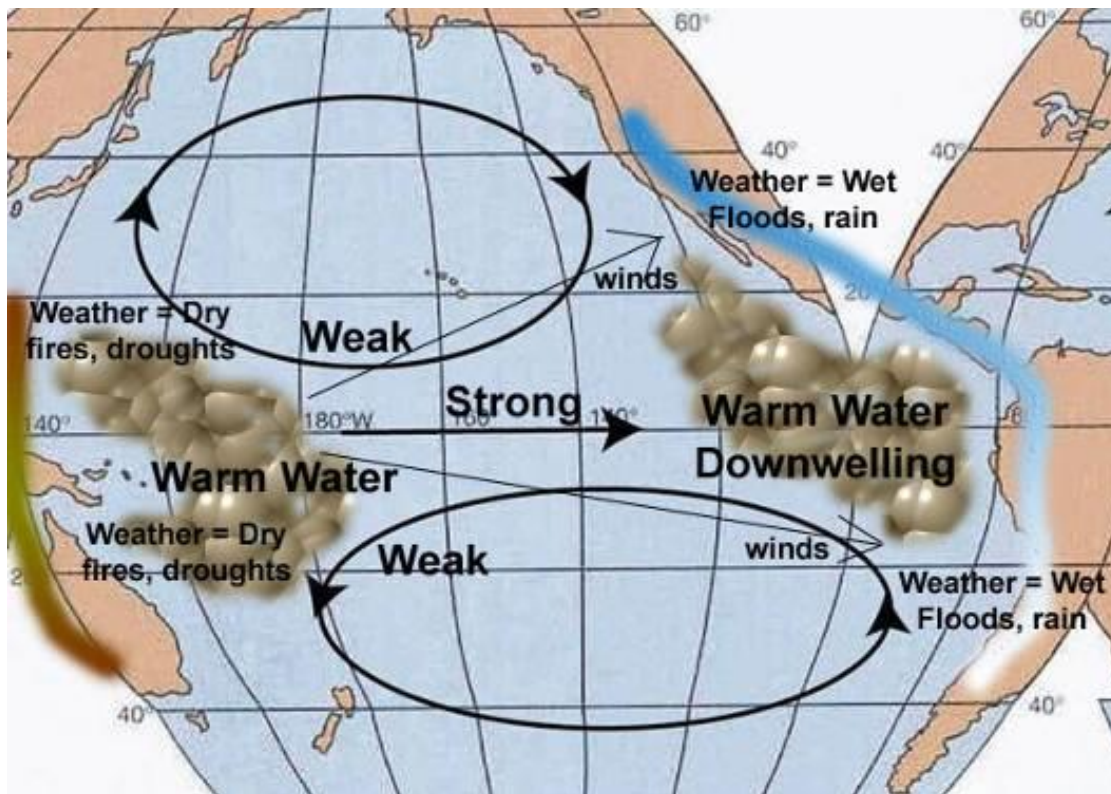


Image: NOAA – These images show sea surface topography and upper ocean temperature data from satellites and buoys. The height of the sea is represented by hills and valleys. Water temperature is shown in color, ranging from 30°C as red to 8°C, shown in dark blue. The image on the right represents "normal" conditions in the equatorial Pacific during January 1997. Notice the lack of a thermocline in the east – as cold water upwells to surface and is pulled from east to west (cold tongue). The image on the left shows El Niño conditions from November 1997. Notice the much warmer waters present in the eastern equatorial Pacific and the deep sharp thermocline. Final note: "Normal" conditions are intermediate between El Niño and La Niña. During a full La Niña, the thermocline in the eastern equatorial ocean would become even less visible and the cold tongue on the surface would become even stronger as globe images above show.



**La Niña** – typical characteristics – (eastern equatorial zone: ocean = upwelling, cold water, atmosphere = dry high pressure; western equatorial zone: ocean= warm pile of water with downwelling, atmosphere = wet low pressure; equatorial currents STRONG; equatorial countercurrent is WEAK.)



**El Niño** – typical characteristics – (eastern equatorial zone: ocean = NO upwelling, warm water, atmosphere = wet, low pressure; western equatorial zone: ocean = reduced pile of warm water, atmosphere = dry, high-pressure; equatorial currents WEAK; equatorial countercurrent is STRONG.)

## El Nino & Coastal Upwelling – Prereading Exercises

1. Based on the figure in the prereading, when was the first- and second-most severe El Nino events in the last 50 years?	2. When was the first- and second-most severe La Nina events since 1950?	
QUESTION	OBSERVATIONS <i>(review charts and record what the data says – no interpretation yet!)</i>	INTERPRETATION <i>(Now analyze the data – what makes these characteristics the way they are?)</i>
3. How does <b>surface water temperature</b> change with <b>latitude</b> in the world ocean (average)? Where is it highest and lowest?		
4. How does <b>water temperature</b> change with <b>depth</b> in the world ocean (average)? Where is it highest and lowest?		
5. Summarize, briefly, the main effects of <b>increasing</b> temperature on marine organisms.		
6. What sources add <b>nutrients</b> in the world's oceans?		
7. Summarize, briefly, the main effects of <b>too high or too low</b> nutrients on marine organisms.		
QUESTION	OBSERVATIONS <i>(what – real data!)</i>	INTERPRETATION <i>(Why? Explanations)</i>
8. How does <b>nutrient content</b> change with <b>latitude and depth</b> in the world ocean (average)? Where is it highest and lowest?		

## El Nino & Coastal Upwelling – Lab Exercises

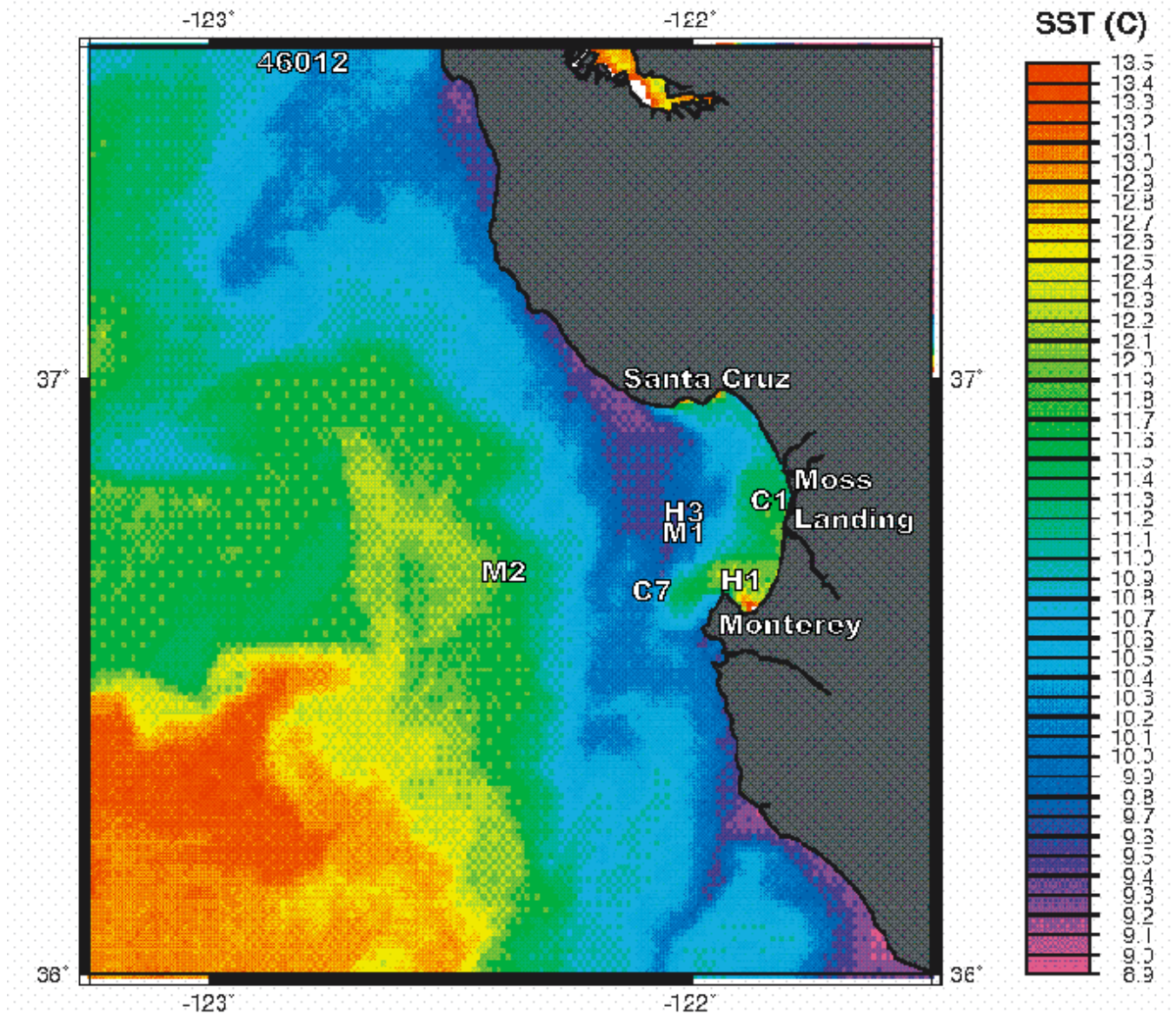
**NEEDED SUPPLIES:** In lab all will be provided; at home you'll have to gather: colored pencils.

### A: COASTAL UPWELLING - MONTEREY BAY CALIFORNIA

Modified from activities by Steve Clark, Monterey Academy of Oceanographic Science (MAOS)

#### PART I. MAP

Below is the 10-year averages of sea surface temperature (SST) for the region off of Monterey Bay. Refer to this map to answer questions on the following pages.



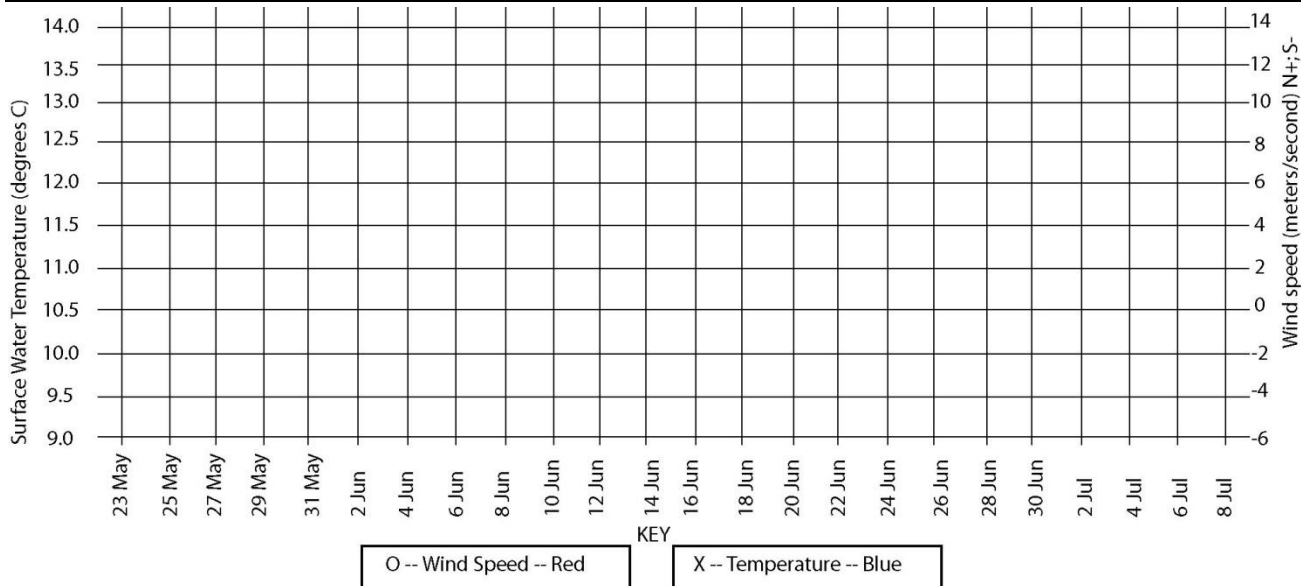
- |   |
|---|
| 1. What is the coldest temperature in the above map? What color?    |
| 2. What is the warmest temperature in the above map? What color?    |
| 3. What is the total range of temperature present in the above map? |
| 4. Where is the warmest water in general in the above map?          |
| 5. Where is the coldest water in general in the above map?          |

**PART II. GRAPH**

Plot both sea surface temperature and wind speed with time. Using the sea surface temperatures at Granite Canyon near Monterey and the wind speed and direction information from buoy 46042 in Monterey Bay, plot the following data on the given graph. Graphing Notes:

- Notice that the scales for plotting temperature and wind speed are on opposite sides of the graph.
- Wind direction is the direction the wind is blowing from.
- Be especially careful when plotting the southerly winds. Negative numbers indicate winds from the south.
- Use two different colored pencils when plotting temperature and wind speed (one color for each).
- Use different marks for your plots of temperature (X) and wind speed (O). Then connect each set of marks (all the X's in one color and all of the O's in the other color) to make two lines on the graph.

Date (1989)	Sea Surface Temperature (°C)	Wind Direction	Wind Speed (m/s)
May 23	10	N	3
25	10	N	8
27	9	N	10
29	9	N	8
31	9	N	4
June 2	10	S	-1
4	12	S	-4
6	13	S	-3
8	12	N	7
10	11	N	5
12	10	N	8
14	10	N	7
16	10	N	7
18	9	N	9
20	9	N	11
22	11	N	4
24	12	S	-4
26	13	S	-6
28	13		0
30	14	S	-1
July 2	13	N	6
4	11	N	9
6	9	N	10
8	9	N	10



**PART III. AN ANALYSIS OF UPWELLING USING THE MAP AND GRAPH.** Answer these questions the map of the sea surface temperatures of the Monterey Bay area and the graph of water temperature and winds.

6. Referring to your graph, describe wind direction and speed as water temperature varies and provide your best hypothesis for why it's true:

Water temperature	Wind direction	Speeds	Why?
Periods of coldest water (maximum upwelling).			
Periods of warmest water (minimum upwelling).			

7. Referring to the map: Review the location and shape of the area of coldest surface water.

<p><b>Explain why some of the cold upwelled water moves westward.</b></p>
<p><b>Explain why some of the cold upwelled water moves south across the bay toward Monterey.</b></p>

8. Why do you think cold upwelled water is concentrated south of the headlands?

--

9. Why is the Santa Cruz beach area so much warmer than the rest of the bay? (Many possible answers – give them some careful thought.)

--

10. Besides following cold water temperature, what other measurable characteristics of the water could you use to follow the two paths of the upwelling water? (Be specific – instead of just “temperature,” say “warm temp,” or “cold temp.”)

--

11. Fishing: Sardines. John Steinbeck wrote about the sardine canneries in Monterey in his book *Cannery Row*. The book describes the fishermen that netted these small plankton-eating fish by the hundreds of tons yearly until they were almost fished out. If they were still plentiful, how would wind direction influence your choice of days to take your boat and crew out sardine fishing? Squid are netted as they swarm in southern Monterey Bay to reproduce. Fishermen turn on bright lights to attract and net them from midnight to 6 a.m. Squid prefer water that is warmer than average. Based on your data which nights in June 1989 would you have picked to go squid fishing?

<p><b>Sardine fishing:</b> Look for what wind direction?</p>	<p><b>Squid fishing</b> Days</p>
--	--------------------------------------

12. Suppose you were offering bay tours to the public and wanted your patrons to see the large, plankton-eating basking sharks that visit Monterey Bay. What area would be optimal for spotting these sharks close to Moss Landing? Why? During summer, there is often a small pod (group) of plankton-eating blue whales south of Monterey. What area would be optimal for whale watching trips departing from Monterey?

<b>Plankton-eating sharks near Moss Landing</b>	<b>Plankton-eating whales near Monterey</b>
<b>Location: Circle on map.</b>	<b>Location: Circle on map.</b>
<p><b>Why?</b></p>	

13. MBARI; The Monterey Bay Aquarium Research Institute (MBARI) has a new remotely operated vehicle (ROV) that can go down into the Monterey Submarine Canyon to a depth of 4,000 meters. During most of the trip down to the bottom the video shows “marine snow” (tiny particles of decaying organisms, feces, and plankton) gently drifting to the bottom. Some of this material will be recycled by upwelling. If you sent MBARI’s ROV down at 37.0° N, 122.5° W, during which days in June 1989 would you have expected maximum marine snow? Why? Remember to consider what the marine snow is composed of, that it drifts down slowly and the growth rate of plankton (population doubles in 2-10 days, depending on species).

<p><b>June Days to find snow?</b></p>	<p><b>Why?</b></p>
---------------------------------------	--------------------

14. Compare the map from Part I of this section about Monterey (average over 10 years) with the NOAA Sea Surface temperature charts (most recent – *available through lab website*). Where are the areas of upwelling today? Do they correspond to the same areas discussed in the lab? Are the temperatures similar? (Note: likely scales/key are different!). What do these differences indicate?

## B: EL NIÑO ANALYSIS

**Purpose:** The analysis of sea-surface temperatures plotted on an ocean map can reveal patterns related to general oceanographic conditions. El Niño is a recurring episode resulting from interaction between the ocean and the atmosphere and has major impact on sea-surface temperatures over vast stretches of the tropical Pacific. This activity compares sea-surface temperature patterns during a major El Niño occurrence to a time more representative of long-term average conditions. The data employed were acquired from temperature sensors carried aboard ships, floating buoys, and satellites which was provided by the Climate Analysis Center of the National Oceanic and Atmospheric Administration.

15. The accompanying maps of the Pacific Ocean display sea-surface temperature patterns at two different times. The lines drawn on the map are constant temperature lines called isotherms. Each isotherm is labeled according to the temperature it represents, in °C.

The difference from one isotherm to the next on the maps is (1°) (2°) (4°). **(Circle correct answer)**

16. The temperature patterns can be highlighted with color. To start, use colored pencils to fill in the color key provided. Note that all temperatures above 28°C will be colored red and all below 20°C will be colored violet. (Hot = red | Cold = blue – please follow the rainbow colors: ROYGBIV)
17. Color the entire Pacific Ocean by referring to the color key. Start by locating on each map the area with the highest reported temperature and color it red. Expand the region by coloring red outward to the 28°C isotherms.
18. Using the next color in your color key, follow the same procedure for the next lower temperature band that ranges between 28°C and 26°C. Continue this process for all the temperature ranges in your color key.
19. Note that only colors representing adjacent sequential temperature ranges can come into direct contact on the map.

For example the 20°-22°C color band and the 24°-26°C color band cannot touch; they must always be separated by a (26°-28°C) (22°-24°C) (18°-20°C) color band. **(Circle correct answer)**

20. Locate on your map a location where the adjacent temperature bands are relatively narrow.

If you were traveling on the map in a direction cutting directly across the bands, you would observe a temperature change that was relatively (small) (large) over a short distance. **(Circle correct answer)**

21. During times typical of average conditions, strong Trade Winds drive warm surface water away from west coast of equatorial South America. The retreating warm water is replaced by cold water upwelling from the depths. During an El Niño event, the trade winds slacken, the upwelling of cold water ceases and the sea surface temperature rises off the west coast of equatorial South America.

By comparing your analysis of the two maps, the maps for (1987) (1988) would indicate the occurrence of an El Niño. **(Circle correct answer)**

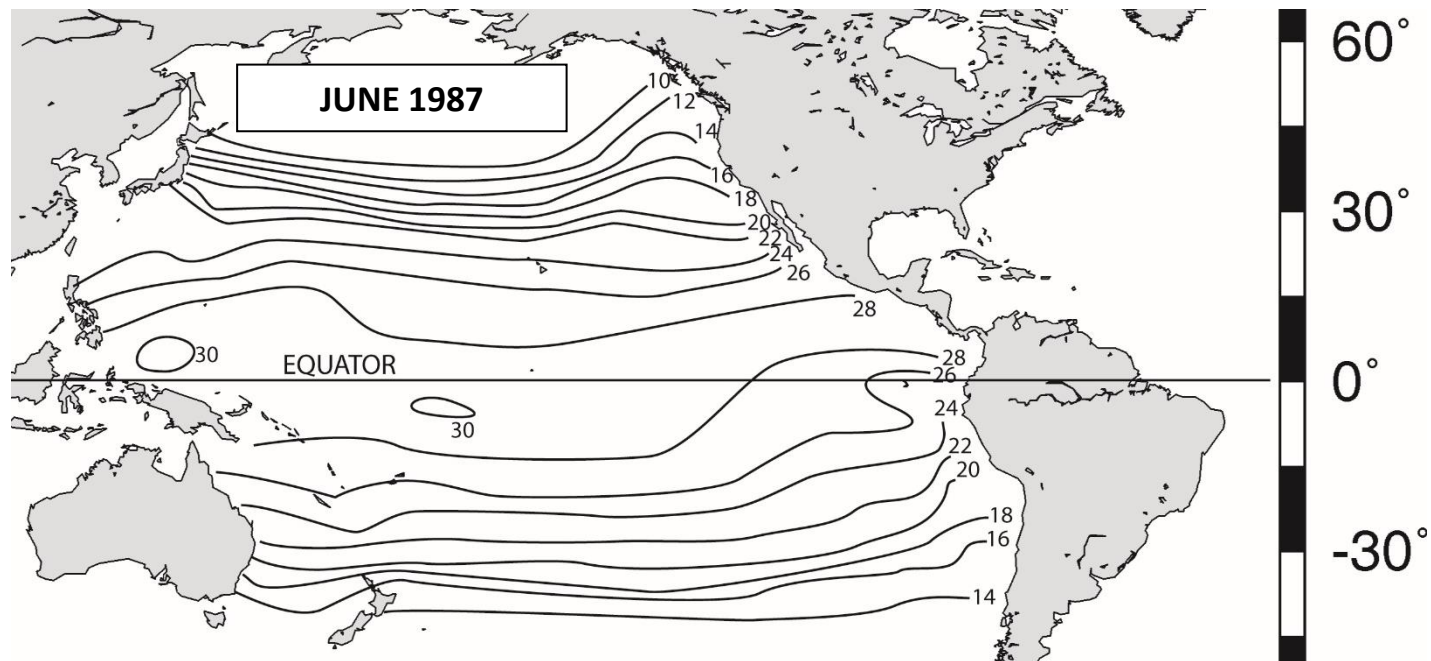
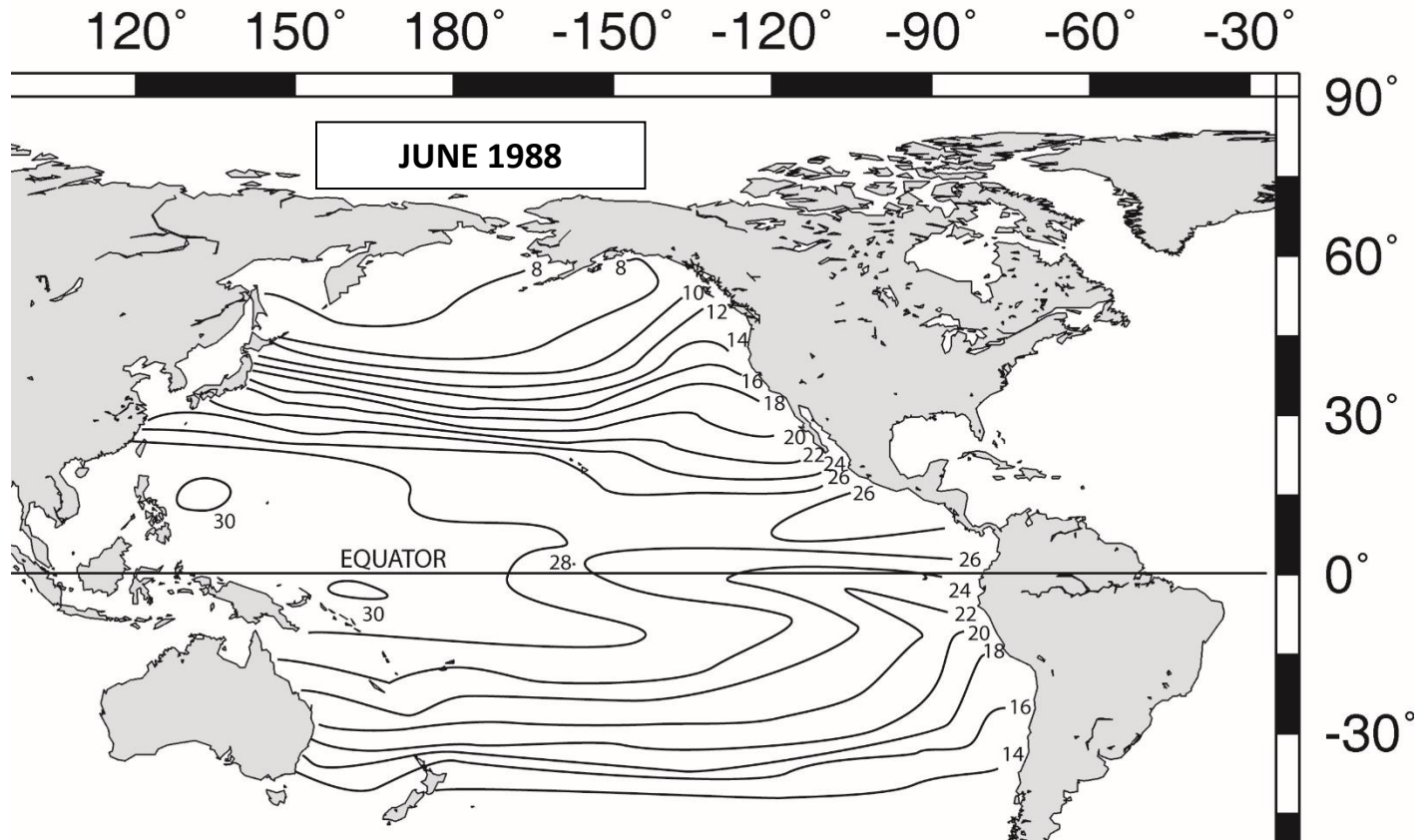
22. Go to lab website and follow Sea Surface Temperature Anomaly links (across entire Pacific – global) to determine if we're experiencing an El Niño right now or not.

**CIRCLE:** | Strong El Niño | Weak El Niño | Weak La Niña | Strong La Niña |

*From prereading material:*

23. What are the main characteristics (causes or effects) of El Niño? Be thorough.

>28°C	26-28°C	24-26°C	22-24°C	20-22°C	<20°C
red	orange	yellow	green	blue	violet



### C: BIOGEOGRAPHY OR WHAT HAPPENS TO FISH POPULATIONS DURING EL NIÑO

**SOURCE:** Adapted from Orange County Marine Institute activity series. Original fish figures from: Eschmeyer, W. and Herald, E., A Field Guide to Pacific Coast Fishes, Houghton Mifflin Co., Boston.

An El Niño event is thought to be triggered when steady westward blowing trade winds weaken and even reverse direction. This change in the winds allows the large mass of warm water that is normally located near Australia to move eastward along the equator until it reaches the coast of South America. It then spreads out along the western coasts of the Americas, affecting water temperatures and weather patterns.

When El Niño effects reach the coastline of southern California, the surface water warms up, prompting changes in the types of the fish that live there. Fish migrate to the northern-most extent of their range to stay with their favored water temperature. During the reverse of El Niño, when colder than normal water is off the coast, fish migrate to the southern extent of their range (La Niña). By looking at fish populations, scientists can study El Niño's effects over time.

In May 1997 an otter trawl was used by personnel on the research vessel Sea Explorer to collect fish off Dana Point in southern California. An otter trawl net is used to collect fish by deploying it off a boat and trailing it in the water (it is not used to collect otters, but was named because of a Scandinavian word for "outer," referring to the outer doors on the leading edge of the net). The fish shown in this activity were caught in May 1997. Satellite and surface water measurements indicated an El Niño had begun to affect the eastern Pacific Ocean at that time. Were its effects visible in the fish population off southern California?

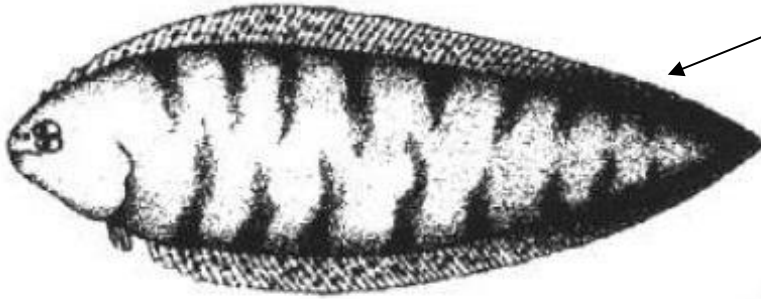
24. Review "Today's Catch" sheet in this activity. Identify each fish (*add name to Catch sheet*). Then find out each of these fish's geographic range using the Fish Keys provided (list geographic range on catch sheet). Note: this range was determined over a long period of time, while El Niño and La Niña and normal times varied. Therefore, the northernmost extent of each range should represent where the fish migrate when their normal temperatures (usually in the middle of their range) also migrate north (warmer water heading north so fish flee north to avoid). Vice versa on the southernmost extent of their range.
25. For each fish, *on the Catch of the Day Sheet*, indicate whether it was in the normal, south, or northern portions of its range when it was caught in Dana Point (Southern California). (*\*Use Google Maps to help – remember: Gulf of California is also known as the Sea of Cortez. Split full range in thirds, then decide in which third fish was caught.*)
26. Using your range locations, indicate whether or not the fish confirm an El Niño is happening. Explain in detail.

27. List the five KEY fish (not just from Today's Catch – use the full Fish ID Key) that would be expected to be caught off of southern California's coast during fully developed El Niño conditions.

28. Consider the drastic changes in southern California fish types that El Niño conditions can bring; do you expect that other forms of marine life--such as marine mammals and sea birds--are also affected? How?

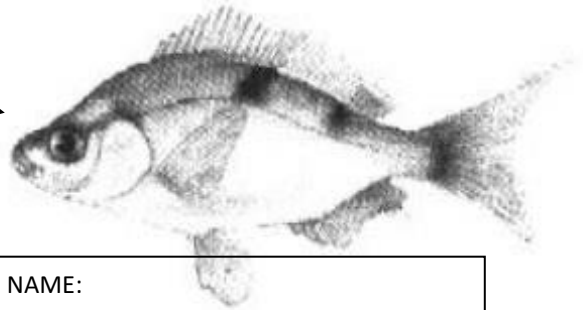
**CATCH OF THE DAY SHEET FOR DANA POINT, CALIFORNIA (SOUTHERN CALIFORNIA)**

*\*For range, use Google Maps to help – remember: Gulf of California is also known as the Sea of Cortez.  
Split full range in thirds, then decide in which third fish was caught.*

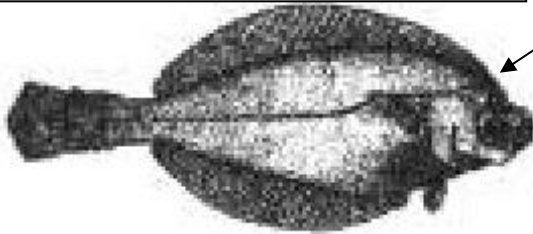


FISH NAME:  
FISH RANGE:  
Part of range where fish found  
(circle: Northern, Middle, Southern )

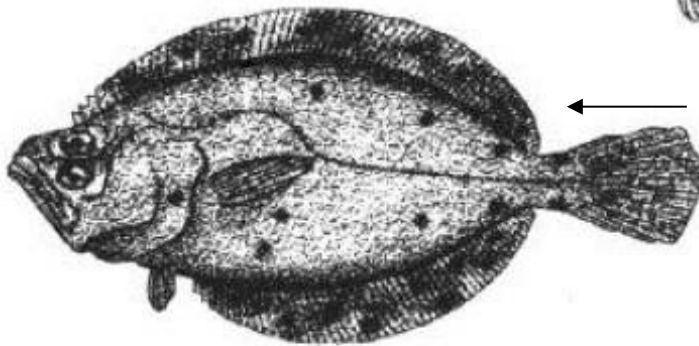
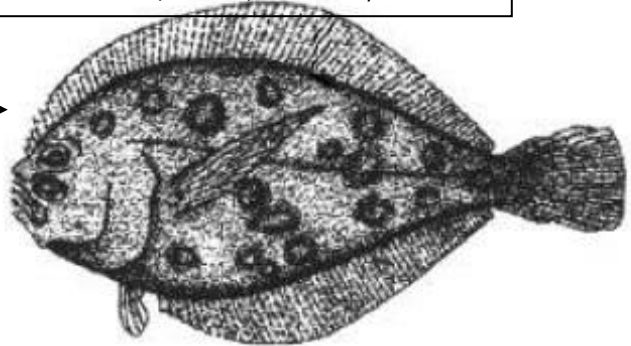
FISH NAME:  
FISH RANGE:  
Part of range where fish found  
(circle: Northern, Middle, Southern )



FISH NAME:  
FISH RANGE:  
Part of range where fish found  
(circle: Northern, Middle, Southern )



FISH NAME:  
FISH RANGE:  
Part of range where fish found  
(circle: Northern, Middle, Southern )



FISH NAME:  
FISH RANGE:  
Part of range where fish found  
(circle: Northern, Middle, Southern )

**D: Distinguishing between El Niño/ La Niña impacts and Coastal Upwelling impacts**

29. What would you expect to happen to the water temperature, river discharge (volume of freshwater in the rivers), and salinity in San Francisco during an El Niño? La Niña? Coastal Upwelling? Why?

	<b>Water temperature change</b>	<b>River discharge change</b>	<b>Salinity change</b>
El Niño			
La Niña			
Coastal Upwelling			

30. How do you distinguish between Coastal Upwelling and La Niña effects off California?

31. Following link on lab website, look at data from the buoy 18 km west of San Francisco, water temperature for the past decade. Do you notice any seasonal fluctuations? How does water temperature today compare with water temperatures during this same month/date over the past 10 years?

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Locate and access public government data portals for real-time data on sea surface temperature globally	A   B   C   D   F	
Use real-time data to determine El Niño / La Niño status and coral reef health status	A   B   C   D   F	
Identify and predict the consequences of El Niño / La Niño tor regions around the Pacific Ocean	A   B   C   D   F	
Identify and predict the consequences of areas of local coastal upwelling	A   B   C   D   F	
Distinguish between the cuases and effects of local coastal upweeling vs. El Niño / La Niño	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

## El Nino & Coastal Upwelling Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

### GENERAL OCEAN CHEMISTRY

#### WATER TEMPERATURE

<i>Where is <b>surface water temperature</b> highest in the world? (Circle appropriate answer) And why?</i>	<b>Poles</b> <b>Mid-latitudes</b> <b>Tropics</b> <b>Equator</b>	
<i>Where in the water column (with depth) is <b>water temperature</b> highest? (Circle appropriate answer) And why?</i>	<b>Surface</b> <b>Mid ocean</b> <b>Deep ocean</b>	

What does <b>increased</b> temperature do to marine organisms?	
--	--

### EL NINO & UPWELLING

#### PACIFIC OCEAN

What do the <b>equatorial currents</b> do in the Pacific during El Nino?	
What do <b>the Trade Winds</b> do in the Pacific during El Nino?	
How are <b>water temperatures</b> affected in the eastern equatorial Pacific during El Nino?	
How are <b>nutrient contents</b> affected in the eastern equatorial Pacific during El Nino?	
How are <b>marine organisms</b> affected in the eastern equatorial Pacific during El Nino?	
How is the <b>weather</b> in the eastern equatorial Pacific affected during El Nino?	

#### LOS ANGELES

What happens to <b>fish in the Los Angeles area</b> during El Nino events? Why?	
---	--

**MONTEREY**

From what direction should the wind be blowing to produce <b>upwelling off Monterey</b> ?	
List three <b>traits</b> of this upwelled water.	
What happens to <b>local weather</b> when the <b>wind stops blowing</b> in that direction?	
What happens to <b>marine life</b> when the <b>wind stops blowing</b> in that direction?	
What would submarines and deep-water organisms see <b>at this time</b> ?	
What <b>types of organisms</b> thrive when upwelling happens? Why?	
What <b>types of organisms</b> thrive when upwelling stops? Why?	

**NUTRIENTS**

What sources add <b>nutrients</b> in the world's oceans?	
Summarize, briefly, the main effects of <b>too high or too low</b> nutrients on marine organisms.	
Where is <b>surface water nutrient content</b> highest in the world? And why? (Circle appropriate answer)	<b>Poles</b> <b>Mid-latitudes</b> <b>Tropics</b> <b>Equator</b>
Where in the water column (with depth) is <b>nutrient content</b> highest? And why? (Circle appropriate answer)	<b>Surface</b> <b>Mid ocean</b> <b>Deep ocean</b>

**SAN FRANCISCO**

How will <b>San Francisco's water temperature</b> change during El Nino? Why?	
How will <b>San Francisco's river discharge</b> change during El Nino? Why?	
How will <b>San Francisco's salinity</b> change during El Nino? Why?	

Be sure you can distinguish between coastal upwelling associated with local winds and global El Nino events.

Be able to determine based on any picture of Equatorial Pacific sea-surface temperatures whether there's an El Nino happening or not.

## KEY

### GENERAL OCEAN CHEMISTRY

#### WATER TEMPERATURE

Where is <b>surface water temperature</b> highest in the world? And why? (Circle appropriate answer)	<b>Poles</b> <b>Mid-latitudes</b> <b>Tropics</b> <b>Equator XXX</b>	Primarily because of difference in direct sunlight. More direct sunlight over equator than elsewhere. Other notes: warmer where shallow water; Western Boundary Currents are warmer
Where in the water column (with depth) is <b>water temperature</b> highest? And why? (Circle appropriate answer)	<b>Surface XXX</b> <b>Mid ocean</b> <b>Deep ocean</b>	Colder water is denser and hence sinks. Warmer water is least dense and hence rises. In addition, once water has gotten deep, and the sun can't reach it, it can't warm up.
What does <b>increased</b> temperature do to marine organisms?	Increased T means increased metabolism and increased toxicity for some poisons. It also might trigger reproduction at abnormal times. It also can induce migration of organism or its food, leading to starvation.	

### EL NINO & UPWELLING

#### PACIFIC OCEAN

What do the <b>equatorial currents</b> do in the Pacific during El Nino?	The normally strong equatorial current weakens. The normally weak reverse current strengthens, bringing warm water into the eastern regions of the equatorial ocean.
What do the <b>Trade Winds</b> do in the Pacific during El Nino?	Trade Winds slow or stop or even reverse.
How are <b>water temperatures</b> affected in the eastern equatorial Pacific during El Nino?	Surface water warms, because upwelling has stopped and warmer waters from the west are moving in.
How are <b>nutrient contents</b> affected in the eastern equatorial Pacific during El Nino?	Nutrient levels drop drastically, because upwelling has stopped.
How are <b>marine organisms</b> affected in the eastern equatorial Pacific during El Nino?	With no nutrients, plankton die off. Organisms that depend on these plankton for food must migrate or die.
How is the <b>weather</b> in the eastern equatorial Pacific affected during El Nino?	Storms and floods will occur in the coastal area, because weather systems normally carried away by the Trade Winds will instead move toward this part of the ocean, travelling over large expanses of ocean en route and picking up lots of water. And since water is warmer, storms will have more energy.

#### LOS ANGELES

What happens to <b>fish in the Los Angeles area</b> during El Nino events? Why?	Fish migrate away from the equator, so northward, because warm water is piling up on the eastern equatorial Pacific and pushing northward and southward along the coasts of North and South America. Fish flee the warm waters and push northward. So off LA, you would see fish that normally lived much further south.
---	--

#### MONTEREY

From what direction should the wind be blowing to produce <b>upwelling off Monterey</b> ?	From the North.
List three <b>traits</b> of this upwelled water.	Cold, nutrient-rich, a bit saltier and denser (because it's from deeper)

What happens to <b>local weather</b> when the <b>wind stops blowing</b> in that direction?	<i>Warmer water means less fog and cooling from the ocean. Coastal temperatures rise.</i>
What happens to <b>marine life</b> when the <b>wind stops blowing</b> in that direction?	<i>Nutrients disappear, so plankton die off. Organisms that eat plankton must migrate to find food or starve. Organisms that live at depth, get an initial feast of increased marine snow, but then lose their food as well.</i>
What would submarines and deep-water organisms see <b>at this time</b> ?	<i>Marine snow.</i>
What <b>types of organisms</b> thrive when upwelling happens? Why?	<i>Plankton-eating organisms like sardines, and the organisms that eat them, like basking sharks, whales, birds, seals and sea lions, etc.</i>
What <b>types of organisms</b> thrive when upwelling stops? Why?	<i>Squid like to come to surface – they prefer warm water. Deep-sea benthos thrives, because they get lots of marine snow to eat, during the initial die-off.</i>

### NUTRIENTS

What sources add <b>nutrients</b> in the world's oceans?	<i>Increase river runoff or rain (fertilizers, waste, cleaning agents, car exhaust); Dissolving at depth of decomposing organic matter; Increased N2 from atmosphere at high P.</i>	
Summarize, briefly, the main effects of <b>too high or too low</b> nutrients on marine organisms.	<i>If low, impedes growth and reproduction. If too high, get blooms followed by die offs and associated O2 loss.</i>	
Where is <b>surface water nutrient content</b> highest in the world? And why? (Circle appropriate answer)	<b>Poles XXX</b> <b>Mid-latitudes</b> <b>Tropics</b> <b>Equator</b>	<i>Highest at poles, because no pycnocline. Can also be high in mid-latitudes during winter when pycnocline disappears. Or in areas of upwelling and off rivers.</i>
Where in the water column (with depth) is <b>nutrient content</b> highest? And why? (Circle appropriate answer)	<b>Surface</b> <b>Mid ocean</b> <b>Deep ocean XXX</b>	<i>Highest at depth under pycnoclines, because they get trapped as decomposition occurs. Can be high at surface as well if there's no pycnocline, or if there's upwelling.</i>

### SAN FRANCISCO

How will <b>San Francisco's water temperature</b> change during El Nino? Why?	<i>Water temperature warms, because warm water is piling up on the eastern equatorial Pacific and pushing northward and southward along the coasts of North and South America.</i>
How will <b>San Francisco's river discharge</b> change during El Nino? Why?	<i>River water volume (discharge) increases because there are more storms and floods in the coastal areas when the trade winds reverse and bring water-laden weather systems toward the eastern Pacific.</i>
How will <b>San Francisco's salinity</b> change during El Nino? Why?	<i>Salinity drops because of the influx of freshwater from increased river discharge.</i>



# Beach Materials

## Beach Sand – General

Beach sand consists of small particles of rocks, minerals, and organic material, broken up, transported, and deposited along beaches. Sand is moved along beaches by longshore transport, a process whereby incoming refracted waves hit the shore with a component of push in one direction. This push picks up sand and water and moves it that direction. For North America this push is usually to the south (since most storms happen to the north, generating waves that move to the south). Sand is also moved onshore and offshore during seasons (onshore during summer; offshore during winter).

Ultimate sources of beach sediment	Ultimate sinks for sand (where it ends up)
<ul style="list-style-type: none"> <li>• Eroded material brought from the backcountry via rivers and distributed along beaches by longshore transport</li> <li>• Local rocks eroding (headlands and cliffs)</li> <li>• Local biological debris (like coral reefs)</li> </ul>	<p>Sand is ultimately removed from the longshore transport system:</p> <ul style="list-style-type: none"> <li>• Wind blows it onshore where it is buried and turned to sandstone.</li> <li>• Submarine canyons pull beach sand offshore, ultimately dumping it at the base of the canyon in a fan on the continental rise.</li> </ul>

## Beach Sand in San Francisco

For the last 2 my, San Francisco Bay has alternately emptied and filled as sea level fell and rose with growing and waning ice ages. Such migrations of the coastline occur regularly, which is why it's so common to find fossils of marine animals far to the west (under today's ocean water) and far to the east. During interglacial times when sea level was high (as it is today), the bay was full of water, and the Sacramento River sediments never reached the Pacific, dropping instead into the Bay. During glacial periods, when sea level was low, the Sacramento River flowed through the Golden Gate and deposited sand along the Pacific shoreline tens of miles west of the present shore.

During the last ice age, 10-15,000 years ago, sea level was 200 ft lower than today; there was no water in the bay; and the shoreline was 20 miles west of Ocean Beach. Wind blew much of this sand inland to form sand dunes that covered most of San Francisco and the continental shelf. Most of these old beach sands and dunes are now covered by the sea and exist as patches of sand several miles offshore (Potato Patch Shoal off the Golden Gate, for example). The dunes still on land are now underlying the majority of San Francisco's urban development, hence the severe shaking experienced in these areas during earthquakes.

Today's source of Ocean Beach sand are these old dune deposits, now covered by water. The sand in the old dunes is ultimately derived from Sierra Nevada granite that, after weathering in the Sierras, was picked up and carried by rivers (ultimately the Sacramento River) to the Pacific Ocean. Waves push these now-covered pockets of sand ashore during the summer months, and waves distribute it southward. (Note: there is no current river source or local erosion source for Ocean Beach sand. Few rocks exist in the area to erode, and the Sacramento River deposits its sediment up in Sacramento. If it weren't for these old, covered deposits of sand, there would be no Ocean Beach.)

Note also that the Pioneer Submarine Canyon sits offshore just south of San Francisco (remember this from the Bathymetry lab). Most of the Ocean Beach sand that is part of longshore transport is sucked offshore just north of Moss Beach and ends up at the bottom of the Pioneer Submarine Canyon. Note also the inlet to San Francisco Bay to the north of Ocean Beach. Can sand move across this inlet to let Marin Headlands beaches feed Ocean Beach? Why or why not?

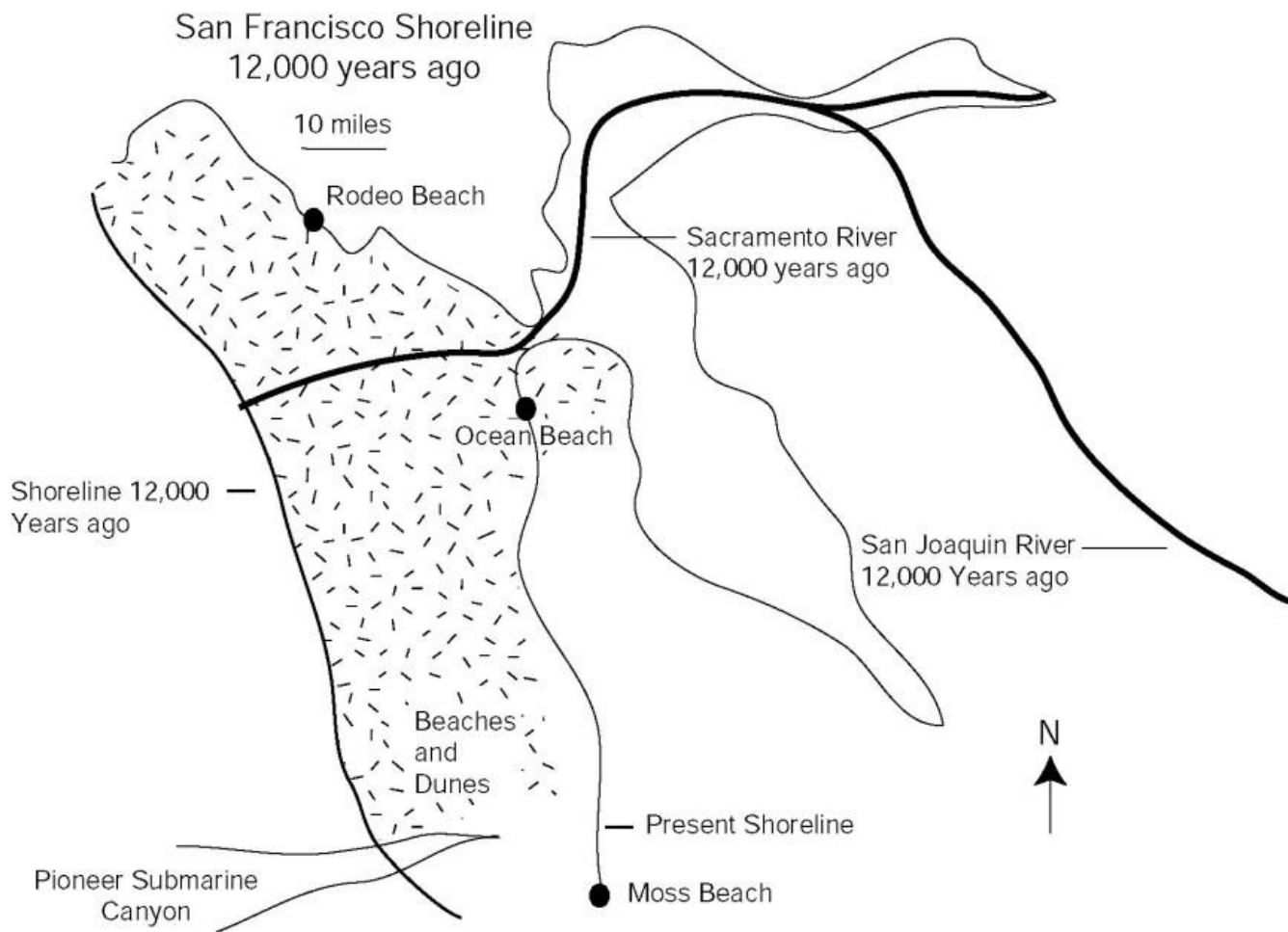
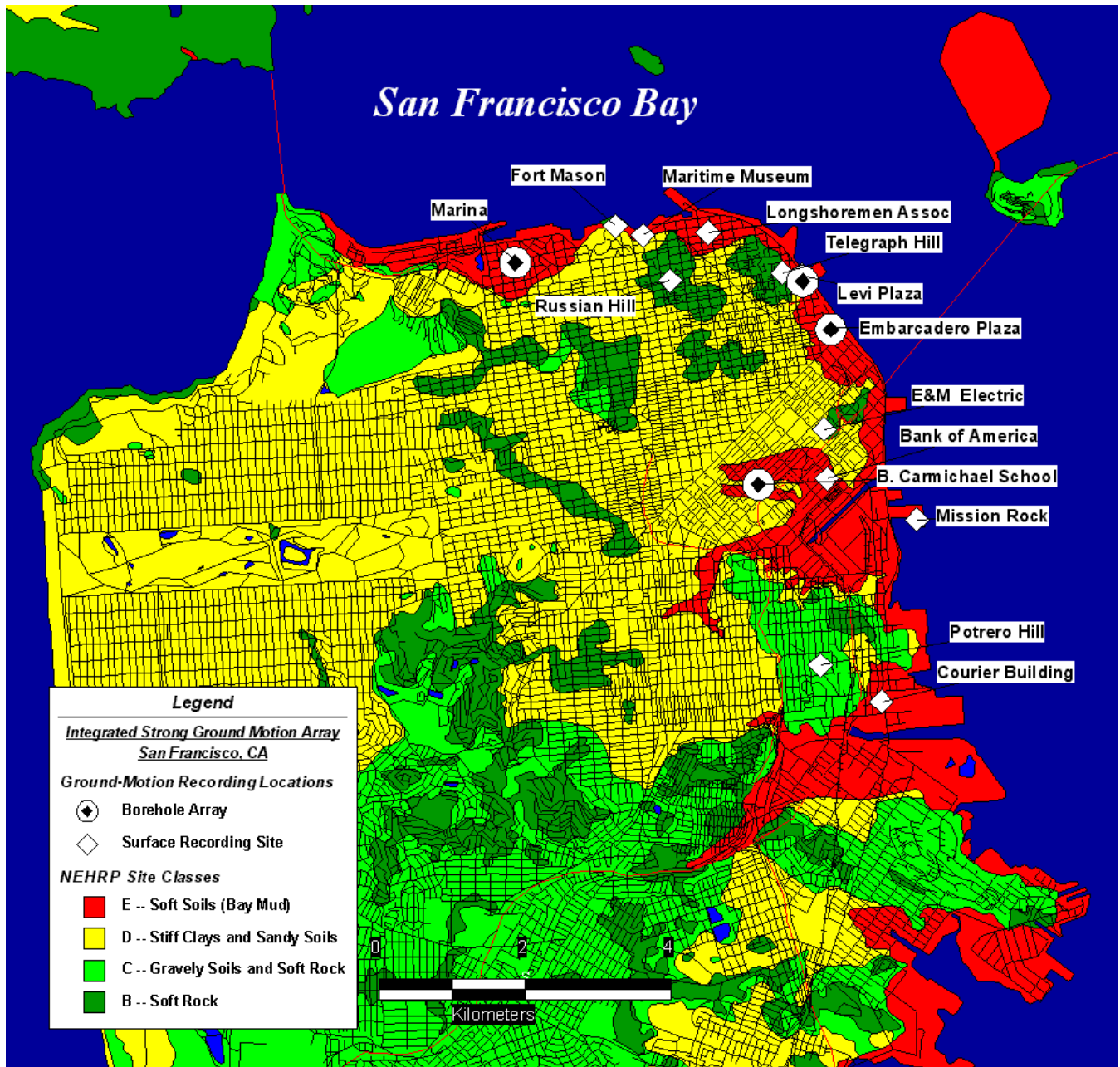


Image below is from the USGS – it is a seismic hazards/shake map. The yellow or lightest colored material indicated in map are the Pleistocene Sand Dunes upon which most of San Francisco is built. The Red material along the edges of the northeast and eastern sides of the city are the mud/fill material added to extend the land area of San Francisco.



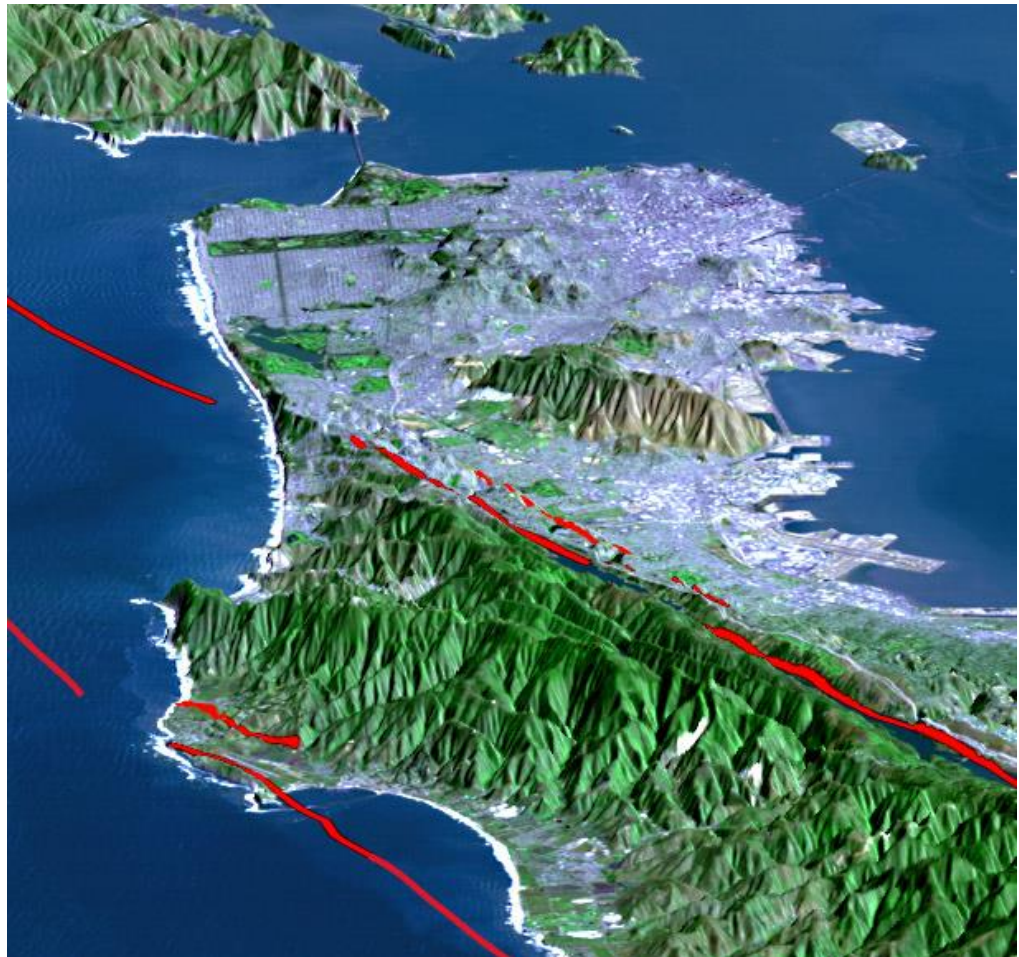
**Grain composition** – As grains physically weather from their parent rock, they are also undergoing chemical weathering. (Physical breakdown/weathering is simply making a grain smaller. Chemical breakdown/weathering is transforming the grain’s composition, from feldspar to clay, for example, or simply by dissolving the mineral.) The longer a grain has been separated from its source, the more exposure it has had to the elements, and the more potential it has to have been chemically weathered. Resistant minerals can exist at Earth’s surface for a long time without chemically weathering. Easily weathered grains cannot. The range of grain composition found in sediment is a good indicator of distance from source. Near source, all compositions can exist. However, after long transit, most of the easily weathered grains should be gone, and the composition of sediment should consist mostly of resistant minerals.

- **Most resistant components:** Quartz (comes usually from granite weathering), Chert
- **Moderately resistant components:**
  - Magnetite (comes usually from granite or basalt weathering)
  - Feldspar (comes usually from granite weathering)
- **Easily weathered components:**
  - Hornblende (comes usually from granite weathering)
  - Rock fragments: Granite, Basalt, Mudstone, Serpentinite
  - Shells (comes from offshore reefs)

*Note: Clay, the mud-sized, highly resistant, main weathering product of most common minerals on Earth’s surface is rarely found on beaches, as the energy level of a beach is too high for most mud-sized particles to remain.*

**Grain size** – Grains are largest near their source (when first weathered off parent rock, grains can really be any size; large grains will dominate, however). As grains are moved away from their source by wind, water, or gravity, they continue to break down, becoming smaller. While small grains are easily transported, only high-energy water can transport large grains.

- Gravel (>2 mm)
- Coarse sand (1.3-2 mm)
- Medium sand (0.7 to 1.3 mm)
- Fine sand (0.06 to 0.7 mm)
- Mud (<0.06 mm)



*Image: USGS – Red lines mark traces of San Andreas and Seal Cove Faults.*

## Beach Materials – Prereading Exercises

1. What is the general direction of longshore transport along the Pacific Coastline?	
2. Describe the grain size and composition of sand that is <b>close</b> to its source. Grain size:  Composition:	3. Describe the grain size and composition of sand that is <b>far</b> from its source. Grain size:  Composition:
4. Based on the map showing different beaches along the San Francisco coastline, the general direction of longshore transport, and <b>any important features in between the beaches</b> , is it possible for Rodeo Beach sand to feed Ocean Beach? Why or why not?	
5. Based on the map showing different beaches along the San Francisco coastline, the general direction of longshore transport, and <b>any important features in between the beaches</b> , is it possible for Ocean Beach sand to feed Moss Beach? Why or why not?	
6. Where does Ocean Beach sand come from? Tell the <b>complete</b> story.	

# Beach Materials – Lab Exercises

## COMPOSITION IDENTIFICATION GUIDELINES

Samples are available for reference. These hints will help with composition ID:

- **BLACK**
  - **Magnetite** – Place a bit of sample onto white paper and hold over a magnet. (Black and magnetic)
  - **Black nonmagnetic** – (includes rock fragments like mudstone, basalt, and serpentinite or black minerals like hornblende and biotite. *Note: basalt can be glassy too, especially fresh basalt glass – will have a dark brownish red glassy look. And glassy basalt will have high amounts of magnetite crystals inside, which might make it slightly magnetic.*)
- **LIGHT COLORED (clear or white)**
  - **Quartz** – Clear and glassy. Typically jagged because it is such a hard mineral.
  - **Feldspar** – Typically white or pink and tablet shaped. Opaque. Distinguishing from shells can be difficult. Look to see if other shells are present for comparison.
  - **Shells** – Typically white or blue. Can come in any shape or size, though usually has pits, ridges, ornamentation, or is thin and curved. Some can be multicolored.
  - **Granite** – Note that the rock granite is composed of the minerals feldspar, quartz, and a nonmagnetic, dark mineral. The rock will look salt-and-pepper colored (multicolored)
- **RED OR GREEN: Chert** – Typically smooth, rounded red or light or bright green (various shades).

## GRAIN SIZE IDENTIFICATION GUIDELINES

Most of the sand you will be looking at is sand sized. Expect it to range from large muds to fine gravels. Use scales provided in prereading to compare against sample, but also be sure to check your answers by comparing samples against each other. Line them up from finest to coarsest and make sure your answers match!

## PERCENTAGE IDENTIFICATION GUIDELINES

Percentages are estimates. Expect there to be differences from one person to another. What shouldn't be different, however, is relative abundance. First thing you should do is ask which size or composition is the most abundant, then next, etc. Make sure your numeric percentages match that relative analysis and add to 100%. Example: Quartz is much much more abundant than Black nonmagnetic which is more abundant than shells, written as Q>>>>B>Sh

## TRAVEL DISTANCE DETERMINATION GUIDELINES

To determine distance traveled, just use grain sizes and composition. Shape and sorting are not useful indicators for beaches, because wave activity on the beach rounds and sorts most grains!

## SOURCE DETERMINATION GUIDELINES

Go back to the composition data to answer this question. Ensure your numbers there match your numbers here. First off, your shell percentage should match your reef percentage (reefs are where shelled organisms live). Reefs are right offshore of the beach and represent little transit. Secondly, all low-resistance components must be locally derived; any transport would have broken them down. Usually, the medium-resistance components are also locally derived, though it is possible for some of them to have been transported a distance. Use other information to make this determination. The resistant components can either have traveled a long distance OR have been locally derived. Use grain size and local rock types to make this decision. For example, a beach of mostly fine-grained quartz has had all the low-to-medium resistance components removed. Grain size and composition indicate long-distance travel. However, a beach with high amounts of quartz, but also feldspar and black nonmagnetic components (likely hornblende) could originate from the breakdown of a local granite, if one exists. Grain size in such a case should be larger than the former case.

## SAND-USE GUIDELINES

Stir sand in jars **thoroughly**. Make sure Petri dish is clean (no sand grain contamination). Take only a pinch of sand out of NEW jar. When done with sand, if you're sure which disposal jar to put it in, put in the OLD jar. (If you're not sure ask!) Clean Petri dish **thoroughly**. You do not want contamination.

**MICROSCOPE SCALES AND GRAIN SIZE AND % CHARTS ARE FOUND IN APPENDIX.**

HAWAII – BIG ISLAND – SAND DATA ANALYSIS			
<b>Composition</b> Relative abundance:		<b>Grain size</b> Relative abundance:	
<b>Most resistant components:</b> Quartz (Q) ____% Chert (C) ____%		Gravel (>2 mm) (G) ____%	
<b>Medium resistant components:</b> Magnetite (M) ____% Feldspar (F) ____%		Coarse sand (1.3-2 mm) (CS) ____%	
<b>Least resistant components:</b> Shells (Sh) ____% Granite (G) ____%		Medium sand (0.7 to 1.3 mm) (MS) ____%	
Dark & nonmagnetic: Basalt, Mudstone, Hornblende, etc. (B) ____%		Fine sand (0.06 to 0.7 mm) (FS) ____%	
		Mud (<0.06 mm) (M) ____%	
Using <b>grain size and composition only</b> (without referencing type of local rock), does this sand appear to have been transported a great distance? Cite evidence.			
Combining the <b>above data</b> with the local rocks listed here, estimate varying source of this beach sand. <b>Local rocks are young basalt lava flows.</b>			
Local rocks	Local reef	Long travelled (longshore transport/rivers)	Other (describe below):
%	%	%	%
<b>DETAILED EXPLANATION OF OTHER CATEGORY IF NECESSARY:</b>			

OAHU (WAIKIKI) SAND DATA ANALYSIS			
<b>Composition</b> Relative abundance:		<b>Grain size</b> Relative abundance:	
<b>Most resistant components:</b> Quartz (Q) ____% Chert (C) ____%		Gravel (>2 mm) (G) ____%	
<b>Medium resistant components:</b> Magnetite (M) ____% Feldspar (F) ____%		Coarse sand (1.3-2 mm) (CS) ____%	
<b>Least resistant components:</b> Shells (Sh) ____% Granite (G) ____%		Medium sand (0.7 to 1.3 mm) (MS) ____%	
Dark & nonmagnetic: Basalt, Mudstone, Hornblende, etc. (B) ____%		Fine sand (0.06 to 0.7 mm) (FS) ____%	
		Mud (<0.06 mm) (M) ____%	
Using <b>grain size and composition only</b> (without referencing type of local rock), does this sand appear to have been transported a great distance? Cite evidence.			
Combining the <b>above data</b> with the local rocks listed here, estimate varying source of this beach sand. <b>Local rocks are old basalt lava flows.</b>			
Local rocks	Local reef	Long travelled (longshore transport/rivers)	Other (describe below):
%	%	%	%
<b>DETAILED EXPLANATION OF OTHER CATEGORY IF NECESSARY:</b>			

<b>CARMEL – SAND DATA ANALYSIS</b>			
<b>Composition</b> Relative abundance:		<b>Grain size</b> Relative abundance:	
<b>Most resistant components:</b> Quartz (Q) ____% Chert (C) ____%		Gravel (>2 mm) (G) ____%	
<b>Medium resistant components:</b> Magnetite (M) ____% Feldspar (F) ____%		Coarse sand (1.3-2 mm) (CS) ____%	
<b>Least resistant components:</b> Shells (Sh) ____% Granite (G) ____%		Medium sand (0.7 to 1.3 mm) (MS) ____%	
Dark & nonmagnetic: Basalt, Mudstone, Hornblende, etc. (B) ____%		Fine sand (0.06 to 0.7 mm) (FS) ____%	
		Mud (<0.06 mm) (M) ____%	
Using <b>grain size and composition only</b> (without referencing type of local rock), does this sand appear to have been transported a great distance? Cite evidence.			
Combining the <b>above data</b> with the local rocks listed here, estimate varying source of this beach sand. <b>Local rocks around Carmel are Granites.</b>			
Local rocks	Local reef	Long travelled (longshore transport/rivers)	Other (describe below):
%	%	%	%
<b>DETAILED EXPLANATION OF OTHER CATEGORY IF NECESSARY:</b>			

<b>RODEO BEACH SAND DATA ANALYSIS</b>			
<b>Composition</b> Relative abundance:		<b>Grain size</b> Relative abundance:	
<b>Most resistant components:</b> Quartz (Q) ____% Chert (C) ____%		Gravel (>2 mm) (G) ____%	
<b>Medium resistant components:</b> Magnetite (M) ____% Feldspar (F) ____%		Coarse sand (1.3-2 mm) (CS) ____%	
<b>Least resistant components:</b> Shells (Sh) ____% Granite (G) ____%		Medium sand (0.7 to 1.3 mm) (MS) ____%	
Dark & nonmagnetic: Basalt, Mudstone, Hornblende, etc. (B) ____%		Fine sand (0.06 to 0.7 mm) (FS) ____%	
		Mud (<0.06 mm) (M) ____%	
Using <b>grain size and composition only</b> (without referencing type of local rock), does this sand appear to have been transported a great distance? Cite evidence.			
Combining the <b>above data</b> with the local rocks listed here, estimate varying source of this beach sand. <b>Local rocks are chert, serpentinite, and basalt.</b>			
Local rocks	Local reef	Long travelled (longshore transport/rivers)	Other (describe below):
%	%	%	%
<b>DETAILED EXPLANATION OF OTHER CATEGORY IF NECESSARY:</b>			

<b>OCEAN BEACH SAND DATA ANALYSIS</b>			
<b>Composition</b> Relative abundance:		<b>Grain size</b> Relative abundance:	
<b>Most resistant components:</b> Quartz (Q) ____% Chert (C) ____%		Gravel (>2 mm) (G) ____%	
<b>Medium resistant components:</b> Magnetite (M) ____% Feldspar (F) ____%		Coarse sand (1.3-2 mm) (CS) ____%	
<b>Least resistant components:</b> Shells (Sh) ____% Granite (G) ____%		Medium sand (0.7 to 1.3 mm) (MS) ____%	
Dark & nonmagnetic: Basalt, Mudstone, Hornblende, etc. (B) ____%		Fine sand (0.06 to 0.7 mm) (FS) ____%	
		Mud (<0.06 mm) (M) ____%	
Using <b>grain size and composition only</b> (without referencing type of local rock), does this sand appear to have been transported a great distance? Cite evidence.			
Combining the <b>above data</b> with the local rocks listed here, estimate varying source of this beach sand. <b>Local rocks are some chert, serpentinite, &amp; basalt.</b>			
Local rocks	Local reef	Long travelled (longshore transport/rivers)	Other (describe below):
%	%	%	%
<b>DETAILED EXPLANATION OF OTHER CATEGORY IF NECESSARY:</b>			

<b>MOSS BEACH SAND DATA ANALYSIS</b>			
<b>Composition</b> Relative abundance:		<b>Grain size</b> Relative abundance:	
<b>Most resistant components:</b> Quartz (Q) ____% Chert (C) ____%		Gravel (>2 mm) (G) ____%	
<b>Medium resistant components:</b> Magnetite (M) ____% Feldspar (F) ____%		Coarse sand (1.3-2 mm) (CS) ____%	
<b>Least resistant components:</b> Shells (Sh) ____% Granite (G) ____%		Medium sand (0.7 to 1.3 mm) (MS) ____%	
Dark & nonmagnetic: Basalt, Mudstone, Hornblende, etc. (B) ____%		Fine sand (0.06 to 0.7 mm) (FS) ____%	
		Mud (<0.06 mm) (M) ____%	
Using <b>grain size and composition only</b> (without referencing type of local rock), does this sand appear to have been transported a great distance? Cite evidence.			
Combining the <b>above data</b> with the local rocks listed here, estimate varying source of this beach sand. <b>Local rocks are GRANITE.</b>			
Local rocks	Local reef	Long travelled (longshore transport/rivers)	Other (describe below):
%	%	%	%
<b>DETAILED EXPLANATION OF OTHER CATEGORY IF NECESSARY:</b>			

How does the **Rodeo Beach** sand compare to **Ocean Beach** sand? Describe similarities and differences below. Facts only, no explanations!

Characteristic	Summary of differences and similarities (do not just restate data – summarize it)
Grain size	
Grain composition	

Based on **grain size and composition** does your data support your answer from the prereading about whether Rodeo Beach sand feeds Ocean Beach? Why or why not?

How does the **Moss Beach** sand compare to **Ocean Beach** sand? Describe similarities and differences below. Facts only, no explanations!

Characteristic	Summary of differences and similarities
Grain size	
Grain composition	

Based on **grain size, composition** does your data support your answer from the prereading about whether Ocean Beach sand feeds Moss Beach? Why or why not?

Use Google Earth & Oceans to locate each of the beaches studied in this lab. Look around the beaches a bit and see what's in the area. Enter their latitude and longitude below: Circle the one you'd most like to visit and explain why.

Waikiki Beach:

Big Island of Hawaii Punaluu Black Sand Beach:

Carmel, CA:

Moss Beach, CA:

Ocean Beach, CA:

Rodeo Beach, CA:

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Analyze the compositional and size characteristics of a sample of sand.	A   B   C   D   F	
Based on your sand analysis, evaluate the sources of that sand and its maturity.	A   B   C   D   F	
Identify, describe, compare, and contrast sands found in six different locations near San Francisco and in Hawaii.	A   B   C   D   F	
Describe the longshore current processes at work along the California Coastline north and south of San Francisco	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

## Beach Materials Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

**Review in class, or go to the website and review flashcards and be able to identify the different sand samples:**

Be sure you recognize where the sand came from (which beach), what the dominant sediment grains are (composition), and what the sand's source history is (where the sand came from).

**GET some sand and do an analysis (with microscope or without)**

MYSTERY – SAND DATA ANALYSIS			
<b>Composition</b> Relative abundance:		<b>Grain size</b> Relative abundance:	
<b>Most resistant components:</b> Quartz (Q) ___% Chert (C) ___%		Gravel (>2 mm) (G) ___%	
<b>Medium resistant components:</b> Magnetite (M) ___% Feldspar (F) ___%		Coarse sand (1.3-2 mm) (CS) ___%	
<b>Least resistant components:</b> Shells (Sh) ___% Granite (G) ___%		Medium sand (0.7 to 1.3 mm) (MS) ___%	
Dark & nonmagnetic: Basalt, Mudstone, Hornblende, etc. (B) ___%		Fine sand (0.06 to 0.7 mm) (FS) ___%	
		Mud (<0.06 mm) (M) ___%	
Using <b>grain size and composition only</b> (without referencing type of local rock), does this sand appear to have been transported a great distance? Cite evidence.			
Combining the <b>above data</b> with the local rocks listed here, estimate varying source of this beach sand.			
<b>Local rocks are ....</b>			
Local rocks	Local reef	Long travelled (longshore transport/rivers)	Other (describe below):
%	%	%	%
<b>DETAILED EXPLANATION OF OTHER CATEGORY IF NECESSARY:</b>			

### SAN FRANCISCO SAND

What is the general direction of longshore transport along the Pacific Coastline?	
Describe the grain size and composition of sand that is <b>close</b> to its source. <b>Grain size:</b>  <b>Composition:</b>	Describe the grain size and composition of sand that is <b>far</b> from its source. <b>Grain size:</b>  <b>Composition:</b>
Is it possible for Rodeo Beach sand to feed Ocean Beach? Why or why not?	

Is it possible for Ocean Beach sand to feed Moss Beach? Why or why not?

---

Where does Ocean Beach sand come from? Tell the **complete** story.

**KEY**

**SAN FRANCISCO SAND**

What is the general direction of longshore transport along the Pacific Coastline?	<i>South</i>
Describe the grain size and composition of sand that is <b>close</b> to its source. <b>Grain size: Gravels, Sands, and muds (ALL)</b> <b>Composition: All</b>	Describe the grain size and composition of sand that is <b>far</b> from its source. <b>Grain size: Fine sands and muds</b> <b>Composition: Clays and quartz</b>
Is it possible for Rodeo Beach sand to feed Ocean Beach? Why or why not? <i>No – The Golden Gate sits between the two (we remember from previous lab that it’s 352 ft deep here – sand can’t move down then back up this zone). Be sure they don’t misunderstand – Sacramento River is NOT under the GG Bridge, but is pushed up – its delta is near Sacramento!</i>	
Is it possible for Ocean Beach sand to feed Moss Beach? Why or why not? <i>No – The Pioneer Canyon sits between the two</i>	
Where does Ocean Beach sand come from? Tell the <b>complete</b> story. <i>Ocean Beach sand comes from old deposits of sand from the ice age. During the last ice age, the Sacramento River dumped large amounts of sand on the Pacific shoreline, 20 miles west of its current location. This sand was picked up by the wind and carried over the SF Peninsula, creating a massive sand dune province. After the ice age, as sea level rose, these dunes were covered. They are now offshore sand bars that are pushed ashore during the summer months.</i>	



## San Francisco Bay Coastal Processes Field Trip

In lecture textbook, read chapter on **Estuaries** and the following text, which is a Special Highlight section on San Francisco Bay (modified from Pinet, Paul, 2000, Invitation to Oceanography, Jones and Bartlett Publishers).

There is a long history of human activity in the San Francisco Bay area, much of which has over time severely affected this coastal ecosystem, including its natural biota, sedimentation patterns, hydrology, and water chemistry. Nevertheless there is reason for optimism, because numerous federal and state agencies, as well as grass-roots organizations, are working hard and cooperatively to develop a scientific understanding of this complex ecosystem in order to mitigate and even reverse the degradation of the bay. The goal is to distinguish the natural from the human-induced changes, so that effective management and regulatory strategies can be implemented to protect the natural integrity and beauty of the Bay Area for future generations.

What specific chemical, biological, and geological changes has San Francisco Bay undergone since 1850? Principally, the damage has been the result of: loss of wetlands, the diversion of water, overenrichment with nutrients, deterioration of water quality, and the introduction of exotic species



### **WATER DIVERSION**

Today, about 40 percent of the freshwater discharge of the Sacramento-San Joaquin watershed is diverted for local consumption. An additional 24 percent is pumped out of the upper bay and exported by aqueducts to southern California. Most of this diverted water is used to irrigate farmland and the demand for additional water is expected to increase because of the profitability of agricultural production. The reduced inflow of freshwater has had grave ecological consequences for the estuary, preventing some fish species from spawning, reducing the phytoplankton biomass, and generally disrupting food webs. The reduced freshwater discharge into the bay is also likely to have modified circulation and sedimentation patterns and the capability of the estuarine water to dilute and flush out contaminants. Several agencies are extensively researching and monitoring the bay to document the effect on the estuary's biological system and water circulation of this reduced inflow of freshwater.

### **NUTRIENT ENRICHMENT**

The urbanization of the area and agricultural practices have substantially increased the levels of nutrients such as ammonia, nitrate and phosphate in the waters of the bay. For example, more than 800 million gallons of municipal wastewater containing 60 tons of nitrogen are discharged annually into San Francisco Bay. This influx of nutrients has not, however, led to eutrophication, because of the richness of the benthos (clams, mussels, crustaceans), which filter out huge quantities of algae and thereby control the phytoplankton biomass of the water. State-of-the-art wastewater treatment has had immediate results in reducing the influx of nutrients to portions of San Francisco Bay, and more such measures and water treatment technology are scheduled to be in place in the near future.

*NOTE: Eutrophication is a process where increased nutrients lead to increased phytoplankton masses (algae) that grow quickly (bloom), then die off after the nutrients are consumed. The die-off and subsequent decomposition of the algae removes oxygen from the environment, leading to potentially fatally low levels of oxygen for the animals in the area.*

## **WATER QUALITY**

Bay waters receive variable loads of a great variety of toxic contaminants from agricultural, industrial, and urban activities. Locally, particularly near wastewater discharge pipes, the concentrations of toxins in bottom sediment commonly is very high. Many of these substances, such as pesticides, PCBs, petroleum hydrocarbons, and trace metals, have long-range consequences for the viability of estuarine organisms, particularly of benthic communities, mammals, such as seals, and birds that feed on marine invertebrates and fish. The high concentrations of cadmium, silver, and lead that have been measured at certain localities in bay muds are dangerous, because these metals are known to interfere with the growth and reproduction of fish, mammals, and birds. Furthermore, shellfish and finfish biomagnify such toxins, so there is concern for the health of humans who consume them. Modern waste treatment procedures and technology can substantially reduce the inputs of contaminants to the bay. Models are being developed and monitoring in the field is currently being used to investigate the way in which contaminants in muds are recycled through ecosystems.

## **WETLAND LOSS**

Since 1950 over 95 percent of the estuary's wetlands have been lost to development, levee construction, pollution, erosion, and rising sea level. Sediment infilling of a bay and its wetlands is a natural process, but it can be greatly accelerated by human activity, such as the gold mining by the Forty-niners during the nineteenth century, when huge quantities of sediment were washed into the bay. Because wetlands are critical habitats for many fish and wildlife, destruction there has had grave consequences for the area's natural biota. For example, the decline of fish diversity in the estuary has been so extreme that today commercial fisheries are limited to harvesting anchovies and herring. The U.S. Geological Survey, the U.S. Army Corps of Engineers, and the San Francisco Bay Conservation and Development Commission are striving to establish new wetlands in parts of the bay that have been diked to create farmland and salt evaporation ponds. More such reclamation projects have been proposed by conservation groups.

## **THE INTRODUCTION OF EXOTICS**

The introduction of exotic species has had devastating effects on the natural populations of San Francisco Bay by displacing or outcompeting them for space and resources. More than 130 species of plants, invertebrates, and fish that are not indigenous to the region have been released into the bay waters since the mid-nineteenth century, some inadvertently (foreign vessels, for example, expel their bilge water with its alien organisms into the bay), some on purpose. Today, just about all of the common large invertebrates that dwell in shallow water are exotic species; of the forty-two species of fish that inhabit the upper bay, twenty have been introduced by humans. Recent investigations have demonstrated convincingly that the damage caused by exotic species to the bay's natural ecosystem can be as great or even greater than the effect of chemical contaminants. Many studies are underway to investigate the specific ecological changes that are associated with the invasion of exotic species, and the results of this research will form the basis for a management program to mitigate what some refer to as "biological contamination."

Nonetheless, the future of San Francisco Bay has never looked better, as private and public individuals and agencies work hard and cooperatively to identify the area's environmental problems. Clever management strategies based on solid scientific research are being designed and implemented with the long term in mind and with a proper balance between the needs of people and the needs of the bay's fauna and flora. Many hope that the general lessons learned here can be used to avert similar problems elsewhere.

# San Francisco Bay Estuary Tidal Wetlands, 1850 and 2000

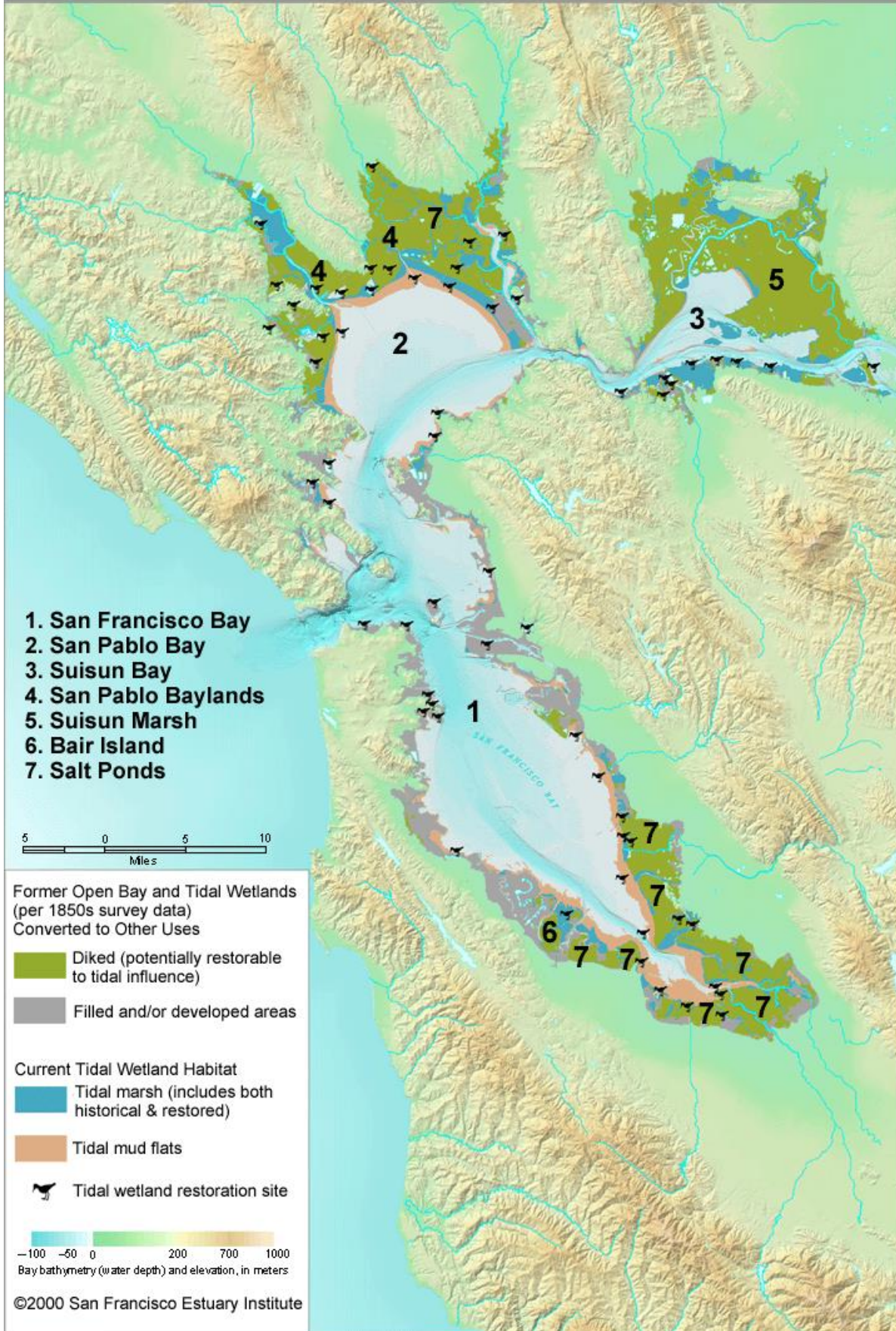
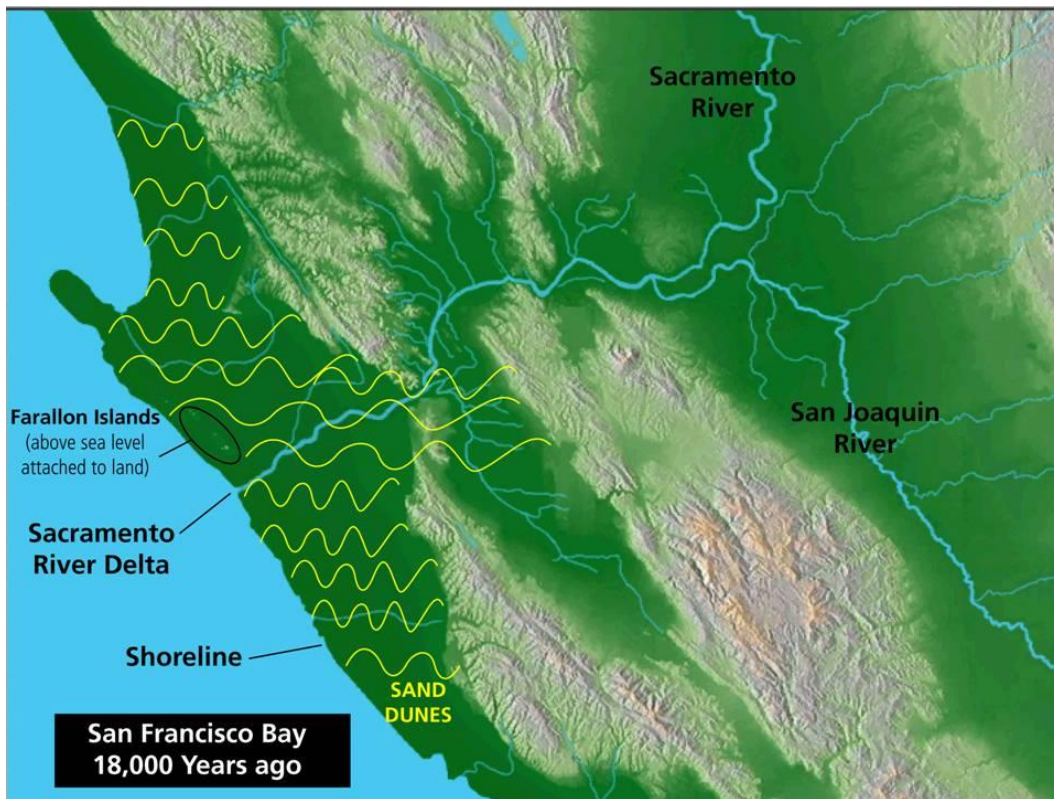
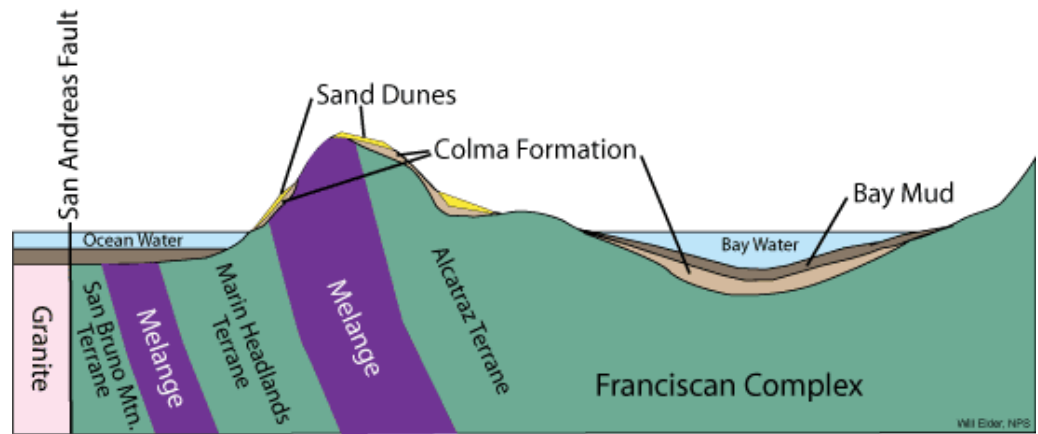


Image used with permission from San Francisco Estuary Institute.

Cross-section from west to east looking North across the San Francisco Peninsula. Note the sand and mud that covers much of the low-lying areas. Sand (Colma Formation) was deposited during ice ages when sea level was lower. Mud is deposited inside the Bay during interglacials, when sea level is higher. Images from: Will Elder, National Park Service



*San Francisco Bay Area coastline (and sea level) at the height of the last ice age, 18,000 years ago. Yellow curved lines represent extent of sand dunes covering continental shelf. Modified from work by Tanya Atwater – UC Santa Barbara*

Ocean Beach has no local rock to erode and has no upcurrent river to distribute sand to it. Longshore current cannot cross over the Golden Gate entrance, because of deep channels carved by tidal currents. Where does Ocean Beach sand come from? It comes from offshore sand deposits, left during the last ice age, when the Sacramento River flowed all the way to the beach (15 miles west of its current location). The Sacramento River, during an ice age, would have contained large quantities of water and sand, making for a large sand delta at the Pacific Ocean. Winds blew this sand onshore, where it covered large expanses of continental shelf, including most of the San Francisco Peninsula. These sands formed a massive sand dune province. Since the ice age, sea level has risen. The current Sacramento River dumps its load in a delta far inland, in Sacramento. Only muds stay suspended in this water as it mingles with the seawater entering San Francisco Bay. Ocean Beach's only source of sand are these offshore dunes that are now underwater and are picked up daily by incoming waves and pushed onto Ocean Beach.

## Tidal Height and Time Corrections

Tidal heights and times across San Francisco Bay – all relative to the time and height of the tides at the Golden Gate Bridge (find that value below and CIRCLE IT).

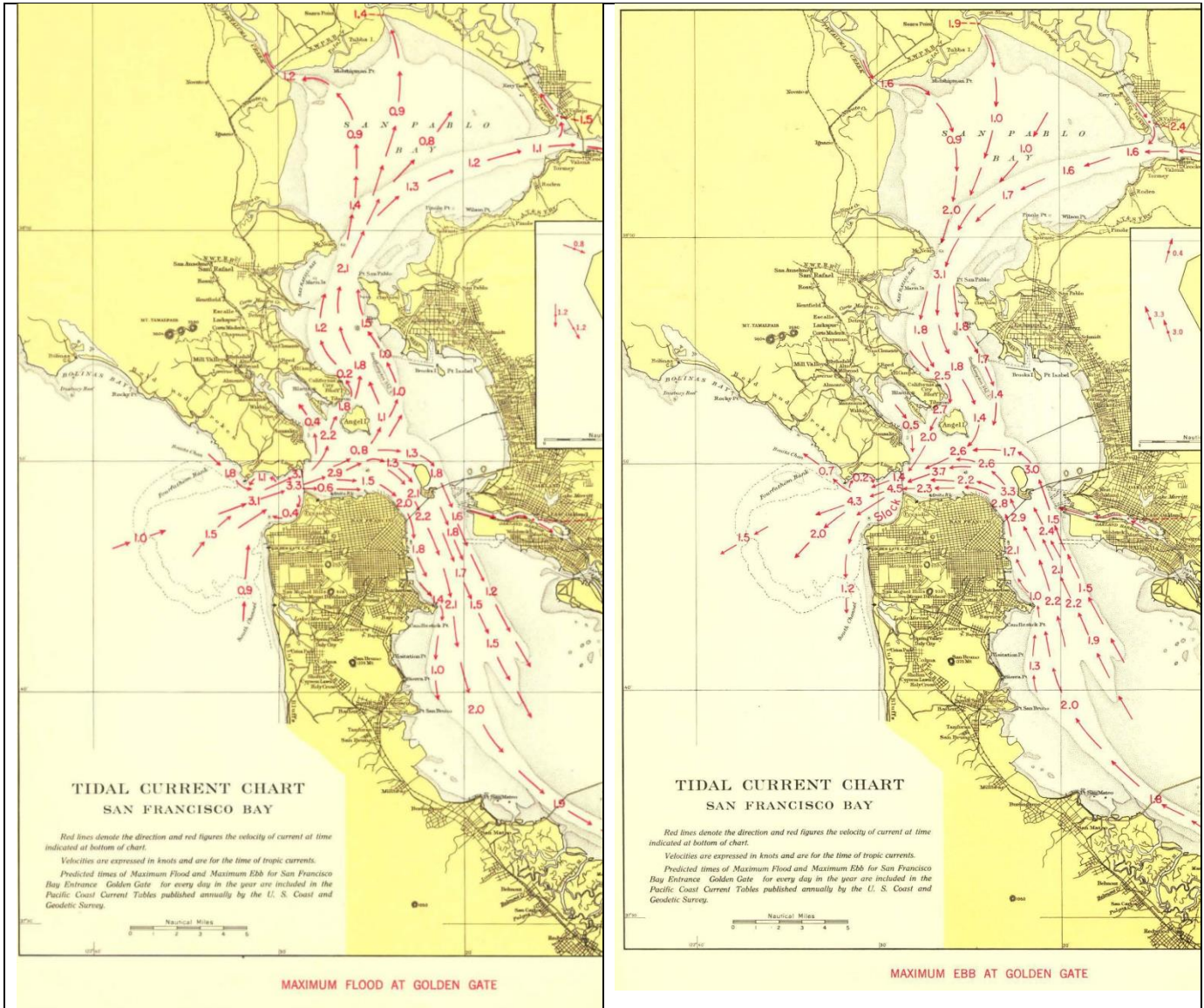
#		Lat	Lon	DIFFERENCES		HEIGHT (ft above MLLW)	
				TIME (hrs: min)		H	L
T 505	Half Moon Bay	37 30	122 29	-1:06	-0:50	-0.3	0.0
#	San Francisco Bay						
T 511	Ocean Beach	37 46	122 31	-0:49	-0:35	+0.1	0.0
T 513	Point Bonita, Bonita Cove	37 49	122 32	-0:17	-0:10	+0.3	0.0
T 515	SAN FRANCISCO (Golden Gate)	37 48	122 28	0:00	0:00	0.0	0.0
T 523	Yerba Buena Island	37 49	122 22	+0:32	+0:40	+0.3	0.0
#	San Francisco Bay, South						
T 539	Oakland Airport	37 44	122 12	+0:47	+0:52	+0.8	0.0
T 543	Hunters Point	37 44	122 21	+0:25	+0:39	+0.9	0.0
T 551	Oyster Point Marina	37 40	122 23	+0:48	+1:07	+1.1	0.0
T 559	San Mateo Bridge (west end)	37 35	122 15	+0:52	+1:20	+1.8	+0.1
T 561	San Mateo Bridge (east end)	37 36	122 11	+0:48	+1:19	+1.8	0.0
T 587	Dumbarton Highway Bridge	37 30	122 07	+1:00	+1:38	+2.6	+0.1
T 603	Guadalupe Slough	37 27	122 02	+1:14	+2:15	+2.7	0.0
#	San Francisco Bay, North						
T 617	Sausalito	37 51	122 29	+0:10	+0:14	-0.3	0.0
T 629	Point Isabel	37 54	122 19	+0:23	+0:33	+0.1	0.0
#	San Pablo Bay						
T 641	Point San Pedro	37 59	122 27	+0:59	+1:01	+0.1	0.0
T 643	Pinole Point	38 01	122 22	+1:12	+1:26	*1.04	*0.92
T 647	Petaluma River Entrance	38 07	122 30	+1:22	+2:11	+0.1	-0.1
T 649	Lakeville, Petaluma River	38 12	122 34	+1:59	+2:50	*1.11	*0.81
#	Carquinez Strait						
T 663	Mare Island Strait	38 06	122 16	+1:47	+2:14	-0.1	-0.2
T 669	Napa, Napa River	38 18	122 17	+2:16	+2:52	+1.4	0.0
T 673	Crockett	38 04	122 13	+1:39	+2:03	-0.2	-0.2
T 675	Benicia	38 03	122 08	+2:11	+2:34	-0.6	-0.3
#	Suisun Bay						
T 679	Suisun Slough entrance	38 08	122 04	+2:45	+3:32	-1.1	-0.4
#	San Joaquin River						
T 703	Antioch	38 01	121 49	+4:04	+4:45	*0.64	*0.51
T 707	Prisoners Point	38 04	121 33	+5:53	+6:45	*0.60	*0.45
T 713	Stockton	37 58	121 17	+6:37	+7:39	*0.68	*0.43
T 735	Grant Line Canal (drawbridge)	37 49	121 27	+8:41	+9:22	*0.63	*0.45
#	Sacramento River						
T 737	Collinsville	38 04	121 51	+3:43	+4:26	*0.65	*0.55
T 741	Rio Vista **<4>**	38 09	121 42	+4:05	+5:13	*0.81	*0.55
<i>Off map:</i>							
T 747	Clarksburg **<4>**	38 25	121 31	+6:25	+8:04	*0.50	*0.27
T 749	Sacramento **<4>**	38 35	121 30	+7:34	+9:34	*0.50	*0.27
#	**<4>** These data apply only during low river stages.						

\*(ASTERISK): TIDAL HEIGHT DIFFERENCE IS A RATIO INSTEAD OF# OF FEET.

EXAMPLE: IN ANTIOCH, THE LOW TIDE IS ABOUT HALF THE HEIGHT (0.51X GGB HEIGHT) OF THE TIDE AT GGB.



Tidal wetlands from the 1850s and 2000. Red stars are tidal locations that correlate with preceding table and indicate the time difference between high tides at this location and those at the Golden Gate Bridge. For example, In Half Moon Bay (HMB), high tide arrives 1 hour and 6 minutes BEFORE it reaches the Golden Gate Bridge. The tide flood current migrates north into the bay and then splits. It arrives at Yerba Buena Island (YBI) 32 minutes AFTER it reached the Golden Gate Bridge. Modified from original image produced in 2000 and used with permission from San Francisco Estuary Institute.



Tidal Charts of San Francisco Bay from U.S. Department of Commerce – 5<sup>th</sup> Edition (1955)  
#s given are speeds in knots (1 nautical mile/hour)

**FULL SAN FRANCISCO BAY**

TIDAL DATUM	VOLUME (Mm <sup>3</sup> )	SURFACE AREA (Mm <sup>2</sup> )	AVG. DEPTH VOL/AREA (m)	MEDIAN DEPTH (m)
MLLW	7142	1138	6.3	2.8
MSL	8446	1219	6.9	3.6
MHHW	9570	1244	7.7	4.4

\*Tidal Datum = zero mark for tidal chart. MSL = mean sea level. MLLW = Mean Lower Low Water. MHHW = Mean Higher High Water. Mean take over previous year. San Francisco experiences two highs and lows roughly every day (24 hours and 50 minutes), one of the highs much higher than the other; one low much lower. 1 Mm = 1 Megameter = 10<sup>6</sup> m = 1,000 km.

## San Francisco Bay Coastal Processes – Prereading Exercises

1. What are the five main changes that San Francisco Bay has gone through since 1850, since human settlement in the area became larger and more permanent? What are the consequences of each?

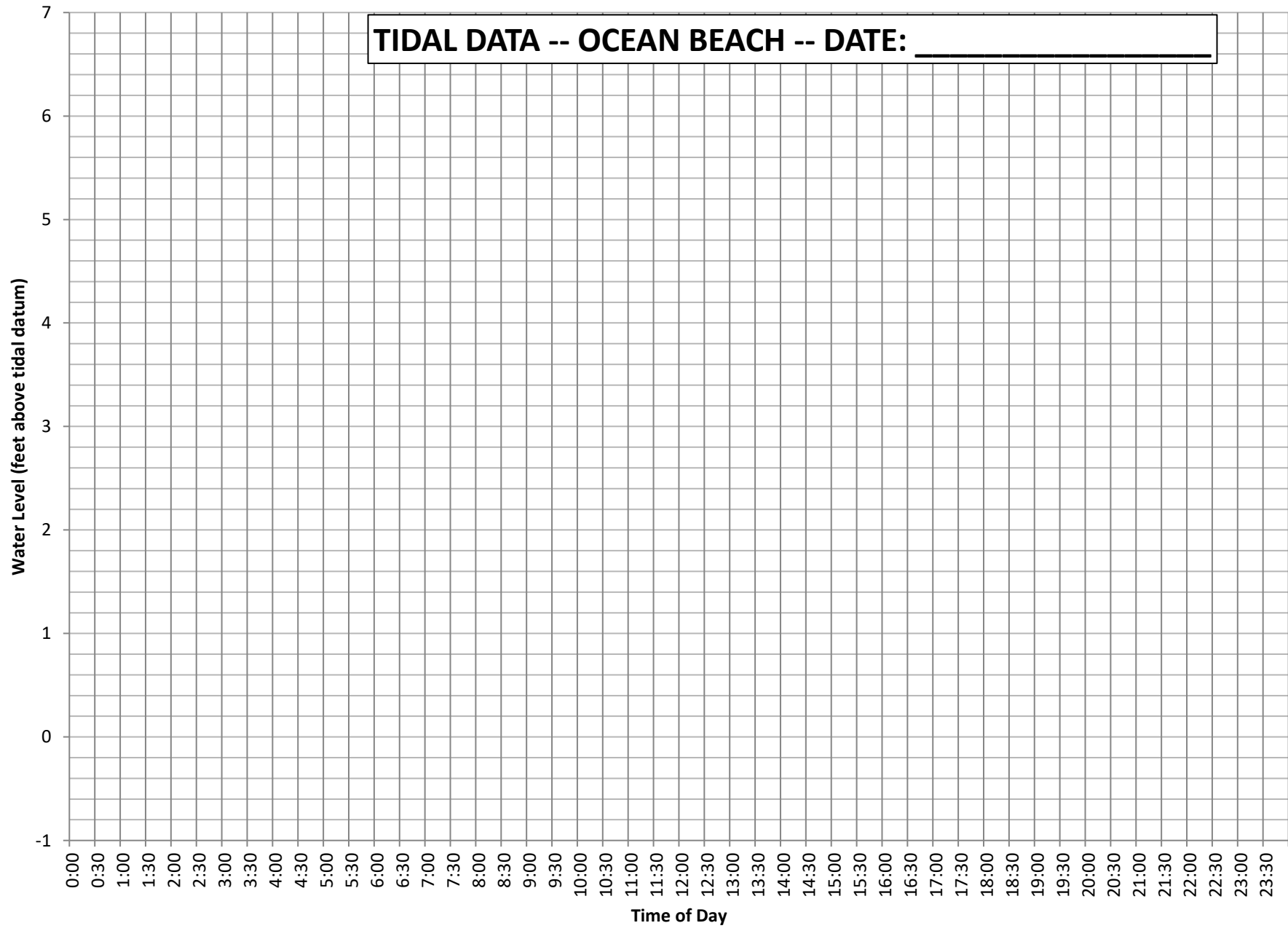
CHANGE	RESULTS OF CHANGE

2. Review the Ground shaking map – USGS – from the last lab (Beach Materials) as well as the cross-section and sand dune maps from this lab. If we were to drill cores through the sediments at the bottom of San Francisco Bay, what will we find and how does it relate to glacials and interglacials?

For the following questions, reference tidal charts and corrections from prereading, as well as the tables and website links.

<p>3. What is the volume difference between MLLW and MHHW in San Francisco Bay (the difference in Bay volume between high tide and low tide)? Where does all that water sit at high tide? Low tide?</p>
<p>4. Find the tidal data link on the class website and determine the tides at the <b>Golden Gate Bridge</b> for the day you're looking up the data (<i>time and height</i>):</p> <p>High: _____   Low: _____   High: _____   Low: _____ DATE: _____</p>
<p>5. Find the tidal data link on the class website and determine the tides for same day at <b>Ocean Beach</b> (<i>time and height</i>). Enter below and graph wave on next page.</p> <p>High: _____   Low: _____   High: _____   Low: _____</p>
<p>6. Based on these data, circle what direction tides seem to move between GGB and OB: _____ CIRCLE: FROM OB TO GGB   FROM GGB to OB</p>
<p>7. Based on these data, what is the <b>time interval</b> between the two at high tide? Low tide?</p> <p>High: _____   Low: _____</p>
<p>8. Based on these data, is there any difference in tidal height between the two locations?</p> <p>High: _____   Low: _____</p>
<p>9. Find the tidal data link on the class website and determine the tides for the same day at the <b>Sacramento River – Rio Vista</b> (<i>time and height</i>):</p> <p>High: _____   Low: _____   High: _____   Low: _____</p>
<p>10. What is the time interval between high tide at OB and high tide at RV?</p>
<p>11. Find the tidal data link on the class website and review the tides for 14 consecutive days at the <b>Golden Gate Bridge</b>. What is the largest range observed (range = difference between high and low tide).</p>
<p>12. Find the tidal data link on the class website and review the tides for 14 consecutive days at the <b>Golden Gate Bridge</b>. What kind of tides does San Francisco Bay experience?</p> <p style="padding-left: 40px;">Circle: diurnal (one high and low per day)   semidiurnal (two highs and two lows per day of equal height) semidiurnal mixed (two highs and two lows per day of varying height)</p>
<p>13. On the following page, fill out the tidal chart for Ocean Beach for the day you are gathered the above data. Curve it properly and label it like the chart from the San Francisco Bay Chemistry Prereading.</p>
<p>14. What's the largest time difference between high tide arriving at the GG Bridge and any other location inside SF Bay? (Give time difference and location.)</p>
<p>15. What's the largest height difference between high tide at the GG Bridge and any other location inside SF Bay? (Give height difference and location.)</p>

**TIDAL DATA -- OCEAN BEACH -- DATE: \_\_\_\_\_**



# San Francisco Coastal Processes Field Trip

## 1. RECORDING CONDITIONS

Date and time arrived at beach:	
Tide level on this beach for this date/time	
TIDAL CURRENTS at this beach for this date/time Water is rising (FLOOD CURRENT) Water is falling (EBB CURRENT)	
Longshore drift direction (& evidence to support answer – in other words, not simply the answer the book gives, look at the beach, design an experiment to determine longshore drift direction, the provide experiment and results here.)	

2. Look carefully at the beach north of the Parking Lot. Note components of a beach profile. Compare with picture on the following page. Not all will be present. Circle on the attached image all the components that are present. Add ones that aren't in the image. Cross off those that are in the image but that are not visible on this beach. Be sure you can recognize each on the beach itself!

3. During summer, sand is pushed up onto the beach. During winter, heavy storms bring high waves, which remove sand and store it offshore.

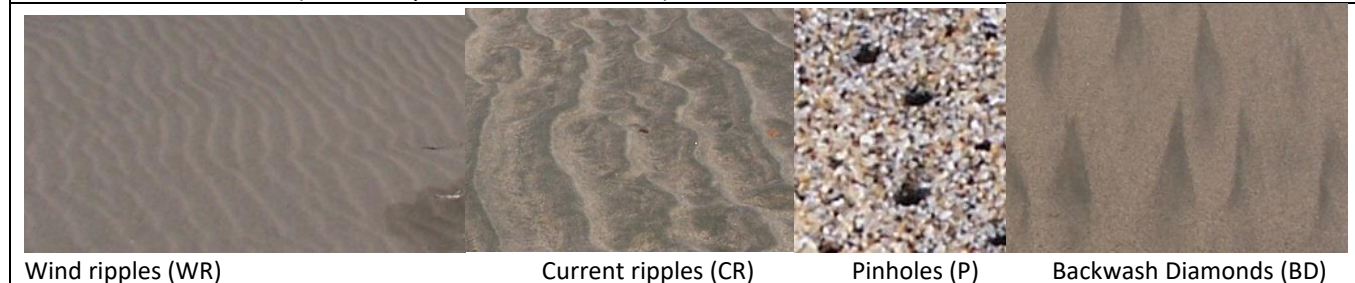
- During what month of the year would you expect the berm to be highest?
- During what month of the year would you expect the berm to be lowest?

4. Assume the cross-section beach profile (the profile of the sand on the beach) on the following page was drawn in April. Draw a second profile line on the cross-section and label it with the October line.

- How does today's date fit with that seasonal process?  
Does it match what you see?
- 6 months from now, what date will it be?  
What would you expect the sand pile on the beach to look like then?

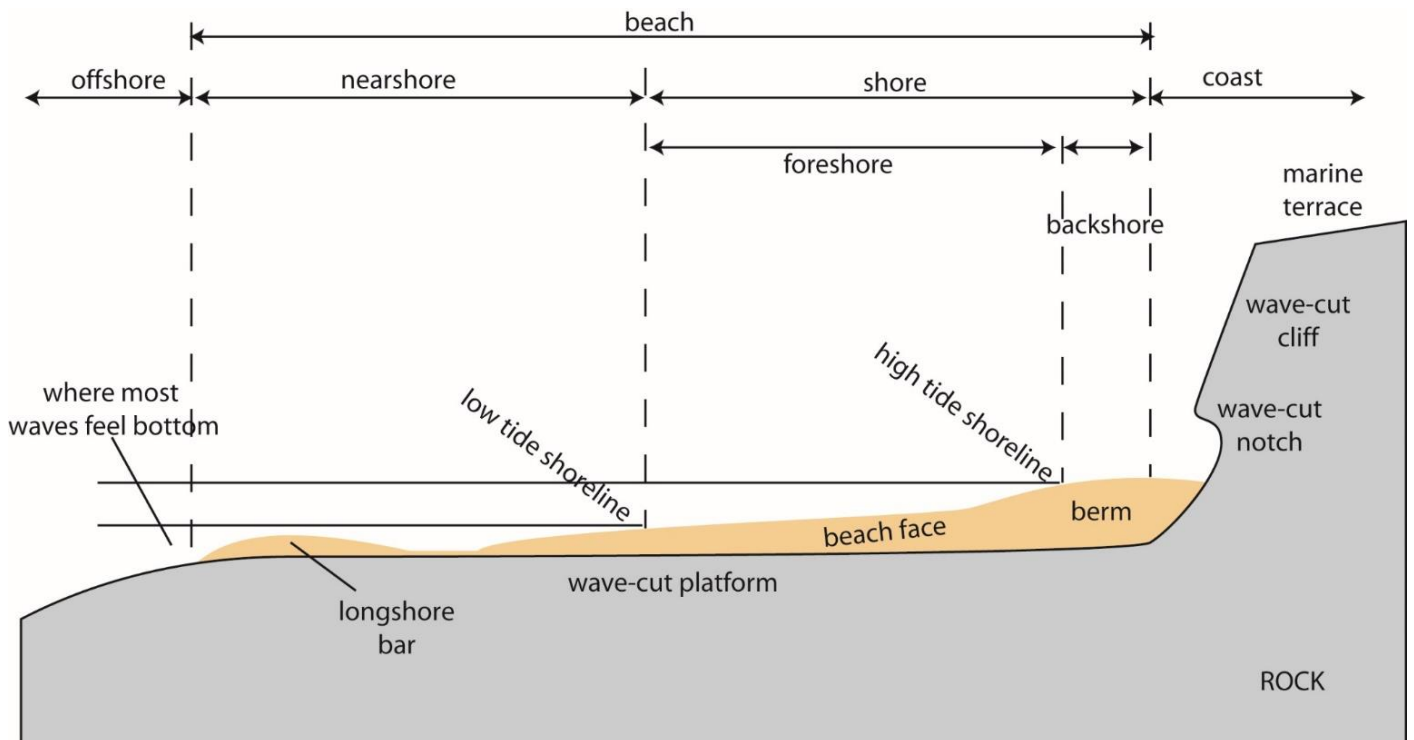
5. Somewhere in the area, you will see plenty of magnetite (iron oxide). Compare the density of a handful of dark-colored sands to light-colored sands. Notice that the magnetite (metallic) sparkles in the sun. Where does this magnetite concentrate along the beach? Where is it most abundant? Make sure you can locate the region of the beach that has the highest magnetite concentration. **Indicate the highest magnetite concentrations on your cross-section with a large M.**

6. Pinholes, backwash diamonds, wind ripples, and current ripples are found throughout the beach. *Pinholes* are not caused by organisms expelling air, but by the sand itself expelling air when swash soaks into the sand and displaces the air that was previously there. *Backwash diamonds* form when backwash is diverted around small obstacles, creating low energy and accumulation of debris behind the obstacle. *Wind and current ripples* form along sand that is pushed by continual movement of wind or water. Find these features on the beach. Indicate on your cross-section where each is found (with the symbol described below).



7. Footsteps made in the sand near the water's edge cause the sand to dry out instead of get wet. Why? Probably because the sand, prior to your footprint, is as closely packed as possible. Its room to hold water between sand grains is at a minimum. When you step on the sand, you disturb it, letting it expand upward and outward and thereby increasing the space between sand grains. This increased room allows the water to sink further into the sand, making the surface sand even dryer. Simulate the above process along the beach today. Comments?

8. Look carefully at the cliff and beach directly in front of the Parking Lot. Walk along it and describe how it differs from the section to the North that you just studied. What do you think is the cause of these differences? (Answer in the space below.)



## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week’s objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Identify, locate, and describe the formation processes of a number of coastal sand features, including pinholes, current ripples, wind ripples, and backwash diamonds.	A   B   C   D   F	
Describe the seasonal changes in sand experienced at Ocean Beach and use these to predict the times of the year when sand will be piled highest and lowest.	A   B   C   D   F	
Characterize the magnetite distribution in the sands at Ocean Beach.	A   B   C   D   F	
Design an experiment to determine longshore current direction along any beach on any given day.	A   B   C   D   F	
Characterize the tides that occur at Ocean Beach and within San Francisco Bay: times, heights, and directions of movement.	A   B   C   D   F	

### INSIGHTS

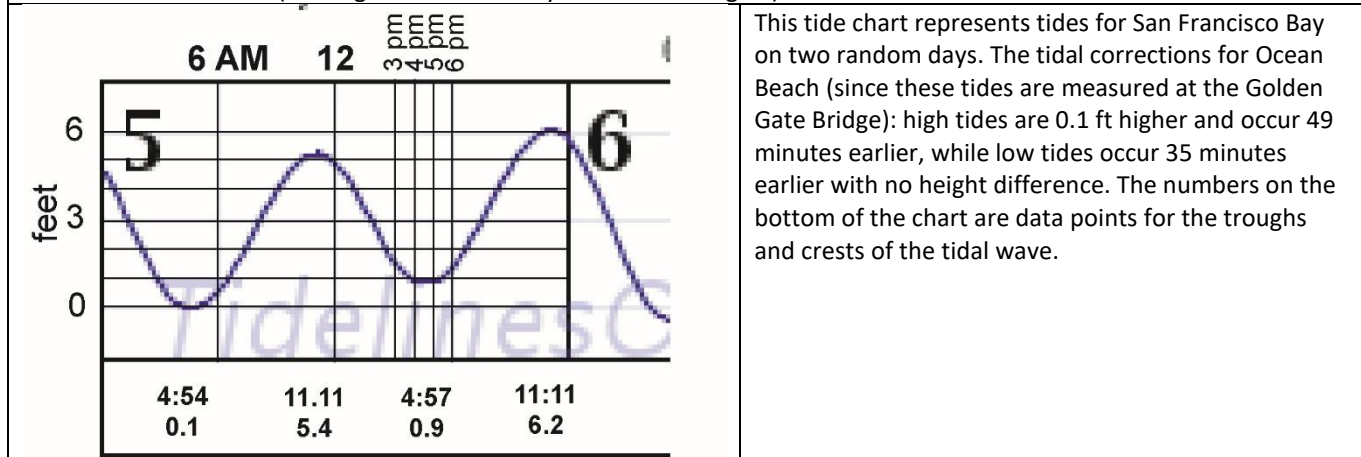
What new insights have you developed this week due to the week’s content? Did anything in particular help you understand something you’ve always wondered about, or made you think about the world with new eyes?

## San Francisco Bay Coastal Processes Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

1. What are the five main changes that San Francisco Bay has gone through since 1850, when humans began settling here? What are the consequences of each of those changes?	
CHANGE	RESULTS OF CHANGE

- |   |
|---|
| 2. What direction do tides move along the California Coast?   |
| 3. What direction does longshore current generally move along the California Coast?   |
| 4. Describe an experiment to determine the direction of longshore current at a specific beach on a specific day.  |
| 5. What is the mean spring tide range (largest monthly difference in height between low and high tide) in San Francisco?  |
| 6. What tidal pattern do we have here in San Francisco? Circle one:<br>Diurnal (one high and low a day)<br>Semidiurnal (two highs and lows a day of the same height)<br>Semidiurnal mixed (two highs and lows a day of different heights) |

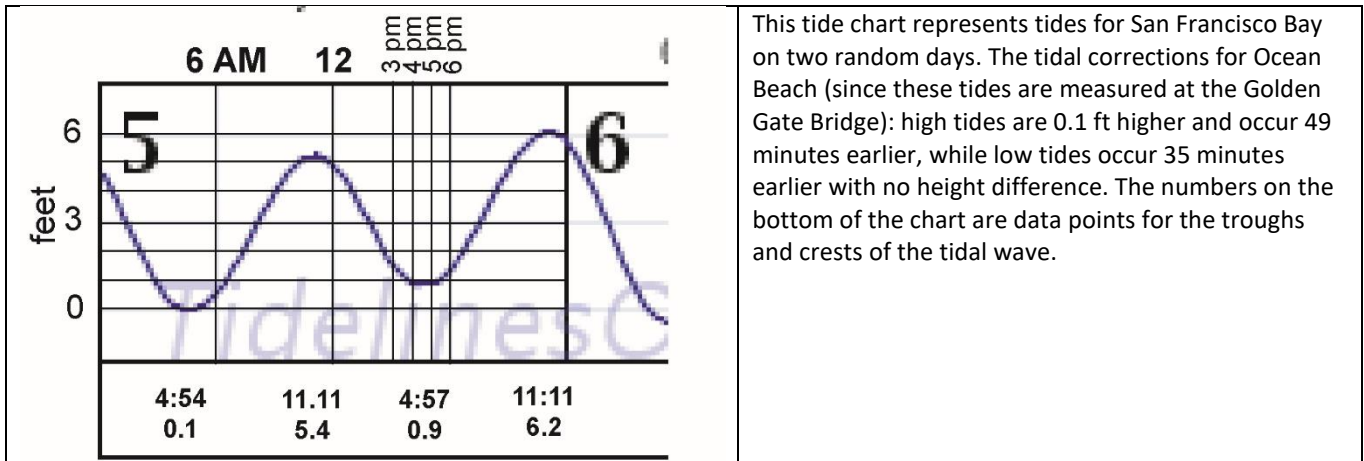


7. At <b>what time</b> on THIS chart will you look for tides that will occur at 4:30 pm at Ocean Beach?
8. What will the level of the tide be at Ocean Beach at 4:30 pm? <b>Be precise!</b>
9. With the following tidal data for a particular day and beach, create a tidal chart like the one above, and estimate what the tide level and current will be at 9 am. (12:13 am 5.9   5:41 am 1   12:00 pm 6.3   6:03 pm -0.1)
10. What type of tidal current is happening at this time? (ebb, flood, slack water)
11. During what month of the year would you expect sand on the berm to be piled highest (most sand on beach)? Why?
12. During what month of the year would you expect sand on the berm to be at its lowest (least sand on beach)? Why?
13. Describe where the largest and smallest grains are found on beaches, and explain how waves, wind, gravity, and humans might have affected the distribution.

## KEY

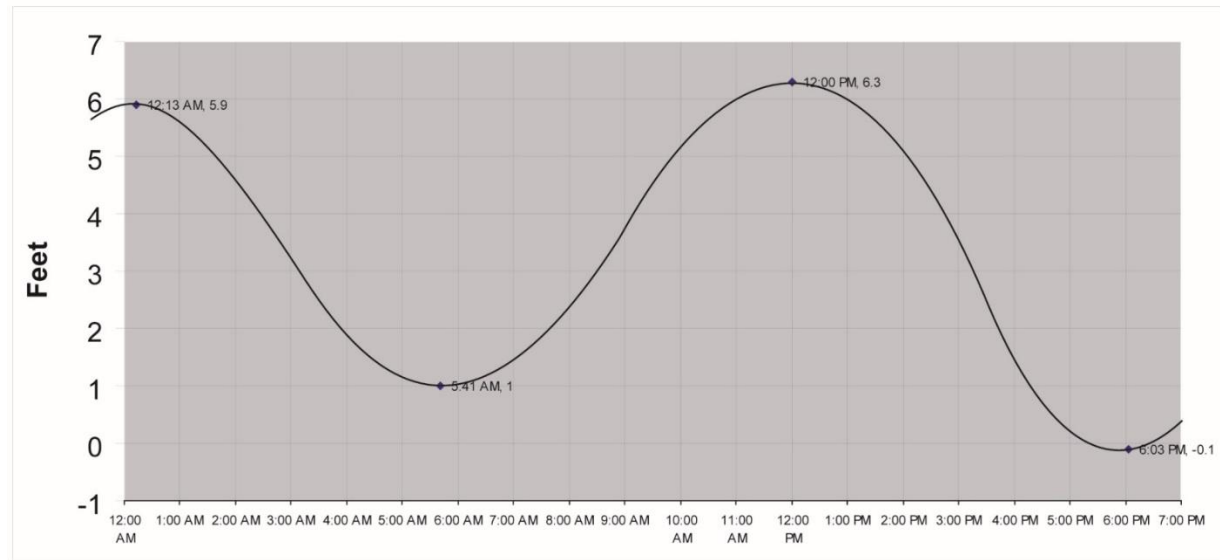
### 1. ECOLOGY CHANGES

CHANGE	RESULTS OF CHANGE
<i>Wetland Loss</i>	<i>Decline of fish diversity</i>
<i>Water Diversion</i>	<i>Decline in fish spawning grounds; phytoplankton biomass drops; harder to dilute and flush out contaminants.</i>
<i>Nutrient Enrichment</i>	<i>Eutrophication possible (loss of oxygen through overuse)</i>
<i>Water Quality</i>	<i>Decrease in growth rates and reproduction; Increase in poisons in shellfish and therefore the humans who eat them.</i>
<i>Exotic Species Introduction</i>	<i>Loss of native species.</i>
2. What direction do tides move along the California Coast? <b>Northward</b>	
3. What direction does longshore current generally move along the California Coast? <b>Southward</b>	
4. Describe an experiment to determine the direction of longshore current at a specific beach on a specific day. <b>Place floating object (log, plastic, swimmer) and watch the direction it moves in the surf zone.</b>	
5. What is the mean spring tide range (largest monthly difference in height between low and high tide) in San Francisco? <b>6-8 ft</b>	
6. What tidal pattern do we have here in San Francisco? <b>Mixed semi-diurnal</b>	



This tide chart represents tides for San Francisco Bay on two random days. The tidal corrections for Ocean Beach (since these tides are measured at the Golden Gate Bridge): high tides are 0.1 ft higher and occur 49 minutes earlier, while low tides occur 35 minutes earlier with no height difference. The numbers on the bottom of the chart are data points for the troughs and crests of the tidal wave.

- At **what time** on THIS chart will you look for tides that will occur at 4:30 pm at Ocean Beach? **5:05 pm**
- What will the level of the tide be at Ocean Beach at 4:30 pm? **1.1 ft**
- With the following tidal data for a particular day and beach, create a tidal chart like the one above, and estimate what the tide level and current will be at 9 am. (12:13 am 5.9 | 5:41 am 1 | 12:00 pm 6.3 | 6:03 pm -0.1) **See below.**



- What type of tidal current is happening at this time? **Flood current.**
- During what month of the year would you expect sand on the berm to be piled highest (most sand on beach)?  
Why? **October/November because summer waves are gentle and push sand on beach (lack of large storms)**
- During what month of the year would you expect sand on the berm to be at its lowest (least sand on beach)?  
Why? **April/May because winter waves have been large from storms and have eroded sand to offshore.**
- Describe where the largest and smallest grains are found on beaches, and explain how waves, wind, gravity, and humans might have affected the distribution. **Gravity carries grains of all sizes off backshore rocks – the largest stay close to the rocks from which they eroded (most of the backshore rocks to erode are brought in by humans – rip rap and parking lot debris). Wind carries small grains of sand from foreshore and deposits in backshore and dunes. Waves pick of intertidal sediment – size determined by energy of the waves. Stronger waves pick up larger grains. Smaller waves leave those larger grains behind.**

# Taxonomic Classification of A SUBSET OF Marine Organisms

(Modified from Garrison T, *Oceanography: An Invitation to Marine Science*, 5th edition, Appendix VI, pp. 475-476)

While you should know the classifications for all the organisms listed here, the **BOLDED TERMS** are the classification levels you are responsible for on exams. Also, please note that this list is a **SUBSET** of marine organisms – there are many more animal phylum, for example, especially various worm phyla, than listed below.

## **PROKARYOTES (no nucleus, no sexual reproduction)**

**KINGDOM BACTERIA:** Single-celled prokaryotes with a single chromosome that reproduce asexually and exhibit high metabolic diversity. Some roles in oceans: base of food chain, converters of nitrogen gas into useful forms for organisms, decomposers. Some species are heterotrophs; some are autotrophs. *Cyanobacteria (stromatolites)*.

**KINGDOM ARCHAEA:** Superficially similar to bacteria, but with genes capable of producing different kinds of enzymes. Often live in extreme environments. Some species are heterotrophs; some are autotrophs.

**\*NOTE: Some classifications combine the two kingdoms above into one: MONERA**

## **EUKARYOTES (nucleus, sexual reproduction)**

**KINGDOM PROTISTA:** Eukaryotic single-celled, colonial, and multicellular autotrophs and heterotrophs.

- single celled
- PHYLUM CHRYSOPHYTA. Single-celled autotrophs with SiO<sub>2</sub> or CaCO<sub>3</sub> shells:  
*Diatoms (SiO<sub>2</sub> shells) with two separate valves (halves); coccolithophores (CaCO<sub>3</sub> shells); silicoflagellates.*
  - PHYLUM PYRROPHYTA. *Dinoflagellates, zooxanthellae*. Mostly single-celled flagellates with two dissimilar flagella. Heterotrophic and autotrophic forms.
  - PHYLUM SARCODINA. Amoebas and their relatives. Single-celled heterotrophs.  
Class Rhizopodea. *Foraminiferans*. CaCO<sub>3</sub> shells  
Class Actinopodea. *Radiolarians*. SiO<sub>2</sub> shells
- multicelled
- PHYLUM CILIATES or CILIPHORA. *Tintinnid*. Single-celled heterotrophs. No shells. Cilia water flow into mouth.
  - PHYLUM **BROWN ALGAE** (PHAEOPHYTA). Brown algae, kelps. *Kelps (oakblade kelp, feather boa kelp, giant kelp, bullwhip kelp), sea palms, rockweed.*
  - PHYLUM **RED ALGAE** (RHODOPHYTA). Red algae, encrusting and coralline forms. *Encrusting and articulated coralline algae, brillo pad algae, Neptune's washcloth, sea sacs, iridescent algae, nori.*
  - PHYLUM **GREEN ALGAE** (CHLOROPHYTA). Multicellular green algae. *Sea strings, sea lettuce, ocean pin cushion.*

**KINGDOM FUNGI:** *Fungi, mushrooms, molds, lichens*; mostly land, freshwater, or highest supratidal organisms; heterotrophic.

**KINGDOM PLANTAE:** Covered seeds. Photosynthetic multicellular autotrophs that evolved from Green algae. Primarily terrestrial. Roots, leaf-bearing shoots; gas exchange through leaves. Waxy coating on leaves prevents excessive water loss. Hardening of cell walls of woody tissues for support on land.

Only division found in marine environment is

DIVISION ANTHOPHYTA. Flowering plants (angiosperms). Most species are freshwater or terrestrial. Marine species include: *eelgrass, manatee grass, surf grass, turtle grass, salt marsh grasses, mangroves.*

**KINGDOM ANIMALIA:** Multicellular eukaryotic heterotrophs.

**PHYLUM PORIFERA.** *Sponges.* Simplest of all marine animals. Sessile. Porous. Filter feeders. No nervous, digestive, respiratory, or circulatory system. Diffusion of wastes, nutrients, gases in and out cell walls. (Separate holes for in/out.) Water drawn into pores by beating of flagellated cells inside body. Body walls supported by spicules ( $\text{SiO}_2$  or  $\text{CaCO}_3$ ). Filters 3000x body volume/day.

**PHYLUM CNIDARIA.** Jellyfish and their kin; all are equipped with stinging cells. 9,000 species. Radial symmetry. Mouth, the only opening, is shaped like hollow pouch: tentacles line opening. Hollow = digestive cavity. Diffusion moves wastes and gases between mouth and body. No excretory or circulatory system. Reproduce by fission of polyps (sessile; mouth up) usually creating colonies or produce medusae (planktonic; mouth down) forms, which swim away, produce sperm and eggs, which combine to create polyp. (Some species do both.) Carnivores, save rare types with zooxanthellae.

Class Hydrozoa. Polyp-like animals that often have a medusa-like stage in their life cycle, such as *Portuguese man-of-war, Hydroids, Siphonophores.*

Class Scyphozoa. Jellyfish with no (or reduced) polyp stage in life cycle. *Sea Nettles, Moon Jellies.*

Class Cubozoa. *Sea wasps.*

Class Anthozoa. Medusa stage absent. Polyps only. *Sea anemones, coral.*

**PHYLUM ROTIFERA.** Ciliated; common in fresh water, in plankton, and attached to benthic objects.

**PHYLUM BRYOZOA.** Common, small, encrusting colonial marine forms. Most widespread and numerous sessile marine animals. Live inside conjoined calcite square boxes. LOPHOPHORES (all have circular structure spirally wound and lined around entire perimeter with ciliated tentacles). U-shaped digestive tract. No head. Filter feeders.

**PHYLUM ECHINODERMATA.** Spiny-skinned, benthic, radially symmetrical, as adults (bilaterally as larvae) most with a water-vascular system: a network of hydraulic canals branching into extensions called tube feet that are used to move, feed, and exchange gases. Internal and external parts radiate from center, often as five spokes. Thin skin covers endoskeleton of hard calcareous plates. Most prickly from skeletal bumps and spines. Digestion with mouth and anus on opposite sides of body. 6000 species. Lack eyes or brain.

Class Asteroidea. *Sea stars.*

Class Ophiuroidea. *Brittle stars, basket stars.*

Class Echinoidea. *Sea urchins, sand dollars, sea biscuits.*

Class Holothuroidea. *Sea cucumbers.*

**PHYLUM MOLLUSCA.** Mollusks. (58,000 marine species). Soft bodied, usually protected by a hard  $\text{CaCO}_3$  shell. Three parts to body: muscular foot, usually used for movement; visceral mass containing most internal organs; mantle: a fold of tissue that drapes over visceral mass and secretes shell if one present. Many have toothed radula used for digging holes in rocks, removing algae from rocks, etc. Most have gills, anus, and excretory pores. Obvious heads, flow-through digestion, well-developed nervous system (with brains). Most have separate sexes with gonads (ovaries or testes). U-shaped digestive tract, with incurrent siphon and excurrent siphons.

Class **Polyplacophora.** Shell with eight plates (articulated). Head reduced. *Chitons.*

Class **Gastropoda.** Asymmetric body plan, usually with coiled shell. Foot cannot attach to sand or mud. Grazers, suspension feeders, predators, some planktonic. Radula rasped across rocks, kelp stipes, or surfaces. 43,000 sp. *Snails, limpets, abalones, pteropods, sea slugs (nudibranchs; no shells), sea hares, whelks.*

Class **Bivalvia.** Enclosed in twin shells. Head reduced. Filter feeders. Paired gills. Dig with foot. Mantle forms siphons that extend to obtain water and eject waste. 13,000 sp. *Clams, oysters, scallops, mussels, shipworms.*

Class **Cephalopoda.** Head surrounded by foot, divided into tentacles. Stiff adhesion discs on tentacles (suction cups) catch prey. Sharp beaks tear and bite. Shells reduced, absent, or internal. Locomotion by jet propulsion using siphon made from mantle. 450 species. *Squid, octopuses, nautiloids, cuttlefish.*

**PHYLUM ANNELIDA.** Segmented bilaterally symmetrical worms. Each segment has its own circulatory, excretory, nervous, muscular, and respiratory systems. Some are specialized, such as the head. Flow-through linear digestive tract.

5400 species. Primary Class: Polychaetes (many bristles). Brightly colored or iridescent with pairs of bristly projections extending from each segment. Can be herbivores, carnivores, deposit feeders, filter feeders (tube dwellers). *Feather Duster worm.*

**PHYLUM ARTHROPODA.** Segmented. Body of two or three parts. Three or more pairs of legs. Jointed appendages (pincers, mouthparts, walking legs, and swimming appendages; and two pairs of sensory antennae). Bilateral symmetry. Exoskeleton. Striated muscles. Head with pair of eyes. Flow-through linear digestive tract. Most successful of all animal phyla.

Subphylum Crustacea. Jawlike mandibles (30,000 species). *Copepods, barnacles, krill, isopods, amphipods, shrimp, lobsters, crabs.*

Subphylum Chelicerata. Clawlike feeding appendages. *Horseshoe crabs, sea spiders.*

**PHYLUM CHORDATA.** (45,000 species); four structures appear at some point during lifetime: notochord, dorsal, hollow nerve chord, gill slits, muscular, postanal tail.

Subphylum **Urochordata.** Notochord disappears in adult stage. U-shaped digestion with incurrent and excurrent siphons. Mostly sessile. Filter feeders. Some colonial. Covered by tunic with 2 openings: water in and water out. *Sea squirts, tunicates, salps.*

Subphylum **Vertebrata.** Notochord or backbone present throughout lifecycle. Flow-through linear digestive tract.

Class **Jawless fishes** (Agnatha). 50 species. Cartilaginous skeleton. Gill slits. Rasping tongue. Notochord. No paired appendages to swim. External fertilization. *Lampreys, hagfishes.*

Class **Cartilaginous fishes** (Chondrichthyes). Cartilaginous skeleton and jaws with teeth. Respiration through gills. Internal fertilization (eggs or live birth); acute senses including lateral line. Paired fins. No swim bladder. Gill slits instead of operculum. *Sharks, skates, rays, sawfish, chimeras.*

Class **Bony fishes** (Osteichthyes). Hard, strong, light-weight bony skeletons and jaws. Operculum covers gills. Most have external fertilization and lay large numbers of eggs. Respiration through gills. Many have swim bladder. *Salmon, pike, parrot fish, barracuda, tuna, eels, sea horses, sea dragons.*

Class **Reptilia.** Tetrapods with scaly skin; respiration via lungs; lay amniotic shelled eggs or give live birth. Ectotherms. Special salt glands concentrate and excrete excess salts from body fluids. Except for one turtle, require warm waters. *Sea snakes* (50 species). *Marine crocodile* (1 species): lives in mangrove swamps and reef islands. *Sea turtles:* small streamlines hells without space to retract head or limbs. No predators as adults, save humans.

Class **Birds** (Aves). Tetrapods with feathers. Forelimbs modified as wings. Respiration through lungs. Internal fertilization. Breed on land. Lay eggs on land. Shelled amniotic eggs. Acute vision. Endotherms. *Penguins* (No ability to fly. Use wings to swim. Great maneuverability.) *Gulls.* 115 species. *Pelicans.* // *Albatross, petrels. Tubenoses.* (Beak: sense airspeed, smells, and ducting for removing saline water from glands.)

Class **Mammalia.** Warm-blooded tetrapods with young nourished from mammary glands of females. Hair. Diaphragm that ventilates lungs. Amniotic sac. Most: live birth. 4300 marine species (evolved from land mammals returning to sea 30-40 Ma).

Order **Cetacea.** 79 species. Fish-shaped bodies; paddle-like forelimbs and no hind limbs. Thick layer of insulating blubber.

Suborder Odontoceti: **Toothed whales;** *Pilot whales, belugas, killer whales, bottlenose dolphins. Porpoise. Sperm whale. Narwhales.*

Suborder Mysticeti: **Baleen whales** *Gray whales.* Short baleen. Can sieve bottom sediments. // *Humpback, fin, sei, blue, Bryde's, minke.* Dorsal fins and grooved distensible throats expand like balloons. Swallowers. // *Black right whale, bowheads.* Lack grooved throats and dorsal fins. Largest baleen. Skimmers.//

Order **Sirenia.** Herbivores. Possess finlike forelimbs and no hind limbs. *Manatees, Dugongs (sea cows)*

Order **Carnivora.** Two marine families. Carnivorous. Possess sharp, pointed canine teeth and molars for shearing. Clawed toes.

Suborder Pinnipedia. Flipper-footed. Can safely come out on land to rest, breed, and give birth. Thick, insulating blubber.

Family Phocidae: True seals; No external ear (hole only). Crawl on land because front flippers are small, and hind flippers cannot rotate forward. Swimming power from large, almost fan-like rear flippers. *Harbor seals, elephant seals.*

Family Otariidae: External ear. Rotatable rear flippers: can walk on land. Swimming power from large front flippers. *Fur seal, sea lion.*

Family Odobenidae: Two long tusks. No external ear. Rotatable rear flippers: can walk on land. Two large air pouches extend from each side of the pharynx; inflate to hold head above water when sleeping, or used as resonance chambers for underwater sounds. *Walrus.*

Suborder Fissipedia. Toe-footed carnivores (usually land animals). No blubber – warmth comes from fur.

Family Mustelidae: Smallest marine mammals. Usually do not inhabit the open ocean. Live among coastal kelp beds, where they dive and hunt for a variety of shellfish and marine invertebrates. Exceptionally thick dark fur; a longer tail; no true flippers. *Sea otters.*

Family Ursidae: Bear family. Only marine species: *Polar bear.* Carnivorous. Depends on the ocean for a majority of food. Large head, heavily built body. Stocky legs terminate in paws, with hairy soles, and five claws. Spend most of the winter asleep in a den living off stored fat reserves.

**Classification by living region/style:**

All organisms can be classified by where/how they live. Be sure to know these definitions and classification schemes!

- **Plankton** – drifters. Live in the water column, often at the surface. Cannot swim faster than currents. (Examples: jellyfish, radiolarian, diatoms.)
- **Nekton** – free swimmers. Live in the water column. (Examples: whales, salmon, squid.)
- **Benthos** – Live in or on the bottom of the ocean (or atop rocks, boats, docks). If attached, known further as SESSILE. (Examples: crabs, tube worms, mussels, sea stars.)
- **Nektobenthos** – Spend significant time living on the bottom, but CAN swim freely. (Examples: octopus, rays, and skates.)

**Feeding Methods**

All organisms can be classified by their feeding methods (see below). Be sure to know these definitions and classification schemes!

<p><u>AUTOTROPHS</u> (make their own food) <b>Producers</b></p>	<p><u>HETEROTROPHS</u> – (eat others to get food)  <b>Deposit feeders</b> – Feed off live or dead organisms that live in or on the seafloor  <b>Filter feeders</b> – Actively move through the water or move water through their bodies, filtering organisms en route  <b>Suspension feeders</b> – Passive – waits for food to hit it (stingers or spines)  <b>Predators</b> – Actively hunts prey  <b>Grazers</b> – Feeds off autotrophs, at the source, like scraping algae off a rock</p>
---	--

# Plankton

Read from lecture textbook the chapter on Plankton. NOTE: **Test:** shell or skeleton

<b>Phytoplankton:</b> free-floating, nonswimming autotrophs <b>Holoplankton:</b> organisms that spend their entire life spans as plankton.	<b>Size</b>
<b>Diatoms</b>	0.005 to 1 mm
<b>Dinoflagellates</b>	0.05 to 0.2 mm

<b>Zooplankton:</b> free-floating, nonswimming heterotrophs <b>Holoplankton:</b> organisms that spend their entire life spans as plankton.	<b>Size</b>
<b>Copepod (adults and larvae)</b>	1 to 10 mm
<b>Foraminiferans</b>	0.1 to 1 mm
<b>Radiolarians</b>	0.1 to 1 mm
<b>Dinoflagellates</b>	0.05 to 0.2 mm

<b>Zooplankton:</b> free-floating, nonswimming heterotrophs <b>Meroplankton:</b> organisms that live as plankton or only part of their life cycle.	<b>Size</b>
<b>Crab larvae (arthropods)</b>	1 to 10 mm
<b>Barnacle larvae (arthropods)</b>	0.5 to 2 mm
<b>Polychaete larvae</b>	0.5 to 2 mm
<b>Gastropod larvae</b>	0.5 to 2 mm

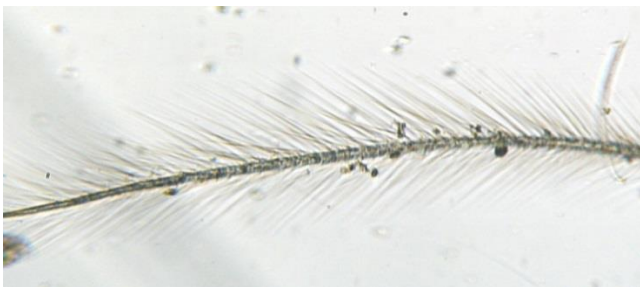
PICTURES BY MELISSA DUBOSE, 2010, CHRISSY FIELD SEAWATER SAMPLE (unless otherwise stated)

## PHYTOPLANKTON: AUTOTROPHIC PROTISTS

### Diatoms

Diatoms are single-celled, autotrophic Protista: Planktonic diatoms are mostly centric and are collected and eaten by zooplankton and by benthic feeding animals such as mussels. Benthic diatoms are mostly pennate. Planktonic diatoms seem to favor turbulent conditions with high nutrient availability. Some diatom species are known to generate toxins that have caused illness and deaths in pelicans and some people. Toxins are transferred to vulnerable consumers by organisms (like anchovies) that are not harmed by it, but concentrate it.

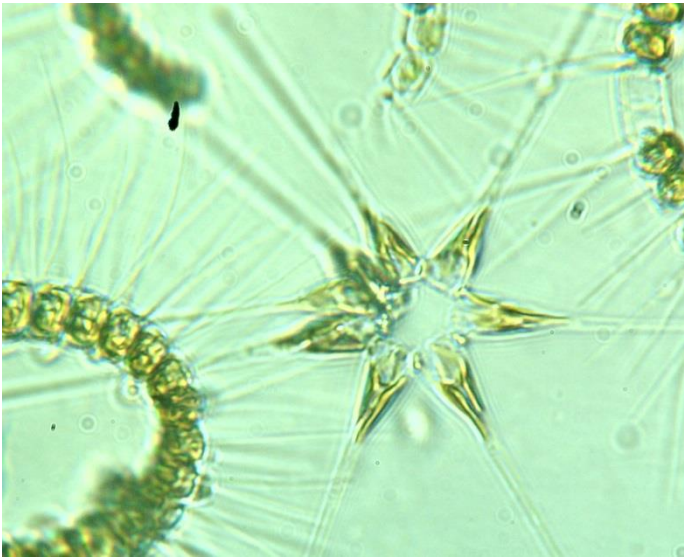
Chain diatoms:



*Diatom, Odontotella*



*Diatom, Chaetoceros socialis*



*Diatom, Asterionella with Chaetoceros on right and left*



*Diatom, Chaetoceros socialis*



*Diatom, Chaetoceros*

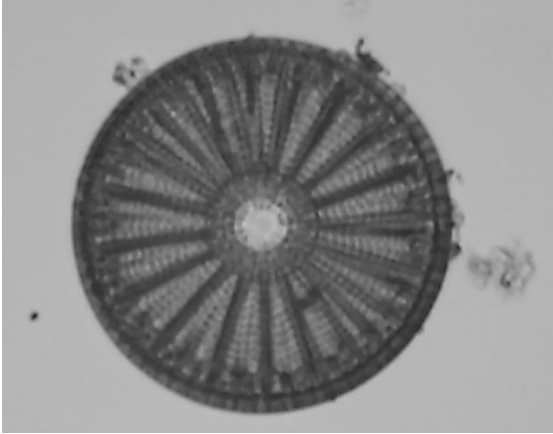


*Diatom, Thalassionema*

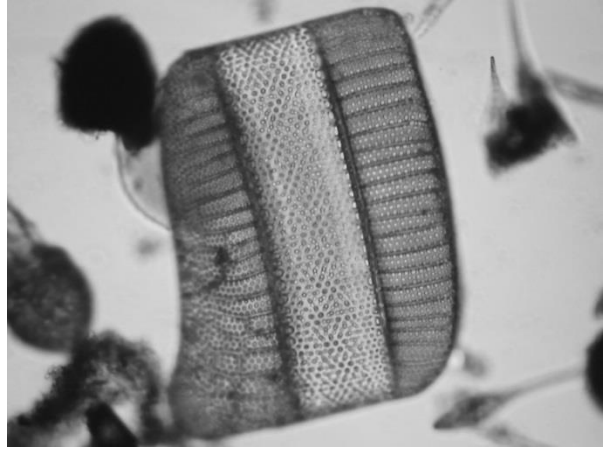


*Diatom, Stephanopyxis*

Centric, Pennate, and Other single-entity (non-chain) diatoms:



*Diatom, Coscinodiscus*



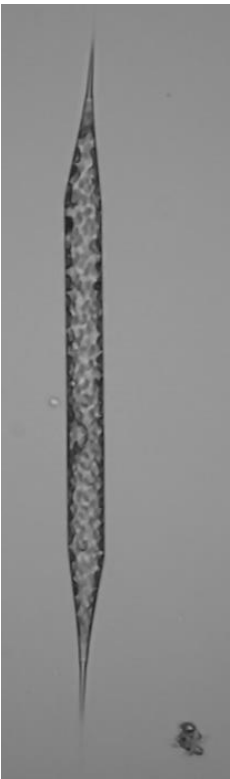
*Diatom, Isthmia nervosa*



*Diatom, Ditylum* (image by Janai Southworth)



*Diatom, Corethron*



*Diatom, Rhizosolenia* **PENNATE FORM**

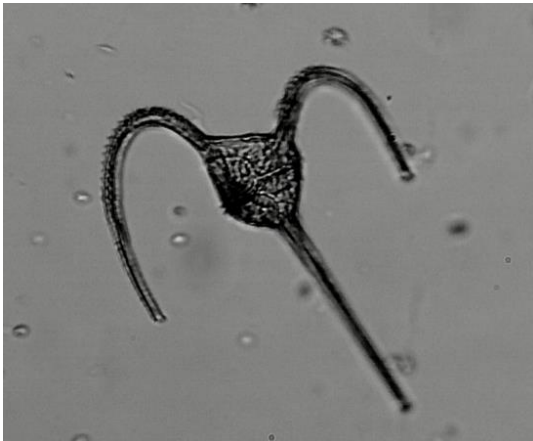


*Diatom, Pillow-shaped species* (Sediment sample – Wiese)

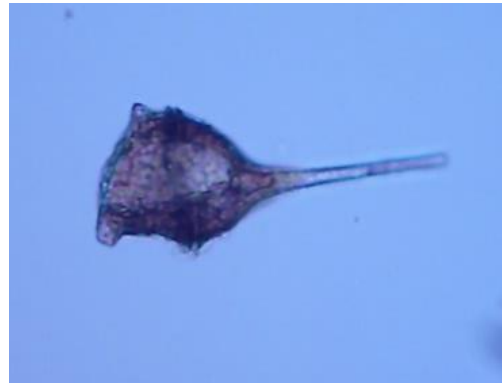
## Dinoflagellates

Dinoflagellates are Protista: Most dinoflagellates are single-celled autotrophs with two flagella. One flagella trails free in the water; the other is wrapped around the waist of the cell like a belt, confined to a groove in the plates. These flagella let the cells swim, sometimes as much as a few meters in one day. Planktonic dinoflagellates seem to favor stratified water with low nutrient supply (above pycnoclines). They are conspicuous year-round in warm seas (where nutrients are typically scarce) and seasonally in colder seas during the summer (after diatoms and other photosynthesizers have reduced the nutrient supply). Where nutrients are abundant, dinoflagellates are usually outnumbered by diatoms. The ability of dinoflagellates to swim from a locally exhausted microneighborhood to a nearby place where nutrients are slightly more abundant may contribute to their success in low-nutrient waters. Note: some dinoflagellates are heterotrophs, and therefore also zooplankton.

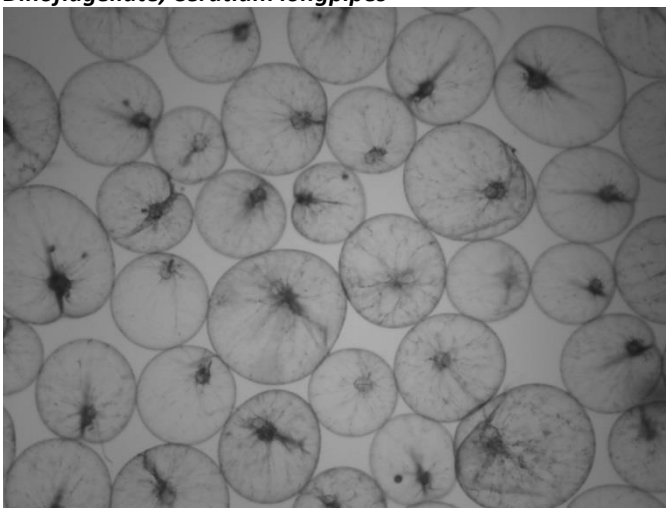
A few species of dinoflagellates manufacture powerful neurotoxins. These species become fantastically abundant under some conditions, increasing from a typical 100 or fewer organisms per milliliter of water to some million or more and giving the water a reddish cast known as a harmful algal bloom (HAB). The toxins liberated during these episodes causes widespread kills of fishes and other organisms. Shellfish collect these dinoflagellates and concentrate toxin without being harmed by it. Someone eating the shellfish (raw or cooked) experiences paralytic shellfish poisoning, characterized by numbness of the lips, dizziness, nausea, and (sometimes) death. There are other illnesses that dinoflagellate toxins are also associated with. Some dinoflagellates, such as the common *Noctiluca* species, are also highly bioluminescent and when present in large numbers, can actually light up the waves of boats and the breaking waves on a beach. Also, some (such as *Noctiluca*) are not photosynthetic.



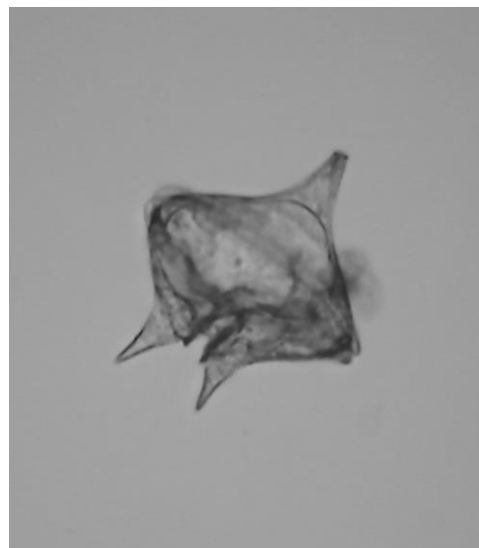
**Dinoflagellate, *Ceratium longpipes***



**Dinoflagellate, *Ceratium***



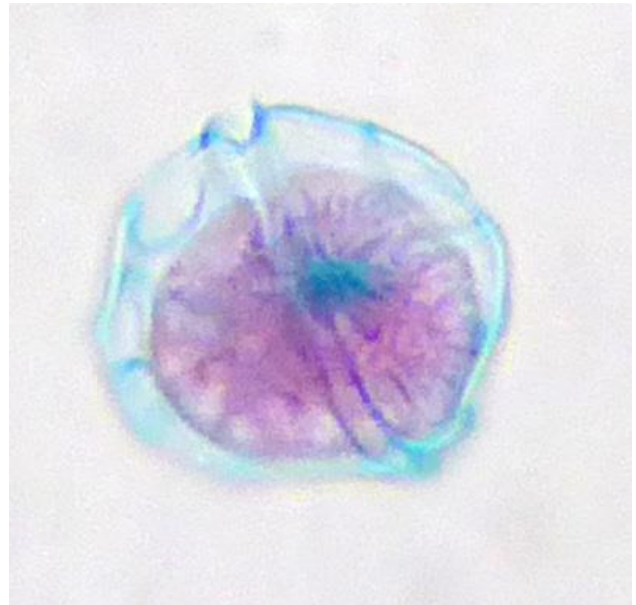
**Dinoflagellate, *Noctiluca* (bioluminescent)**



**Dinoflagellate, *Protoperidinium***



*Dinoflagellate, Noctiluca (bioluminescent) (Wiese)*

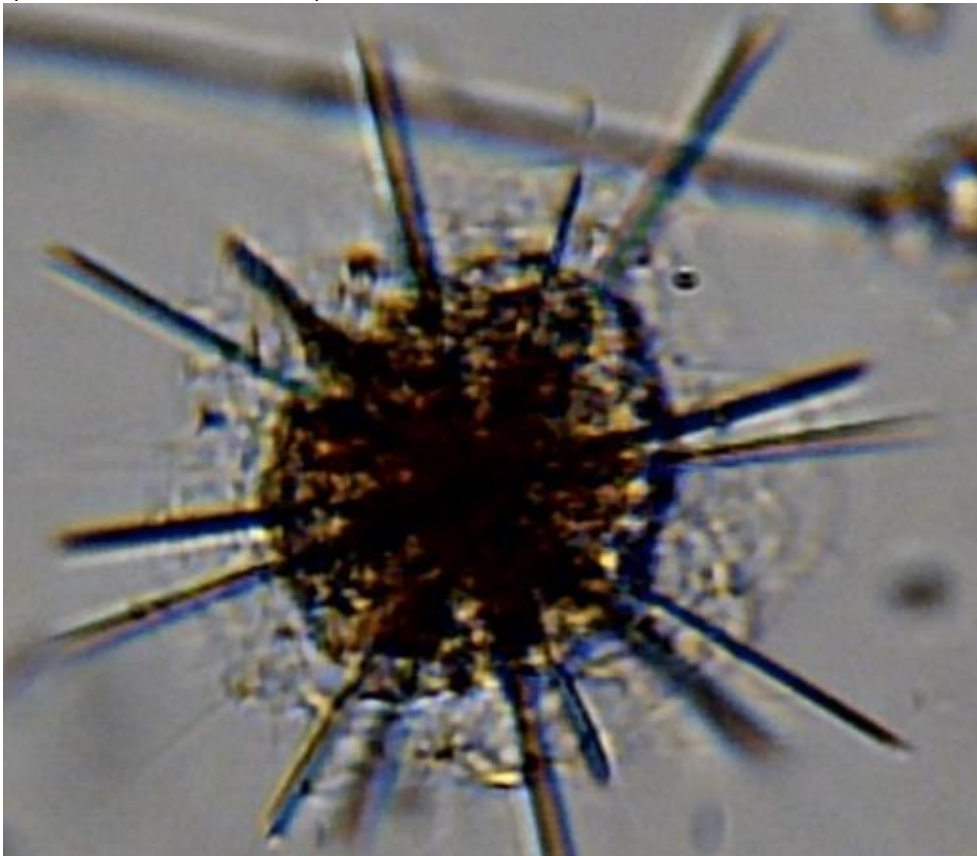


*Dinoflagellate (Wiese)*

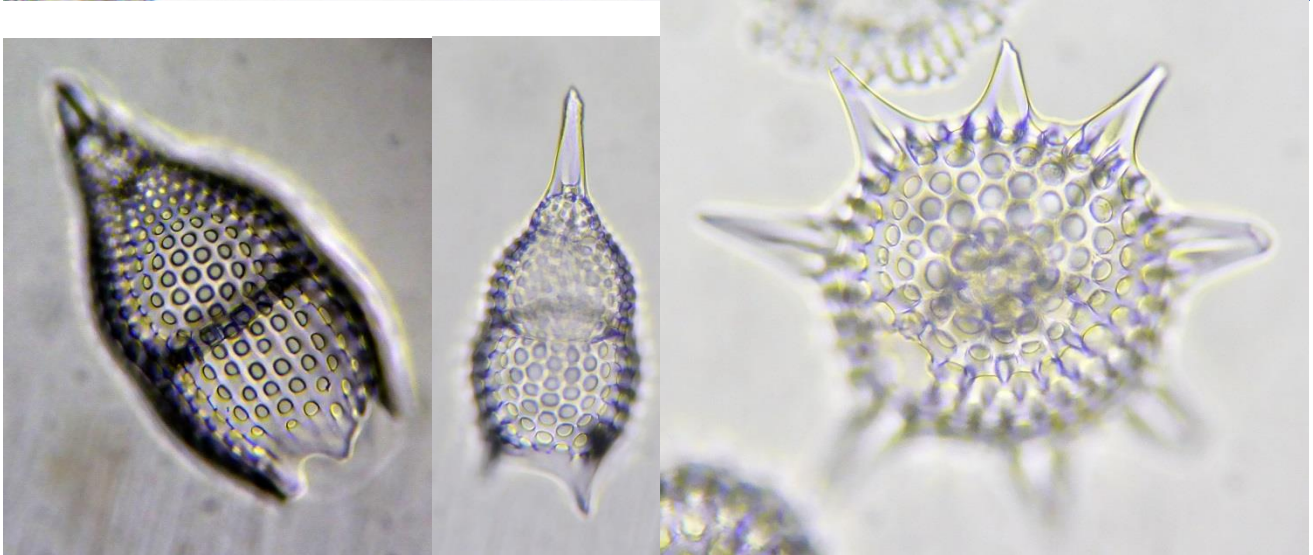
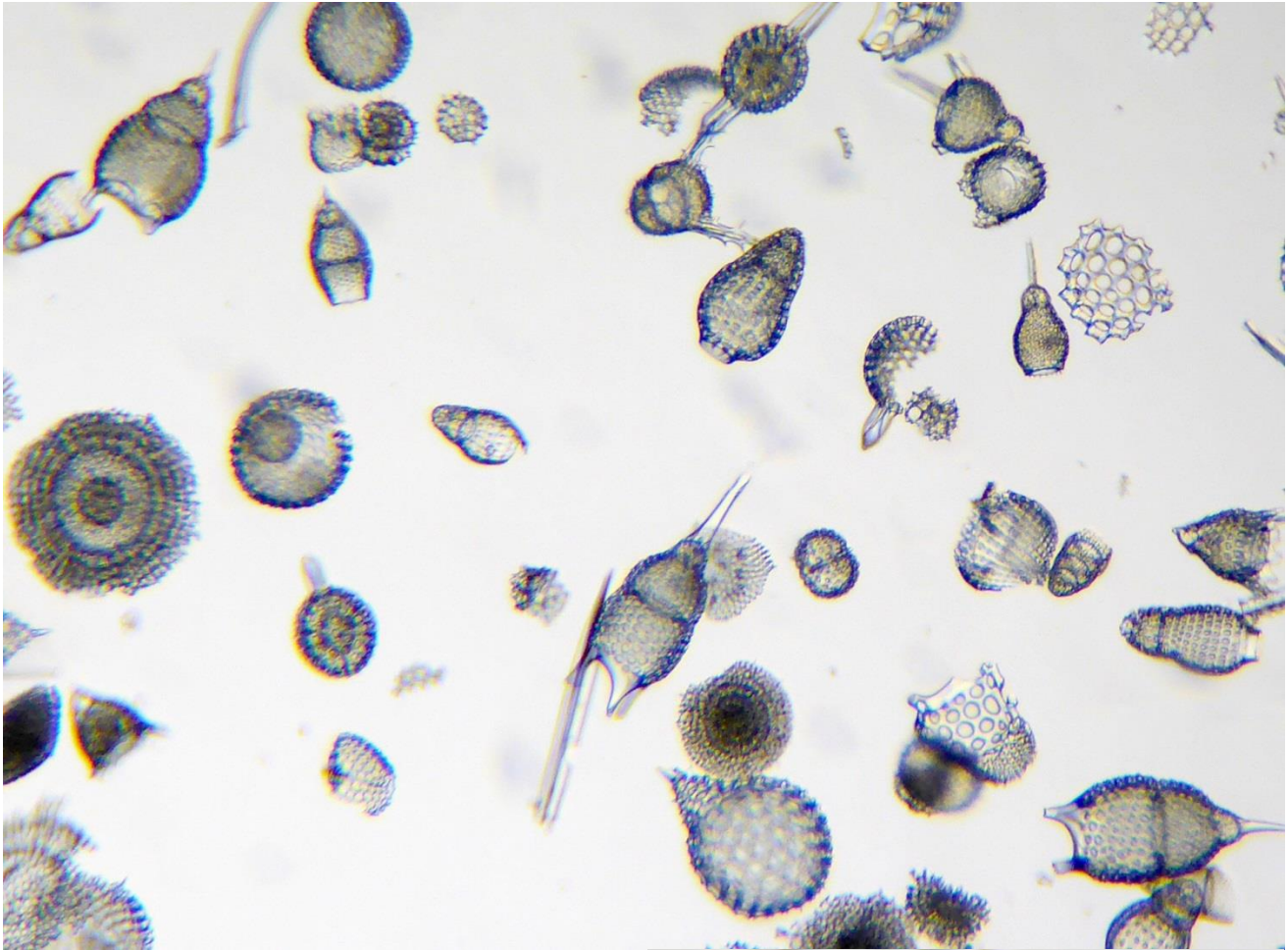
## ZOOPLANKTON

### Radiolaria

Radiolaria are single-celled, unclassified Protista. They are all heterotrophs with ornate shells riddled with holes and made of  $\text{SiO}_2$ . Their single cell extrudes itself through the holes (looking like a skin of bubbles and called vacuoles of cytoplasm). The glass spines that extrude and interfingered with thinner, shorter softer pseudopodia called by spines. Often there are multiple concentric spheres of shell material (all with holes). The inner spheres are called medullary spheres. The outer sphere is called the cortical sphere.



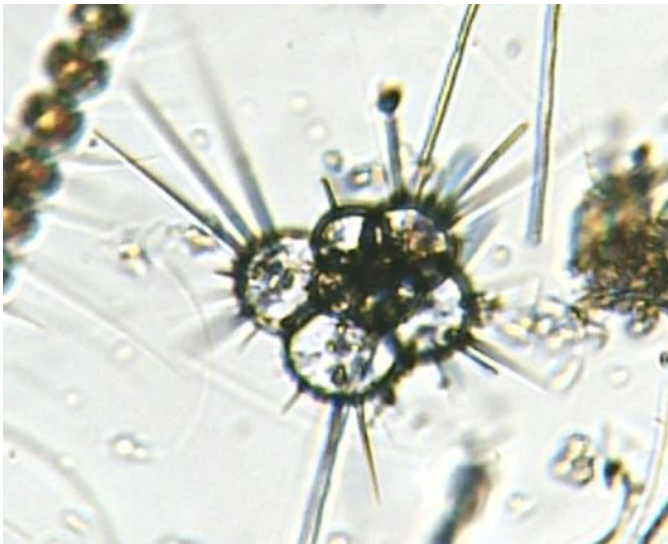
*Radiolarian: Live species*



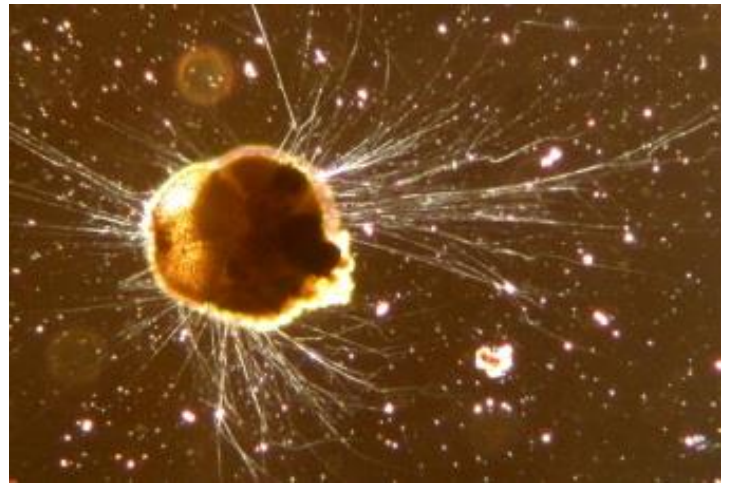
Radiolarians – Sediment samples (shells leftover after organism decomposes; image: K. Wiese)

**Foraminifera**

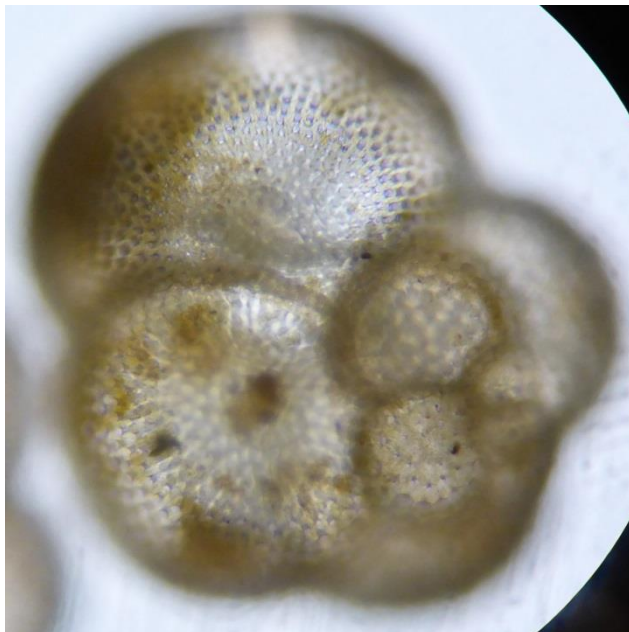
Foraminifera are single-celled Protista. They are all heterotrophs with ornate shells riddled with holes and made of CaCO<sub>3</sub>. Tests consist of several chambers segmented together in a pattern of spirals, zigzags, or concentric spheres. As a foraminiferan grows, it adds larger chambers to its test.



**Foraminifera, *Globigerina bulloides* species.** Globular skeleton (hidden in interior) has thin spines, each covered with cell cytoplasm. The spines dissolve after the organism dies.



*Live Ammonia tepida benthic foraminiferan collected from San Francisco Bay. Phase-contrast photomicrograph by Scott Fay, UC Berkeley, 2005.*

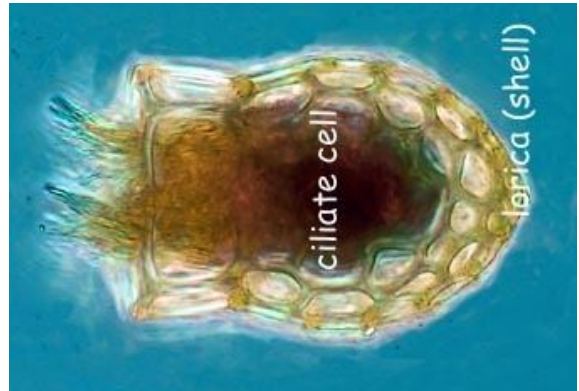


*Foraminifera shells (three above) -- Wiese*

**Other organisms you might see in this lab:**

**TINTINNIDS**

**Kingdom: Protista; Phylum Ciliates;** Single-celled heterotrophs. No shells. Cilia (hairs) create water flow into mouth. They swim in a jumping pattern. Vase-shaped external cases. Up to 0.2 mm wide.



GNU Free Documentation License

**ANNELID POLYCHAETE WORMS**

Kingdom **Animalia**. Phylum **Annelida**: Segmented bilaterally symmetrical worms. Each segment has its own circulatory, excretory, nervous, muscular, and respiratory systems. Some are specialized, such as the head. 5400 species. Primary Class: **Polychaetes** (many bristles). Brightly colored or iridescent with pairs of bristly projections extending from each segment. Can be herbivores, carnivores, deposit feeders, filter feeders (tube dwellers). *Feather Duster worm*.



*Polychaete worm larvae -- Images from San Francisco Bay seawater -- Wiese*



*Polychaete worm larvae (including trochophore stages) (K. Wiese)*

**CRUSTACEAN (ARTHROPODS)**

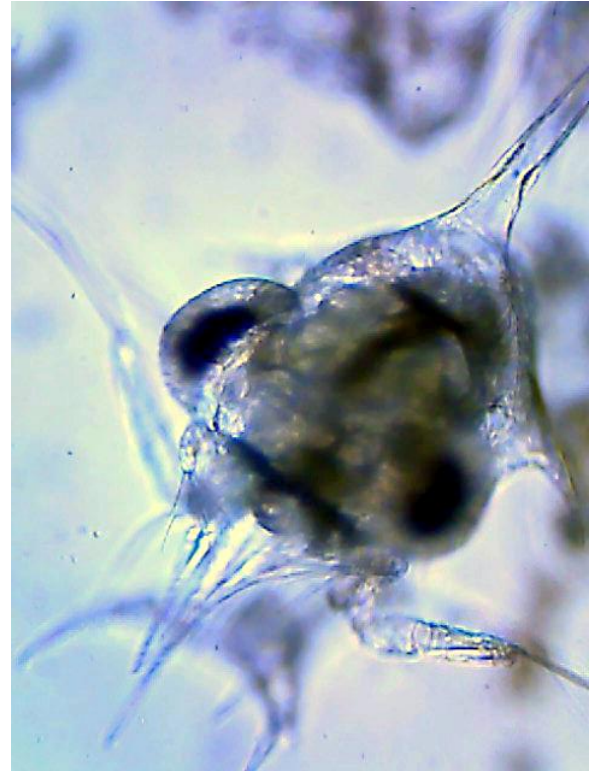
**Domain Eukarya: Kingdom Animalia: Phylum Arthropoda:** Segmented. Body of two or three parts. Three or more pairs of legs. Jointed appendages (pincers, mouthparts, walking legs, and swimming appendages; and two pairs of sensory antennae). Bilateral symmetry.

Exoskeleton. Striated muscles. Head with pair of eyes. Most successful of all animal phyla.

Subphylum Crustacea: Jawlike mandibles (30,000 species). *Copepod, barnacles, krill, isopods, amphipods, shrimp, lobsters, crab, euphysiids.*



*Copepod larvae ~1 mm (nauplius)*



*Crab larvae (Wiese)*

**BARNACLES:**



**Barnacle Nauplii Larvae ~ 1 mm (Alyxe Anderson) | Cyprid Larvae Stage**



**Arthropod, Amphipod, Ampithoe (with Dinoflagellates – Noctiluca in background)**



**Arthropod, Copepod, Calanoid**

### **MOLLUSCA – GASTROPODS**

Phylum **Mollusca**: (58,000 marine species). Soft bodied, usually protected by a hard  $\text{CaCO}_3$  shell. Three parts to body: muscular foot, usually used for movement; visceral mass containing most internal organs; mantle: a fold of tissue that drapes over visceral mass and secretes shell if one present. Many have toothed radula used for digging holes in rocks, removing algae from rocks, etc. Most have gills, anus, and excretory pores. Obvious heads, flow-through digestion, well-developed nervous system. Most have separate sexes with gonads (ovaries or testes).

Class **Gastropoda**: Asymmetric body plan, usually with coiled shell. Foot cannot attach to sand or mud. Grazers, suspension feeders, predators, some planktonic. Radula rasped across rocks, kelp stipes, or surfaces. 43,000 sp. *Snails, limpets, abalones, pteropods, sea slugs (nudibranchs; no shells), sea hares, whelks.*



**Mollusk, Gastropod veliger (larvae)**



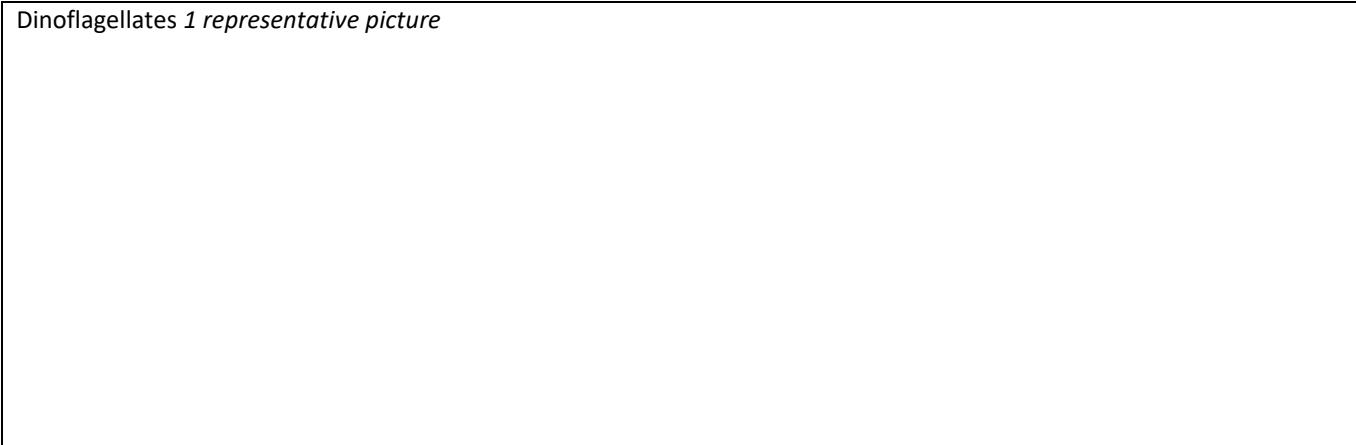
**Mollusk, Gastropod veliger (Wiese) (larvae)**

## Plankton – Prereading Exercises

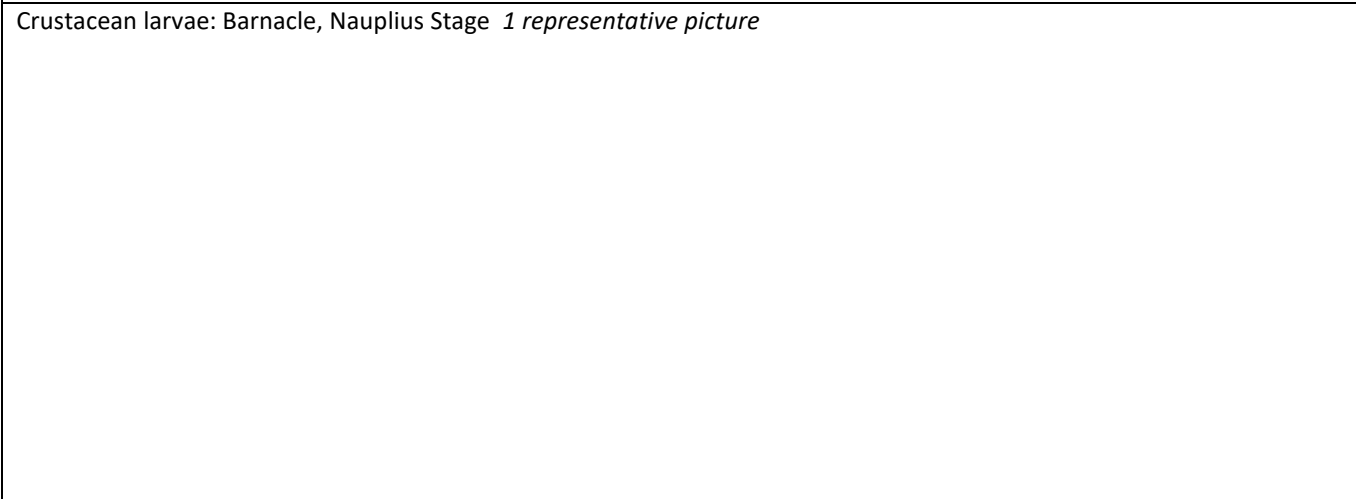
REVIEW the marine classification materials that precede this lab in your manual (and associated videos on website) and for each organism listed below:

- **GIVE DETAILED TAXONOMIC CLASSIFICATION (KINGDOM, PHYLUM, ETC.)**
- Give **species name** (most detailed common name you can find)
- **List at least FOUR major traits** that organisms from that phylum or class all have in common.
- **Draw one a picture of the organism showing detail and scale and labelling features.** (Review drawing instructions from marine rocks and sediments lab – spend no more than 5 minutes per drawing).
- **Indicate feeding method** (*producer, deposit feeder, filter feeder, suspension feeder, predator, grazer*).


Dinoflagellates 1 representative picture



Crustacean larvae: Barnacle, Nauplius Stage 1 representative picture



Tintinnid 1 representative picture



Mollusk Gastropod Larvae *1 representative picture*

Copepods *1 representative picture*

Polychaete larvae *1 representative picture*

## Plankton – Lab Exercises

### SEAWATER PLANKTON IDENTIFICATION

1. Use microscopes to observe seawater sample. ***DO NOT USE ANY BUT 2 SMALLEST OBJECTIVES ( $\leq 100X$ )! DO NOT TRY TO USE THE 400X OR BIGGER OBJECTIVES. The largest objective will hit the large slides.***
2. INDICATE **TAXONOMIC CLASSIFICATION** and **NAME** of organisms.  
(Use lab and class reference material to identify each organism.)
3. **Draw pictures that show detail and label features.**
4. **Indicate feeding method** (*producer, deposit feeder, filter feeder, suspension feeder, predator, grazer*).
5. **Include SCALE!** Use the field of view scales to approximate size for each drawing. Use 100x objective to study smaller phytoplankton or look at finer detail in the larger organisms.

### **Plankton – Princeton Harbor, Pillar Point, or Pacifica (circle)**

Be sure to find, identify, and sketch at least 1 dinoflagellate, 1 diatom, 1 copepod, and 1 larval organism. After that, fill your pages with drawings of the other creatures you see. Spend no more than 45 minutes on this sample.

\*DRAWING REMINDER: good drawings can be completed in 5 minutes, but require good observation skills and an understanding of the organisms' body plans, patterns, and features. Refer to the images in the textbook as a guide.

## Plankton – Fort Point

Be sure to find, identify, and sketch at least 1 dinoflagellate, 1 diatom, 1 copepod, and 1 larval organism. After that, fill your pages with drawings of the other creatures you see. Spend no more than 45 minutes on this sample.

\*DRAWING REMINDER: good drawings can be completed in 5 minutes, but require good observation skills and an understanding of the organisms' body plans, patterns, and features. Refer to the images in the textbook as a guide.

## Plankton – Oyster Point

Be sure to find, identify, and sketch at least 1 dinoflagellate, 1 diatom, 1 copepod, and 1 larval organism. After that, fill your pages with drawings of the other creatures you see. Spend no more than 45 minutes on this sample.

\*DRAWING REMINDER: good drawings can be completed in 5 minutes, but require good observation skills and an understanding of the organisms' body plans, patterns, and features. Refer to the images in the textbook as a guide.

## Plankton – Location Comparison

Carefully review the plankton in the same and complete this table for this location:

Sample Location:	Princeton Harbor (Pillar Point or Pacifica): Circle	Fort Point	Oyster Point
Date and time of sample collection:			
Salinity (if available for testing)			
Tide Level at sample location at that time (from tide charts provided in lab)			
Current type at location at sample time (circle)	Ebb / Flood	Ebb / Flood	Ebb / Flood
Population density (circle) based on clarity of water (describe)	High   Medium   Low	High   Medium   Low	High   Medium   Low
Estimated abundance as a percentage of all organisms seen (best estimates)			
Dinoflagellates			
Diatoms			
Tintinnids			
Copepod adults			
Copepod larvae			
Barnacle larvae			
Mollusk larvae			
Polychate larvae and adults:			
Other:			
Other:			
Other:			
Other:			
Other:			
<b>TOTAL</b>	100%	100%	100%

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Identify, name, and taxonomically classify a variety of planktonic species found in San Francisco Bay.	A   B   C   D   F	
Distinguish between meroplankton and holoplankton.	A   B   C   D   F	
Distinguish between zooplankton and phytoplankton.	A   B   C   D   F	
Explain the traits that classify an organism as plankton.	A   B   C   D   F	
Capture observations of the shape and features of living marine organisms with labeled drawings and scales.	A   B   C   D   F	
Compare and contrast plankton species found in Pillar Point, Fort Point, and Oyster Point.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

## Plankton Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. Just like on the exam, **show ALL work.** (You may use a calculator.)

For each classification below, list what all members of that group have in common. Be thorough; include at least 4 traits. Include a few examples of the organisms.

1. <b>Protista</b>
2. <b>Ciliates:</b>
3. <b>Dinoflagellates:</b>
4. <b>Radiolaria:</b>
5. <b>Foraminifera</b>
6. <b>Brown Algae</b>
7. <b>Diatoms:</b>
8. <b>Annelids</b>
9. <b>Arthropods</b>
10. <b>Mollusk – Gastropod</b>

**Define and give examples of the following feeding types for organisms of the planktonic community:**

11. <b>Deposit Feeder (including scavengers)</b>
12. <b>Filter Feeder</b>
13. <b>Suspension Feeder</b>
14. <b>Grazer</b>
15. <b>Predator</b>
16. <b>Producer</b>

Review and be able to **name** and **classify** each of the above organisms. Help provided in flashcards on website.

Note: classification means:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

## KEY

1-10: For shared traits, look to *Taxonomic Classification Sheet* that precedes the marine biology labs.

Define and give examples of the following feeding types for organisms of the planktonic community:

11. <b>Deposit Feeder (including scavengers)</b> <i>None until larvae turn into adults and settle to seafloor (some)</i>
12. <b>Filter Feeder</b> <i>Copepods, all larvae with cilia</i>
13. <b>Suspension Feeder</b> <i>Radiolaria, Foraminifera</i>
14. <b>Grazer</b> <i>Anything that eats the diatoms directly, not filtering them</i>
15. <b>Predator</b> <i>Some of the worms and fish larvae; some dinoflagellates</i>
16. <b>Producer</b> <i>Diatoms and most of the dinoflagellates</i>

Review online flashcards (lab website) for naming and classifying each organism seen in seawater. Note: if the group didn't see these organisms, they will not be on the exam. The online flashcards contain many more organisms that you will be responsible for identifying, as they include most organisms that might be encountered from one semester to the next. Look to flashcards to review:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

## Aquarium Field Trip – Prereading Exercises

Review the internet resources on the class website (ALL the ones listed for this section) and use them draw images as required below. (NOTE: you will need to identify and label pertinent features during the lab, so be sure to review them carefully before starting the lab.) Within each box below,

- **GIVE DETAILED TAXONOMIC CLASSIFICATION (KINGDOM, PHYLUM, ETC.)**
- Give **species name** (most detailed common name you can find)
- **List at least FOUR major traits** that organisms from that phylum or class all have in common.
- **Draw one a picture of the organism showing detail and scale and labelling features.** (Review drawing instructions from marine rocks and sediments lab – spend no more than 5 minutes per drawing).
- **Indicate feeding method** (*producer, deposit feeder, filter feeder, suspension feeder, predator, grazer*).

Medusae and Polyp Cnidarians (choose one)

Cephalopods

Bony Fish

Cartilaginous Fish

Echinoderms (sea star, sea urchin, sea cucumber – choose one)

Carnivora (seals or sea lions – choose one)

## Aquarium Field Trip – Lab Exercises

By observing living organisms in action, you can determine their place on the food chain and their ecological niches. For each organism in this lab, you will be drawing a picture. Instructions are in the boxes below. REMEMBER: good pictures can be drawn in 5 minutes, but require careful observation and include a SCALE. Definitions to assist:

**Organism name:** Be specific; instead of just Fish, determine what kind of fish, like Yellowfin Tuna.

**Taxonomic Classification:** Mollusk, Cnidarian, Bony Fish, Jawless Fish, Cartilaginous Fish, Bird, Reptile, Cetacea, Sirenia, Carnivora  
(Use in-class Classification sheet for reference.)

**Feeding Method:** Producer, Grazer, Suspension or Filter Feeder, Deposit Feeder (includes Scavenger), Predator

**Adaptations:** Special traits that organism adapted to be most productive in its habitat. Find these discussed or observed in the exhibit!

<p><b>FIRST TASK:</b> Travel to the back of Pier 39 and observe the sea lions. These Carnivora differ from true seals in that they can rotate their back flippers and walk on them, and they have external ears. Be sure to make good observations and draw one individual. Goal: to be able to distinguish these from seals. <i>**Also give taxonomy and feeding method.**</i></p>	<p>Drawing with labels:</p> <div style="height: 200px; border: 1px solid black;"></div>
---	---

Find and draw pictures of 4 different **BONY FISH**. In each picture, be sure to **label all the fins, lateral lines (if exist), and gills (operculum coverings)**.

Organism	Feeding Strategy	Adaptations	Sketch and scale
Giant Sea Bass			
Anchovies or Sardines (circle)			

Organism	Feeding Strategy	Adaptations	Sketch and scale
Sturgeon			
Eel of some kind: SPECIFIC NAME:			

Find and draw pictures of 3 different **CARTILAGINOUS FISH**. In each picture, be sure to label all the fins, lateral lines (if exist), and gill slits. Make one of your organisms one of the rays and/or sharks upstairs in the touch tank.

Organism	Feeding Strategy	Adaptations	Sketch and scale
Bat ray			
Leopard Shark			
Other:			

Find these specific other nonfish, pelagic organisms in the aquarium. Complete the following information for all. (If neither of these organisms is available in the aquarium – be sure to ask before giving up – then leave these blank.)

Organism	Classification	Feeding Strategy	Adaptations	Sketch and scale (identify and label known features)
Moon Jelly (or other species, if available)				
Octopus				

**BENTHOS – Now’s the time to look at a few benthic creatures:** Find and draw pictures of these different **BENTHIC ORGANISMS**. In each picture, be sure to label all **VISIBLE FEATURES**. Absolutely go to the touch tank on the upper level for **MOST** of these.

Organism	Classification	Feeding Strategy	Adaptations	Sketch and scale (identify and label known features)
Sea urchin <b><u>Detailed name:</u></b>				
Sand Dollar <b><u>Detailed name:</u></b>				
Sea star <b><u>Detailed name:</u></b>				

Organism	Classification	Feeding Strategy	Adaptations	Sketch and scale (identify and label known features)
Sea cucumber <b>Detailed name:</b>				

**ECOLOGICAL QUESTIONS RELATED TO ORGANISMS FROM THIS PARTICULAR LAB/FIELD TRIP:**

<p>Estuarine organisms tend to be less diverse than marine or freshwater species. (Diversity = variety of species). Populations (number of individuals), however, can be quite large. What are the extreme challenges these estuarine marine species face that create less diversity?</p>
<p>Name a marine species found in San Francisco Bay that can also be found living in freshwater streams and lakes.</p>
<p>Name a marine species found in San Francisco Bay that can also be found living in saltwater.</p>
<p>List at least five marine species you saw that are BENTHIC</p>
<p>List at least five marine species you saw that are NEKTON</p>
<p>List at least five marine species you saw that are NEKTOBENTHOS</p>
<p>List as many marine species as you can that you saw that are PLANKTONIC</p>
<p>Describe the adaptation of one marine species that struck you as having the narrowest niche (limited location in which it can live) and why it's true.</p>
<p>Describe the adaptation of one marine species that struck you as having the widest niche (unlimited location in which it can live) and why it's true.</p>

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week’s objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Identify, name, and taxonomically classify a variety of nektonic and benthic species found in San Francisco Bay.	A   B   C   D   F	
Distinguish between bony fish and cartilaginous fish. Explain the traits that classify an organism as nekton.	A   B   C   D   F	
Distinguish among the main feeding methods and give a marine organism example of each found in San Francisco Bay	A   B   C   D   F	
Capture observations of the shape, features, and adaptations of a variety of fish with labeled drawings (including fins) and scales.	A   B   C   D   F	
Describe the main challenge that limits species diversity in an estuary.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week’s content? Did anything in particular help you understand something you’ve always wondered about, or made you think about the world with new eyes?

## Pelagic Organisms (Aquarium) Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. For each classification below, list what all members of that group have in common. Be thorough; include at least 4 traits. Include a few examples of the organisms.

1. <b>Cnidarians</b>
2. <b>Mollusca – Cephalopods</b>
3. <b>Echinoderm</b>
4. <b>Chordata</b>
5. <b>Vertebrata</b>
6. <b>Jawless Fish</b>
7. <b>Cartilaginous Fish</b>
8. <b>Bony Fish</b>
9. <b>Mammalia</b>
10. <b>Carnivora</b>

**Define and give examples of the following feeding types for organisms found in San Francisco Bay (and seen in the aquarium):**

11. <b>Deposit Feeder (including scavengers)</b>
12. <b>Filter Feeder</b>
13. <b>Suspension Feeder</b>
14. <b>Grazer</b>
15. <b>Predator</b>
16. <b>Producer</b>

Review and be able to **name** and **classify** the organisms seen in the aquarium.

Note: classification means:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

Be sure to review the unique qualities and adaptations of estuarine organisms that allow them to be competitive in the San Francisco Bay estuary.

## KEY

1-10: For shared traits, look to *Taxonomic Classification Sheet* that precedes the marine biology labs.

**Define and give examples of the following feeding types for organisms of the planktonic community:**

11. <b>Deposit Feeder (including scavengers)</b> <i>Leopard shark and rays and skates; halibut, sole and other bottom fish; most of the crabs and shrimp; sturgeon, sea cucumber</i>
12. <b>Filter Feeder</b> <i>One method used by some sea cucumbers (also deposit feeders); anchovies</i>
13. <b>Suspension Feeder</b> <i>Anemones and jellyfish</i>
14. <b>Grazer</b> <i>Purple sea urchin, Kelp crab,</i>
15. <b>Predator</b> <i>Most sharks and fish (some can be both deposit feeders AND predators), including eels, sea stars</i>
16. <b>Producer</b> <i>Kelp</i>

Review online flashcards (lab website) for naming and classifying each organism seen in aquarium. Note: if the group didn't see these organisms, they will not be on the exam. The online flashcards contain many more organisms that you will be responsible for identifying, as they include most organisms that might be encountered from one semester to the next. Look to flashcards to review:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

Be sure to review the unique qualities and adaptations of estuarine organisms that allow them to be competitive in the San Francisco Bay estuary. (See notes from lab key in regards to the organisms you studied in the lab. Most important requirement: ability to handle changing salinities and hence osmotic pressures.)

## Fouling Organisms – Prereading Exercises

**Fouling organisms** are those that grow in and on human infrastructure and floating ships, buoys, etc., “fouling” the intakes and valves and breaking down the material of which that infrastructure is made.

Review the internet resources on the class website (ALL the ones listed for this section) and use them draw images as required below. (NOTE: you will need to identify and label pertinent features during the lab, so be sure to review them carefully before starting the lab.) Within each box below,

- **GIVE DETAILED TAXONOMIC CLASSIFICATION (KINGDOM, PHYLUM, ETC.)**
- Give **species name** (most detailed common name you can find)
- **List at least FOUR major traits** that organisms from that phylum or class all have in common.
- **Draw one a picture of the organism showing detail and scale and labelling features.** (Review drawing instructions from marine rocks and sediments lab – spend no more than 5 minutes per drawing).
- **Indicate feeding method** (*producer, deposit feeder, filter feeder, suspension feeder, predator, grazer*).

Multi-celled Protista (Red, Green, & Brown Algae): choose one

Bryozoans (specifically, draw a single adult organism – they are found in colonies, but draw just a single one)

Porifera

Tunicates

Isopod, Amphipod, and Barnacle Crustaceans; Choose One

Bivalves (Mussel), Chitons, and Gastropods (& Limpets & Snails); Choose One

## Fouling Organisms – Lab Exercises

### BENTHIC ORGANISMS IDENTIFICATION

For each sample provided, sketch a unique specimen. (Make drawings good enough for you to use them to recognize the species again!) **SEE WEBSITE or in-class INSTRUCTIONS FOR NUMBER AND TYPE OF REQUIRED PICTURES!**

Put drawings in the correct box, and make sure that for each box below, you:

- **GIVE DETAILED TAXONOMIC CLASSIFICATION (KINGDOM, PHYLUM, ETC.)**
- Give **species name** (most detailed common name you can find)
- **List at least FOUR major traits** that organisms from that phylum or class all have in common.
- **Draw one a picture of the organism showing detail and scale and labelling features.** (Review drawing instructions from marine rocks and sediments lab – spend no more than 5 minutes per drawing).
- **Indicate feeding method** (*producer, deposit feeder, filter feeder, suspension feeder, predator, grazer*).

#### TUNICATES

**BRYOZOANS**

**PORIFERA**

**ALGAE**

**CNIDARIANS**

**MOLLUSCS**

--

**ARTHROPODS**

--

**EXOTICS: As of 1995: "The San Francisco Estuary can now be recognized as the most invaded aquatic ecosystem in North America. Now recognized in the Estuary are 212 introduced species."**

Most of the organisms you saw in today's lab and in the plankton lab are introduced species including: The compound tunicates, the stalked tunicates, the branching sponges, the bryozoans, the anemones, and the mussel. (Plankton: most of the ciliates/tintinnids and many of the diatoms.)

Describe at least three mechanisms by which these species could have been introduced to San Francisco Bay by humans.

What are the main consequences of introducing new species to an ecosystem?

Is there any way to reduce the negative consequences of these introduced species? If so, how?

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week’s objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Identify, name, and taxonomically classify a variety of fouling organisms found in San Francisco Bay.	A   B   C   D   F	
Capture observations of the shape, features, and feeding methods of a variety of fouling organisms with labeled drawings and scales.	A   B   C   D   F	
Describe the main ways in which species are introduced to San Francisco Bay and the primary consequences.	A   B   C   D   F	
Describe the primary locations where fouling organisms are found and primary mechanisms for finding a space to attach.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week’s content? Did anything in particular help you understand something you’ve always wondered about, or made you think about the world with new eyes?

## Fouling Organisms Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam.

For each classification below, list what all members of that group have in common. Be thorough; include at least 4 traits. Include a few examples of the organisms.

1. <b>Brown Algae</b>
2. <b>Green Algae:</b>
3. <b>Red Algae:</b>
4. <b>Angiosperm/Plants:</b>
5. <b>Annelids</b>
6. <b>Arthropods</b>
7. <b>Bryozoans</b>
8. <b>Mollusk</b>
9. <b>Porifera</b>
10. <b>Urochordata</b>

**Define and give examples of the following feeding types from the fouling organisms community:**

11. <b>Deposit Feeder (including scavengers)</b>
12. <b>Filter Feeder</b>
13. <b>Suspension Feeder</b>
14. <b>Grazer</b>
15. <b>Predator</b>
16. <b>Producer</b>

Review and be able to **name** and **classify** each of the organisms in this lab.

Note: classification means:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

Review the amount, sources, and consequences of introduced species in San Francisco Bay.

## KEY

1-10: For shared traits, look to *Taxonomic Classification Sheet that precedes the marine biology labs*.

**Define and give examples of the following feeding types from the fouling organisms community:**

11. <b>Deposit Feeder (including scavengers)</b> <i>none</i>
12. <b>Filter Feeder</b> <i>Mussels, oysters, bryozoans, tunicates, sponges, tube worms</i>
13. <b>Suspension Feeder</b> <i>Anemones, hydroids</i>
14. <b>Grazer</b> <i>Amphipods, isopods</i>
15. <b>Predator</b> <i>Skeleton shrimp, pile worms</i>
16. <b>Producer</b> <i>Sea lettuce, various types of red algae.</i>

Review online flashcards (lab website) for naming and classifying each organism seen in aquarium. Note: if the group didn't see these organisms, they will not be on the exam. The online flashcards contain many more organisms that you will be responsible for identifying, as they include most organisms that might be encountered from one semester to the next. Look to flashcards to review:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

Review the amount, sources, and consequences of introduced species in San Francisco Bay.

- *Some estimates indicate that 99% of the species in San Francisco Bay are introduced.*
- *Sources: ship ballast water, bait fish tossed into water (bait fish themselves from other parts of the country), aquarium dumping, purposeful farming of oysters or fish species, sessile larval organisms attaching to bottoms of boats that then travel among water bodies.*
- *Consequences: outcompete native species (because predators haven't evolved yet to feed on this new organism), and thus completely transform the ecosystem/food web – removing food sources and space.*



# Tidepooling Field Trip

## Intertidal Pollution and its Ecological Effects

Water quality in the intertidal zone is an increasing challenge to the organisms that live and feed within this zone. Humans have used the oceans for waste disposal since the dawn of civilization, always assuming that the natural mixing within and the vastness of the combined resource would prevent this waste from being detectable. Today we are facing a number of significant failures in this process. The core of the problem is that humans produce a lot of waste and continually seek acceptable locations for waste disposal. As we fill up the existing open spaces on land, we look more and more to the oceans as a replacement or supplement. Today, waste disposal occurs in landfills, deep underground in rocks, and in the oceans. What pollutants affect the intertidal environment? Humans dispose of many unwanted materials in the ocean – any of which cause harm to the life within or the life that depends on the oceans can be deemed a pollutant. These pollutants combine to reduce water quality, marine populations, and marine diversity.

### Pollutant sources to the intertidal:

Pollutants enter the intertidal coastal waters through runoff during rains, through atmospheric deposition, wind-transported debris, and rivers. These pollutants can include:

- Homes, farmlands, and urban centers along the coast lead to runoff and storm drains that carry:
  - Oil, Antifreeze, Detergent, Pesticides, Fertilizers, Heavy Metals
- Sewage – residential or city – with varying levels of treatment contribute:
  - Prescription medications, drugs, heavy metals, increased nutrients, fresher-than-normal water
  - For example, more than 800 million gallons of municipal wastewater containing 60 tons of nitrogen are discharged annually into San Francisco Bay.
- Industry contributes waste in the form of various effluents, specifically heavy metals like mercury, cadmium, lead, and arsenic.
- Power plants dump hot, relatively fresh water
- 1950's era nuclear-waste-in-a-barrel dumping
- Plastics and other wind-carried waste from urban/residential centers
- Large-scale oil spills, during oil-tanker accidents or coastal/off coastal oil rig explosions
- Antibiotics and disease from large-scale shrimp and fish farming, especially in places such as Thailand and Indonesia that used to be large Mangrove forests.
- Nutrients also enter waterways from human and animal wastes, phosphate-rich rocks, wastes from laundries, cleaning and industrial processes, lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, and discharges from car exhausts. Phosphates also are used widely in power plant boilers to prevent corrosion

### What are the major sinks for these pollutants?

- Sediments (especially heavy metals)
- Organisms
  - Mercury methylation via grasses then bioaccumulation and biomagnification up the food chain
  - Filter feeders or deposit feeders take in suspended particulates, some like sponges sifting through up to 3,000 times their body mass in a single day
  - Heterotrophic organisms ingest plastics and other floating materials when eating

### IMPACTS

- Habitat damage – especially sensitive ones like coral reefs or kelp beds, which can be destroyed.
- Wildlife ingestion – especially plastics – can lead to internal injury, intestinal blockage, starvation, and death; ingestion of heavy metals or hormones can affect reproduction and growth.

One major example of harmful impacts is the decline in the local sea otter population. It is believed that part of their reduction in numbers is the result of increased toxic bacteria related to the dumping of cat litter down toilets. The bacterial species has been found in the carcasses of many dead sea otters.

“What's killing the sea otters? Sometimes the cause is clear: a shark bite, a bullet, an outboard motor. But about one-quarter of last year's fatalities have been traced to a pair of protozoan parasites, *Toxoplasma gondii* and *Sarcocystis neurona*, that are known to breed in cats and opossums. Could sea otters be dying because California cat owners are

flushing used litter down the toilet? State legislators were sufficiently convinced of the threat to pass a bill--signed into law last week by Governor Arnold Schwarzenegger--that raises the maximum fine for harming a sea otter to \$25,000 and requires that all cat litter sold in California carry a warning label advising cat owners not to dump their pet's droppings into toilets or storm drains. But cat litter is only a small part of the problem. Thorny-headed worms dropped into the ocean by seabirds are known to be killing otters, as are toxic algae blooms triggered by urea, a key ingredient in fertilizer. And sea otters, because they feed on shellfish that tend to accumulate whatever floats their way, are particularly susceptible to PCBs and other man-made pollutants.

<http://www.time.com/time/magazine/article/0,9171,1538645,00.html#ixzz1lcE7I7cJ>

Another example of harmful impacts is the change in genders of varying fish populations due to increased female hormones (from the dumping of birth-control pills) in the water supply.

"More than 1,000 new chemicals are released into the environment each year, resulting in a growing potential for health risks. Increasing evidence suggests that exposure to some of these chemicals, called endocrine disrupters, can adversely affect the immune, reproductive, and endocrine systems of wildlife by interfering with natural hormones. The USGS is investigating the effects that these chemicals may have on wildlife species. Because waterways are the ultimate recipients of agricultural and industrial contaminants, aquatic animals often serve as sentinels or early indicators of environmental stress. Field and laboratory studies are underway to examine the effects of herbicides, paper mill effluent, and sublethal doses of mercury on largemouth bass. Results of these studies suggest that a variety of structurally diverse pollutants can alter sex steroid hormone levels, which could lead to reproductive impairment and population declines. USGS scientists are exploring environmental factors related to massive juvenile alligator mortality in Lake Apopka, and the effect of contaminants on various mussel species in their early stages of development. Findings suggest that mussels in early stages of development, or offspring of exposed females, may be particularly sensitive to the toxic effects of certain contaminants. USGS work will be expanded to learn more about the mechanisms of hormone actions and clarify the direct and multigenerational effects of contaminant exposure." <http://pubs.usgs.gov/fs/FS-010-99/>

"Concentrations of atrazine commonly found in agricultural streams and rivers caused reduced reproduction and spawning, as well as tissue abnormalities in laboratory studies with fish," said USGS scientist Donald Tillitt, the lead author of the study published in *Aquatic Toxicology*. Fathead minnows were exposed to atrazine at the USGS Columbia Environmental Research Center in Columbia, Mo., and observed for effects on egg production, tissue abnormalities and hormone levels. Fish were exposed to concentrations ranging from zero to 50 micrograms per liter of atrazine for up to 30 days. All tested levels of exposure are less than the USEPA Office of Pesticides Aquatic Life Benchmark of 65 micrograms per liter for chronic exposure of fish. Thus, substantial reproductive effects were observed in this study at concentrations below the USEPA water-quality guideline." <http://www.physorg.com/news193492127.html>

"Last summer, USGS scientists sampled 139 rivers and streams, finding hundreds of prescription and over-the-counter drugs and personal care products lingering in the nation's water supply, including birth control pills, estrogen replacement drugs, ibuprofen, bug spray, sunscreen, mouthwash and antibacterial soap. In many cases, these tiny drug particles were found in river water that is recycled - flowing from one city's sewer plant into another city's drinking water system. Many cities can't afford the charcoal filters required to screen out the final traces of these byproducts, so they end up in the drinking water, experts say. Rural homeowners who use well water are at an even greater risk. "This study raised a bunch of red flags," says Dana Kolpin, lead author of the USGS study. "At these low concentrations, I think there are going to be long-term effects that may take several generations to show up." The dangers of endocrine-disrupting water pollutants such as dioxin and polychlorinated biphenyls (PCBs) are well known - they have been linked to a variety of reproductive health problems, from endometriosis to low sperm counts. Synthetic hormones in the water may have similar health effects - on both people and wildlife - at very low levels of exposure. Bisphenol A, a component of plastic that is also used as a fire retardant, causes female mice to reach puberty earlier than normal. Bisphenol A forms a weak bond with the body's estrogen receptors. It can scramble a cell's natural communication system and cause it to replicate too quickly. That, in turn, raises concerns about breast cancer in humans. What happens if this compound, which is active at low levels of exposure, combines with estrogen from a birth control pill in the water? These estrogens also could have an additive effect with chemicals such as PCBs, which are found in animal tissue. A recent study by researchers at Michigan State University found mink that were fed a diet of PCB-laden fish from the polluted Housatonic River in Connecticut had offspring with lower birth weights and higher infant mortality rates. Until recently, people thought the estrogens in birth control pills were rendered inactive by the body because the kidneys tack on an extra sugar molecule before they are excreted, says William Owens, a toxicologist who researched estrogen patches for Procter & Gamble. But now, scientists have learned bacteria in sewage treatment plants chew off that sugar molecule. A British researcher, John Sumpter, contributed to this discovery while studying fish living near a London wastewater treatment plant. He found male fish that were producing eggs. After he found the compound estradiol in the fish tissue, he concluded estrogens from birth control pills were part of the problem." [www.mcsbeaconofhope.com/.../Water%20is%20Becoming%20a%20Dangerous%20Drug.doc](http://www.mcsbeaconofhope.com/.../Water%20is%20Becoming%20a%20Dangerous%20Drug.doc)

The high concentrations of cadmium, silver, and lead that have been measured at certain localities in bay muds are dangerous, because these metals are known to interfere with the growth and reproduction of fish, mammals, and birds. Furthermore, shellfish and finfish biomagnify such toxins, so there is concern for the health of humans who consume them.

“Alkali and metal processing, incineration of coal, and medical and other waste, and mining of gold and mercury contribute greatly to mercury concentrations in some areas, but atmospheric deposition is the dominant source of mercury over most of the landscape. Once in the atmosphere, mercury is widely disseminated and can circulate for years, accounting for its wide-spread distribution. Natural sources of atmospheric mercury include volcanoes, geologic deposits of mercury, and volatilization from the ocean. Although all rocks, sediments, water, and soils naturally contain small but varying amounts of mercury, scientists have found some local mineral occurrences and thermal springs that are naturally high in mercury. Methylation is a product of complex processes that move and transform mercury. Atmospheric deposition contains the three principal forms of mercury, although inorganic divalent mercury (Hg(II)) is the dominant form. Once in surface water, mercury enters a complex cycle in which one form can be converted to another. Mercury attached to particles can settle onto the sediments where it can diffuse into the water column, be resuspended, be buried by other sediments, or be methylated. Methylmercury can enter the food chain, or it can be released back to the atmosphere by volatilization. The concentration of dissolved organic carbon (DOC) and pH have a strong effect on the ultimate fate of mercury in an ecosystem. Studies have shown that for the same species of fish taken from the same region, increasing the acidity of the water (decreasing pH) and/or the DOC content generally results in higher mercury levels in fish, an indicator of greater net methylation. Higher acidity and DOC levels enhance the mobility of mercury in the environment, thus making it more likely to enter the food chain. Mercury and methylmercury exposure to sunlight (specifically ultra-violet light) has an overall detoxifying effect. Sunlight can break down methylmercury to Hg(II) or Hg(0), which can leave the aquatic environment and reenter the atmosphere as a gas.

How does mercury enter the food chain? The exact mechanisms by which mercury enters the food chain remain largely unknown and may vary among ecosystems. Certain bacteria play an important early role. Bacteria that process sulfate (SO<sub>4</sub><sup>=</sup>) in the environment take up mercury in its inorganic form and convert it to methylmercury through metabolic processes. The conversion of inorganic mercury to methylmercury is important because its toxicity is greater and because organisms require considerably longer to eliminate methylmercury. These methylmercury-containing bacteria may be consumed by the next higher level in the food chain, or the bacteria may excrete the methylmercury to the water where it can quickly adsorb to plankton, which are also consumed by the next level in the food chain. Because animals accumulate methylmercury faster than they eliminate it, animals consume higher concentrations of mercury at each successive level of the food chain. Small environmental concentrations of methylmercury can thus readily accumulate to potentially harmful concentrations in fish, fish-eating wildlife and people. Even at very low atmospheric deposition rates in locations remote from point sources, mercury biomagnification can result in toxic effects in consumers at the top of these aquatic food chains.

Methylmercury [CH<sub>3</sub>Hg] is the most toxic form. It affects the immune system, alters genetic and enzyme systems, and damages the nervous system, including coordination and the senses of touch, taste, and sight. Methylmercury is particularly damaging to developing embryos, which are five to ten times more sensitive than adults. Exposure to methylmercury is usually by ingestion, and it is absorbed more readily and excreted more slowly than other forms of mercury. Elemental mercury, Hg(0), the form released from broken thermometers, causes tremors, gingivitis, and excitability when vapors are inhaled over a long period of time. Although it is less toxic than methylmercury, elemental mercury may be found in higher concentrations in environments such as gold mine sites, where it has been used to extract gold. If elemental mercury is ingested, it is absorbed relatively slowly and may pass through the digestive system without causing damage. Ingestion of other common forms of mercury, such as the salt HgCl<sub>2</sub>, which damages the gastrointestinal tract and causes kidney failure, is unlikely from environmental sources.”  
<http://www.usgs.gov/themes/factsheet/146-00/>

The marine population’s health is important to human civilization because it supports the food chain from which we partake. As fish populations dwindle, so do our food resources.

Are these impacts necessary? Could we find alternative ways to handle our waste? With increasing world population and the extreme poverty that exists in many places in the world, this problem is not going to get better soon. While first-world countries join together to implement international ocean protection schemes, the third-world countries remain the home to many of the first-world industries fleeing our environmental protection laws. Hungry populations think less about protecting the ocean when the immediate need is a family to feed.

## SOLUTIONS

What can we do?

- Multiple levels of treatment at sewage disposal plants. However, that costs more money, and the communities have to be willing to support it.
- Recycling and repackaging to use biodegradable materials
- Storm drains that enter catchments might provide intermediate space for treatment.
- Public education on how to dispose properly of materials and what happens to materials left on the land.
- Increasing wetlands, where sediment can collect, and heavy metals and other large molecules can be removed and buried in the sediment.
- Creating a coastal corridor, so that buildings and other structures have to stay beyond the erosion zone and thus will be less likely to fail in storms.
- Modern waste treatment procedures and technology can substantially reduce the inputs of contaminants to the bay. Models are being developed and monitoring in the field is currently being used to investigate the way in which contaminants in muds are recycled through ecosystems.
- Continued legislation to monitor our coastal waters – to collect data on our systems, and to develop plans to reduce our impact. See following list of references for more information.

“Michigan Clean Marina Program Partners to Reduce Waste: The Michigan Clean Marina Program recently partnered with Mondo Polymer Technologies, Inc. to launch a pilot shrink-wrap recycling program. The recycling program collected shrink-wrap at 50 marinas in southeast Michigan. Shrink-wrap is commonly used for protecting recreational boats stored outside during the winter season from snow, ice, water and debris and frequently discarded in the trash when removed in the spring. The pilot recycling program has been very successful, diverting more than 125,000 pounds of shrink-wrap from the land fill in 2007. In addition, each participating marina reduced their waste disposal costs by an average of \$250, since they generated less waste. The recycled shrink-wrap is reused to manufacture parts of barrier systems on roadways. Based on the overwhelming response to the pilot program, the Michigan Clean Marina Program coordinators expect to expand the shrink-wrap recycling efforts throughout the state in the future. – The Michigan Clean Marina Program is a partnership of the Michigan Boating Industries Association, Michigan Sea Grant and the Michigan Department of Environmental Quality.”

## REFERENCES

USGS – Water Quality of San Francisco Bay – “For almost four decades the U.S. Geological Survey has maintained a program of research and observation in San Francisco Bay. The program includes regular measurements of water quality along a 145 kilometer transect spanning the length of the entire estuarine system. This website describes the measurement program, displays results of water quality measurements, and makes the full data set available to all interested users.”

<http://sfbay.wr.usgs.gov/access/wqdata/>

Clean Water Act Section 305b Report 2006 – Water Quality Assessment of the Condition of California Coastal Waters and Wadeable Streams

NOAA – National Oceanic and Atmospheric Association – “The Coastal Nonpoint Pollution Control Program was established by Congress in 1990 to encourage better coordination between state coastal zone managers and water quality experts to reduce polluted runoff in the coastal zone.”

<http://coastalmanagement.noaa.gov/nonpoint/welcome.html>

NOAA Marine Debris Program – “The NOAA Marine Debris Program serves as a centralized marine debris capability within NOAA in order to coordinate, strengthen, and increase the visibility of marine debris issues and efforts within the agency, its partners, and the public.” <http://marinedebris.noaa.gov/>

San Francisco Public Utilities Commission [http://sfwater.org/custom/lims/beachmain1.cfm/MC\\_ID/5/MSC\\_ID/14](http://sfwater.org/custom/lims/beachmain1.cfm/MC_ID/5/MSC_ID/14)  
Southwest Ocean Outfall Regional Monitoring Program Eight-Year Summary Report 1997 – 2004

California Coastal Commission – “The Coastal Commission, in partnership with coastal cities and counties, plans and regulates the use of land and water in the coastal zone. Development activities, which are broadly defined by the Coastal Act to include (among others) construction of buildings, divisions of land, and activities that change the intensity of use of land or public access to coastal waters, generally require a coastal permit from either the Coastal Commission or the local government. The Coastal Act includes specific policies (see Division 20 of the Public Resources Code) that address issues

such as shoreline public access and recreation, lower cost visitor accommodations, terrestrial and marine habitat protection, visual resources, landform alteration, agricultural lands, commercial fisheries, industrial uses, water quality, offshore oil and gas development, transportation, development design, power plants, ports, and public works. The policies of the Coastal Act constitute the statutory standards applied to planning and regulatory decisions made by the Commission and by local governments, pursuant to the Coastal Act.”

<http://www.coastal.ca.gov/>

Surfrider – “The Blue Water Task Force (BWTF) is the Surfrider Foundation’s water quality monitoring, education and advocacy program. It is utilized by our Chapters and members to alert citizens and officials in their communities about water quality problems and to work toward solutions. BWTF has demonstrated success by raising public awareness of coastal water pollution levels and precipitating the establishment of state and local government water quality monitoring programs in many communities where the program has been implemented.”

<http://www.surfrider.org/whatwedo3c.asp>

EPA – Environmental Protection Agency – “The Oceans and Coastal Protection Division (OCPD) envisions clean and safe oceans and coasts that sustain human health, the environment, and the economy. The mission of OCPD is to protect and restore our ocean and coastal ecosystems by promoting watershed-based coastal management, preventing pollution of the marine environment, monitoring and assessing coastal conditions, and establishing effective partnerships.”

<http://water.epa.gov/type/oceb/index.cfm>

CALFED Bay-Delta Program – “The CALFED Science Program was established to develop scientific information and synthesis for the state of scientific knowledge on issues critical for managing the Bay-Delta system. That body of knowledge must be unbiased, relevant, authoritative, integrated across state and federal agencies, and communicated to Bay-Delta decision-makers, agency managers, stakeholders, the scientific community, and the public. The Lead Scientist is responsible for leading, overseeing, and guiding the Science Program.”

[http://www.science.calwater.ca.gov/events/workshops/workshop\\_ammonia.html](http://www.science.calwater.ca.gov/events/workshops/workshop_ammonia.html)

Napa Sonoma Marsh Restoration – “The U.S. Army Corps of Engineers, with the California Coastal Conservancy as the non-federal sponsor, is conducting a Feasibility Study and preparing an EIR/EIS which involves the technical analysis of alternatives for the restoration of nearly 10,000 acres of wetlands and associated habitats within the former Cargill salt pond complex in the North Bay, which is now owned by the California Department of Fish and Game, a partner in the study. The habitat restoration plan is for the 9,850 acres of former salt ponds and remnant slough and marsh habitat, now referred to as the Napa River Unit of the Napa-Sonoma Marshes State Wildlife Area.”

<http://www.napa-sonoma-marsh.org/>

South Bay Salt Pond Restoration Project – “the largest tidal wetland restoration project on the west coast.”

<http://www.southbayrestoration.org/>

California Coastal Conservancy – “The Coastal and Estuarine Land Conservation Program (CELCP) is administered by the National Oceanic and Atmospheric Administration (NOAA), Office of Ocean and Coastal Resource Management. NOAA has been awarding land acquisition grants for up to \$3 mill for acquisition projects in the coastal and bay regions of the nation since 2002. The California Coastal Conservancy is the lead state agency for the state.”

<http://scc.ca.gov/>

Sea Otter Alliance

<http://www.seaotterresearch.org/>

## INTERIDAL LIFE

As you can see from the following pictures, different organisms live in different niches in the intertidal environment. Some niches can be limited by environmental conditions – temperature, desiccation, etc. Others can be limited by predators or more competitive organisms that exclude them from certain niches. For example, You can see in the Rodeo Beach image that mussels are located in a narrow band in the upper tidal zone. This is the zone at which they are more successful than any other organism at getting resources. They might be able to survive in deeper waters as well, but they are limited in that direction by their predator – the sea star – which can't handle desiccation and so stays in the lower tidal zone when the tides are out. Mussels are also limited in the upper zones by land predators, such as birds, raccoons, and bear. They also need to be under water at least a portion of the day, as they are filter feeders and get their food from the water column. Can you see any other zonation in the pictures? Kelp? Seaweeds? Barnacles? Crabs?

The intertidal niches we will be viewing during the field trip consist of:

Splash zone (covered by water only during storms that coincide with high tides)

Upper tidal zone (between Spring High and Neap High tides – covered twice a day only when not a neap tide)

Middle tidal zone (between Neap High and Neap Low tides – so ALWAYS covered at least twice daily with water)

Lower tidal zone (between Neap Low and Spring Low tides – so uncovered twice a day only when not a neap tide)

Subtidal zone (below Spring Low – ALWAYS covered by water)

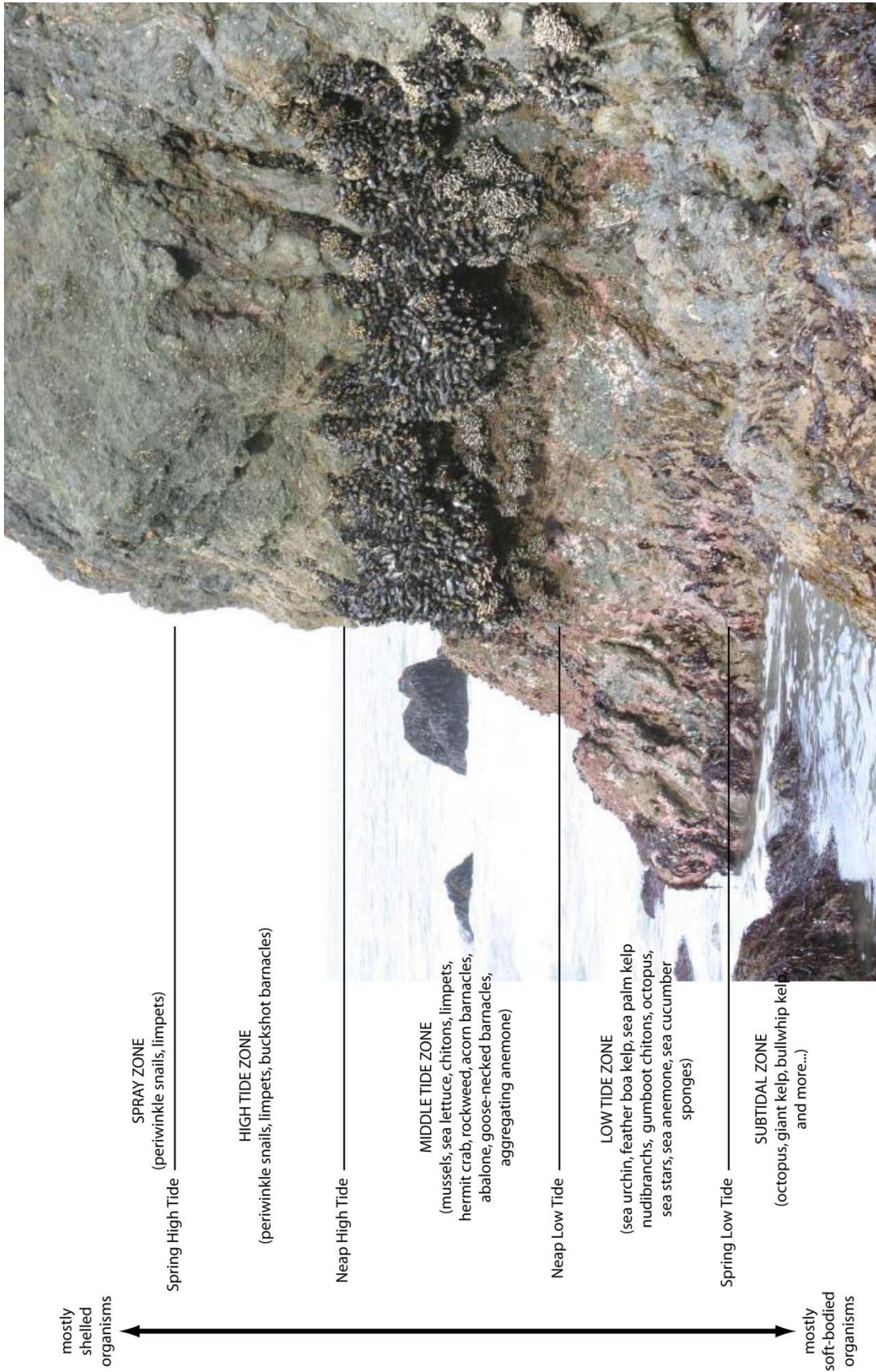
Other special niches:

Tide pools (always covered by water – of varying depths – but stagnant)

Surge channels (always covered by water – of varying depths – but with wave swash and backwash pushing in and out of channels on regular intervals)

During this lab, you have these tasks:

- Get up close and personal with California intertidal coastal life
- Observe the niches of various organisms and think about what factors dictate their ranges
  - Splash zone
  - Upper tidal zone
  - Middle tidal zone
  - Lower tidal zone
  - Subtidal zone
    - Tide pools
    - Surge channels
- Participate in an ongoing research project to catalog the diversity of certain organisms found in these tidepools.



Rodeo Beach, Marin Headlands, Intertidal – ©Katryn Wiese

## Tidepooling Field Trip – Prereading Exercises

**For in-person field trip, bring a camera, if you have one, so you can photograph unidentified species for our project.**

1. Which of the intertidal niches described in prereading will be the most susceptible to pollution? Why?

2. Sea otters eat sea urchins. Sea urchins eat kelp. What happens to the kelp forest when sea otter populations dwindle?

3. What has happened to the sea otter population recently? Why?

4. Sea snails – nudibranchs and dorids – are gastropods that eat anemones and hydroids (cnidarians) and use the ingested stinging cells in their own defensive behaviors, by putting the stinging cells into the cerata on their backs to catch potential predators. What happens to these organisms when anemone populations dwindle?

5. Abalone were once highly abundant on the California intertidal coast. Now you'll be lucky to find any. Their greatest predators are humans. Abalone are grazers and scrape algae (seaweeds) off rocks. What happens to the ecosystem when abalone disappear?

6. Solitary corals do not live connected to clones in a large branching structure. Instead, they live alone in a single calcium carbonate house. They are the only corals to grow along the California coastline. Unlike the more common corals of the tropics, these corals prefer cold water and are typically found under ledges in surge channels. What does that mean about their ability to withstand time outside water?

## Tidepooling Field Trip – Lab Exercises

The lab itself is a chance to explore! BE CAREFUL. Touch, but do not harm. This reserve is a protected area – nothing can be removed. For online students, find modified instructions on website.

### WHAT LIES WHERE?

You will make a transect from high tide to low tide, and every few feet, you will stop and spend 5 minutes observing and describing location and relative abundances of organisms present:

Location	Niche	Organisms Found in decreasing abundance. <i>(example: Mussels, gooseneck barnacles, owl limpet, ...)</i>
Splash zone, beach	CIRCLE: surge channel tide pool   rock top   rock side under ledge   sandy flats flat rock platform	
1/6 more toward low tide zone	CIRCLE: surge channel tide pool   rock top   rock side under ledge   sandy flats flat rock platform	
1/6 more toward low tide zone	CIRCLE: surge channel tide pool   rock top   rock side under ledge   sandy flats flat rock platform	
1/6 of the toward low tide zone	CIRCLE: surge channel tide pool   rock top   rock side under ledge   sandy flats flat rock platform	
1/6 more toward low tide zone	CIRCLE: surge channel tide pool   rock top   rock side under ledge   sandy flats flat rock platform	
1/6 more toward low tide zone	CIRCLE: surge channel tide pool   rock top   rock side under ledge   sandy flats flat rock platform	
At lowest tide level	CIRCLE: surge channel tide pool   rock top   rock side under ledge   sandy flats flat rock platform	

# WHO AM I?





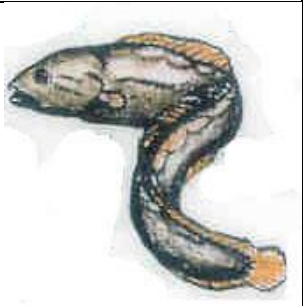
THE FOLLOWING is a list of the most common organisms you will find. Use this list to help identify species for the above project. **For each one that you see in today's field trip, check the box and enter the scale.**

## AUTOTROPHS

	<p><b>Feather Boa Kelp</b> <i>Egregia menziesii</i> <b>Brown Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		<p><b>Tar patch algae</b> <i>Mastocarpus spp./Ralfsia spp</i> <b>Red algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>
	<p><b>Sea Palm</b> <i>Postelsia palmaeformis</i> <b>Brown Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		<p><b>Articulated Coralline Algae</b> <i>Calliarthron sp</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>
	<p><b>Rockweed</b> <i>Fucus</i> <b>Brown algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		<p><b>Encrusting Coralline Algae</b> <i>Calliarthron sp</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>
	<p><b>Neptune's Washcloth</b> <i>Chondracanthus exasperatus</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		<p><b>Brillo Pad Algae</b> <i>Endocladia muricata</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>
	<p><b>Fir Needle</b> <i>Anelopus japonicus</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		<p><b>Black Pine</b> <i>Neorhodomela larix</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>
	<p><b>Iridescent Algae</b> <i>Mazaella splendens</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		<p><b>Sea sacs</b> <i>Halosaccion glandiforme</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>
	<p><i>Prionitis lanceolata (Harvey)</i> <b>Red Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		
	<p><b>"moss" Ocean Pin Cushion</b> <i>Cladophora columbiana</i> <b>Green Algae</b> <b>Feeding: Producer</b> <b>Scale:</b></p>		<p><b>Surf Grass</b> <i>Phyllospadix sp</i> <b>Plant</b> <b>Feeding: Producer</b> <b>Scale:</b></p>









**HETEROTROPHS**







	<p><b>Aggregating Anemone</b> <i>Anthopleura elegantissima</i> <b>Cnidarian</b> <b>Feeding: Suspension</b> <b>Scale:</b></p>		<p><b>Sunburst Anemone</b> <i>Anthopleura sola</i> <b>Cnidarian</b> <b>Feeding: Suspension</b> <b>Scale:</b></p>
	<p><b>Giant Green Sea Anemone</b> <i>Anthopleura xanthogrammica</i> <b>Cnidarian</b> <b>Feeding: Suspension</b> <b>Scale:</b></p>		<p><b>Orange Cup Coral</b> <i>Balanophyllia elegans</i> <b>Cnidarian</b> <b>Feeding: Suspension</b> <b>Scale:</b></p>
	<p><b>Northern Red Anemone</b> <i>Urticina felina</i> <b>Cnidarian</b> <b>Feeding: Suspension</b> <b>Scale:</b></p>		<p><b>Abalone</b> <i>Haliotis spp.</i> <b>Gastropod Mollusk</b> <b>Feeding: grazer</b> <b>Count and scale:</b></p>
	<p><b>Eroded Periwinkle</b> <i>Littorina keenae</i> <b>Gastropod Mollusk</b> <b>Feeding: Grazer</b> <b>Scale:</b></p>		<p><b>Owl Limpet</b> <i>Lotta gigantea</i> <b>Gastropod Mollusk</b> <b>Feeding: Grazer</b> <b>Scale:</b></p>
	<p><b>Ribbed Limpet</b> <i>Lottia digitalis</i> <b>Gastropod Mollusk</b> <b>Feeding: Grazer</b> <b>Scale:</b></p>		<p><b>Black Turban Snail</b> <i>Tegula funebris</i> <b>Gastropod Mollusk</b> <b>Feeding: Grazer</b> <b>Scale:</b></p>
	<p><b>California Mussel</b> <i>Mytilus californianus</i> <b>Bivalve Mollusk</b> <b>Feeding: Filter feeder</b> <b>Scale:</b></p>		<p><b>Day or Red Octopus</b> <i>Octopus cyanea or rubescens</i> <b>Cephalopod Mollusk</b> <b>Feeding: Predator</b> <b>Scale:</b></p>
	<p><b>Boring Clam</b> <i>Penitella sp</i> <b>Bivalve Mollusk</b> <b>Feeding: Filter feeder</b> <b>Scale:</b></p>		<p><b>Gooseneck Barnacle</b> <i>Pollicipes polymerus</i> <b>Arthropod</b> <b>Feeding: Filter feeder</b> <b>Scale:</b></p>

	<p><b>Acorn Barnacle</b>  <i>Balanos Glandula (adult) or Semibalanus cariosus Balanos Glandula (adult) or Semibalanus cariosus</i>  <b>Arthropod</b>  <b>Feeding: Filter feeder</b>  <b>Scale:</b></p>		<p><b>Buckshot Barnacle</b>  <i>Balanos Glandula (young) or Chthamalus spp.</i>  <b>Arthropod</b>  <b>Feeding: Filter feeder</b>  <b>Scale:</b></p>
	<p><b>Purple Shore Crab</b>  <i>Hemigrapsus nudus</i>  <b>Arthropod</b>  <b>Feeding: Deposit feeder</b>  <b>Scale:</b></p>		<p><b>Kelp Crab</b>  <i>Pugettia producta</i>  <b>Arthropod</b>  <b>Feeding: Grazer</b>  <b>Scale:</b></p>
	<p><b>Lined Shoreline Crab</b>  <i>Pachygrapsus crassipes</i>  <b>Arthropod</b>  <b>Feeding: Deposit feeder</b>  <b>Scale:</b></p>		<p><b>Hermit Crab</b>  <i>Pagurus samuelis</i>  <b>Arthropod</b>  <b>Feeding: Deposit feeder</b>  <b>Scale:</b></p>
	<p><b>Broken Back Shrimp</b>  <i>Heptacarpus brevirostris</i>  <b>Arthropod</b>  <b>Feeding: Deposit feeder</b>  <b>Scale:</b></p>		<p><b>Red Rock Crab</b>  <i>Romaleon antennarium</i>  <b>Arthropod</b>  <b>Feeding: Deposit feeder</b>  <b>Scale:</b></p>
	<p><b>Bryozoan</b>  <i>Cryptosula pallasiana or Eurystomella spp. or Watersipora subtorquata</i>  <b>Feeding: Filter feeder</b>  <b>Scale:</b></p>		<p><b>Purple Sea Urchin</b>  <i>Strongylocentrotus purpuratus</i>  <b>Echinoderm</b>  <b>Feeding: Grazer</b>  <b>Scale:</b></p>
	<p><b>Purple Sponge</b>  <i>Haliclona Permollis</i>  <b>Porifera</b>  <b>Feeding: Filter feeder</b>  <b>Scale:</b></p>		<p><b>Tidepool sculpin</b>  <i>Oligocottus maculosus</i>  <b>Bony fish</b>  <b>Feeding: Deposit feeder/predator</b>  <b>Scale:</b></p>
	<p><b>Prickleback or Monkeyface Eel</b>  <i>Cebidichthys violaceus</i>  <b>Bony fish</b>  <b>Feeding: Predator</b>  <b>Scale:</b></p>		<p><b>Harbor Seal</b>  <i>Phoca vitulina richardii</i>  <b>Carnivora</b>  <b>Feeding: Predator</b>  <b>Scale:</b></p>

## COUNTING!

THE FOLLOWING ORGANISMS need to be counted. **For each one you see during your visit to the tidepools, indicate with a tick mark below and an estimate scale.**

Organism	Description	Niche (tidal zone and location within the tidal zone)
	<p><b>Opalescent Hermissenda</b>  <i>Hermissenda opalescens</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Colorful Aeolid</b>  <i>Aeolidiella chromosoma</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Red Dorid</b>  <i>Rostanga pulchra</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Spotted Triopha</b>  <i>Triopha maculata</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Heath's Dorid</b>  <i>Geitodoris heathi</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Sea Lemon</b>  <i>Peltodoris nobilis</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Orange-peel Doris</b>  <i>Acanthodoris lutea</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>White-spotted Dorid</b>  <i>Doriopsilla fulva</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	

Organism	Description	Niche (tidal zone and location within the tidal zone)
	<p><b>California Sidegill</b>  <i>Berthella californica</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>San Diego or Ringed Dorid</b>  <i>Diaulula sandiegensis</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Goddess Dorid</b>  <i>Doris odhneri</i>  <b>Gastropod</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Leather star</b>  <i>Dermasterias imbricata</i>  <b>Echinoderm</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Bat star</b> <i>Patiria miniata</i>  <b>Echinoderm</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Sunflower star</b>  <i>Pycnopodia helianthoides</i>  <b>Echinoderm</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	
	<p><b>Ochre star</b>  <i>Pisaster ochraceus</i>  <b>Echinoderm</b>  <b>Feeding: predator</b>  <u><b>Count and scale:</b></u></p>	

Organism	Description	Niche (tidal zone and location within the tidal zone)
	<p><b>Giant-spined star</b>  <i>Pisaster giganteus</i>  <b>Echinoderm</b>  <b>Feeding: predator</b>  <b><u>Count and scale:</u></b></p>	
	<p><b>Woody Chiton</b>  <i>Mopalia lignose</i>  <b>Polyplacophora</b>  <b>Feeding: grazer</b>  <b><u>Count and scale:</u></b></p>	
	<p><b>Black or Leather Chiton</b>  <i>Katharina Tunicata</i>  <b>Polyplacophora</b>  <b>Feeding: grazer</b>  <b><u>Count and scale:</u></b></p>	
	<p><b>Lined Chiton</b> <i>Tonicella Lineata</i>  <b>Polyplacophora</b>  <b>Feeding: grazer</b>  <b><u>Count and scale:</u></b></p>	
	<p><b>Gumboot Chiton</b>  <i>Cryptochiton stelleri</i>  <b>Polyplacophora</b>  <b>Feeding: grazer</b>  <b><u>Count and scale:</u></b></p>	
	<p><b>Mossy Chiton</b>  <i>Mopalia muscosa</i>  <b>Polyplacophora</b>  <b>Feeding: grazer</b>  <b><u>Count and scale:</u></b></p>	

## Weekly Reflection

Take a moment to reflect on your comfort level and mastery of the week's objectives and describe an action plan for how you will practice or improve on anything that challenged you.

Weekly Objective	Self-Assessment of Mastery Level	Action plan for improvement
Identify, name, and taxonomically classify a variety of organisms found in the intertidal zone in San Francisco Bay.	A   B   C   D   F	
Describe the zonation found within the intertidal region -- specifically the variation in tidal height, exposure, species, and potential pollution impacts.	A   B   C   D   F	
Evaluate the impacts of the loss of a species to the health of the rest of the ecosystem.	A   B   C   D   F	

### INSIGHTS

What new insights have you developed this week due to the week's content? Did anything in particular help you understand something you've always wondered about, or made you think about the world with new eyes?

# Tidepooling Practice Sheet

Remember – the exam questions come directly from the labs, so to do well on the exam, be sure to study ALL the questions on the labs and be able to correctly answer them on the exam. To assist, this study sheet gives you a chance to practice SOME of the skills from the previous lab. BE CAREFUL – just because a question appears on this sheet doesn't mean it will show up on the exam. AND if it doesn't show up here, that doesn't mean that it will NOT show up on the exam. For each classification below, list what all members of that group have in common. Be thorough; include at least 4 traits. Include a few examples of the organisms.

1. <b>Protista</b>
2. <b>Ciliates</b>
3. <b>Dinoflagellates:</b>
4. <b>Radiolaria:</b>
5. <b>Foraminifera</b>
6. <b>Brown Algae</b>
7. <b>Diatoms:</b>
8. <b>Green Algae:</b>
9. <b>Red Algae:</b>
10. <b>Angiosperm/Plants:</b>
11. <b>Annelids</b>
12. <b>Arthropods</b>
13. <b>Bryozoans</b>
14. <b>Cnidarians</b>
15. <b>Echinoderm</b>
16. <b>Mollusk</b>
17. <b>Porifera</b>
18. <b>Chordata</b>
19. <b>Urochordata</b>
20. <b>Vertebrata</b>
21. <b>Jawless Fish</b>
22. <b>Cartilaginous Fish</b>
23. <b>Bony Fish</b>
24. <b>Mammalia</b>

25. **Carnivora**

**Define and give examples of the following feeding types from the tide pool community:**

- |  |
|--|
| 26. <b>Deposit Feeder (including scavengers)</b> |
| 27. <b>Filter Feeder</b>                         |
| 28. <b>Suspension Feeder</b>                     |
| 29. <b>Grazer</b>                                |
| 30. <b>Predator</b>                              |
| 31. <b>Producer</b>                              |

Review and be able to **name** and **classify** each of the organisms found in the Tidepools.

Note: classification means:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

- |   |
|---|
| 32. <b>Review the changes in organisms as we moved from the high tide to the low tide zone.</b>                             |
| 33. <b>Review the interdependence of the sea otter/purple sea urchin/giant kelp populations.</b>                            |
| 34. <b>Review the effects of humans on tidepool organisms.</b>  |
| 35. <b>List some of the special adaptations intertidal organisms have developed to handle the high wave activity.</b>       |
| 36. <b>List some of the special adaptations intertidal organisms have developed to handle the potential for drying out.</b> |

## KEY

1-25: For shared traits, look to *Taxonomic Classification Sheet that precedes the marine biology labs.*

26. <b>Deposit Feeder (including scavengers)</b> <i>Brokenback Shrimp (and other shrimp species), Hermit crabs, Shoreline crabs, Sculpin, Seagulls</i>
---

27. <b>Filter Feeder</b> <i>Mussels, Sponges, Barnacles, Bryozoans</i>
28. <b>Suspension Feeder</b> <i>Anemones</i>
29. <b>Grazer</b> <i>Chitons, Turban snails, Abalone, Kelp crab</i>
30. <b>Predator</b> <i>Sea stars, nudibranchs, seals, sea lions, Pelicans, Octopus</i>
31. <b>Producer</b> <i>Kelp, all seaweed, algae</i>

Review online flashcards (lab website) for naming and classifying each organism seen at tidepools. Note: if the group didn't see these organisms, they will not be on the exam. The online flashcards contain many more organisms that you will be responsible for identifying, as they include most organisms that might be encountered from one semester to the next. Look to flashcards to review:

- detailed phylum, subphylum, etc. where appropriate
- feeding method
- location (where they live)

You will receive extra credit for all the accurate subphylum information you give (beyond required), BUT if it's wrong, you'll be marked off.

<p>32. <b>Review the changes in organisms as we moved from the high tide to the low tide zone.</b></p> <ul style="list-style-type: none"> <li>• See last figure on last page of prereading.</li> <li>• At Pillar Point and Moss Beach, Sea Palm and Feather Boa kelp are found only in lowest tide zone along with sea urchins and most of the sea stars. Mussels and gooseneck barnacles are found in upper middle tidal zone. Ocean pin cushion ('moss') is found only in the high tide zone. Iridescent algae is found throughout. Turban snails are found in high and middle tidal zone. Buckshot barnacles in the high tide zone. Giant Green Sea anemones in the lower middle and lower tidal zone. Aggregating anemones are found in the middle tidal zone. Nudibranchs tend to be found in the lower tidal zone only. Sea grasses are in the surge channels where there's sands or muds – usually upper middle or high tide zones.</li> <li>• There are a number of other zonal changes that are legitimate based on the results of the field trip.</li> </ul>
<p>33. <b>Review the interdependence of the sea otter/purple sea urchin/giant kelp populations.</b> See prereading – sea otter eats purple sea urchin which eats giant kelp. If sea otter populations diminish (as they have around Pillar Point and Moss Beach), then the purple sea urchin populations explode. These then attack the giant kelp, and there are no giant kelp forests. In Monterey Bay, there is a healthier sea otter population and hence a healthy giant kelp population.</p>
<p>34. <b>Review the effects of humans on tidepool organisms.</b></p> <ul style="list-style-type: none"> <li>• Humans harvest food (algae, snails, urchins, and more) from the intertidal zone.</li> <li>• Human populations produce pollutants that contaminate tide pools, especially a problem during periods of rain (runoff picks up debris on ground) and low tide (when tide pools can collect this pollution).</li> </ul>
<p>35. <b>List some of the special adaptations intertidal organisms have developed to handle the high wave activity.</b></p> <ul style="list-style-type: none"> <li>• Many possible options here – including:</li> <li>• Echinoderms (sea stars and urchins) with tube feet that use a water vascular system to attach to rock</li> <li>• Byssal threads for mussels (stick to rock)</li> <li>• Pedal discs for anemones (stick to rock)</li> <li>• Holdfasts for kelp (stick to rock)</li> <li>• Exoskeletons glued to rock (barnacles)</li> <li>• Strong suction by foot for snails and gastropods (stick to rock)</li> </ul>
<p>36. <b>List some of the special adaptations intertidal organisms have developed to handle the potential for drying out.</b></p> <ul style="list-style-type: none"> <li>• Many possible options here – including:</li> <li>• White sand stuck to tentacles of closed-up anemones (especially the aggregating anemones)</li> <li>• Mucous coating on top of some sea stars (especially the leather star and sunflower star)</li> <li>• Shells that close up (gastropods, bivalves, chitons)</li> <li>• Move to tide pools and hide in cracks or under seaweed (crabs and shrimp and tidepool sculpin)</li> </ul>

## APPENDIX: Microscope and Grain Size and % Scales

### SCALES FOR MICROSCOPE WORK:

#### Binocular SWIFT Compound

Objective magnification	Eye piece magnification	Total Magnification	Field of View diameter
4X	10X	40x	5.00 mm
10X	10X	100X	2.00 mm
40X	10X	400X	0.50 mm
100X	10X	1000X	0.20 mm

*\*DON'T USE THE LARGEST OBJECTIVE*

#### Binocular SWIFT dissecting

Objective magnification	Eye piece magnification	Total Magnification	Field of View diameter
1X	15X	15x	14 mm
2X	15X	30X	7 mm

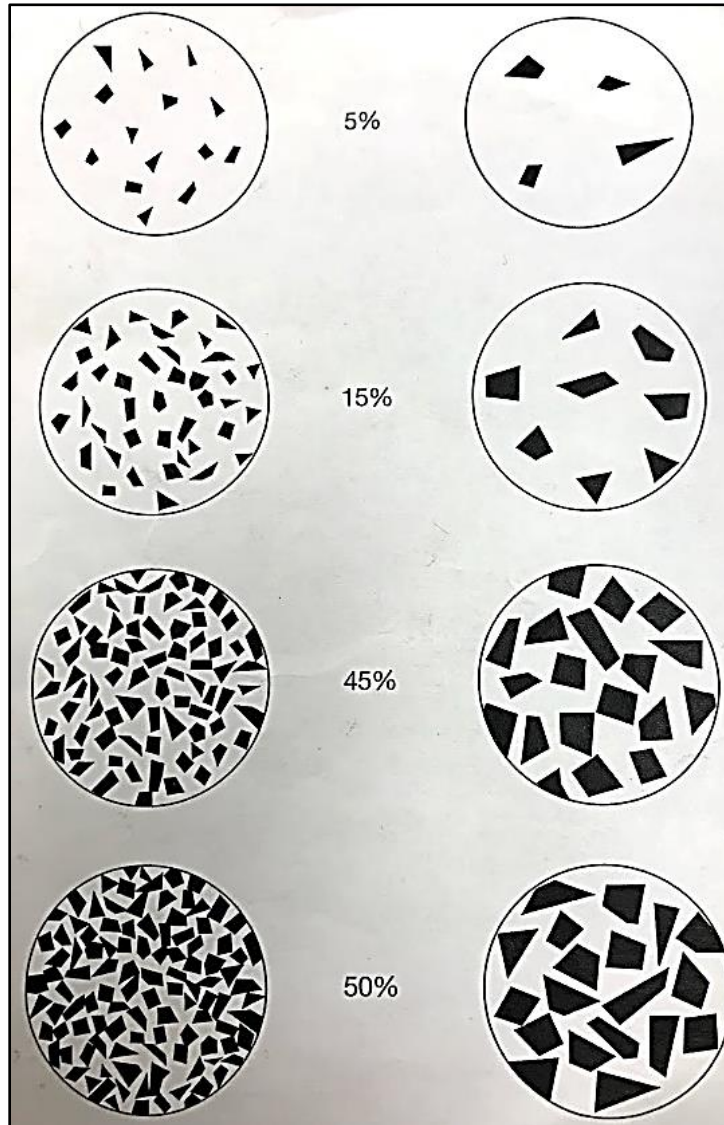
#### Binocular UNITRIN dissection

Objective magnification	Eye piece magnification	Total Magnification	Field of View diameter
1X	10X	10x	
2X	10X	20X	

#### Binocular Boreal dissection

Objective magnification	Eye piece magnification	Total Magnification	Field of View diameter
2X	10X	20x	9 mm
4X	10X	40X	5 mm

Grain size and composition % reference chart



Grain size and shape and sorting reference chart

