Duxbury Docents Training Manual

For Volunteer Docents at
Duxbury Reef, Bolinas, CA
A California State Marine Conservation Area

January 2023

Environmental Action Committee of West Marin

The Environmental Action Committee of West Marin (EAC) is a 501c3 non-profit organization based in Point Reyes Station in western Marin County, California. Established in 1971, our mission is to protect and sustain the unique lands, waters, and biodiversity of West Marin. We achieve this goal through environmental advocacy, education, and engagement opportunities. For more information about EAC or for additional copies of this report, please visit eacmarin.org.

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Acknowledgments and Credits

The Duxbury Docents Training Manual and training program was developed by EAC in collaboration with organizations and individuals who have contributed and provided support.

This manual and docent training program have been prepared and instructed by Kent Khtikian, California Academy of Science Rocky Shore Intertidal Naturalist Program; Leslie Adler-Ivanbrook and Morgan Patton, Environmental Action Committee of West Marin; Ben Becker, National Park Service; Kathy Ann Miller, University of California, Berkeley; Joe Mueller, College of Marin; and Rebecca Johnson, California Academy of Science, with staff presentations from California Department of Fish and Wildlife, National Marine Sanctuaries, Marin County Parks and Open Space, Point Reyes National Seashore. *A special thanks to the Friends of Fitzgerald Marine Reserve who generously shared their volunteer and docent training manual with EAC that has been adapted for use at Duxbury Reef.*

Thank you to the members of EAC for their financial support and our contributing organizations who provided advice, expertise, coordination, and financial support, without which this program would not be possible including: Supervisor Dennis Rodoni, Max Korten, Samantha Haimovitch, Krista Hanoff, Jason Olivotti at Marin County Parks and Open Space; Marin County Fish and Wildlife Commission; Ben Becker, National Park Service; Rebecca Johnson, California Academy of Sciences; Kris Lannin Liang, Tom Ciotti, and Keith Mangold at Friends of Fitzgerald Marin Reserve; Marin MPA Watch Volunteers; Calla Alison, Nicole Palma, Aubrie Fowler, David McGuire, and Paul Hobi Golden Gate Collaborative and MPA Collaborative Network; Resources Legacy Fund; and the California Ocean Protection Council.

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Welcome

I have the honor of welcoming you to the *Duxbury Docents* program with the Environmental Action Committee of West Marin (EAC)! You are joining an organization steeped in decades of advocacy, education, and stewardship protecting the lands, waters, and biodiversity of coastal Marin County. As a Duxbury docent, you are taking a critical step to protect what you love at Duxbury Reef as an environmental steward.

I spent my childhood in Bolinas at my Great Grandmother's house in Dogtown and many days exploring Duxbury. I've always heard Duxbury referred to as, the place *we are loving to death.* When I joined EAC's team in 2015, I wanted to change that.

I found a pathway for change in the MPA Watch program that collects human use data and builds community relationships. Our MPA Watch partner, Rebecca Johnson, biologist from the California Academy of Science, introduced me to Kent Khtikian, a Rocky Shore Intertidal Naturalist, to join MPA Watch. This was a pivotal moment. Kent also wanted to change what was happening to the place he loved so much, so we teamed up. We focused on data collection, education, and compliance issues.

Kent's love for Duxbury Reef had him out as a one-man docent program providing education to visitors and collecting human activity data for the MPA Watch program for years. I worked on strengthening MPA Watch, advocating to regulatory agencies and elected officials to raise Duxbury's profile. Then, in 2019, we put it all together and published a report, *Duxbury Reef Community Docent Proposal*, and pitched it to Supervisor Dennis Rodoni and Marin County Parks for a partnership to protect the reef. In January 2020, we succeeded and began to plan the launch that was unfortunately delayed by almost two years due to the pandemic. This program would not be possible without Kent.

Now, after all these years of work, Duxbury's community docent program is coming to life to protect the fragile habitat and species and inspire the next generation of environmental stewards! This project is made possible by a coalition of people and organizations working together. In early 2021, EAC welcomed Leslie Adler-Ivanbrook as our Program Manager and she and Kent have worked diligently to develop the training program in partnership with our guest instructors, Joe Mueller, Rebecca Johnson, Kathy Anne Miller, Ben Becker, and the Friends of Fitzgerald Marine Reserve who provided their manual as an outline for our program.

Thank you for dedicating your time to Duxbury. I know that together, we will wash away the stain of *loving Duxbury to death* and bring to life the example Margaret Meade so eloquently stated, "Never doubt that a small group of thoughtful and committed individuals can change the world. In fact, it's the only thing that ever has." On behalf of the entire EAC community and our partners, welcome and thank you!!

Sincerely,

Morgan Patton, Executive Director

Part 1. Docent Responsibilities

Job Description

Duxbury Docents program trains and coordinates volunteers to provide the public with educational information about the rocky intertidal habitat on Duxbury Reef State Marine Conservation Area (Duxbury SMCA) in Bolinas, California (part of California's network of Marine Protected Areas), and the Greater Farallones National Marine Sanctuary. The goal of the program is to facilitate learning so that all visitors can help protect the sensitive habitat as they explore on the reef.

Duxbury Docents teaches volunteers to engage with visitors on the reef about the marine life and ecology of the reef, marine protected areas (MPAs), how to conduct MPA Watch surveys and report potential violations of regulations, appropriate tidepool stewardship and safety protocols and appropriate interaction with the public including school groups.

Duxbury docents enjoy the benefits of both learning through training and observation about the intertidal marine life at Duxbury Reef, as well as the satisfaction gained from sharing information with the visiting public to support protection of the reef and inhabitants.

Job Duties:

- Interact with diverse members of the public, of varied ages, individuals, and group sizes.
- Deliver *Duxbury Docents* four pillars of public education engagement:
    - Friendly, positive, and inquisitive public interactions
    - Share Rules and Regulations of Duxbury SMCA
    - Information about ecology and marine life
    - Safety and stewardship practices (tidepool etiquette)
- Provide two low-tide shifts per month (approximately 3-4 hours in duration).
- Conduct an MPA Watch survey and shift report during each docent shift.
- Communicate and schedule shifts online using Google calendars and email platforms.

Requirements

1. Must be 18 year of age or older, or accompanied by a guardian.
2. Must attend all *Duxbury Docents* training sessions.
3. Must attend enrichment training sessions when offered, and whenever possible.
4. Physically able to move about freely and comfortably on the intertidal reef surface, which can be slippery and uneven.
5. **Duxbury docents are expected to model and set an example of how to explore the tidepools without disturbing the natural habitat for all the inhabitants of the reef.**

Benefits

- Healthy recreation that gets you outside exercising your mind and muscles!
- Supporting the stewardship of a sensitive, protected marine habitat.
- Complementary resource: Field Guide to North American Seashore Creatures.
- Complementary uniform – hat, identification tag, and vest.
- Invitations to EAC special events and subscription to the EAC's online newsletter.

Docent Job Duties

Docents are expected to engage with the visiting public at Duxbury Reef to provide education about Duxbury Reef's habitats and species through *friendly, positive, and inquisitive interactions*. Examples are provided below. Docents are also required to collect data during their shift that includes conducting an MPA Watch survey and completing a shift report. The MPA Watch survey and shift report provide valuable information on how people are using Duxbury Reef SMCA. Recording the number of visitor interactions and comments helps us evaluate the program.

Types of Visitor Services Docents Provide

Docents should expect to engage with three general types of visitor groups that require different engagement and communication approaches and styles that includes the general public, youth and school groups, and adult groups.

1. General Public

Two to three docents will be scheduled to provide roving general education services to the visiting public on low tide days when visitation is expected to be high:

- Provide education about Duxbury Reef's habitats and species through friendly, positive, and inquisitive interactions.
- Information about MPA regulatory protections for Duxbury Reef.
- Tidepool safety and stewardship guidelines.

2. Groups

EAC coordinates with Marin County Parks and Open Space to obtain information about school groups and other large groups wanting to visit Duxbury Reef.

- Docents must communicate with EAC when they receive a docent tour request and refer the group contact to our webpage for the link to fill in the *Duxbury Docents* Tour Request form.
- Docent tours are semi-formal. The docents' role is to educate; provide overview information and answer questions, support learning.
- Docents are not expected to deliver educational curriculum, lead a formal tour, or be responsible for group management.
- Docents will sign up on a shared Google Calendar to cover low-tide shifts for general visitor engagement and special visitor groups of their choice as coordinated by EAC, and based on preference and comfort levels. There are 2-3 docents per shift.

Registered Groups: Youth and Schools

School groups registered with Marin County Parks may receive the assistance of two docents to support the educational goals for the group. Docents do not deliver educational curriculum to the school groups.[1]

The service includes:

- Introductions of docent team
- Overview of Duxbury Reef geologic and biologic setting
- Overview of MPA regulatory protections for Duxbury Reef
- Tidepool safety and stewardship guidelines
- Question and answers
- Support learning as groups explore Duxbury Reef and encourage responsible stewardship practices

Registered Groups: Adult or Mixed Age

Groups of more than 12 people who registered with Marin County Parks may receive the assistance of two docents to provide the educational services for the group. Docents do not deliver educational curriculum.

- Introductions of docent team
- Overview of Duxbury Reef geologic and biologic setting
- Overview of MPA regulatory protections for Duxbury Reef
- Tidepool safety and stewardship guidelines
- Question and answers
- Support learning as groups explore Duxbury Reef and encourage responsible stewardship practices

[1] Field trip curriculum is not provided. School groups will either have their own teacher developed curriculum or are contracted with a third-party to deliver a specific curriculum and materials.

Visitor Engagement Guidelines

- *Beach or Reef*?
  - The rocky intertidal reef is the focus area for docenting.
  - You need not approach visitors who are moving out of the intertidal area, unless there is a risk of injury to the visitor (i.e. they are sitting against a bluff face, or sitting in an area where there have been rockfalls falling), or they are damaging the bluffs (e.g. kids are climbing up or battering the bluff face).
- *Approach with a Smile & Provide a Positive Education Experience*.
  - This is very important – When approaching visitors, do so with a smile and easy, non-confrontational body language. Introduce yourself as a Duxbury docent.
  - Note that occasionally, someone may get irritated. *Remain cordial, with a helpful, positive or neutral attitude*, and give people who seem uncomfortable or agitated with your presence plenty of space.
  - The main goal is to educate positively. But if an interaction at all becomes uncomfortable, it's best to step away cheerfully. Please describe the interaction on your datasheet, giving the approximate time of day.
- *Educator – Not Enforcement*
  - Remember, Duxbury docents are educators, not enforcers.
  - Do not insist on tidepool practices or compliance with MPA regulations. You may report potential violations of MPA regulations on your shift report and to:

    Cal-TIP (888) 334-2258
    Marin County Parks Office (415) 473-6387

Example Openers: Ways to Approach the Public

Good morning / afternoon! My name is _____. I'm a docent here at Duxbury Reef and I am here to answer questions and share information about the reef and it's amazing marine life. What have you seen today? Have you been here before?

- *If they are interested in talking and engaging:* You can share quick fun fact, or metaphor/ analogy, invite them to share what they know or are curious about.

- *If they are not interested in talking or engaging:* Let them know you are around if they have any questions about what they are seeing and happy to help.

Example Comment: To Include While Engaging Visitors

We bring this to the attention of everyone that it is visiting the reef: Duxbury is a Marine Protected Area and of special biological significance. The intention of an MPA is that the creatures here will repopulate parts of the coast more heavily impacted by us. So that this area can remain healthy and open to visitors we ask everyone to observe 3 simple, good tidepooling practices:

- *Use eyes, not hands;*
- *Don't step in water pools; try to step on bare rock instead of algae or other marine life.*
- *Leave everything in its place. No taking.*

At that point you can tell them to enjoy the reef.

Docent Shift Report Datasheets

There are two parts to the Shift Report. The first part is the MPA Watch survey, and the second portion is the Shift Report and they both appear on the same datasheet.

Top Portion: MPA Watch Survey

Docents must complete an MPA Watch survey during their shift. The data form is included on the shift report datasheet.

MPA Watch is a statewide network of groups monitoring how people use and engage with California's MPAs to better understand visitation and use trends of the MPA Network. Data on both consumptive uses (e.g. recreational and commercial onshore and offshore fishing, collecting organisms) and non-consumptive uses (e.g. surfing, beach recreation, tidepooling, kayaking, etc.) is collected on a standard data form and is consistent through the state.

The accessible data can be used by agencies, academia, and local communities to inform management and programming decisions. In fact, MPA Watch data showing increasing visitation at Duxbury Reef was presented to agencies to help support the development of the Duxbury Docents program.

There are approximately 12 MPA Watch organizations through the state of California. Marin MPA Watch data is shared with California Department of Fish and Wildlife, Point Reyes National Seashore, Marin County Parks and Open Space, Greater Farallones National Marine Sanctuary, and other organizations or agencies studying the MPAs.

- Duxbury Docents are trained on MPA Watch protocols during their docent training series.
- Docents must conduct MPA Watch surveys at each shift (timing may vary, and up to the docent) to capture important data on human activity and numbers of visitors. The survey form is part of the Shift Report form.
- Docent training materials will include a copy of the Marin MPA Watch Volunteer Manual.

Conducting the MPA Watch Survey

- Use the shift data sheet to document the MPA Watch observations
- Transect Name: AG BEACH 03: Docent Program
- Site and Conditions Information: Name, Date, Weather, Tide Conditions, Time (note that MPA Watch survey start and end time is at the top of the datasheet. It is *different* than the shift start and end time in the lower section of the sheet).
- Parking Lot: Count the number of cars in the parking lot and record on datasheet.
- Walk to the bottom of the trail that leads to the beach and out on to Duxbury Reef (about middle of the reef). Look ahead, to the left on the reef, and then to the right (counting activities along the rocky reef, sandy beach adjacent to the reef, and in the ocean within 1,000 ft. of low tide offshore) and tally the activities observed (recreation, tidepooling, fishing, dogs on and off leash, etc.) in the appropriate column (rocky, sandy.

Important Notes: *Duxbury Docent surveys are slightly different than other trained MPA Watch volunteers at Duxbury Reef, as a new survey transect was created as a 5-10 minute observation "snapshot" in each direction to monitor activities on the rocky reef.*

Bottom Portion: Shift Report

Shift Reports provide important information on the conditions, visitation, general information, feedback, and includes a MPA Watch survey. Information collected in the shift report will be used to evaluate the program, and reviewed if there is an emergency, complaint, or other issues. The Shift Report is the complete documentation of a docent's experience on the Duxbury Reef during their shift, It is important to document both positive and negative interactions so we have a complete understanding of the days' activities.

Information collected in the Shift Report includes:

- Name
- Date and time (start and end) of shift
- Number of visitors engaged
- Number of potential violations regulations observed
- Notes for comments, descriptions of interactions and observations and other feedback

Submit the MPA Watch Survey and Shift Report to the *Duxbury Docents* program manager once the shift is complete (leslie@eacmarin.org).

west marin environmental action committee

Duxbury Docent Program

Daily Shift Report

Cal-TIP (888) 334-2258
Marin County Parks Office
(415) 473-6405

MPA Watch Survey Transect: DUXBURY DOCENT

Full Name: _____		Date: _____/_____/_____	Start Time: _____	End Time: _____
Clouds: clear (0%) partly cloudy (1-50%) cloudy(>50%cover)	Rain: Yes / No	Visibility: perfect / limited / shore only	Wind: calm / breezy / windy	
Air Temperature: cold / cool / mild / warm / hot		Beach Status: open / posted / closed / unknown	Tide Level: low / med / high	

On-Shore Activities	Reef / Beach		Off-Shore Recreation & Boating Activities	
Recreation (walking, resting, playing, etc. NOT tidepooling)	Rocky	Sandy	Offshore Recreation (swimming, bodysurfing, etc.)	
Wildlife Watching			Board Sports (surfing, boogie boarding)	
Domestic animals on-leash			Stand Up Paddle Board	
Domestic animals off-leash			Non-Consumptive Diving	
Tidepooling (not collecting)			Consumptive Diving (nets, poles, traps, etc.)	
Hand collection of biota			Consumptive Fishing Boat (traps, nets, etc.): ***Tally & write gear type next to total***	
Driving on beach/shore (includes bikes and e-bikes)			Paddle Boat (Kayak, etc.)	
Shore-based hook and line fishing			Non-Consumptive Boat (Whale Watching, Coastguard, research, etc.): ***Tally and write type next to total***	
Shore-based fishing: ***Tally & list gear type next to total***			Non-Consumptive Boating (powerboat, jetski, sailboat): ***Tally & write type next to total***	

MPA Watch Comments	
Did you observe:	☐ scientific research ☐ education ☐ beach closure ☐ large gatherings: #_____ ☐ enforcement activity
Did you report a violation?	☐ **Yes** ☐ No
If Yes, how many?	
Who did you report to?	☐ **DFW (Cal Tip)** ☐ **Federal Park** ☐ Marin County Parks ☐ **Sheriff** ☐ Other: _____
How did you report?	☐ Phone ☐ Text ☐ App ☐ Website ☐ Email ☐ Person

Duxbury Docent SHIFT REPORT:

Shift Start Time (Arrival Time):	
Shift End Time (Leave Parking Lot):	
Number of Visitors you talked to: (Tally)	
Number of potential violations observed or interrupted:	
Engagement Details: (describe positive and challenging interactions); add info on reverse side or email if additional space is needed.	
General Report (questions, concerns, etc.):	
Additional Materials or Supplies Needed?	

Part 2: Stewardship & Safety

Stewardship Education: Regulations to Protect the Reef

The primary job of a docent is to engage and educate visitors about the Duxbury Reef SMCA and diverse marine life. This also includes teaching visitors about the MPA regulations that exist to protect the habitats and species. Tidepool etiquette or guidelines are very important to follow, for both *Duxbury Docent* volunteers and the visiting public. To protect the health of the reef and the safety of visitors, **Duxbury docents are expected to model and set an example of how to explore the tidepools without disturbing the natural habitat for all the inhabitants of the reef.**

Duxbury Reef is a California Marine Protected Area (MPA). MPAs are named, discrete geographic marine or estuarine areas designed to protect or conserve marine life and habitat. There are five different marine protected areas classifications used in California's MPA network: State Marine Reserves; State Marine Conservation Areas; State Marine Parks; State Marine Recreational Management Areas; and Special Closures.

Duxbury Reef is adjacent to and contiguous with Marin County's Agate Beach Park and Point Reyes National Seashore and is part of the Greater Farallones National Marine Sanctuary. It is designated by California as an Area of Special Biological Significance, and a State Marine Conservation Area where all marine life and physical resources are protected.

It is unlawful to injure, damage, take, or possess any living, geological, or cultural marine resource for recreational and/or commercial purposes, with the following specified exceptions:

- **The recreational take of finfish* from shore and abalone is allowed but must comply with California Department of Fish and Wildlife regulations .[2] [3]**
- **Violations are a misdemeanor offense punishable by up to six months in jail and a $1,000 fine.**

DOCENT TIP: What's Allowed and Not Allowed:

- **The collection of rocks, shells, algae or seaweed, and any marine life (except as noted above) is not allowed.**
- **Finfish are defined as any species of bony fish or cartilaginous fish (also includes sharks, skates and rays). Recreational hook and line /poke pole fishing is allowed.**
- **Recreational abalone fishery is closed until April 2026.**

[2] California Department of Fish and Wildlife regulations include fishing license requirements, fishing seasons, and closures.

[3] See complete list of regulations from the California Department of Fish and Wildlife at www.wildlife.ca.gov/Conservation/Marine/MPAs/Network/North-Central-California

Remember that docents are not enforcement personnel. If potential violations are observed, they should be reported to:

Marin County Sheriff (415-479-2311) and/or the California Department of Fish and Wildlife at CalTIP (888- 334-2258).

Duxbury Reef State Marine Conservation Area

North Central California - Established May, 2010

What is a California marine protected area (or "MPA")?
An MPA is a type of managed area whose main purpose is to protect or conserve marine life and habitats in ocean or estuarine waters. California's MPA Network consists of 124 areas with varying levels of protection and 14 special closures, all designed to help safeguard the state's marine ecosystems. Most marine conservation areas such as Duxbury Reef State Marine Conservation Area provide some opportunity for commercial and/or recreational take (species and gear exceptions vary by location - see reverse).

One goal for California's MPAs was to strategically place them near each other to form an interconnected network that would help to preserve the flow of life between marine ecosystems. Within that network each MPA has unique goals and regulations, and non-consumptive activities, permitted scientific research, monitoring, and educational pursuits may be allowed.

Why was this location chosen for a state marine conservation area?
One of the goals for Duxbury Reef State Marine Conservation Area is to protect one of the largest shale reefs in North America, as well as the sandy beaches and surfgrass beds found there. During low tide, the shale reef's fractures and channels form extensive tidepools filled with seaweed, monkeyface pricklebacks, porcelain crabs, turban snails, and other tidepool dwellers. California mussels and gooseneck barnacles cling to rock surfaces, sifting bits of food from the water that washes over them with the returning tide. The conservation area's sandy seafloor and surfgrass beds support perch, flatfish, nudibranchs, crab, and other species.

Duxbury Reef State Marine Conservation Area overlaps portions of Point Reyes National Seashore, Duxbury Reef Area of Special Biological Significance and the Greater Farallones National Marine Sanctuary. Placing a state marine conservation area here provides moderately high levels of protection for marine life and the habitats they use.

Report poachers and polluters
Call CalTIP: 1 (888) 334-2258
or text 847411 - begin message with "Caltip" followed by the details.

CALIFORNIA MARINE PROTECTED AREAS

Quick Facts: Duxbury Reef State Marine Conservation Area

- **MPA size:** 0.69 square miles
- **Shoreline span:** 2.8 miles
- **Depth range:** 0 to 10 feet
- **Habitat composition:**
  Rock: 1.52 square miles
  Sand/mud: 0.06 square miles

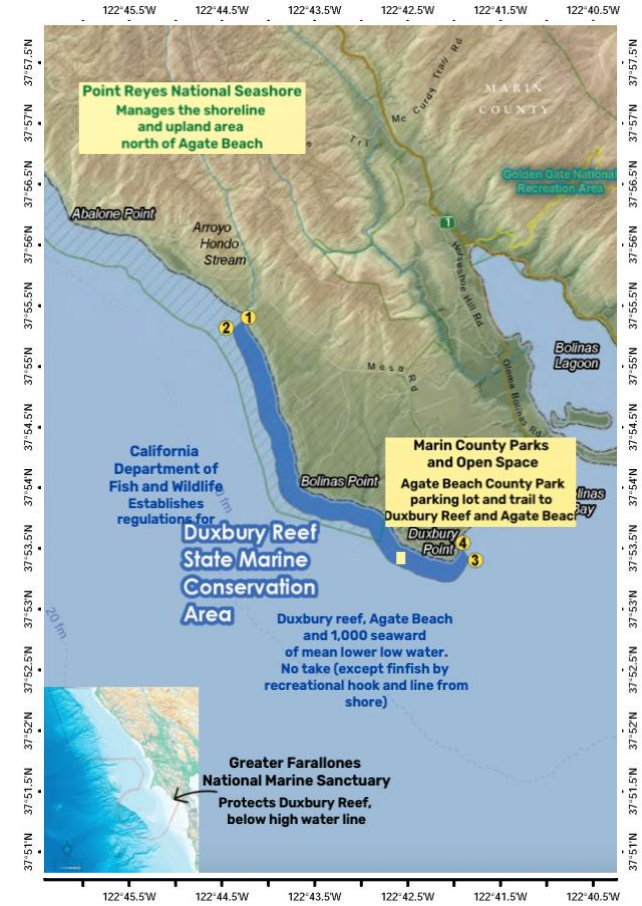
Further Information:

- MPA Website: www.wildlife.ca.gov/MPAs
- MPA and Sportfishing Interactive Map: www.wildlife.ca.gov/OceanSportfishMap
- Email: AskMarine@wildlife.ca.gov

Photos - ***Upper:*** **Rocky shoreline at Duxbury Reef State Marine Conservation Area.** *photo © jennconspiracy, CC BY-NC-ND 2.0* ***Lower right:*** **Monkeyface prickleback at Duxbury Reef State Marine Conservation Area.** *photo © Tamara Schwarz CC BY-NC 2.0* ***Lower left:*** **Mussel bed at the conservation area.** *photo © M. Dettling CC BY-NC 2.0*

Duxbury Reef State Marine Conservation Area

North Central California - Marin County



Version 2, September 2022

This map has been modified to indicate additional agency jurisdictions at and near Duxbury Reef.

Duxbury Reef State Marine Conservation Area Boundary and Regulations *from* California Code of Regulations Title 14, Section 632

Boundary:

This area is bounded by the mean high tide line, a distance of 1,000 feet seaward of mean lower low water, and the following points:

37° 55.514' N. lat. 122° 44.179' W. long.①;
37° 55.420' N. lat. 122° 44.310' W. long.②;
37° 53.650' N. lat. 122° 41.910' W. long.③; and
37° 53.770' N. lat. 122° 42.020' W. long.④

Permitted/Prohibited Uses:

1. It is unlawful to injure, damage, take, or possess any living, geological, or cultural marine resource for recreational and/or commercial purposes, with the following specified exceptions:

a. The recreational take of finfish* from shore and abalone** is allowed.

*Finfish are defined here as any species of bony fish or cartilaginous fish (sharks, skates and rays).
**Note: The recreational abalone fishery is closed until April, 2026.
Take may be authorized for research, restoration, and monitoring purposes under a scientific collecting permit. See California Code of Regulations Title 14, Section 632(a).
The information in this document does not replace the official regulatory language found in the California Code of Regulations Title 14, Section 632. View these regulations online at www.wildlife.ca.gov/Conservation/Marine/MPAs/Network.

Guidelines: Tidepooling & Safety

All visitors, whether in groups or individuals, should be asked to observe these rules for good tidepooling etiquette.

DOCENT TIP: Three tidepooling practices to share with visitors, to protect this MPA so that it can be kept in good health and open for future visitors:

1. Look with your eyes not with your hands
2. Walk gently being mindful of what you are stepping on, which means attempting to avoid algae beds on the exposed reef and not stepping in pools of water
3. There is no taking allowed of anything

Simply stating those 3 practices get the most important and most relevant points across without getting into long-winded explanations of numerous "rules" which people are not there to hear. Stating other rules not included in those 3 may best be reserved when you observe a violation of one of them (e.g. kids scrambling up the bluff; dogs playing fetch on the reef) and directed to the person(s) engaged in that activity (or if a child then to their parent). Gauge your audience and attention to help prioritize your communication on this.

Tidepooling Best Practices

1. **Observe with your eyes, not with your hands.** Many creatures found on the reef can be injured if picked up by even the most well-meaning person. Limited, gentle, two-finger touching of immobile, firmly attached marine life is ok, e.g. mussels, limpets, chitons, barnacles, sponge, tunicates, sea stars and urchins (only if firmly attached to the reef) and plants or algae. Do not touch or disturb mobile, unattached, or lightly attached marine life such as fish, eels, crabs, nudibranchs, hermit crabs, snails or octopus. This includes never feeding reef animals.

2. **Leave everything in its place.** Never pick up or move any rocks, animals and algae, including shells. Many creatures are specifically adapted to the conditions in the tidepool where they are found (including presence or absence of other species, temperature, degree of exposure to wave force, extent of exposure to light, size of space beneath larger rocks, etc.).

3. **Take care where walking. Walk gently on exposed rock and avoid stepping in pools of water, on plants, algae, or animals**. Creatures and algae on the reef can be crushed by footsteps. Try to step on the bare rock, try not to scuff feet. Do not walk through the tide pools, even small shallow pools, as small invertebrates are sheltering, may only be feeding when the tide is out, and egg masses are present in shallow pools or on

exposed rock but are easily destroyed. Remember there are many invertebrates (including juveniles) sheltering in the fields of exposed algae, hidden beneath the algae, and they are crushed as visitors walk through the algae.

4. Stay away from the bottom of cliffs. No climbing on or digging at fragile cliffs. The cliffs are unstable and can crumble or collapse suddenly and unexpectedly and can result in severe injury or death. Also, increasing the natural rate of bluff erosion increases the sediment load in the tide pools and can be harmful.

5. Run and play on the sandy beach only, not on the reef. Visitors may slip and harm themselves and wildlife if these activities take place on the reef.

6. Take your time. The longer you look, the more life you will notice that you did not initially see.

7. Dogs must be leashed and should not be taken into the intertidal zone.

8. Maintain 100-foot distance (6 car lengths) from any marine mammal. Seals and sea lions are sometimes observed along the Reef. Avoid making the animals aware of your presence. Remember that pups may be left alone on the beach while the mother feeds. Do not touch or take photographs with the animals.

9. Always watch the ocean and stay aware of the rising tide.

Part 3. Marine Protected Areas (MPAs)

Duxbury Reef is a State Marine Conservation Area, a California Marine Protected Area (MPA). MPAs are named, discrete geographic marine or estuarine areas designed to protect or conserve marine life and habitat.

MPAs are among the most useful tools for helping protect and restore habitats and marine life in the ocean, complementing other conservation efforts by providing a place for marine life to recover and thrive. MPA's are expanding worldwide; since 2014 protected areas have increased from 3.4 to over 7 percent of the world's oceans.

MPAs are similar to national and state parks and forests on land in that they were created to protect and restore ocean habitats and increase the health, productivity, and resilience of ocean ecosystems.

In addition, many coastal areas have been and are important to native peoples, who rely upon marine resources and the environment for their livelihoods and cultural values. Some California MPAs protect cultural heritage sites as well as sites of historical significance. Overall, MPAs provide natural classrooms, cherished recreational spots, and opportunities for exploration.

National Marine Sanctuaries are also marine protected areas though managed on the federal level. They are part of an ecologically and oceanographically interconnected system. California has four national marine sanctuaries: Channel Island NMS, Cordell Bank NMS, Greater Farallones NMS, and Monterey Bay NMS. Duxbury Reef is within the Greater Farallones National Marine Sanctuary. The Chumash Sanctuary is currently being considered as an additional sanctuary in Southern California.

The waters off the coast of California are some of the most biologically rich in the world, but the ocean is showing significant signs of overuse and declining health due to habitat destruction, climate change and associated impacts, and depleted fisheries. California's state MPAs were created in 1999 through California legislation the Marine Life Protection Act or MLPA.

The MLPA required the Department of Fish and Wildlife (CDFW) to design and manage a system of MPAs throughout the state and required CDFW to bring together stakeholders (commercial and recreational fishermen, commercial industry, recreation, scientists, conservation groups, and more) to create the network. Meetings were held throughout the state that eventually defined where locations would be ideal for protection, function as a network, and include local and tribal input.

Through this public process, 124 MPAs were created, covering approximately 16 percent of all coastal state waters. California's network of MPAs are being viewed as a global model for community engagement, management, and monitoring.

California's network of 124 MPAs that span from the California / Oregon border all the way to the California / Mexico border.

California MPA Regions

The network of California MPAs is divided into five regions and managed by the California Department of Fish and Wildlife.

1. North Coast (Del Norte, Humboldt and Mendocino Counties)
2. North Central Coast (Mendocino, Sonoma, Marin, San Francisco and San Mateo)
3. San Francisco Bay
4. Central Coast (San Mateo, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara)
5. South Coast (Santa Barbara (mainland), Los Angeles, Orange, San Diego, Island MPAs)

California MPAs in Marin County

Marin County is home to 9 MPAs in the North Central Coast Region (listed from north to south):

1. Estero de San Antonio (State Marine Recreational Management Area)
2. Drakes Estero (State Marine Conservation Area)
3. Estero de Limantour (State Marine Reserve)
4. Double Point /Stormy Stack (special closure)
5. Point Reyes Headlands (Special Closure)
6. Point Reyes State Marine Conservation Area (waters off Chimney Rock)
7. Point Reyes State Marine Reserve (includes Drakes Beach)
8. Point Resistance Rock (Special Closure)
9. Agate Beach/Duxbury Reef (State Marine Conservation Area)

California's Marine Parks and Ecological Reserves in Marin County

Additionally, Marine Parks and Ecological Reserves are located in Marin County within the San Francisco Bay Region:

1. Corte Madera Marine Park (Ecological Reserve; pending MPA designation; SF Bay)
2. Marin Islands (State Marine Park; pending MPA designation; SF Bay)

Types of MPAs

There are different designations for each type of MPA. Some allow fishing (or take or consumptive), some allow specific types of fishing, some do not allow any fishing.

All MPAs allow recreational access both onshore and offshore, except for Special Closures. Special Closures, which are remote, and not anywhere people would generally be recreating, are designated to protect highly sensitive seabird nesting or marine mammal haul-out sites.

MPA Designations in Marin County

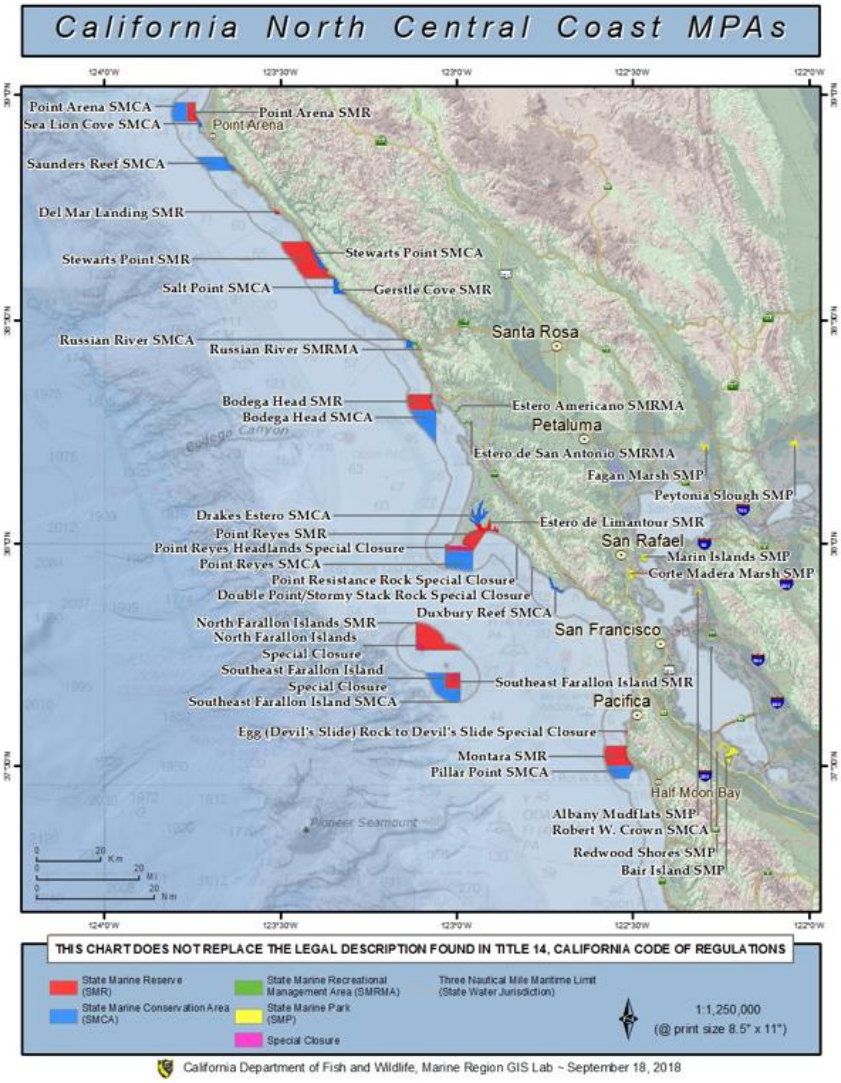
- State Marine Reserve (red)
  All fishing and take prohibited.

- State Marine Conservation Area (blue)
  Some recreational and commercial fishing activities permitted; specifics based on local fisheries, different in each region (e.g. Duxbury Reef).

- State Marine Recreational Management Area (green)
  Designation that limits recreational take of marine resources while allowing for legal waterfowl hunting to occur; provides subtidal protection equivalent to an MPA (restrictions vary).

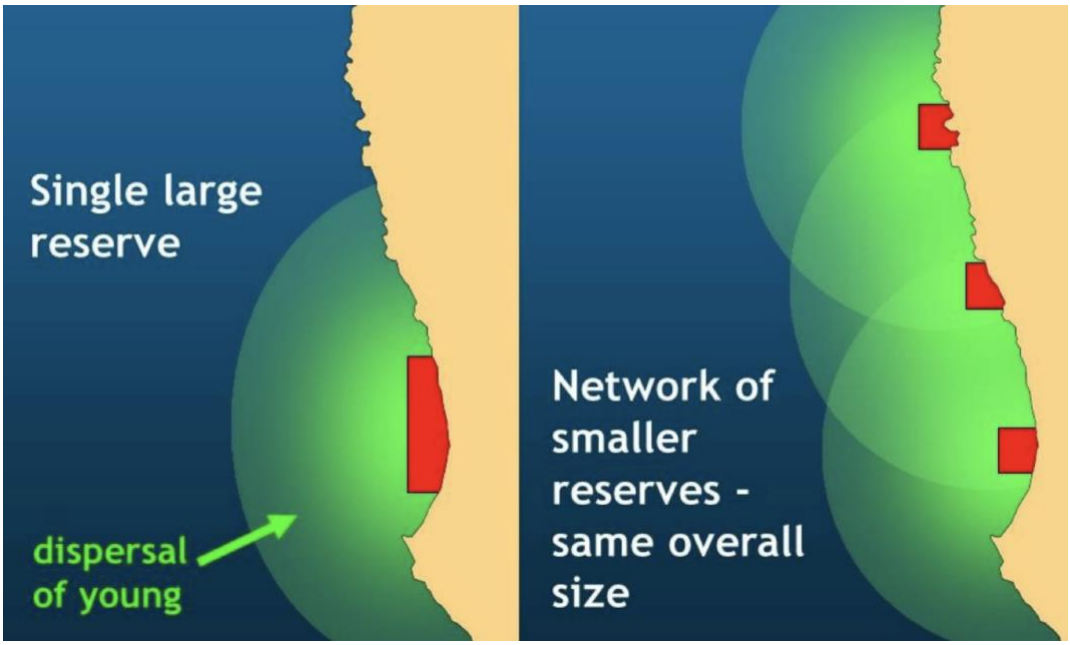
- Special Closure (pink)
  Access Limited (always or seasonally).

There are many activities that the public can enjoy in MPAs, including tidepooling, swimming, diving, boating, fishing, wildlife viewing, surfing, and more.

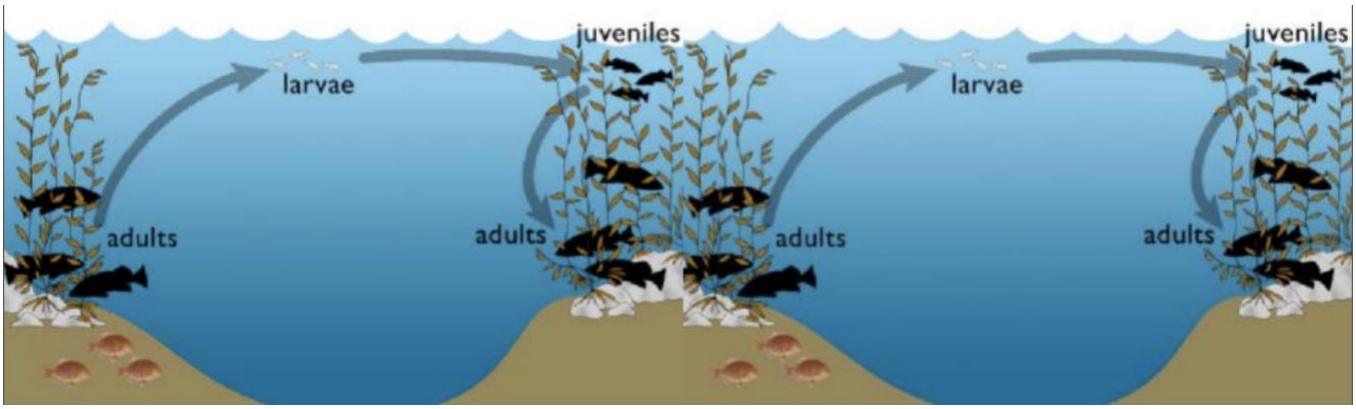


MPAs: Interconnected Network

When thinking about MPAs, it's important to first consider how an MPA is designed to protect habitat and species. For example, a single large MPA protects fish populations from fishing in one local area and their young disperse to areas around the large reserve.



A connected network of smaller MPAs will protect fish populations from multiple locations along the shore, allowing dispersal of their young to adjacent and overlapping zones, replenishing a larger portion of the California coastline than a single MPA. An interconnected MPA network protects the entire ecosystem, complex marine communities, and the species interactions within them.



MPAs: Management

The MPA Management Program is a collaboration between the California Department of Fish and Wildlife, the California Fish and Game Commission, the California Ocean Protection Council, the MPA Statewide Leadership Team, California Native American Tribes, and non-governmental partners to ensure adaptive management and engagement across the ocean community.

Four Management Focal Areas:

Four focal areas were established to ensure appropriate management of the MPA network. These include:

Education and Outreach

The California Department of Fish and Wildlife and local organizations collaborate and create educational materials and programming with coordinated messaging to reach the public in consistent and cohesive manner. Vital to managing MPAs is that people understand what MPAs are, the public benefit of MPAs and the special local features that the MPA protects.

Research and Monitoring

Scientific monitoring is conducted by broad set of partners including agency and university research, community science, tribal governments, and fishermen. Research and monitoring evaluate progress toward meeting MPA Network goals and the information collected helps to inform adaptive management decisions. Research and monitoring are essential to track changes in marine life populations and habitats that are protected by MPAs. The MPA Monitoring Program combines rigorous science, communication, and evaluation and is carried out by multiple state partners.

MPA Watch is one active community science program that has documented increased visitation and compliance issues at Duxbury Reef. From EAC's Community Docent Program Proposal:

> Marin MPA Watch volunteers have observed large numbers of students visiting the reef on field trips in addition to other beachgoers. Visitors have been observed participating in activities that disturb habitats including, walking in pools of water, playing "fetch" in the intertidal with off-leash dogs, collecting of biotic and abiotic resources (including poaching), fishing from watercraft within the MPA, and handling invertebrates. The rate of on-shore consumptive activity (taking or collecting) from January 1 – July 29, 2020 compared to 2014-2019 has increased by 100% from a rate of 3.2 activities per survey mile to a rate of 6.4 activities per survey mile.

Enforcement and Compliance

The California Department of Fish and Wildlife is the primary responsible agency, but partner agencies also provide an additional enforcement or compliance presence. In 2016, California Department of Fish and Wildlife established a Marine Enforcement District, which includes 40 wildlife officers focused solely on enforcing marine regulations including MPAs.

CDFW wardens infrequently visit Duxbury Reef, but potential violations observed should be called into CalTIP (888- 334-2258).

Policy and Permitting

Coordination between the primary managing agencies and partners is essential to maintain a consistent vision for the California MPA Network. For instance, the Department of Fish and Wildlife uses scientific data and staff expertise to provide management recommendations to the Fish and Game Commission to aid in their rule-making decisions. Furthermore, the Department of Fish and Wildlife reviews and issues Scientific Collecting Permits, required when take or possession of fish and wildlife occurs for research, educational, or propagation purposes.

MPA Management Strategies:

The California Department of Fish and Wildlife applies different strategies to monitor the health and ecological benefits of MPAs, these include:

Adaptive Management

The California Department of Fish and Wildlife defines adaptive management as "a management policy that seeks to improve management of biological resources, particularly in areas of scientific uncertainty, by viewing program actions as tools for learning." Successful adaptive management detects and responds to changing environmental or socioeconomic conditions.

This means that future management is informed by the results of scientific monitoring. The Duxbury Docent program is a good example of this, as MPA Watch documented increased human activity and potential poaching since 2015 that highlighted the need for a docent program.

Long-Term Monitoring

Long-term monitoring seeks to understand the conditions and trends of marine populations, habitats, and ecosystems across regions. Multi-partner programs have established extended time series or novel monitoring of under-sampled metrics (e.g., human use metrics) that can contribute to long-term MPA monitoring.

Community Science

Community science is when members of the public contribute to scientific research in some way. Community science can generate large amounts of reliable, cost-effective data and provide important education and outreach. The role of community science in MPA monitoring is increasing, as multiple programs improve and standardize their sampling methods to meet traditional scientific standards.

Traditional Ecological Knowledge (TEK)

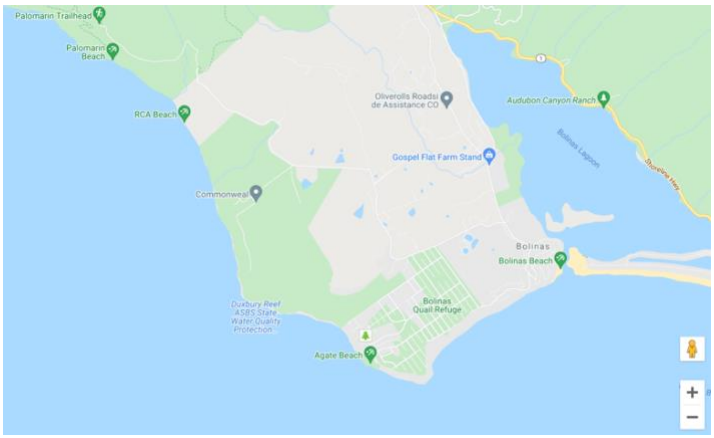
Traditional Ecological Knowledge (TEK) is the product of keen observation, patience, experimentation, and long-term relationships with the resources. Many California Native American Tribes continue to regularly harvest marine resources within their ancestral territories and maintain relationships with the coast for ongoing customary uses.

DOCENT TIP: MPA KEY TAKE-AWAYS:

- MPAs are marine waters set aside primarily to protect or conserve marine life, and its associated habitat. Think of MPAs like underwater parks.
- MPA planning was adopted through public-private partnership and organized into five MPA regions that were designed to function as an ecological network.
- Within MPAs, fishing and collecting is regulated, but most public uses of MPAs are NOT regulated.
- MPAs have varying levels of protections and allowed uses: "no-take" zones and "some-take" fishing.
- All MPAs (except for special closures) allow for onshore and offshore no-take recreational activities.

Part 4. Duxbury Reef and Geologic History

Agate Beach and Duxbury Reef lie at the southernmost end on the Point Reyes peninsula. Agate Beach Marin County Park provides parking behind the bluff, with a trail that leads down to the beach and reef. The combination of sandy beach to the north of the trail end, and shale reef to the north and south provides a diverse habitat that supports a rich assemblage of marine species. It is part of the Greater Farallones National Marine Sanctuary, and it is designated as a California State Marine Conservation Area, one of 124 Marine Protected Areas (MPAs) in California's MPA network.



Duxbury Reef is the largest soft shale reef in California and one of the largest in North America. It lies along the San Andreas Fault, which ruptured 30 million years ago as the movement of the Pacific Plate in this region started moving north, relative to the North American Plate adjacent to it. This touches on the fascinating geologic history of this area.

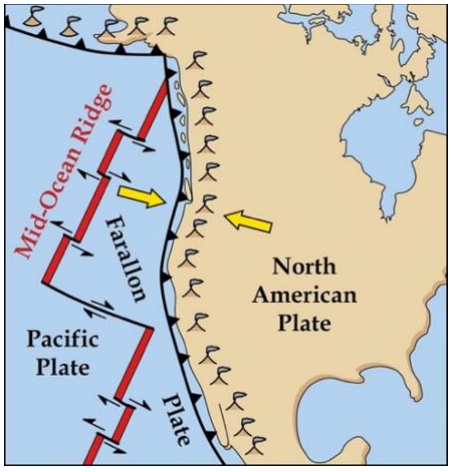
The granitic rocks of the Point Reyes peninsula originated in southern California. The granite basement rocks were first created in southern California from the subduction of the Farallon Plate under the North American Plate about 80 million years ago. The Farallon plate subduction melted the crustal material as it was thrust deep into the Earth. In time, the molten rock cooled as it rose closer to the surface, and subsequently uplifted to form what is now the Sierra Nevada mountains. Some of these rocks in the south were pushed west and seaward by tectonic action along a fault toward the ocean.

As the Farallon Plate subduction ended along the much of the California Coast about 30 million years ago, the resulting northward movement of the Pacific Plate created the San Andreas Fault. This slowly pushed these rocks more than 300 miles north, though they were mostly undersea at that time. Sediment layers accumulated on top of the granite during the following millions of years and lithified (hardened) through burial. The fine-grained, silica rich Monterey shale that makes up Duxbury Reef is composed of hardened sediment (volcanic ash and diatoms) that accumulated

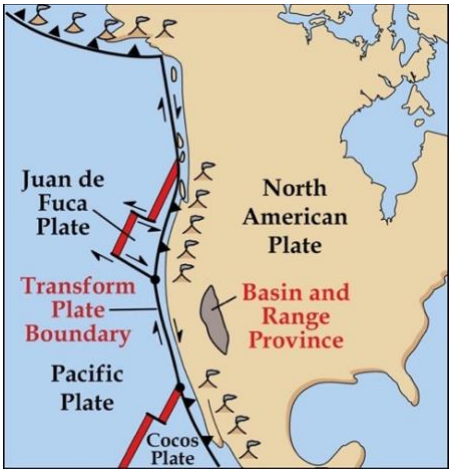
between 23 to 5 million years ago as this chunk of granite moved north. Uplift by compression of the crust margins as it pushed north exposed the shale rock to the atmosphere. Erosion over time by wind, runoff and waves sculpted the rock to form the reef we see it today in Marin County.

Maps below and learn more at:
www.nps.gov/subjects/geology/plate-tectonics-transform-plate-boundaries.htm)

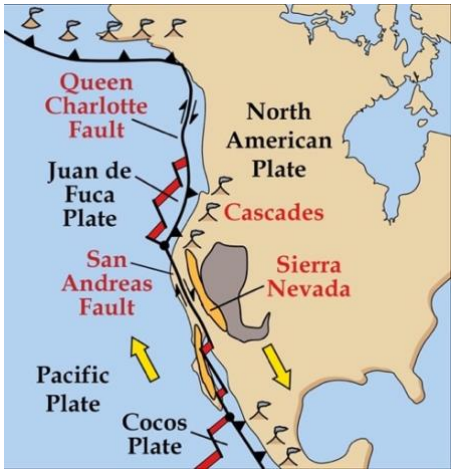
40 million years ago



20 million years ago



Present



Part 5. Oceanography

Oceanography is the branch of Earth science concerned with the ocean. Although oceanography includes the study of biology (marine organisms and ecosystem dynamics), much of oceanography is devoted to the geological, physical, and chemical characteristics of the oceans.

This section will focus on the chemical and physical factors that have the greatest impact on the intertidal ecosystem at Duxbury Reef: the chemistry of seawater, tides, currents, and coastal upwelling.

Seawater: Physical and Chemical Characteristics

- Water transports energy around the globe through ocean currents (from tropics to the poles).

- The temperature of the water does not change as rapidly as air temperature, so species that live below the intertidal are not faced with large, daily temperature changes. In the intertidal, species must be adapted for frequent and extreme temperature changes that result from exposure at low tide.

- Salinity is the measure of total ions dissolved in water. The primary ones are sodium and chloride. Others include sulfate, magnesium, calcium, and potassium.
    - Salinity increases due to evaporation and freezing.
    - Salinity decreases due to precipitation and runoff (rivers, creeks).
    - Most organisms are adapted to a very narrow salinity range. In the intertidal, organisms face large salinity changes at low tide because of evaporation of water from tide pools or input of freshwater as rain or runoff.

- Dissolved gases are important for marine organisms. Phytoplankton need carbon dioxide for photosynthesis and animals need oxygen to breathe for cellular respiration.
    - Hypoxia (too little oxygen) or anoxia (no oxygen) in sediments, tide pools, or whole ocean regions can result in the death marine organisms.

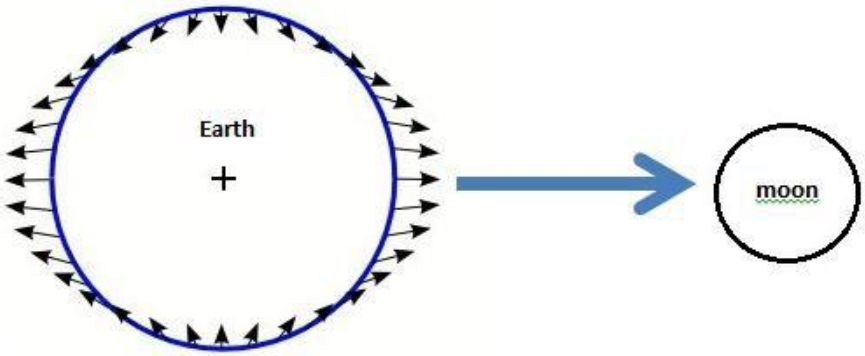
- pH is the measure of the number of hydrogen ions in water. When pH is low you have an acid, when it is high you have a base. A pH of 7 is neutral. Seawater currently has a pH of 8.1 (slight base).
    - Organisms are adapted to a narrow pH and temperature range, outside of which their enzymes fail to function properly. The ocean is rapidly becoming acidic due to human actions. As more CO2 is released into the air, more dissolves into the ocean. When CO2 dissolves in seawater, it forms carbonic acid. Since the industrial revolution, the pH of seawater has decreased from 8.2 to 8.1. Because the pH scale is logarithmic, this is a 30% increase in the acidity of the ocean. Ocean acidification makes it

increasingly harder for organisms to build calcium carbonate shells and skeletons.[4]

Tides

What causes tides?

- Tides are caused by the gravitational pull of the moon and sun upon the earth.
- Because the moon is closer, its gravitational effect is greater on the earth.
- All surfaces are pulled toward the moon and the sun. Water, being more flexible than land, bulges up in the direction toward the moon and the sun.
- The sun and the moon each create separate tidal 'bulges' on the surface of the earth that can add to or subtract from one another. This is the reason some tides are more extreme than others.



Ebb, Slack, and Flood

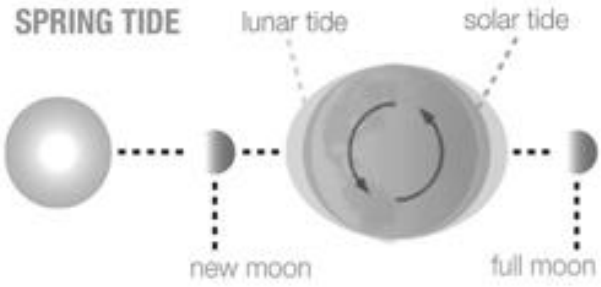
Ebb and flood 'tides' can appear like a tidal current, causing the movement of water into and out of a bay. At ebb tide, the water recedes, or moves out of the bay between the high and low tide. A flood tide in the bay pushes the incoming flow of water between low and high tide. The point at the crest or trough of a tide wave, when there is no water movement, is referred to as slack. This is the period between ebb and flood.

[4] *Learn more about ocean acidification at: www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification*

Types of Tides

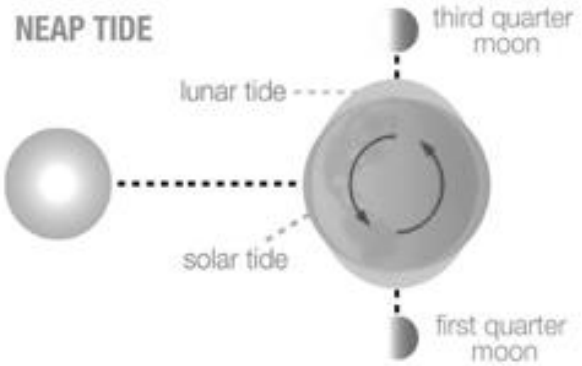
Spring Tides

These tides occur when the sun and moon are in line with the earth. These tides reach the highest highs and lowest lows. Normally this will occur at the full and new moon.



Neap Tides

These tides occur when the sun and the moon are at right angles to the earth. The gravitational pulls of the sun and the moon partially cancel each other out (the gravitational pull of the sun is only 46% that of the moon, so they do not completely subtract from one another). The result is a less extreme difference between high and low tides. Normally this will occur at the times of first quarter and third quarter of moon.



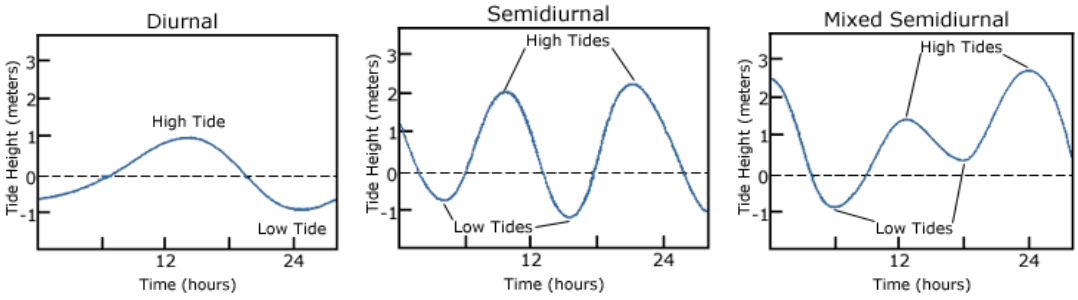
Tide Patterns

There are three patterns of tides that occur on earth. There are multiple patterns because the continents interfere with the movement of the tidal 'bulges' around the planet and because the depth of the ocean floor varies from one location to another. California tides are considered mixed semidiurnal.

- Semidiurnal Tides
  Two high tides (of nearly equal height) and two low tides (of nearly equal height) per day

- Diurnal Tides
  One high tide and one low tide per day

- Mixed Semidiurnal Tides
  Two high tides (of different heights) and two low tides (of different heights per day.



Images from NOAA Ocean Service Education
"http://oceanservice.noaa.gov/education/kits/tides/media/supp_tide07a.html"

How is +0.0 ft. tide calculated?

A tide height of 0' is the mean of the lower low water level (MLLW). An average of low-low tides for a specific area is calculated over an 18.6-year period. An 18.6-year period was picked because this represents a repeating tidal cycle. Extremely low-low tides occur every 18.6 years because of the exact alignment of the sun, moon, earth, the tilts of the moon and earth, along with up to 100 other factors.

The specific area is normally associated with a port, since these calculations were originally created for shipping concerns. Captains of ships knew they were normally okay if the tide was a positive one. A +0.0 tide at San Francisco would not be the same height as a +0.0 at Vancouver. The California coast +0.0 tide is approximately 3.3 feet above sea level.

Tide heights for Duxbury Reef are based on calculations from the San Francisco Golden Gate tide gauge (located just inside the bay at the Presidio of San Francisco). The low tides at Duxbury occur about 31minutes before the low tide predicted at the Golden Gate; so, any tide predictions for Duxbury Reef are adjusted to be 31 minutes before those at the Golden Gate (and subtract about 51 minutes for high tide calculations). The height of the tides at Duxbury are, for practical purposes, predicted to be the same as those in San Francisco, so only the time needs to be converted.

When do low tides occur?

The tides are approximately 50 minutes later each day due to two factors. The first is that the Earth spins on its own axis every 24 hours and the second is that the moon rotates around the Earth once every 28 days. It takes a particular point on earth 24 hours to come back to the same place, respective to a stationary point on space. But by then, the moon will have moved 1/28th of its orbit. So, for a point on earth to return to the same place relative to the moon (the important factor for tides), it requires 24 hours + 1/28 of 24 hours, i.e. 24 hours and 50 minutes. High and low points of the tides occur about 6 hours apart.

The Intertidal Zone

The intertidal zone is the area along the edge of a landmass that is sometimes underwater and sometimes exposed due to tides. The intertidal is divided into zones because the area of the intertidal closer to shore is exposed more frequently or for a longer period of time than the areas farther from shore. The four zones are low tide (usually wet), mid-tide (wet and dry), high tide (wet during high tide) and plash zone (usually dry except during the very highest tides and wave splash).

Currents

Currents are continuous, directed movements of water. They are driven by forces ranging from wind to Earth's rotation (and the Coriolis Effect) to salinity and temperature. Currents transfer thermal energy around the globe. Ocean currents are all connected through a three-dimensional current system sometimes called the "great ocean conveyor belt."

What is the Coriolis Effect?

As a result of the earth's rotation around its axis, anything that moves large distances on the earth's surface tends to bend to the right in the northern hemisphere, and to the left in the southern hemisphere. To understand this, use the following example. You are sitting on a merry-go-round and throw a ball to someone standing on the ground. The ball moves in a straight line, but to you and an observer it looks like the ball was thrown in a curved path.

Surface Currents and Gyres

The Coriolis Effect applies to winds and ocean currents. Surface currents are caused by prevailing winds as well as the Coriolis Effect.

- In the northern hemisphere, surface ocean currents typically move clockwise around the ocean basin north of the equator.
- In the southern hemisphere, they move in a counterclockwise direction.
- The 5 main current systems are called gyres. The gyres push more toward their centers, creating a slight bulge in the middle of each ocean basin.
- In the North Pacific Ocean, a large area ('garbage patch') approximately twice the size of Texas contains tons of pieces of plastic (from large items to microsplastics), which have been forced to the center of the gyre (like a plastic toy caught in the whirlpool of a draining bathtub). This plastic has also been found filling the stomachs of seabirds like the albatross and many marine animals, mistaking the plastic for food, causing injury and death.

What is coastal upwelling?

Coastal upwelling occurs when prevailing seasonal wind blowing parallel to the shore moves surface waters away from the coast, which are then replaced by water that 'wells up' from deep below. These lower ocean layers are rich in nutrients and therefore support a greater abundance of sea life. In California, this upwelling tends to be seasonal.

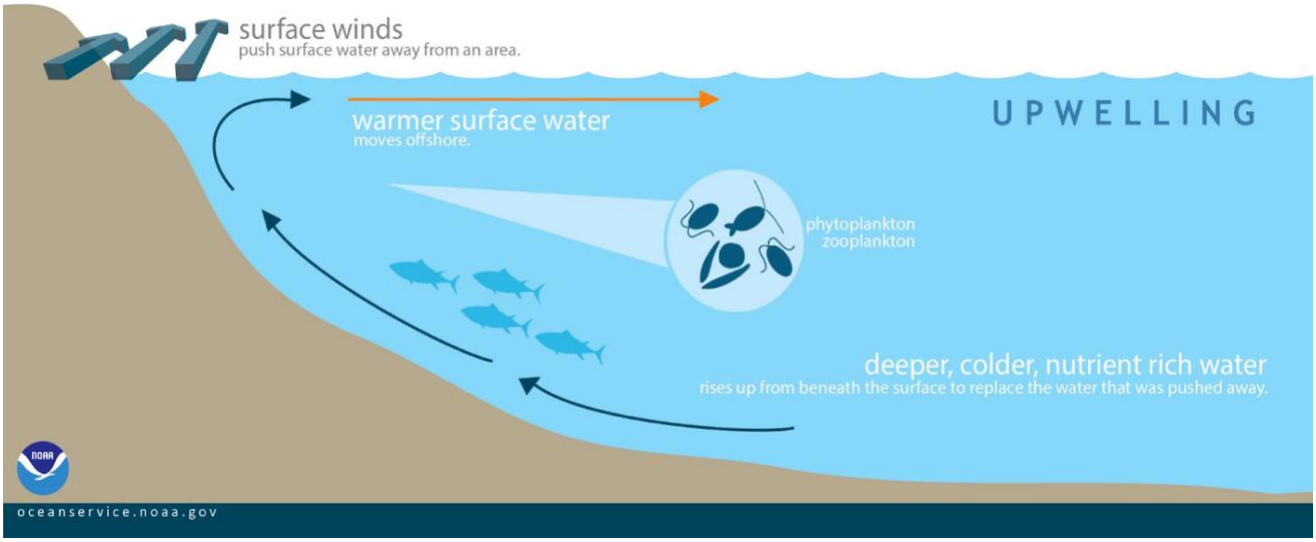
For our area, it normally occurs in the early spring and summer (March through September). This is when our winds come from the northwest. To understand coastal upwelling and its impact on marine life, several concepts need to be understood.

1. As organisms die and decay in the ocean, they sink toward the bottom layers. They normally either fall to the bottom, or are suspended in the lower layers of the ocean. This means the nutrients that algae and animals need are at the deeper depths, and in many

areas, not at the surface where most marine life is living.

2. The effect of the wind on surface waters in the ocean decreases with depth, so the deeper layers are moving at slower and slower speeds. Eventually, the effect of the wind is not felt at all in the deeper layers.

3. On the eastern sides of the ocean basins, prevailing seasonal winds blow from the north parallel to the coast. Because of the Coriolis Effect, the surface water is pushed slightly west, offshore. Cold deep water moves up to replace it, producing coastal upwelling. This cold nutrient-rich deep water delivers those nutrients (released from decay) into the photic (light) zone (upper 200 meters) where most algae and animals are living. This results in very productive waters. Because of the greater amount of nutrients in the water, blooms of phytoplankton occur, similar to how fertilizer or compost boosts growth in gardens or farms. The phytoplankton is what most oceanic life directly or indirectly depends on. It is the base of the ocean food web.



Part 6. Marine Ecology

The term **ecology** comes from the Greek 'oikos' (οἶκος) meaning "house." It is the study of the relationship between organisms and the natural environment (including both non-living features and the other organisms that live there).

Duxbury Reef contains a densely packed community of organisms in relationship with each other and the physical features of the ocean and rocky intertidal shore. This section will focus on how the intertidal habitat, seawater inundation, life histories, and relationships among species determines what organisms live on the reef and where.

Levels of Organization

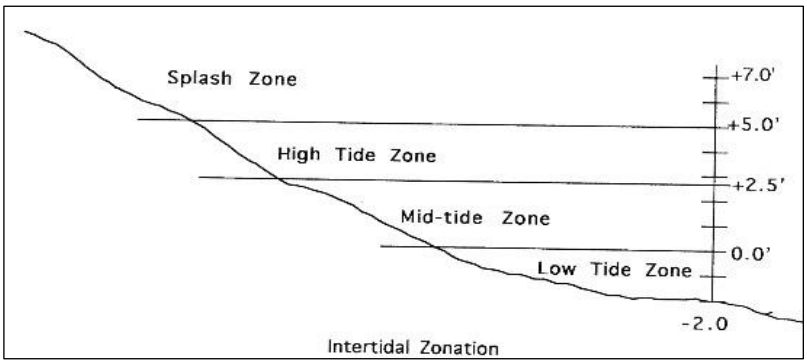
- Organisms: individuals living things
- Populations: a group of individuals from a species living in one place
- Communities: populations of multiple species in one place
- Ecosystems: the biological communities and abiotic conditions of a region
- Biosphere: the whole area around the earth where life exists

Key Ecological Terms:

- Habitat: the type of environment where a species is known to live
- Niche: the role of a species in a community
- Biome: a type of environment (e.g. the rocky intertidal)
- Biodiversity: a measure of the total number of species and relative abundance of each in a location
- Trophic Levels (and food webs): the feeding relationships between species
- Keystone Species: species that exert a disproportional role in their ecosystem/food web

Intertidal Zonation

Key factors of the intertidal



- Four zones are defined in the intertidal.
- Species tend to congregate within a zone most favorable to them.
- The upper limit of species distribution is limited by its ability to deal with the physiological stress.
- The lower vertical range tends to be limited by its ability to compete with other intertidal species.
- Basic needs of tide pool creatures are space, food, oxygen, water, and shelter.
- Wave action or wave stress – wave action generates tremendous force, and intertidal organisms must withstand being crushed or swept away by this action.

- Predation by terrestrial and marine animals – As the water recedes or floods, tide pool animals are exposed to the predation by terrestrial and marine animals.

Organisms subjected to changing conditions

- Lack of water
  Organisms must protect themselves from desiccation (extreme water loss) which can be caused by wind, sun, or long exposure time between the tides.

- Temperature
  Change from hot to freezing – Tide pool animals must tolerate temperature extremes, especially in shallow pools. Most open ocean marine organisms are accustomed to a stable temperature that fluctuates only a few degrees (Fahrenheit) throughout the year. Depending on the time of year, tide pool temperature can fluctuate around 30 degrees Fahrenheit in a 24-hour period. Organisms that do not maintain a constant body temperature, like we do, use outside temperature to influence their metabolic rate. At extreme cold and warm temperatures, they 'shut down' to minimize damage to their tissues.

- Salinity
  Tide pools exposed for long periods of time lose water due to sun and wind (evaporation). As the volume of water decreases, the concentration of salts increases. Most intertidal organisms have fluid in their bodies that has a concentration of solutes similar to seawater. When the tide pool they are in gets too salty, they risk dehydration due to osmotic water loss (water moves from areas of lower solute concentration to higher concentration). Most upper intertidal animals are adapted to cope with somewhat gradual changes in salinity associated with low tide exposure. However, sudden changes in salinity do not give the organism time to adjust, and can be lethal.

- Oxygen levels
  In water – wave action mixes surface water in the open ocean and results in high levels of dissolved oxygen. Isolated bodies of water, like tide pools, may have extreme fluctuations in oxygen levels over the course of a day. Dissolved oxygen may be depleted as the temperature in the tide pools rises (as temperature increases, the dissolved oxygen saturation point of water decreases, meaning that oxygen escapes from the week bonds that hold it in the water as water temperature rises). In addition to temperature, dissolved oxygen levels are affected by photosynthesis (when the sun is out) and by respiration.

Intertidal Zones

1. Splash Zone

- The area above high-water mark; only reached by seawater at extremely high tides or severe storms; normally reached only by splash or spray of waves.
- 75 to 100% exposure time.
- Creatures subject to the extreme temperature changes and to desiccation (life threatening loss of water).

Species adaptations to desiccation:

- green algae – storing water in plant
- rock louse – has exoskeleton
- periwinkle snails – clamps tightly to the rocks, keeping moisture in
- fingered limpets – cuts into the rock and using its strong foot, clamps tightly to the rock keeping moisture in
- acorn barnacles – seal themselves within their shells with a calcareous operculum. Also, they can survive feeding only a few hours a month when the tide is high enough to submerge them
- beach hoppers – do not like to be submerged in water

2. High Tide Zone

- Area covered at most high tides, but uncovered for long periods between tides
- 35 to 75% exposure time.
- Creatures must be adept in surviving on land and sea because they are awash twice a day.

Species adaptations to desiccation:

- lined shore crabs, porcelain crabs – ability to move to more favorable area
- black turban snail – can seal themselves on a rock, or withdraw into their shell closing it off with the operculum to retain moisture
- hermit crabs – can move to more favorable areas. Can also withdraw into its shell, and close it off with its claw to retain moisture
- rockweed, pin cushion algae, sea lettuce, brillo pad algae – retains water
- flatworms – live on underside of rocks where moisture remains

3. Middle Tide Zone

- Covered by all high tides and uncovered most times the tide ebbs.
- 7 to 35% exposure time.
- Dense cover of algae provides protection for a large variety of animals.
- Creatures face threats of high salinity and depleted oxygen at low tides.

Species adaptations to desiccation:

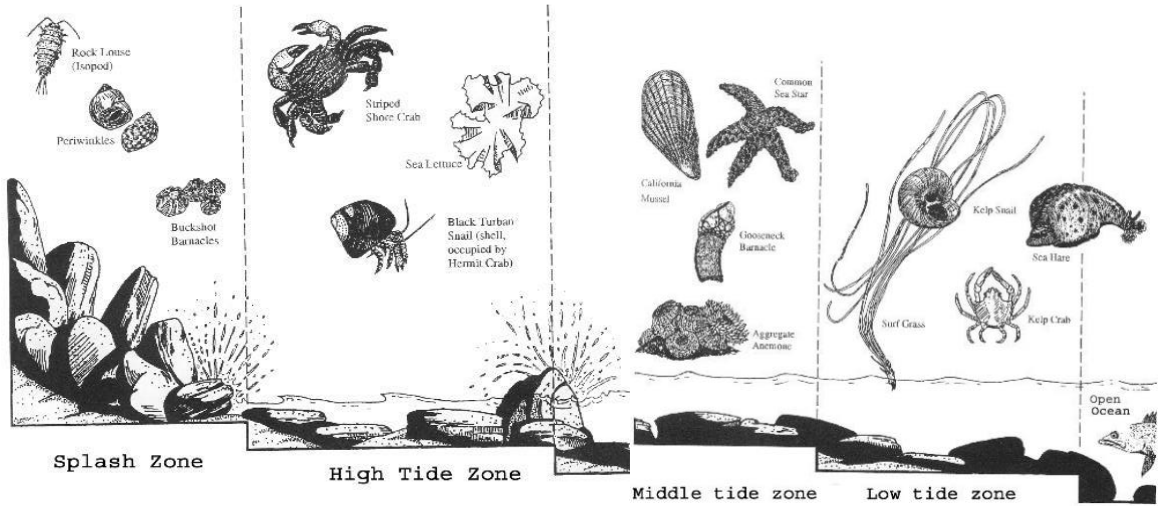
- snails – can seal themselves on rock, or withdraw into their shell closing it off with the operculum to retain moisture.
- anemones – retract tentacles and cover themselves with rocks and shells to reflect the heat. Absorb and retain water.
- small fish – large gills or the ability to gulp oxygen from the air allow the fish to survive in pools where oxygen is low.
- mussels – clamp shell closed to retain moisture.
- barnacles – clamp shell closed to retain moisture.
- sea stars – move to other areas; skin can be out of water for hours without drying.
- chitons – foot grasps the rock tightly to prevent water loss.
- red algae, sea sack algae – retains water.

4. Low Tide Zone

- Exposed only during minus tides.
- Less 7% exposure time.
- Characterized by bright green surf grass and large brown kelps.
- Diversity of species is key to this zone, rather than domination by a few.

Species adaptations to desiccation:

- giant green anemone – closes up and holds water.
- sea urchin – home of rounded hole holds water.
- abalone – seals itself to rock.
- brown kelps – retains water.
- kelp and rock crabs – can move to wetter area.



Life History Strategies

by Sabarijah Hopkins (modified)

Organisms require energy for:

Growth

- Not born sexually mature.
- All juveniles must grow; in some species this happens faster than others.

Maintenance and Repair

- Keeping homeostasis.
- As we reach maturity, energy switches from growing to keeping healthy.

Reproduction

- Passing on genes.
- Once we hit maturity, much energy goes here.
- As we age, more energy is pumped into maintenance so less is available to reproduce.

Reproduction Table 1: Strategy

Reproduction Strategy	PRO	CON
Broadcast Fertilization: Ochre stars, solitary & aggregating anemones	• Reduced time and energy in finding a mate and completing fertilization. • Spawning events usually bring many individuals together. • Spreads population to new sites.	• Individuals need to put out lots of eggs/sperm to increase chance of fertilization.
Copulation: Many crustaceans	• Almost guaranteed that all eggs will be fertilized.	• Must spend energy finding a mate and energy courting / copulating.
Cloning: Aggregating anemone (can also broadcast spawn)	• Individual will be perfectly suited to the environment the adult is in. • No mates needed.	• No genetic variation – in the event of a change in environment (such as illness) if one individual is susceptible, they all are!

Reproduction Table 2: Care of Young

Care of Young	PRO	CON
No Care: Ochre stars, Sunburst Anemone	• Energetically cheap – eggs are made and released.	• Many eggs are needed to beat the odds of survival. Out of 1 Million eggs, 15 might make it.
Egg Cases: Whelks, rays	• Not cheap, but not expensive. Can leave eggs and go.	• Cases are sitting ducks for predators. • Energy & time are required to make case.

Brooding: 6 rayed star, purple urchins, barnacles	• Fertilized eggs are safe from egg predators. • No energy spent in building special cases. • Once eggs hatch, the job is done.	• Slows brooding parent down and makes them susceptible to predation. • Size of parent limits number of offspring 'brooded'. • Offspring susceptible to predation after hatching.
Maternal / Paternal Care: Sea otters, Harbor Seals	• Offspring have better survival odds. • Fewer eggs are needed. • Young get adult protection from predators.	• Lots of energy required to raise. • Only leave few offspring. • Parents more vulnerable to predators.
Direct Development & Sessile or Benthic Various mollusks	• Energy not wasted on transformations. • Born where parents are successful	• Juveniles will compete with adults for resources. • Area may already be at capacity.
Larval Stages & Planktonic early life stage Crustaceans, sea stars	• Juveniles don't compete with adults for same resources • Settle in area with little competition	• Transformation risky and expensive.

Trophic Dynamics: Who Eats What?

Producers – also known as autotrophs

- Make their own food
    - Plants/algae are primary producers: make their own food through photosynthesis
    - Plants/algae manufacture organic materials (food) from inorganic materials (water, carbon dioxide and nutrients) using sunlight as their source of energy
    - *Examples: phytoplankton, kelp, red and green algae, surf grass*

Consumers – also known as heterotrophs

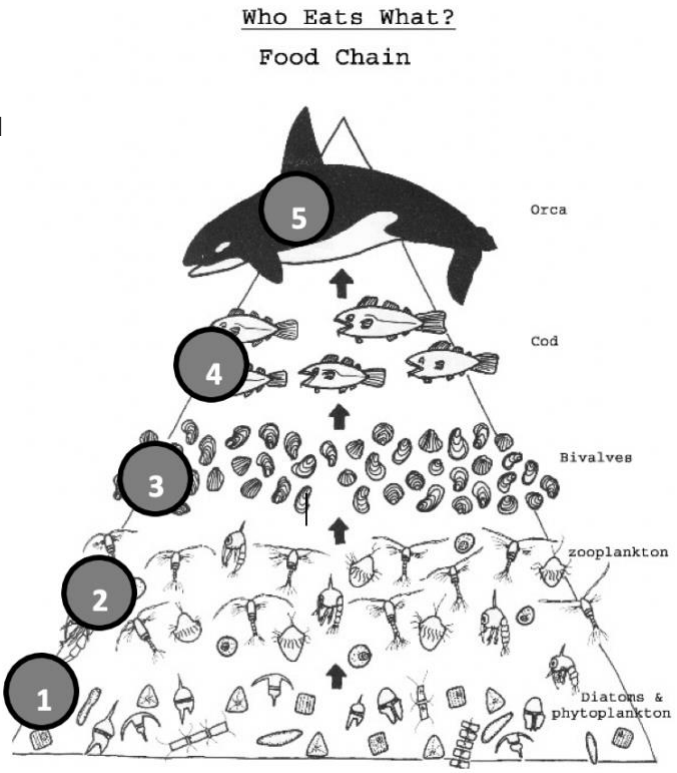
- Gather and consume organic material
    - **herbivores** – eat plants/algae (e.g. limpets)
    - **carnivores** – eat meat (e.g whelk, anemone, perch)
    - **omnivores** – eat both plants/algae and animals (e.g. barnacles)
    - **scavengers** – eat leftovers and dead organism (e.g. hermit crab)

Mixotrophs – both produce and consume

- Example: dinoflagellates (a group of unicellular algae / phytoplankton)

Decomposers – bacteria break down dead organisms into inorganic materials to be reused by producers.

Example of a Simple Food Chain
Image from "Exploring Tidepools"



1. **Diatoms** and other phytoplankton create own food using water, carbon dioxide, and nutrients using sunlight through photosynthesis (producers).
2. **Zooplankton** eat diatoms and other phytoplankton (consumers).
3. **Bivalves** eat zooplankton and phytoplankton (consumers).
4. **Cod** eat bivalves like mussels and cockles (consumers).
5. **Orcas** eat cod (consumer).
6. When the orca dies, **scavengers** will eat as much of the remains as possible. Then bacteria (**decomposers**) will break down what is left into inorganic materials (nutrients – not energy) to be absorbed by phytoplankton, returned to the food chain.

Keystone Species

by Sabarijah Hopkins (modified)

A keystone species increases the local diversity of the area by preventing the prey species from dominating the community. "The keystone species concept was defined as a single *carnivore* that preferentially preyed on and controlled the abundance of prey species that, in turn, could competitively exclude other species and so dominate the community." (Payne, 1969)

Kelp Forest Example:

- Huge stands of brown kelp algae grow hundreds of meters high during peak growing seasons in March through June (up to a meter a day!).
- The stands create a complex habitat by providing food to herbivores hiding places from predators, and a congregation of herbivores for predators to hunt.
- Some sea otters[5] that live in kelp stands eat sea urchins.
- Sea urchins like to eat kelp.

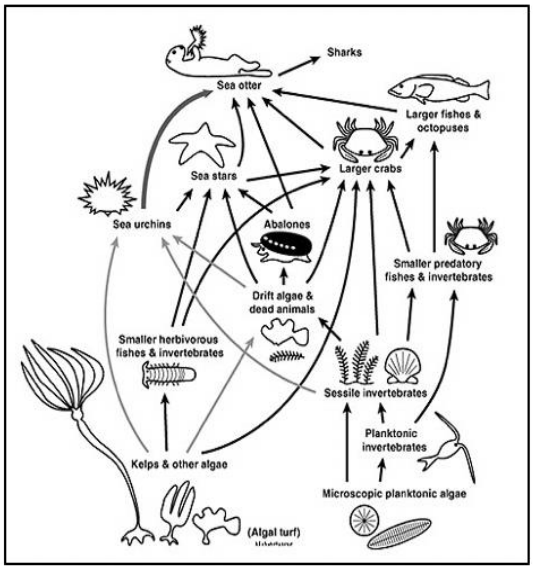
What happens when there are no sea otters?

- Sea urchins begin feeding on brown kelp at the base of the holdfast.
- Once the holdfast is weakened, the huge stand of kelp may be easily dislodged by ocean swells.

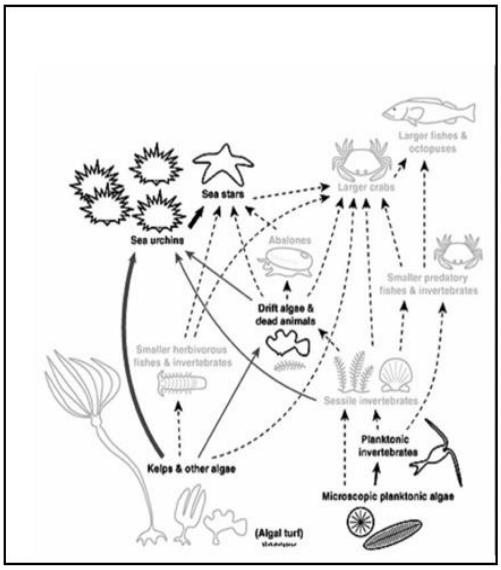
[5] Sea otters were extirpated from Marin County

- When the large kelp stands are removed, the urchins continue to graze the sea floor preventing the kelp from being able to reestablish.
- Urchins can live for years waiting for nutrients to float by them, so the absence of kelp stands does not cause their population to decline.

Kelp forest with sea otters



Kelp forest without sea otters



Ochre Stars as a Keystone Predator

We don't have sea otters at Duxbury Reef, but ochre stars play a similar keystone role. The recent loss of kelp forests in Northern California has occurred because of the reduction in sea stars by wasting disease. Without sea stars (or sea otters) to prey on urchins, the urchin population has grown and decimated the kelp forests.

Additionally, by preying on mussels, sea stars open up areas of the rocky intertidal for algae, barnacles, limpets, and other invertebrates to settle and live. Without them, much of the rocky intertidal would be dominated by mussel beds. The overall impact of the sea star is to increase the number of different species living in the intertidal. However, other ecological studies have shown that this is not the case in all rocky intertidal habitats. Along some coastlines, mussel bed establishment is limited by tide exposure, or recruitment of larval invertebrates. Some long-term studies also indicate that mussel bed monocultures are also subject to wave stress, and over long periods of time waves rip off huge mussel clumps and open the area to new species.

Predation by ochre stars is often the main (but not the only) factor controlling mussels.

DOCENT TIP:
Sea urchins belong in the tidepool environment at Duxbury Reef. Some people try to collect them with the kelp story in mind, not realizing the reef is a different habitat, and that urchin reduction programs are organized activities led by scientists north of Marin County.

Symbiosis (living together)

Over the course of evolution, many marine plants, algae, and animals have improved their chances of survival by developing a close association with some other organism.

3 general types of symbiotic relationships

- mutualism – both organisms benefit from living together
- commensalism – 1 organism benefits, the other is unaffected
- parasitism – 1 organism benefits, the other is harmed

Reasons for symbiosis

- protection
- food
- cleaning
- transportation

Examples:

- Fish and sea anemone – fish entices creatures into the anemone; fish feeds on scraps that the anemone doesn't consume.
- Cleaner fish and shark – cleaner fish obtains food by eating parasites on the shark; shark rids itself of parasites.
- Hermit crab with anemones on shell – anemone feeds on scraps of food that float away as the hermit crab eats; anemone provides protection for hermit crab.

Endosymbiosis

- One organism lives inside the body or cells of another organism.
- Example: zooxanthellae (flagellated, autotrophic protists) that live inside of animals, especially Anthozoans like the giant green anemone and many hard corals. They provide the host animal with energy (organic molecules like glucose) and the host provides protection, shelter, and nutrients (the host's cellular wastes – nitrogen and phosphorous compounds and carbon dioxide).

Part 7. Phylogenetic Classification

The system arranges organisms based on evolutionary, biochemical, anatomical, and physiological relationships. Throughout this manual English and Latin names are provided for each species. There is no universal agreement on English names for species. The same species often has different English names in different geographic locations or in different texts, or multiple English names in the same location, or a single English name may refer to multiple species.

DOCENT TIP:
When talking to visitors default to using a common / English name. Most visitors will not remember or know Latin names.

This manual includes common Common / English along with the Latin names as they are established by scientific convention, and are universally and uniformly applied (and altered/corrected at times on the discovery of new information).

Three Domains of Life

1. **Bacteria** – currently consists of 9 Kingdoms
   - "true bacteria"
   - includes cyanobacteria
2. **Archaea** – currently consists of 2 Kingdoms
3. **Eukaryota** – currently consists of 10 Kingdoms
   - organisms with nucleated cells (and membrane-bound organelles)
   - includes plants, fungi, animals, algae, etc…

Kingdom – at least 21 Kingdoms

Eukaryotic Kingdoms include:

Grouped as "Protista"

a. ***Alveolata*** – includes dinoflagellates
b. ***Stramenophila*** – includes diatoms and brown algae (like kelp)
c. ***Rhodophyta*** – includes red algae
d. ***Chlorophyta*** –green algae
e. ***Plantae*** –Plants
f. ***Fungi*** – non-photosynthetic, such as fungi and molds
g. ***Animalia*** – multicellular non-photosynthetic, such as animals

Phylum (Phyla)
Class (Classes)
Order (Orders)
Family (Families)
Genus (Genera)
species (species)

Scientific Names

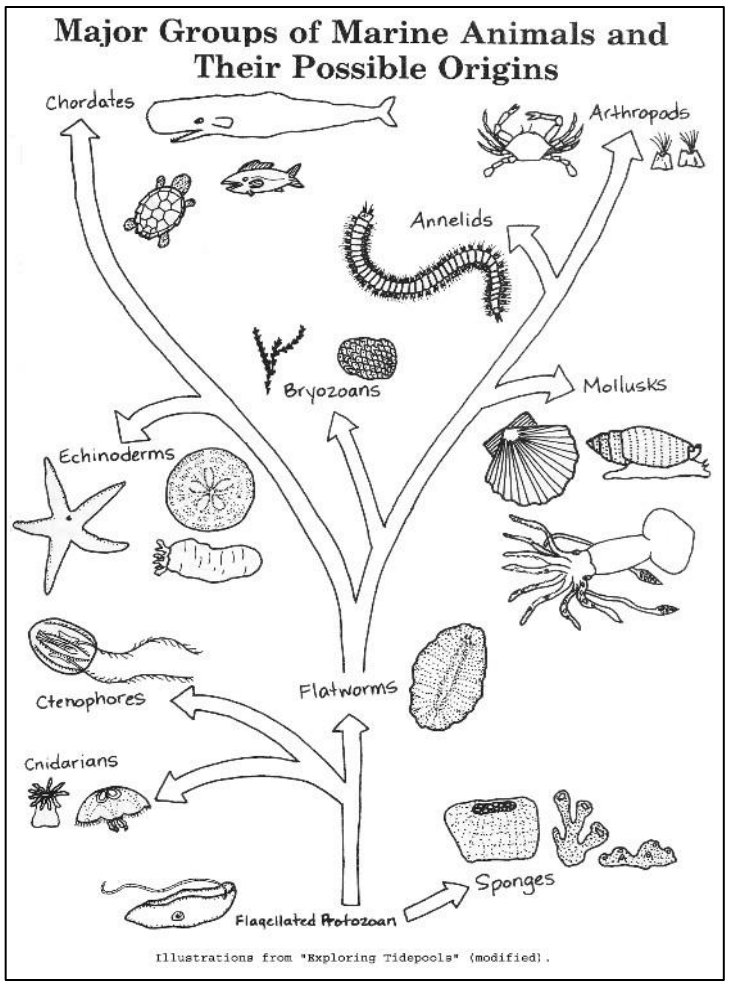
Each organism has a scientific name consisting of 2 parts. The scientific name is either underlined or in italics. Example: Humans are *Homo sapiens*

- Genus name – capitalized
- species name – never capitalized

Major Phyla of Marine Animals

Phylum:

Porifera	sponges
Ectoprocta	bryozoans
Platyhelminthes	flatworms
Nemertea	ribbonworms
Nematoda	roundworms
Sipuncula	peanut worms
Annelida	segmented worms – earthworms, tube worms, other polychaetes
Echinodermata	spiny skinned – sea stars, urchins, brittle stars, sea cucumbers
Cnidaria	stinging cells – sea anemones, corals, jellies, hydrozoans
Ctenophora	sticky cells – comb jellies
Mollusca	soft bodies – snails, nudibranchs, chitons, clams, mussels, octopus, squid
Chordata	stiffening rod or backbone – tunicates, whales, seals, fish birds



Part 8. Plankton

Description

- Small floating or freely swimming plants and animals in the water.
- Unicellular organism or multicellular algae and animals at mercy of waves, tides, and currents for transportation.
- Nearly all other marine creatures, directly or indirectly, depend on plankton as a source of food (organisms that can swim against currents are called nekton).

Note: The gray-white or yellowish suds-like foam we see along the shore is composed of a mucous material that holds together colonies of diatoms in the open ocean as well as other organic compounds from decomposition. It is usually not pollution.

Phytoplankton (unicellular algae)

- Free floating 'plant-like' plankton (algae).
- Creates own food through photosynthesis.
- Needs to be near surface where light is available for photosynthesis.
- Through photosynthesis, phytoplankton changes inorganic nutrients into food and releases oxygen into the water.
- Important producers – constitute the base of the marine food web.
- Minute in size (microscopic), single cells or chains or colonies.
- Diatoms and dinoflagellates are examples.

- Diatoms
  - Unicellular golden colored algae.
  - Cell wall composed of silica (a glass-like structure).
  - The living diatom is enclosed within this shell of silica, with half of the shell fitting over the other (like a lid over a box).
  - Single most important food source in ocean.
  - Mostly reproduce asexually (cell division).
  - Can be responsible for harmful algal blooms – (sometimes causing the domoic acid poisoning of marine mammals and birds).

- Dinoflagellates
  - Propel themselves using 2 flagella in grooves along their body with corkscrew motion.
  - Can photosynthesize.
  - Ranks 2nd to diatoms in importance as food producers.

- Reproduce through simple cell division.
- Some species are responsible for harmful algal blooms (red tides).

Note: Cyanobacteria, also called blue-green algae because they use the same pigments for photosynthesis as red algae, are important intertidal and oceanic unicells. Early in Earth's history, cyanobacteria had an important role in the accumulation of oxygen in our atmosphere. Many cyanobacteria are known to carry out nitrogen fixation (converting gaseous nitrogen into nitrogen compounds that can be used by other primary producers). In the uppermost intertidal zone, cyanobacteria comprise the "black zone" (and are very slippery when wet).

Zooplankton

- Small animal plankton.
- Live near the surface to feed on phytoplankton.
- Holoplankton – spend entire lives in floating state (e.g. krill, copepods).
- Meroplankton – exist as plankton only for a limited part of their development, such as eggs and larvae (e.g. crabs, sea urchin, sea star eggs and larvae).

Plankton Classification by Size

- Femto and pico plankton – viro and bacterioplankton
- Nanoplankton – protozoans (unicellular animal–like protists), and phytoplankton
- Microplankton –primarily eggs and larvae of invertebrates and phytoplankton
- Macroplankton copepods, amphipods
- Megaplankton – large jellyfish and their relatives (Portuguese Man o' War and By– the–Wind Sailors) which move at the mercy of currents

Size distribution:

Prefix	Femto-	Pico-	Nano-	Micro-	Meso-	Macro-	Mega-
Size	0.00002 –0.0002 mm	0.0002– 0.002 mm	0.002– 0.02 mm	0.02–0.2 mm	0.2–20 mm	20–200 mm	>200 mm
Virioplankton							
Bacterioplankton							
Phytoplankton							
Zooplankton							
Nekton							

Part 9. Marine Plants and Algae

Description

- Flowering plants have leaves, stems, roots, and flowers.
- They contain internal vessels (vascular tissues) that conduct fluid up and down the plant.
- Photosynthesis occurs primarily in leaves.
- Less than 100 species in ocean.
- Grow in salt water.
- Strong roots anchor them to rock or into the sediment.
- Flowering and pollination occur underwater.
- Pollen drifts in water currents and attaches to the stigma of the flower with which it collides.
- Vast beds – important nursery grounds for invertebrates and fishes.
- Many populations threatened by coastal development.

Flowering Plants

Local Species

- Surf Grass (*Phyllospadix scouleri*)
    - The only flowering plant found in Duxbury's intertidal. Grows at mid intertidal elevation.
    - *P. scouleri* requires a rocky substrate and its beds are exposed at low tides. Male and female flowers are born on different plants and there are many more female plants than males.
    - The flowers are in spikes at the base of the leaves and do not have petals. Flat leaves are 2–3mm wide and up to 3 feet long. The pollen is spread by water movement which can occur underwater, but most pollination takes place on the surface of the sea at very low tides.
    - Seedlings cannot establish themselves directly on rocks or colonize bare areas. Instead they germinate among algae, such as red coralline algae, attaching themselves by means of small barbs and intertwining their roots among the algae as they grow. They also send out rhizomes which can colonize new areas.
    - When established, the surf grass may dominate the habitat, forming important habitat for a diverse invertebrate community including snails, limpets, crustaceans, and algae.

DOCENT TIP:

Patches of Surf Grass (*P. scouleri)* are found at low tides in relatively shallow pools of water.

- Visitors often step in these pools, unknowingly killing the invertebrates (e.g. the shell-less nudibranch) that take refuge under the surf grass at low tides, and destroying the egg masses of those invertebrates.
- This can be used as an example when reviewing tidepooling rules with visitors. A good reminder of why they should not step in any pools of water.
- Be particularly watchful of visitors with waterproof foot wear.

Surf Grass should not be confused with eel grass (*Zostera marina*).

Z. marina is not found on Duxbury Reef. *Z. marina* grows in sandy/muddy substrates and can be found in Drakes Estuary and the Bolinas estuary. *Z. marina* blades are 6-7 mm wide and up to 3 feet long; they are usually submerged (subtidal). In contrast, *P. scouleri* require a rocky substrate and its beds are exposed at low tides. Like *P. scouleri*, *Z. marina* also forms important habitats for other marine creatures.

Algae

Description

- No vascular tissues.
- Do not have roots, stems leaves or flowers.
- California has over 800 kinds of multicellular marine algae or "seaweeds".
- Important producers of organic matter in the ocean.
- Important sources of oxygen (releases vast quantities into the water during photosynthesis).
- Important absorbers of carbon dioxide.
- Provides habitat, protection, and food, shade and warmth for invertebrates.
- Photosynthesis occurs in all parts (cells, blade, stipe, holdfast).
- Size of algae range from microscopic unicells to giant kelp.

Types of Algae

- Pelagic algae – living in the water column (rare; Sargasso Sea).
- Phytoplankton – free floating, unattached, microscopic.
    - *example: diatoms and dinoflagellates*
- Benthic seaweeds – attached to substrate and multicellular (benthic = bottom or surface dwelling).

Multicellular Algae (Kelp and Seaweed)

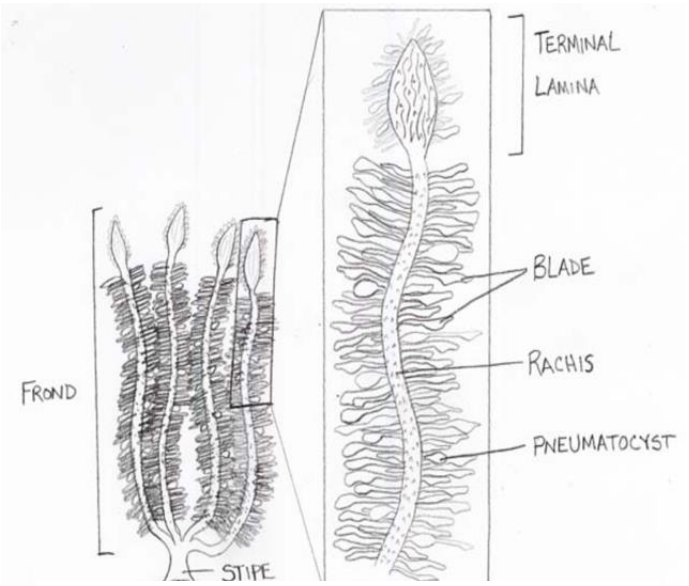
- Green algae
    - Common at higher intertidal zones.
    - Bright green color.

- Red algae
    - Most abundant; 4,000 kinds worldwide.
    - Various shades of red, pink, purple, reddish brown, greenish.
    - Many diverse shapes and textures.
    - Coralline seaweeds are stony, with calcium carbonate walls.
    - Some species contain carrageenan or agar in their cell walls.

- Brown algae
    - Includes rockweeds and kelp.
    - Often olive-brown or golden in color.
    - Kelps (one order of brown algae) are fast-growing in cold, nutrient rich water.
    - 21 species of kelp in California.
    - Kelp forests are important habitats, threatened by warming seas.
    - Giant kelp (*Macrocystis*) can attain up to 100 feet in length.
    - Algin – a gel-like derivative of kelp that is used as a commercial stabilizer in many products.
    - Kelp blades are edible and used for and for vitamins and minerals.

Anatomy of Multicellular Kelp

- *Thallus* – the name for the complete body of the organism; all portions of the thallus are able to photosynthesize.
- *Blade* –flattened portion of algae that increases surface area for photosynthesis and gas/nutrient exchange.
- *stipe* – stem like structure that provides support, and acts as a shock absorber in surf.
- *holdfast* – structure that anchors the body to the substrate. Serves only to anchor, not to absorb water and nutrients as roots do.
- *pneumatocysts* – air bladders. Gas filled bulbs that buoy up the thallus when the tide comes in, ensuring they get enough light for photosynthesis.
- *mucus* – protects the algae from drying out, and keeps larvae from settling on it, enhances flexibility.



Feather boa kelp (Friday Harbor Lab, Marine Botany; www.depts.washington.edu/fhl/mb/Egregia_Meegan/morphology.html

Protection from Herbivory

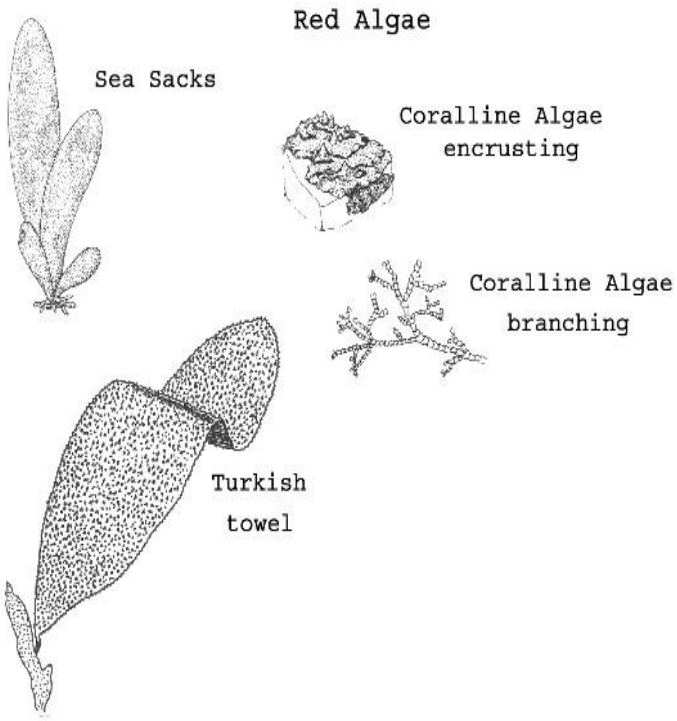
- Some seaweeds avoid being eaten by being tough or having calcium carbonate in their walls, e.g. coralline algae. Over time, lined chitons are found on and have adapted to be able to eat coralline algae, as do urchins, though it is not preferred.
- Some species have noxious compounds (e.g., phenolics).
- Many seaweeds grow quickly to overcome herbivory.
- Hide reproductive output.
- Some perennial and some annual.
- To prevent drying out during low tide, hold water internally, by aggregating in mats that hold water externally, or simply by drying out (holding enough cellular water) and rehydrating when the tide returns.

Local Species

Green algae

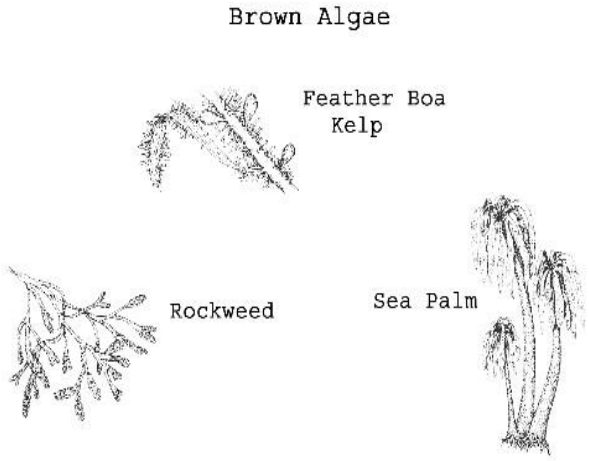
- Sea lettuce (*Ulva spp.*): Bright green; double layer of cells in flat or ruffled sheets or tubes; edible; found in areas disturbed by sand abrasion or wave action
- Pin cushion (*Cladophora columbiana*): Bright green, spongy, clumps of branched filaments forming dense mats. Holds water like a sponge.

Red algae

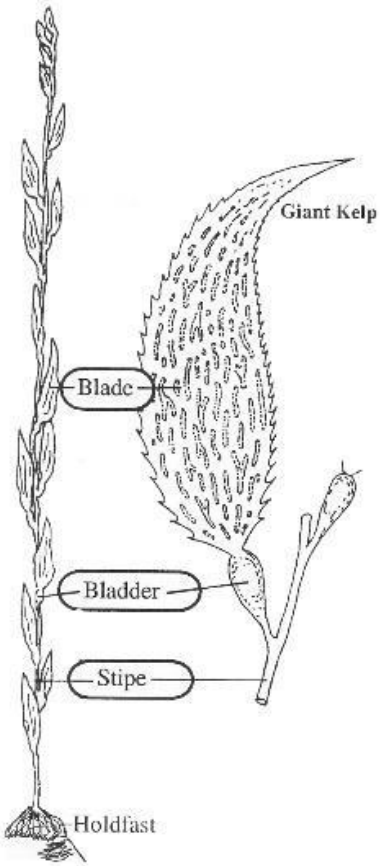


- Sea sac (*Halosaccion glandiforme*): Finger-like sacs containing sea water to prevent drying out at low tide; mid intertidal.
- Purple laver (nori) (*Pyropia* spp.): Brown, reddish, purple membranes, often on upper intertidal rocks. Sushi!
- Coralline algae (*Calliarthron tuberculosum / Bossiella spp. / Corallina* spp): Pink, stiff, jointed or encrusting on rocks; low intertidal.
- Turkish towel (*Mastocarpus spp.*): Brownish red to deep purplish; rough texture; blades have many bumps; upper to mid-intertidal. Has an alternate, crustose phase called tarspot.
- Tar spot (*Mastocarpus spp./Ralfsia spp.*): Dark brown to black crusts that grow on rocks. They are smooth or have prominent radial and concentric ridges. A phase of Turkish towel.
- Iridea (*Mazzaella flaccida/splendens*): Rubbery blades with iridescent, "oil-slick" sheen in mid-low intertidal.
- Wirebrush (also called scouring pad algae) (*Endocladia muricata*): Stiff, dark or reddish-brown clumps with small spines along its axis in the upper intertidal.

Brown algae



- Feather boa (*Egregia menziesii*): Resembles long feather boas with long, flat, strap-like fronds fringed with small blades and pneumatocysts from a heavy, perennial holdfast.
- Rockweeds (*Fucus distichus / Pelvetiopsis californicus / Pelvetiopsis limitata / Silvetia compressa):* Olive green to brownish flattened, or compressed, dichotomously branched blades with or without a midrib in the upper intertidal. Mature branches have swollen, warty stipes.
- Bull kelp (*Nereocystis luetkeana*): Has a very long stipe extending from a subtidal holdfast at the ocean floor. It is an annual, with single pneumatocyst holding up a cluster of blades. Sometimes cast ashore on the beach.
- Giant kelp (*Macrocystis pyrifera*): Also grows tall. Long stipe attached with a holdfast to bottom, with many blades along the length to the top. A fast grower, perennial.



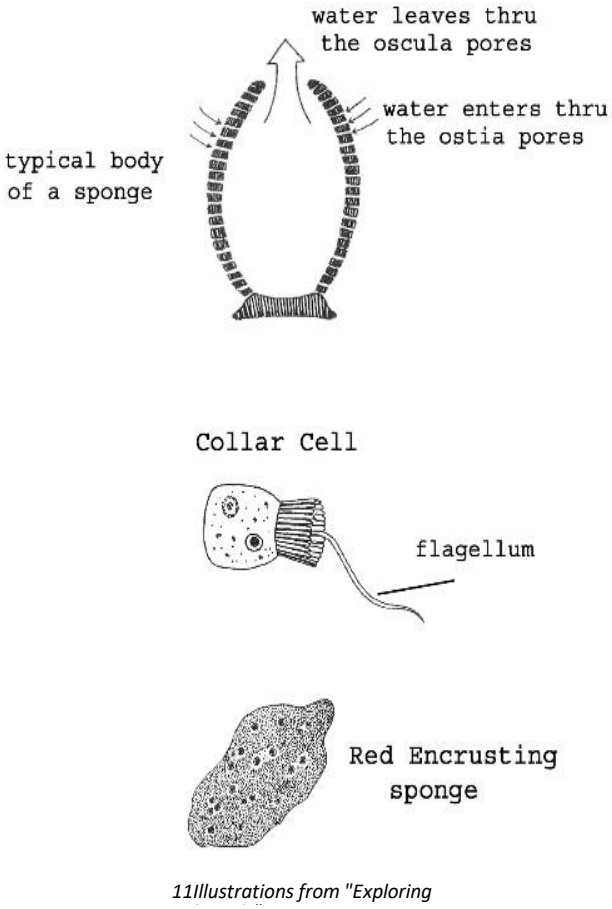
Part 10. Phylum: *Porifera* (Sponges)

Description

- *Porifera* means "pore-bearers".
- About 5,000 species.

General Anatomy

- Asymmetrical
- Able to aggregate and reorganize back into a sponge shape a few hours after being separated by straining through a screen; when cells of different species are mixed, they generally reaggregate into their individual species.
- In California tide pools, most are small and encrusting.
- Primitive, simple animals (simplest of all multi-cellular animals).
- Lack distinct tissues and organs.
- Permanently attached to substrate.
- Benthic (bottom dwellers).
- Basic functions of life are carried out by individual cells acting independently of one another, rather than by tissues or organs.
- Reproduce asexually (by breaking off and growing separate sponge identical to parent) and sexually. Gametes are produced by specialized collar cells that develop into gametes. Most sponges are hermaphrodites (both simultaneous and sequential).



11Illustrations from "Exploring

- No nervous system; no power of locomotion.
- No digestive tract.
- Respiratory exchange thru body surface.
- No circulatory system.
- Body is perforated throughout by a system of water canals that open to the surrounding water. Water enters through minute pores (ostia) in the body surface, passes through chambers (collar cells) lined with flagellum, passes through further canals and emerges through one or more larger openings (oscules/oscula) at the surface. Flow through the body is driven primarily by the flagella, but there is additional "passive flow" due to external water currents.
- Pores all over body. 2 types of pores on the surface:
  (a) ostia – many tiny incurrent pores – water enters through these pores.
  (b) oscula (osculum) – few large excurrent pores – water leaves through these pores.
- Collar cells – have delicate collar around a base of a whip-like flagellum. These cells line the passageways throughout the sponge.

- Flagella (tail of collar cells) beat to create water currents within the sponge, bringing in food and oxygen and removing wastes.
- Spicules – type of supporting structure – interlocking pointed pieces. Can be made from calcium or silica. Taste bad to many potential predators.
- Spongin – protein fibers that some sponges have that give it shape and protect it.
- Some large sponges house mollusks, crustaceans, worms, and fish.
- In some sponges, a symbiotic alga lives in its tissues. Sponges receive oxygen and nutrients from the algae made during the algae's photosynthesis.

Ecology

- Filter feeders – numerous tiny pores on the surface allow water to enter and circulate through a series of canals where plankton and organic particles are filtered out and eaten.
- Food – fine organic particles and small plankton.
- Predators – snails, nudibranchs, sea stars, fishes, chitons.
- May reproduce either sexually (egg and sperm) or asexually (budding/cloning).
- Powers of regeneration.
- Life cycle: egg – larvae (free swimming) – adult (turns inside out when becomes adult – so tail that was on outside is now inside).
- Life span – several months to 50.

Local Species

- **Boring sponge:** Appears as small yellow dots and pores on a shell surface. Usually found living on barnacles and shells. Special cells secrete an acid that eats away at the calcium carbonate (shell). This process creates a honeycomb of channels, and the shell will eventually disintegrate.
- **Red and purple encrusting sponges:** Various species of *Haliclona* (most commonly at Duxbury is *H. permolis*). Encrusting and forming flat sheets of up to 4 cm thick. Oscules usually regularly spaced, shaped like small volcanoes. Colors violet to rose, occasionally pale orange or yellow. Seeks out overhangs and darker crevices in mid and low intertidal.
- **"Crumb of Bread Sponge"** (*Halichondria panicea*): Variable shapes on rocks, kelp stipes, in mussel beds. Sometimes in masses up to 17 cm in diameter. At Duxbury uncommonly seen in intertidal and usually found separated from substrata washed up ashore. Usually a pale yellow or pale orange. Looks like a chunk of bread that a mouse has been nibbling on.
- **Stalked vase sponge** (*Leucilla nuttingi*): Small clusters of white or tan slender vase-shaped tubes, 1–2 cm tall. On sides of deeply shaded rocks, often nestled in algae. Inconspicuous due to small size.

> DOCENT TIP:
> **Do not sweat species identification of sponges.** Just sharing information general ecology information on sponges will teach the public so much!
>
> There are, for example, several possible (less common at Duxbury) species of red encrusting sponges that are distinguishable from *Heliclona* only by close examination of the oscula, e.g. star shaped in *Ophiltaspongia pennata* or irregularly spaced in *Plocamia karykina*.

Part 11. Phylum: *Cnidaria* (Anemones, Corals, Hydroids, and True Jellies)

(pronounced nidaria or nye-daria)

Description

- Name means "stinging animal".
- Hollow-bodied animal that has tentacles with stinging cells used for catching food and for protection.
- Live as individual animals or in colonies of animals living together.
- About 5,500 species.

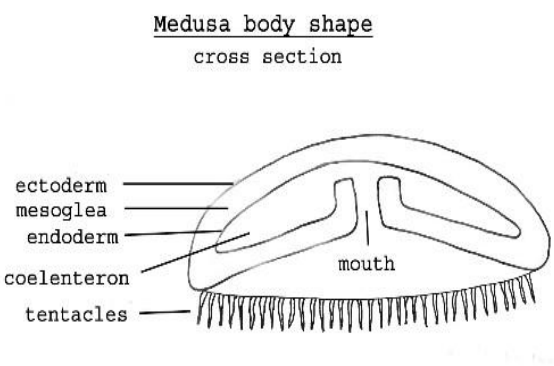
Types

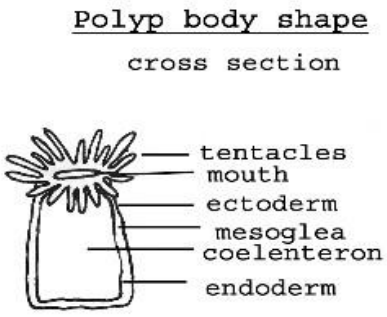
Three major classes of this phylum – all found at Duxbury

- Class *Anthozoa* – sea anemones
- Class *Scyphozoa* – jellyfish
- Class *Hydrozoa* – hydroids, by-the-wind

Two basic body shapes *(some have both body shapes during their lifetime; others spend their entire life as one or the other)*:

- **Medusa** – mouth facing down and tentacles dangling; swimming or floating species. *Example – jellyfish*
- **Polyp** – closed end is attached to a substrate with mouth and tentacles facing up. *Example – sea anemone or coral*





2 Illustration from "The Seaside Naturalist

Ecology

- Mostly carnivores.
- Benthic (bottom dwellers), sessile (attached), and pelagic (live in water column).
- Symbioses with endosymbiotic algae called zooxanthellae. The algal symbionts convert inorganic carbon into carbohydrates for use by each partner and release oxygen to the animal host in the process. To accommodate the algae, the anemone provides concentrated carbon dioxide and access to sunlight.

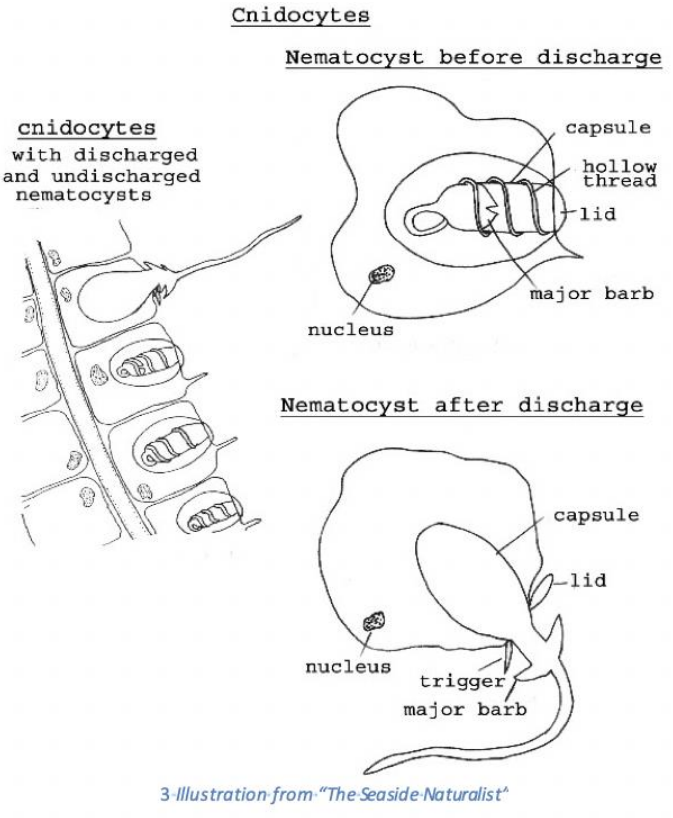
General Anatomy

- Radial symmetry – similar parts of body are arranged and repeated around a central axis (looks the same from all sides, no head, front or back.
- They have an oral (mouth) surface and an aboral surface.
- Relatively simple animal, no internal organs, only have tissues (and only 2 tissue layers).
- Simple gut – gastrovascular cavity (one entrance to body – used as mouth and anus).
- Respiratory exchange through body surface.
- No circulatory system.
- Lacks brain or true nerves – have specialized nerve cells that interconnect to form a decentralized nerve net, transmits impulses in all directions. Can tell if member is of the same species and/or a member of its own group.
- Ring of tentacles surrounding a mouth, which opens into a hollow body that is lined with digestive cells.
- Can regenerate tentacles.
- Have specialized cell type called cnidocytes – used for feeding and defense. The stinging cells contain a tiny fluid-filled capsule (nematocyst) that contain a coiled hollow harpoon-like barb that can be quickly ejected when triggered by tactile or chemical stimuli.

The lid springs open when the trigger is tripped, allowing the nematocyst to be shot forward, releasing venom when it penetrates the prey or enemy. The venom either stuns the animal so it can be captured as prey, or repels it if it is the enemy.

Nematocysts are discharged in large numbers. Once the prey is stunned, it will use its tentacles to move the prey to its mouth, and then into the gut where the food is digested.

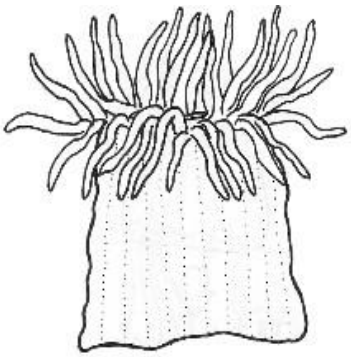
Nematocysts are used only once. New ones are then formed from nearby cells. Toxins in the nematocysts of some species are more toxic than in others.



3 Illustration from "The Seaside Naturalist"

Class *Anthozoa* –Anemones & Corals

Description



Sea Anemone

- Live as solitary polyps.
- Most live attached to rocks, shells, or submerged objects, but few burrow in sand or mud.
- Essentially sessile, but anemones can change locations – can glide along on basal disc, or crawl on their side, or ride on currents.
- Body is hollow tube open at one end (mouth/anus).
- Tentacles, covered with cnidocytes, surround the mouth.
- When disturbed, to avoid desiccation, or when feeding, they force water out of the body column, fold inwardly, pulling in their tentacles and food with them. Unwanted food materials are cast out through a central mouth opening.
- Tubercles/verruca– muscular hollow adhesive structures that look like warts or bumps on the column of the anemone by which the anemone holds bits of shell and other debris to protect it from solar radiation and desiccation when tide goes out. Can be used to aid in the identification of what species the anemone is – either in rows or scattered.
- Acrorhagi – fighting tentacles; special fighting arms to keep other anemones away.
- Tentacles can be regenerated.
- Use tentacles to sting and trap food.
- Food –zooplankton, small fish, various small invertebrates such as shrimp, crabs, and isopods.
- Only digest protein.
- Predators – nudibranchs, snails, fish, sea stars, sea turtles.
- Reproduction – some reproduce sexually, releasing eggs and sperm; some reproduce asexually such as longitudinal fission (divide in ½ to generate genetically identical clone); some reproduce both sexually and asexually.
- Life cycle: egg – larvae – polyp

Local Species

- Aggregating anemone (*Anthopleura elegantisma*): 1 – 2" across. Lives in colonies. Reproduce both sexually and asexually by longitudinal fission (cloning). Verrucae usually in longitudinal rows on bottom 5/6ths of columns. Usually in a line of a crevice in the substrata holding water or moisture. Mid-intertidal Hosts endosymbiotic algae (zooxanthellae).

> DOCENT TIP:
> On Duxbury, most anemones are olive to bright green (depending on the species of algal symbionts present) with tentacles tipped in pink. Individuals on the periphery of a clone-group exhibit aggressive behavior toward individuals from a different clone-group. When contact is made with genetically different clone-group, knob like swellings (acrorhagi) with large nematocysts located just outside the ring of tentacles push out toward and stinging the other anemone – killing the tissue that is so touched. A "no man's land" will then develop between two sets of clones. It covers itself at low tide with small rocks and shells to provide UV protection and conserve moisture. Feeds on isopods, amphipods and other small animals. Predated on by nudibranchs and leather stars (*Dermasterias imbricata*).

- Giant green anemone (*Anthopleura xanthogrammica*): Up to 8 to 10 inches across; solitary. Verruca – random and irregular. Column and base green to dark greenish brown; tentacles greenish, bluish or white, not banded, never pink at tips; the oral disk flat, green or greenish blue. The green pigment is due in part to the anemone's epidermis and in part to symbiotic algae (zooxanthellae) that lives in the gut of anemone. Favors deep pools and channels. Mid and low intertidal. Reproduces sexually by broadcasting gametes; does not reproduce asexually. Does not exhibit the aggressive behavior towards other members of its species that is exhibited by aggregating anemone. Eats detached mussels, crabs, small fish. Predators are nudibranchs which feed on the tentacles and leather stars (*Dermasterias imbricata*).

> DOCENT TIP:
> The hermit crab *Pagurus samuelis* can often be observed walking up and down the column of the anemone and even walking through the tentacles, without being stung. It is thought that the hermit crab becomes so coated with mucus from the anemone that the anemone responds to the crab as though it were its own tissue. Grows approximately 1 inch in 10 years.

- Sunburst anemone (*Anthopleura sola*): Variously colored tentacles with (usually) pink, lavender, or blue tips, in 5 rings around oral disk and are numerous, thick, and pointed. The column is covered with vertical rows of adhesive verrucae. One can distinguish the species from *A. xanthogrammica* by their coloration (especially colored tips of the tentacles and clearly marked radial stripes on the oral disk), and the fact that their adhesive

tubercles are arranged in vertical rows while those of *A. xanthogrammica* are not. Normal geographic range from southern CA to Baja, but are found at Duxbury Reef. Reproduce sexually. Solitary. Mid– intertidal to subtidal. Usually found in crevices.

> DOCENT TIP:
> To identify Sunburst anemone (*A. sola)*, examine the oral disk. The oral disk of *A. sola* has radial stripes, the oral disk of *A. xanthogrammica* usually has no radial stripes or hardly distinguishable green stripes.

- Moonglow Anemone (*Anthopleura artemisia*): Normally only the tentacles and oral disk are exposed, with the rest of the anemone buried in the substrata. At low tide the anemone may withdraw below the surface of the substrata. Individuals are solitary as in *A. xanthogrammica*, but they can divide asexually by longitudinal fission as in *A. elegantissima*. Like *A. elegantissima* they will attack other individuals who are nearby using their special white spherule tentacles (acrorhagia) which are located outside of the outer ring of tentacles. Contain algal symbionts (but some recent information suggests that they do not even though they may sometimes be green in color). Tubercles ("verruca") are restricted to the upper two thirds of the column so lower part of column is smooth and white or pink. Oral disk may be bright pink, orange, or green. Tentacles may be solidly colored or banded, and may be red, white, black, blue, gray, brown, or green.

> DOCENT TIP:
> Moonglow anemone are common in sandy substrata (e.g. Bolinas Lagoon), but on Duxbury they live in holes made by boring clams (piddocks – *Penitella penita*).

- Proliferating (brooding) anemone (*Epiactis prolifera*): Size is ½" across – greenish, red or brown with narrow white lines/stripes radiating on oral disk which do not reach the mouth. Column has no verrucae. All brooding anemones begin life as a female. As they mature, they grow testes and become simultaneous hermaphrodites. Eggs are fertilized inside the cavity. The young move out of the mouth and down the side of the anemone to the base of the column. The young develop around the base of the column and will move away when large enough.

Class *Scyphozoa* – True Jellies

Description

- Each a single organism.
- Consist mostly of mesoglea (gelatinous substance).
- Most bell shaped.
- Tentacles usually hang from the bell margin.
- Mouth underneath bell.
- 4 to 8 oral arms leading to mouth (to capture food and aid in ingestion).
- Both tentacles and oral arms have nematocysts, and sometimes the bell is also covered with the nematocysts.
- Move by pulsations of bell, but not strong swimmers; waves and currents move them horizontally, the jellyfish controls vertical movement.
- Food – small animals, usually fish and crustaceans.
- Predators – sea turtles, sunfish (mola–mola), nudibranchs.
- Reproduction – dioecious (male and female separate).
- Life cycle: egg – larva – polyp stages – young medusa – adult jellyfish
- Alternation of medusa/polyp body forms.

Local Species

- Moon jellies (*Aurelia aurita*): Translucent bell, with 2 horseshoe shaped organs in the middle of the bell, 15 inches across, 250 hair like tentacles hang from the bell margin. The sticky mucus covered tentacles catch small plankton and the oral arms sweep off this food and bring it to the mouth by means of cilia. Individuals tend to migrate toward the surface during the day and downward at night. Tentacles can cause a slight rash in humans Not typically in tidepools, but can be tossed ashore by winds and storms.

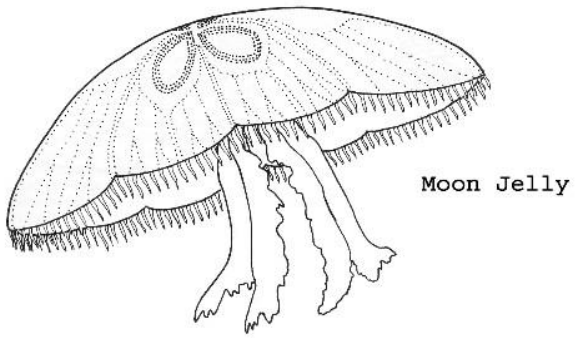


Illustration from "The Seaside Naturalist"

- Pacific Sea Nettle (*Chrysaora* fuscescens): Amber colored bell, darkest at the margins. Long tentacles; up to 1 meter in diameter (though usually smaller), sting is mildly toxic to humans. Also not typically found in tidepools.

Class *Hydrozoa* – Hydroids

Description

- Small and inconspicuous – less than 2" wide.
- Consist of feathery or bushy colonies of tiny polyps.
- Attaches to surfaces.
- Hydroids have different types of polyps – those to gather food, those for defense (sting), those that are reproductive (produce hydromedusae).
- Colony is at least partly surrounded by an envelope of chitin.

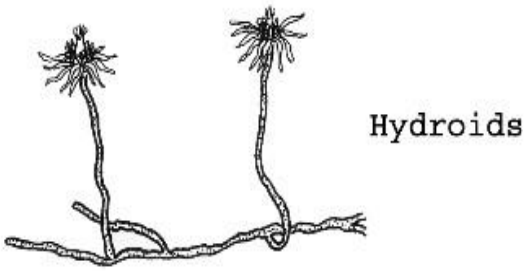


Illustration from "The Seaside Naturalist"

- Food – plankton
- Predators – nudibranchs, shrimp.
- Reproduction life cycle – medusa – egg – larvae – young polyp –adult colony (alternation of medusa/polyp body forms)

> DOCENT TIP:
> Hydroids, even individual colonies no bigger than what can be held in the palm of a hand, provide a protective forest for many other small animals and may be almost a whole universe in itself; many best seen with a hand lens and patience.

Order *Siphonophores* – not one animal, but a colony of animals

- Portuguese man-o'-war – gas filled sac acts as float, brilliant purple blue color, float can reach 1 foot in length, tentacles trail up to 50 ft. Not in this area. Not a true jelly (Scyphzoa). Not found at Duxbury Reef.

Local Species

- Ostrich Plume Hydroid (*Aglaophenia latirostris*): Favorite food of several species of nudibranchs. Low intertidal. Often growing on bushy red algae. Arranged in clusters, each plume consists of a simple stalk (corbulae) with numerous closely set lateral branches (hyrocladia), arising alternately on opposite sides giving the plume a feather-like appearance. The gonophores are within corbulae, which occur in series on some branches of the hydroid and can readily be seen without magnification (they look like small clusters of eggs deposited on the hydroid). All parts of the colony are connected by a continuous tubular gut and all food ingested by one polyp is available to other parts of the colony.

> DOCENT TIP:
> Ostrich Plum Hydroid *(A. latirostris)* is commonly found cast ashore after a storm.

- By-the-wind sailor (*Velella velella*): Order *Anthoathecata.*

Illustration from "The Seaside Naturalist"

A purplish-blue elliptical hydroid. Each "individual" with its sail is really a hydroid colony, comprised of many polyps with specialized functions. There are polyps that are both feeding and reproductive ("gonozoids"), and polyps that defend the colony ("dactylozoids"). Polyps are connected by a canal system that enables the colony to share whatever food is ingested by individual feeding polyps. Any polyps near where the 'raft' and 'sail' should be, also help generate the gas-filled, cellophane-like raft (helps it to float) and sail (catches wind). They drift in large numbers together in the ocean – 10,000 at a time. The celophane-like sail is made up of a chitinous material. The sail is mounted diagonally from the northwest to southeast (right-handed) on the long axis of the elliptical body (in the northeast Pacific). This causes the animal to tack at a 45- degree angle of the true wind direction – away from the beaches on our west coast.
In the northwest side of the Pacific (Japan), the sails are oriented from northeast to southwest (left-handed). In the southern hemisphere, the distribution is reversed. When the right-handed and left-handed *Velella* mix in the ocean, the wind blowing separates them to the correct coast. When northerly winds blow, the *Velella* are blown away from the shore. When winds shift to a southerly or westerly direction in early spring, they are washed up on the shore.

> DOCENT TIP:
> Not an intertidal animal. Masses of By-the-Wind (*V. velella)* may be seen at Duxbury stranded ashore at the high wave mark in the spring.

  - Food – catch their prey, generally zooplankton, by means of tentacles that hang down in the water and bear nematocysts.
  - Predators – violet snail (*Janthina exigua*) – has thin, delicate shell; ½ inch long. They produce a mucus that forms a float which the snail clings to. When the snail comes in contact with a *Velella*, it takes residence on the sailor's raft. It then grazes on the polyps, attaching on the base where the stinging tentacles can't reach.
  - Habitat – warm temperate waters of open ocean (example: as far north as Oregon on the Pacific Coast and to Cape Hatteras on the Atlantic Coast)
  - Reproduction – each by-the-wind sailor is a colony of all male or all female polyps. The reproductive polyps bud off medusae (free-swimming animals) that are all the same sex for that colony. The medusae live on their own, and at the right time, they release their gametes into the sea. Once fertilization takes place, they sink to the bottom of the ocean (up to 4,000 meters), and start to divide. They create a structure called a strobila, which looks like a number of saucers stacked on a stick. Once they are ready, these 'saucers' sluff off (process is called stobilation) and float to the top of the water. At this point they will start to divide into different polyps, and specialization in the polyps takes place. A complete colony is formed.

Part 12. Marine Worm Phyla

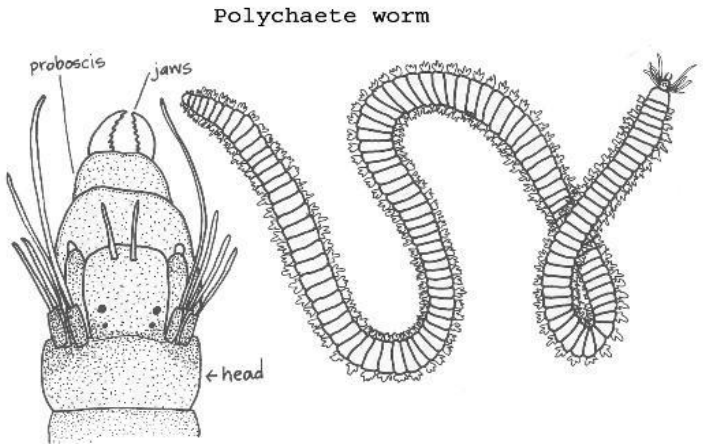
The term "worm" does not designate any single group of organisms. Rather "worms" are an informal, catch-all grouping of any soft-bodied, cylindrical animal. There are 5 phyla of "worms". Only *Annelida* (segmented worms) are covered here.

DOCENT NOTE:
Flat worms were observed on Duxbury but are rare and may have been last seen about 20 years ago.

Phylum: *Annelida* (Segmented Worms)

*Since most marine worms in this Phylum are in Class *Polycheata,* no others are discussed.

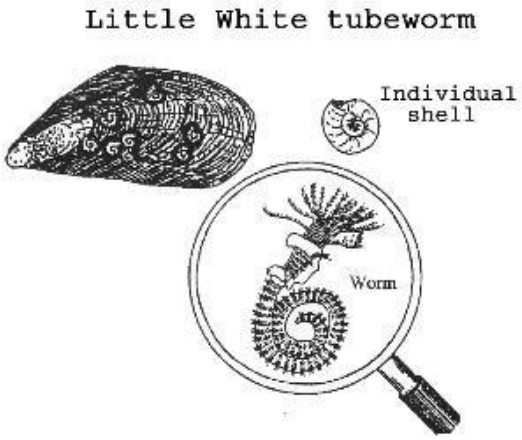
Description



- Bilaterally symmetrical.
- Most are bottom dwellers, and many are permanently attached to a substrate within a tube of their own construction.
- Mostly benthic.
- Complete digestive tract (separate mouth and anus)
- Respiratory exchange thru gills; feather like gill plumes.
- Closed circulatory system (blood remains in vessels).
- Reproductive system.
- Coelom – a fluid filled body cavity that encases internal organs.
- Pair of eyes and other sense organs.
- Rings around its body – which divide its bodies into segments.
- Only trunk is segmented.
- Neither head (contains brain) or terminal end (contains anus) is a true segment.
- Each segment bears identical lateral nerves, blood vessels, and excretory organs.
- Waves of muscular contractions which elongate and contract allow movement.
- Parapodia – a pair of fleshy appendages that each segment of worm has; used in
- respiration, filter feeding, and locomotion.
- Proboscis, often armed with jaws, used to capture prey.
- Food – Can be suspension feeders, detritivores, or carnivores
- Predators – fish, birds, worms, anemones, crustaceans, sea stars.
- Reproduction – Usually dioecious (sexes separate).
- Egg and sperm released into water; spawn in water.
- Can regenerate lost parts.
- Life cycle: egg – larvae – adult.
- Breeding season – spring and summer.
- Age – about one year.

Two Types

- Sedentary – feed on plankton or detrital particles; often live encased in a tube. Many live singly or in groups, in a wide variety of tubes they build, either temporary or permanent. Tubes can be made of mucus, protein, bits of seaweed, cemented mud particles, sand grains or tiny fragments of shells. Tube dwellers have reduced parapodia and are suspension feeders.
- Errant (free swimming) – mostly carnivorous, has specialized structures for prey capture.



Local Species

- Tube cluster worms (*Phragmatopoma californica*): Colonies of worms forming tubes of cemented grains, usually in masses, placed in a honeycomb arrangement, each tube with a flared rim. Anterior end of individual worms have a crown of lavender tentacles. The crown of ciliated tentacles extends when the animal is submerged trapping plankton, organic detritus and sand grains. The sand is transported to an organ which applies a liquid cement and builds selected grains into the wall of the tube. Found in mid and low intertidal.
- Feather–duster (*Eudistylia polymorpha* & *Sabella crassicornis*): Anterior end with a plume of branched feathery gills used for both respiration and filter feeding. Gills may be maroon, orange or brown (frequently with some white banding for *E. polymorpha* or dotted with distinct eyespots for *S. crassicornis*. The eyespots (both species) are light sensitive. When a sudden shadow falls on the plume, the worm instantly retracts into its tube. Found in low intertidal.

> DOCENT TIP:
> Rare to see these beautiful creatures; identifiable only when submerged and gills are exposed.

- Limy tube worm (*Serpula vermicularis*): White calcareous tubes, often coiled, cylindrical, smooth usually found on undersurface of rocks, overhangs, where sheltered from wave force. Crown/gills are vivid red. Like other tube worms, the small hair–like cilia on the gill filaments set up currents which increase the flow of water and minute food particles through the gills. Found in low intertidal.

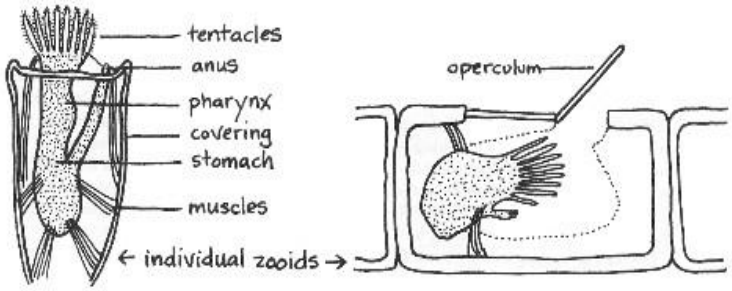
> DOCENT TIP:
> You are more likely to find this species when they have been separated from the substrata and washed ashore after a storm.

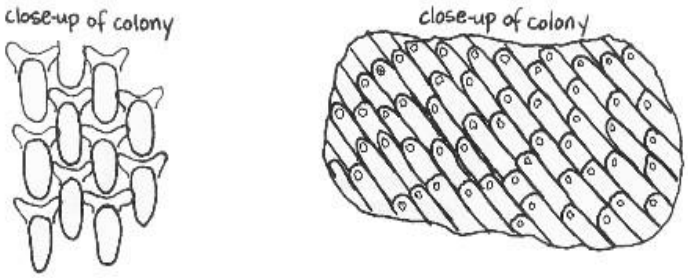
- Bloodworm (*Glycera americana*): Slender, usually iridescent pink worm, found in the sandy patches of the lower intertidal areas. The first body segment is shaped like a cone (as if the face of the animal is covered by a funnel), tapered to a point (often with annulated rings). Total body length up to 350 mm (13.8 inches). Their pharynx, when everted into a proboscis, has 4 hook-like teeth, is very large relative to the size of the animal, and can be up to about 115 mm (about 4.5 inches) or 1/3 its body length when the proboscis is fully extended. The jaws are a powerful instrument used for burrowing, anchoring itself in the sandy substratum, and capturing prey. Like other species of *Glyceridae*, it burrows very quickly with a series of jerky motions. The teeth are equipped with poison glands containing a neurotoxin. The bite is painful and can cause inflammation that may last a considerable time in humans. Called “bloodworms” because if the body is punctured, quantities of bright red fluid, rich with hemoglobin, are released.

Part 13. Phylum: *Ectoprocta* (Bryozoans)

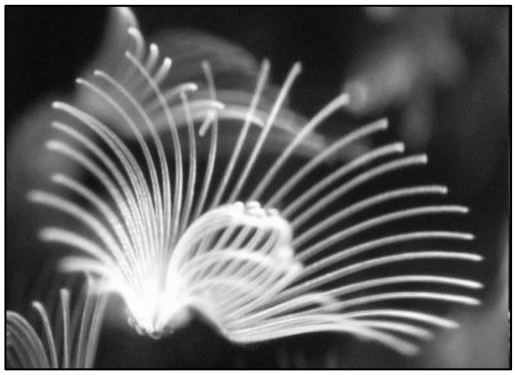
Description

- "Moss animals"
- At least 5,000 species.
- Bilateral symmetry.
- Respiratory exchange through body surface.
- No circulatory system.
- Attached to substrate, benthic.
- Resemble moss, coral, or worms.
- Colonial; colonies can be branching or encrusting; encrusting form is most common.
- Zooid – individual bryozoan animal, usually less than 1mm long.
- Diameter less 1/32 inches.
- Variety of shapes.
- Specialized individuals:
  - Autozooids – collect food for the colony; compose the major portion of the colony.
  - Heterozooids: are fed by autozooids.
  - Kenozooids: strengthen the colony.
  - Vibracula: clean the colony.
- Complete digestive tract (separate mouth and anus).
- Coelom – internal organs are enclosed in a fluid-filled body cavity. It cushions and protects the internal organs, allowing them to grow independently of the rest of the body.
- Zooids are enclosed in a protective exoskeleton covering (zooecium) secreted by themselves (usually calcium carbonate).
- Lophophore – a specialized food-catching organ; it is a circular or horse-shoe shaped fold of the body wall that encircles the mouth and contains ciliated tentacles. They are extended from an opening in the exoskeleton and are rapidly withdrawn when disturbed.
- Food – suspension feeders on plankton and detritus.
- To capture food, it extends its lophophore into the water, fanning out its tentacles. Once food is trapped by the lophophore, it is moved into the





Illustrations from "The Seaside Naturalist"



Lophophore

animal's mouth by cilia that line the tentacles. It then enters the animal's U-shaped digestive tract, which leads to an anus outside the lophophore.

- Predators – nudibranchs, sea slugs, snails.
- Reproduction – both asexual and sexual, depending on the species. Many species are hermaphroditic – Some alternate the production of sperm and eggs. Others produce both simultaneously, allowing self-fertilization. Some species protect fertilized eggs within a special area of the colony.
- Some can rejuvenate themselves. Will self-digest itself, fall to bottom of case, and then grow new body and throw out old.

> DOCENT TIP:
> Bryozoa are often mistaken for bushy types of hydroids, encrusting algae, or sponges. A simple identification test is to gently rub a finger over the colony. If it is in the lowest part of the intertidal, and rough, sometimes feeling like a fine sandpaper, it is probably a bryozoan.

Local Species

- Kelp encrusting bryozoan (*Membranipora tuberculate*): Colony forms a white "crust" to several centimeters in diameter, consisting of a single layer of zooids having a fine honeycomb appearance. Low intertidal especially on red algae and on shells.

> DOCENT TIP:
> *M. tuberculate* is often found at Duxbury on floating brown algae (esp. *Macrocystis pyrifera* – "giant kelp") which has been cast ashore.

- Rosy bryozoan (*Dendrobeania laxa* and *Eurystomella bilbiata*): *D. laxa* is a branching colony, with branching "leaves" (like corn flakes in shape) of variable size forming a tangled mass; usually rust, or dull reddish color.

> DOCENT TIP:
> Attached to substrata (rocks and shells) in very low intertidal where it is protected from strong surf. *E. bilbiata* is a flat encrusting colony in a single layer sheath on the substrata.
>
> - At Duxbury, is rose-red or red-orange. *E. bilbiata* is preyed upon by a common Duxbury nudibranch, Hopkins Rose (*Hopkinsia rosacea*); the color of *H. rosacea* closely matches that of *E. bilbiata* and the pigment of the nudibranch is taken from this bryozoan.

Part 14. Phylum: *Mollusca*

Description

- Unsegmented soft bodied animal protected by a shell, and with a muscular foot.
- More species of mollusks in the oceans than any other phylum – about 200,000 species.

Types

- Class *Polyplacophora* – several overlapping shells arranged in a row, such as chitons.
- Class *Gastropoda* – single shell such as snails, limpets, abalone, nudibranchs.
- Class *Bivalvia* – 2 shells hinged together such as clams, scallops, mussels, oysters.
- Class *Cephalopoda* – squids and octopi.

General Anatomy

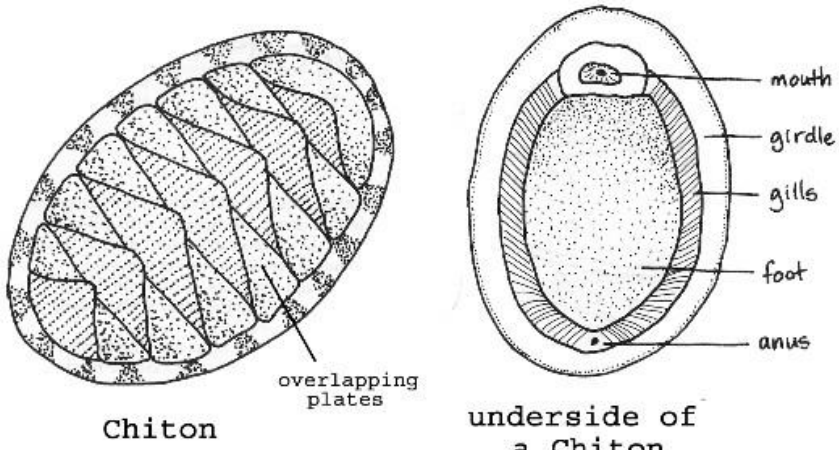
- Bilaterally symmetrical.
- Benthic (bottom dwellers) and pelagic (live in water column).
- Some have organs for touch, taste, light, and equilibrium.
- Complete digestive tract (separate mouth and anus); digestion involves salivary and digestive glands that release enzymes which break down food into simpler molecules.
- Respiratory exchange through paired gills which are located between the mantle and foot.
- Circulatory system that transports nutrients and oxygen. A muscular heart pumps blood to all tissues. Most (except cephalopods) have an open circulatory system (blood flows out of vessels into open blood spaces). Cephalopods have a closed circulatory system (blood remains in vessels and can be more efficient directing oxygen to organs).
- Coelom – internal organs protected by thin fluid filled body cavity.
- Simple brain in gastropods, bivalves, and chitons – set of "local brains" or ganglia clusters of nerve cells located in several body parts.
- Complex brain in cephalopods – large brain that coordinates and stores information received from the environment. Intelligent and remarkable capacity for learning.
- Body defined into 3 regions:
    - Head – contains mouth, eyes, and sensory organs (in bivalves head is indistinct).
    - Foot – muscular and fleshy – used for crawling, swimming, or burrowing.
    - Visceral mass – contains organs of respiration, circulation, reproduction, digestion, and excretion. Organs include a heart, a stomach, intestines, gonads, and kidneys.
- Shell – calcareous (limestone) – portable shelter – by withdrawing into the shell, it can protect itself from desiccation, mutilation, and predation. Shell grows with the animal and provides a place for the attachment of muscles.
- Shell is modified or not existent in cephalopods.
- Mantle – thin layer of tissue that covers visceral mass, encloses respiratory system and secretes a hard shell that protects the soft body. Hangs over the body, touching the shell only in a few places.
- Radula – feeding organ for all mollusks, except bivalves. The radula is a tongue-like structure covered with backward curving fine teeth. It is adapted for grazing, scraping, grasping, or cutting. Made largely of chitin. (Note: some mollusks have a modified radula, or no radula at all).
- Predators – birds, humans, sea stars, crabs, fish, snails.

- **Reproduction** – most are dioecious (sexes separate) – except nudibranchs (simultaneous hermaphrodites) and some limpets (sequential hermaphrodites).

Class *Polyplacophora* (chitons)

Description

- 800 species.
- Flattened oval body, covered by shell made up of 8 overlapping shell plates.
- When dislodged, rolls up in ball.
- Girdle – mantle that is around the external edge of the shell.



Illustrations from "The Seaside Naturalist"

- Internal organs not coiled. (coiled in gastropods).
- Indistinct head, lack of tentacles and lack of eyes.
- Foot and girdle clamp tightly to rocks so it can withstand turbulent waves and currents.
- Feed at night when submerged; some species returning to home spot ("home scar") in the substrata.
- Radula has metal oxide imbedded in it – very strong.
- Radula is used to graze on algae; herbivore.
- Dioecious (sexes separate).
- Eggs and sperm released into water; fertilization external.

Local Species

- **Mossy chiton** (*Mopalia muscosa*): Brown to green – with fleshy tan or cream–colored mantle around dorsal perimeter of shell plates covered with mossy looking stiff hairs. Exhibit homing behavior, moving in a radius of up to about 50 cm. Grazing range of two *M. muscosa* generally do not overlap. Feed primarily on red (*Mastocarpus* and *Encoldadia*) and green (*Cladophora*) algae but may also consume animal matter. Found in mid and lower intertidal.

> **DOCENT TIP:**
> Often seen with epibiotic algae on plates.

- Gumboot or brick chiton (*Cryptochiton stelleri*): Largest species of chiton (up to 16 inches), mantle fully covers all plates.

> DOCENT TIP:
> On occasion found at Duxbury in the deepest pools and channels of the very lowest part of the intertidal in areas protected from strong wave action; this *C. stelleri* is more often subtidal in kelp beds and will be seen at Duxbury cast up on the shore when separated from the substrata.

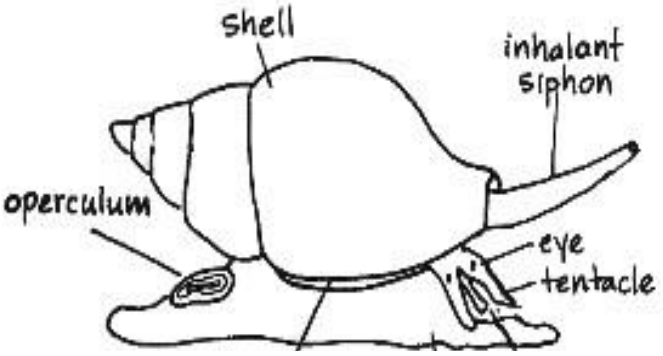
- Lined chiton (*Tonicella lineata*): Body is an elongated oval, about 5 cm long. Plates are low, rounded, smooth shiny, with sinuous or zigzag lines running from plate to plate. Girdle is nude and leathery with alternating bands of color. Found in low intertidal on rock faces covered with encrusting coralline algae (its favorite food). Predators – *Pisaster ocharus*. Intertidal *T. lineata* only move about when covered by high tide.
- Nuttall's chiton (*Nuttallina californica*): Body elongated oval, to 5 cm. Plates rough and beaked in appearance, dark brown or blackish with whiteish blotches. Girdle is wide, covered with short, rigid spines. Often covered with algae, found in mid intertidal.

> DOCENT TIP:
> Often hidden under coralline algae in crevices or depressions or wedged between mussels and barnacles.

- Hind's chiton (*Mopalia hindsii*): Body elongated oval to 10 cm. Plates are low, broad, with granular corrugations; light in color to dark olive–grey or brownish, sometimes with white markings on tops of plates. Plates often overgrown with epibiotic bryozoans, barnacles. Girdle is wide, thick, with sparse, slender hairs. Noticeable notched end in the girdle (at the posterior end). Of the species of chitons at Duxbury, only *M. hindsii* and *M. ciliata* have a notch in their girdle. Feeds on algae, sponges and small crustaceans. Under rocks, on shoreward sloping rock faces or in crevices in middle and low intertidal.
- Woody chiton (*Mopalia* lignose): Body elongated to 8 cm. Plates appear smooth (but have longitudinal rows of small, fine pits under magnification). Plates are all about the same width, and have purple–brown, mahogany, greenish, or white streaks or lines. Girdle is narrow with sparse, short hairs. Feeds on different algae, primarily on diatoms and the green algae *Ulva* (sea lettuce), and occasionally bryozoans and acorn barnacles. Found on sides of or under large suspended boulders in middle and lower intertidal. Negatively phototaxic.
- Hairy chiton (*Mopalia ciliata*): Body elongated to 7 cm. Wide girdle has short brown hairs, with a distinct notch. The larger end plate, which is at the chiton's anterior end (over its head), has 10 ridges that radiate from the center of where the middorsal ridge meets the plate. Plates are variously colored. It is an omnivorous feeder feeding about 50% on algae/diatoms and 50% on hydroids, sponges and bryozoans. Commonest in well–protected crevices, under rocks and on shoreward sloping sides of rocks, sometime among mussels, in middle and lower intertidal.

Class *Gastropoda* (Gastropods)

Description



Snail Anatomy

Illustration from "The Seaside Naturalist"

- "Stomach foot" = gastropod
- One shell (univalve) (some do not have shells as adults).
- About 75,000 species.
- Most common and most varied of the mollusks.
- Coiled mass of vital organs enclosed in a shell, with a creeping foot.
- Sole-like muscular foot adapted for crawling. Ciliated cells on underside of foot secret a mucus trail over which the animal moves.
- Normally have well-developed head with tentacles, eyes, and radula.
- Simple eyes detect light intensity.
- Tentacles – feeler and chemical receptors.
- Operculum – a horny disc attached to the foot that acts as a door when the animal pulls itself inside its shell. Keeps animal from drying out when out of water at low tide. Also thwarts predators. (Not all species have an operculum).
- Inhalant siphon – rolled up section of the mantle used to keep a current of water circulating over their gills. Also with sensory probe.
- Food – Most snails use radula to scrape algae from rocks; most are herbivores, but some are predators.
- Carnivorous snails (such as a whelk) have a modified radula that can be used to drill, cut, or capture prey. The radula and mouth are contained in a proboscis that can be protruded to strike the prey. While holding a bivalve in a death grip with its foot, a whelk can wedge apart the 2 shells of the bivalve with the edge of his own shell. Once the shell is opened, the whelk can insert its proboscis and eat the bivalve body.
- Several sets of ganglia (clusters of nerve cells), no single brain.
- Predators – crabs, seastars, snails, birds, fish, octopus, humans.
- Reproduction – most dioecious (sexes separate).
- Fertilization internal for most snails. Fertilized eggs are deposited into a protective ribbon, string, case, or capsule that is attached to the bottom. Fully developed miniature snails emerge from the egg.
- Fertilization external for some snails – release egg and sperm into water.
- Life cycle: protected eggs – larva – adult.

Types

- Limpets
- Abalone
- Snails
- Nudibranchs

Limpets

- Flat one-piece shell, uncoiled body.
- Most have a definite place of their own on a specific rock.
- Some species are homing, creating a home scar in the substrata that fits shell.
- Uses foot to grip surface, prevents drying during low tide.
- At night, limpets wander around scraping algae off the rocks with its radula.
- Food – algae; an herbivore.
- Predators – crabs, snails, birds.
- Reproduction – broadcast spawning.

Local Species

There are about 11 species of limpets that are found on Duxbury. *Below is a description of the 6 that are the most common.*

- Rough (or ribbed) limpet (*Collisella scabra*): Synonym genus is Lottia. Distinct/strong ribbing, scalloped margin, gray or gray-black. Will form a home scar. Moves at high tide, returning to home scar after grazing on microalgae. The homing behavior develops only when *C. scabra* is 5mm in length. *C scabra* favors horizontal and gentle sloping substrata. Show no escape behavior when exposed to sea stars. High and mid intertidal areas.
- Finger limpet (*Collisella digitalis*): Apex is in anterior quarter of shell and may overhang. Has prominent radial ridges which are more pronounced on the posterior end than on the anterior end. The shell may be elliptical, with the anterior end narrower than the posterior. Favors vertical or overhanging rock faces close to and above high-water mark.

  DOCENT TIP:
  Distinguishing rough limpets from finger limpets: *C. scabra* strongly scalloped or ridged but the ribs anterior to the apex (high point on the shell) are just as strong as posterior ribs, and the ribs often actually project as points beyond the margin of the shell; apex is approximately at the anterior third of the shell. In contrast, for *C. digitalis*, the ridges are more pronounced on the posterior end than on the anterior end and the apex is in the anterior quarter of the shell and may be overhanging the anterior end of the shell.

- Shield limpet (Collisella pelta): Gray, smooth perimeter, radiating rays; may have weak ridging. Feed when submerged, favoring spring tides. Will attempt to escape sea stars. Found in all intertidal tidal zones.

  DOCENT TIP:
  C. digitalis, *C. pelta* and *C. scabra* are the three most common limpets at Duxbury.

- Dunce cap (*Collisella mitra*): Round, pointed, high apex, dull white, no ribbing. Found in low intertidal.

> DOCENT TIP:
> You will find *C. mitra* most often washed up on the shore rather than in the intertidal.

- Black limpet (*Collisella asmi*): Greyish or black. Shell is smooth without any ridges or with very fine ridges visible near the shell's perimeter. Usually found living on black turban snails (*Chlorostoma/Tegula funebralis*) but sometimes on mussels (*Mytilus californianus*). As with other limpets, this species grazes on microalgae on the turban snail's shell. *C. asmi* will move from one host to another, probably after microalgae are exhausted on current host when the turban snails are aggregated together at low tide. It avoids shells that are not occupied, and seems to prefer shells occupied by snails to those occupied by hermit crabs.

> DOCENT TIP:
> Look for *C. asmi* on turban snails clustered in crevices as low tide. You may see other species of snails living on *C. funebralis*; however, they will probably not be black, they will be juveniles of other species, and their shell will be flatter than *C. asmi*.

- Owl limpet (*Lottia gigantea*): A very large limpet (adults to 9 or 10 cm long). Apex very near the anterior margin of the shell (near the first one-eighth), and decidedly lower than the highest part of the shell, which is posterior to it. The exterior of the shell is almost always badly eroded and is usually a light brown with whitish spots. Has some radial ribs (often worn), and the margin may be slightly scalloped. Territorial. Some individuals are "homing", returning repeatedly to the same scar that exactly fit the margin of its shell. Territories are usually about 1,000 square centimeters. They dislodge other limpets and small barnacles from their territory (the rock around them is usually seen to be bare except for microalgae which it grazes on but allows to grow – often in a distinctive patch). Radular teeth are hardened with the iron-containing compound geothite and have silica on their base plates.

> DOCENT TIP:
> This limpet can grow much larger than other limpet species at Duxbury. It is the only one (especially the only large one) with the apex so far anterior and lower than the highest part of the shell. You will find it in mid intertidal, usually on a vertical rock face. The rough limpet *Colisella scabra* is often found on *Lottia's* shell.

Abalone

- Blood contains properties useful against penicillin-resistant bacteria but lacks blood clotting mechanism. Can bleed to death when cut by careless person or a predator.
- Muscular grip – as strong as 254 pounds.
- Predators – cabezon fish, moray eels, crabs, octopus, sea stars, sea otters, humans.
- Food – algae grazers; mostly on microalgal films on the rocks though adults capture pieces of kelp with their foot and consume them.
- Reproduction – broadcast spawners.

Local Species

- Red Abalone (*Haliotis rufescens*): Have historically been at Duxbury. *H. rufescens* is primarily subtidal, but (rarely) may be in the inaccessible rocky, wave-swept areas in the low intertidal. Exterior of shell of *H. rufescens* is rough and lumpy or wavy, pinkish or brick red unless overgrown with algae or encrusted with invertebrates. Boring sponges (*Cliona celata*) often inhabit the older portions of the shell. Underside of the shell has a prominent pink border but otherwise is pearly. *Rufescens*' shell is thick and the muscle scar in the center is prominent. Usually has only 3-4 open respiratory holes. Sexually mature at 6 years; can live 30 years or more.
- Black Abalone (*H. cracherodii*): It is black, exterior of shell is smooth, oval, evenly convex, smaller than *H. rufescens*. The muscle scar is generally not distinct. There are usually five to seven small, open respiratory holes and the rims of the holes are flush with the rest of the shell. *H. rufescens* usually has only 3-4 open holes which are slightly raised, like small volcanic cones. *H. cracherodii* usually has 5-7 open holes which are smooth/flush with the surface of the shell (i.e do not look like mini-volcanoes). *H. cracherodii* at one time was the most abundant large marine mollusk on the West Coast of N. America and have historically been at Duxbury.

DOCENT TIP:
Once abundant, abalone are currently protected species south of the Golden Gate. Black abalone are on the endangered species list.

North of the Golden Gate commercial fishing of abalone is prohibited, but limited "recreational" fishing of Red Abalone (only) may be permitted by free diving (not scuba). *However, because of population decline, recreational fishing of red abalone is closed north of the Golden Gate until at least April 1, 2026.*

Black abalone are found in the low intertidal however, they are extremely rare. If seen their location should be kept secret and only reported to the docent supervisor at EAC West Marin. *Persons with scuba gear observed diving from kayaks or other watercraft off Duxbury should be reported to CDFW.*

Snails

- Seal themselves to rocks with mucus produced by its foot and pulls itself into shell.
- Creates a tight seal to rock which prevents it from drying out at low tide.
- Food – some graze on algae, other prey on barnacles, other snails, and bivalves.
- Predators – sea stars, snails, birds.
- Reproduction – broadcast spawners (turban snails) or females lay egg cases.

Local Species

- Black Turban Snails (*Tegula funebralis*): Shell is black or purple above (usually worn at the apex) and white below, coiled, with a definite raised spire (but the shell is only about as tall as wide); no siphonal notch or canal in aperture, interior of the shell is pearly. *Columella* (i.e. axis around which the shell coils) has two small nodes visible at the lip of the aperture. Has an operculum which is thin and horny with spiral lines. Many predators – sea otters, octopuses, red rock crab (*Cancer antennarius*) and seastars, esp. *Pisaster ochraceus* at Duxbury, and humans. Principle threat is humans. *T. funebralis* is long-lived and slow growing and would have difficulty withstanding an intensive fishery. Defenses – chemicals emitted by seastars and crabs are detected by *T. funebralis* and stimulate it to seek higher ground, above predators' foraging range. *T. funebralis* eats algae, microalgae and a microscopic film that covers rock; harvested with radula. Epibiosis: frequently carry small/juvenile limpets, including *Collisella asmi* (Black Limpet), *C. digitalis* (finger limpet), and *C. pelta* (shield limpet); all limpets will move off the *T. funebralis* as the limpet matures – with the exception of *C. asmi* which will reach adult size and remain for life on *T. funebralis*. Mid-intertidal.

> DOCENT TIP:
> Black Turban Snails *(T. funebralis)* is a species which is frequently taken by poachers at Duxbury. Keep an eye out for that.

- Brown Turban Snails (*Tegula brunnea*): Shell is brown or orange above and white below, coiled, with a raised spire that is up to twice the diameter. The aperture has no siphonal notch or canal, the interior of the shell is pearly, and it has a thin, horny operculum with spiral lines. The columella has one node. Feeds on algae. They have softer teeth than do many other gastropods so it is thought that they probably eat more soft algae and less coralline algae than other gastropods. Low intertidal and subtidal.

> DOCENT TIP:
> At Duxbury you are just as likely to find Brown Turban Snails *(T. brunnea)* shells that are unoccupied by *T. brunnea* than to find them occupied by *T. brunnea*.

- Angular Unicorn Whelk (*Acanthina spirata*): A predatory snail. Prey includes *Littorina* (snails), barnacles. Has a sharp tooth on the outer lip of the aperture. When attacking a barnacle, the snail assumes a position above the opening of the barnacle shell so that the spine/tooth is directly above the line of contact with the closed plates of the barnacle. The

A. spirata usually takes this position when the tide is out and the barnacle is thus closed. When the tide comes back in over the area, the natural reaction of the barnacle is to open up and begin feeding activity. As soon as this occurs, the snail quickly inserts its spine into the opening between the plates, the proboscis is everted and the soft parts of the barnacle are consumed. Toxic material that paralyzes the prey may play some role in predation. *Littorina* comprises about 90% of their diet; the prey is contacted by outstretched head tentacles. Then captures *Littorina* by uplifting and extending the anterior part of the *A. spirata*'s foot. *Littorina* are then drilled. Takes 15–60 hours to drill and eat a *Littorina*. *Littorina* snails pursued may run away and crawl up on top of the predator's shell. They move up and down with the tide and are most active when submerged. Middle intertidal, usually take shelter in pools or crevices at low tide.

- Leafy Hornmouth (*Ceratostoma foliatum*): Grows up to 10 cm high, but usually no more than 8 cm long. The body whorl has three wide flanges or varices. Outer lip of aperture has a very strong protruding tooth near anterior end; operculum is also horny. The siphonal canal forms a closed tube and is bent backward/upwards. Coloring varies from gray, white to yellow–brown on body whorl, interior is white. The juvenile shell is sculptured with numerous longitudinal ribs crossed at right angles by equally spaced spiral cords. As the shell size increases the longitudinal ribs become channeled into groups that form projecting flanges, called varices. One of the varices ends on the closed siphonal canal and another ends on the previous canal, which is still visible but unused. The body whorl is much larger than the whorls in the spire. *C. foliatum* is carnivorous, on Duxbury, it eats mainly barnacles such as *Balanus glandula*, and bivalves such as *Penitella pineta* and *Mytilus californianus*. It drills through their protective shell with its radula. After drilling through the shell *C. foliatum* injects digestive enzymes into the prey's body cavity and sucks out the dissolved tissue. Sexes are separate and may form large groups during spring copulation. After copulation, females lay their eggs in a communal mass nearby in stalked, yellow, flattened egg cases about 13 mm long, attached to rocks. Sexually matures in about 4 years and can live 16 years or more. Found on rocky faces near barnacles and bivalves. Most common in low intertidal areas of strong surf.

DOCENT TIP:
Frilled Dogwinkle (*Nucella lamellosa*), rarely but sometimes found at Duxbury, is sometimes confused with *C. foliatum* in some tide pool guide books and laminated picture guides. The 3 large longitudinal flanges/varices, the tooth on the outer lip of the aperture, and the closed siphonal canal are all missing from the *N. Lamellosa*.

DOCENT TIP:

- Nuttall's Hornmouth (*Ceratostoma nuttalli*) is also similar to *C. foliatum*, with a range previously limited to south of Monterey. The distinguishing characteristics of these two species are: *C. nuttali* has 5 whorls, the spaces between them not heavily sculpted; *C. foliatum* has 6 or 7 whorls, the spaces between them are strongly sculpted. The outer lip of the aperture on *C. foliatum* has a slender single protruding tooth, like the tooth found on the angular unicorn whelk (*Acanthina spirata*).

- Dire Whelk (*Searlesia dira*): Common on Duxbury. Middle intertidal, usually not extending into subtidal. Do not migrate up and down with tides. Roam most actively when submerged in calm water. At low tide and in rough water they are often inactive and shelter in pools and crevices. Locomotion by means of muscular waves traveling from front to rear of foot. A carnivore, eating snails, limpets and barnacles. Dead organisms are detected from a distance and carrion may be fed on my multiple individuals at once. Proboscis extends out fully the length of the shell, which facilitates feeding on large prey, also worms in tubes, and on prey being digested by the everted stomach of starfish. They do not drill the shells of prey, but must insert the proboscis past the opercular plates of barnacles and snails and under the shell edge of limpets. Might secrete material that anesthetizes prey. Sexes are separate. Longevity is uncertain but may be 15+ years.

- Eroded Periwinkle (*Littorina planaxis* (aka *keenae*): Columella wide, light in color; exterior grey–brown, sometimes white spots; interior of aperture brown except for white band curving inward at base. Occupies a higher vertical position on the shore than any other marine mollusk species in CA. It lives out of the water most of the time – can survive out of water 2–3 months (maybe longer). Secretes a mucus holdfast, in air or under water, which is disposed of by the proboscis and radula before the animal moves again. Juveniles and smaller adults remain in lower part of splash zone, large adults higher. The grazing by *L. planaxis* results in considerable erosion of the rock face; the rasping activity of the radulae of *littorines* may deepen certain high tidepools by 1 cm ever 16 years. (Molluscan radula are worn away in front and are continually replaced from behind.) *Littorina planaxis* is older name, modern sources now mostly using *L. keenae*. 8–19 mm (3/4 inch), larger and more squat than checkered periwinkle (*L. scutulata*), with white stripe inside aperture (not found in *L. scutulata*). Can be 20 ft above high water (this condition does not exist at Duxbury), whereas *L. scutulata* can only be a few feet above high water. *L. planaxis* is never found in intermediate zone, where as *L. scutlata* is numerous in both high and intermediate zones.

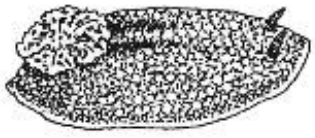
- Checkered Periwinkle (*Littorina Scutula*): Shell brownish to nearly black, often with lighter bands or spots in a checkered pattern; aperture purplish within, lacking white band curving inward to very edge of aperture. Migrate up and down with the rising and falling tide. In tidepools they emerge by night and submerge by day. Adults tend to have smoother shell, immatures have fine spiral threads. Stalked tentacles used to see and taste. *Littorina scutulata* is smaller than *L. planaxis*. Height is greater than diameter and looks more slender than *L. planaxis*.

Characteristics Common to both Eroded and Checkered Periwinkles: Herbivores, using their file-like tongue, the radula, to feed on diatoms and algae attached to intertidal rocks. Breaks down its food by mixing it with mucous on the radula before bringing the food into its mouth. Sea stars, whelks, and some fish eat periwinkles. Periwinkles can live for many days without food or water by retaining moisture in their gills. They close themselves into their shells with a horny door (operculum) which retains moisture in the gills and keeps out fresh water. With the shell closed by the operculum, they excrete a sticky mucous that hardens, firmly attaching the animal to the rock or blade of seagrass (also forms a second barrier to unfavorable conditions). They can adapt to a variety of environmental conditions, including extreme heat and wind, low tide, severe wave action, and submergence at high tide. Can withstand submersion in fresh water for several days, which kills all true marine animals. Separate sexes, reproduction in spring and summer. Eggs laid in elongated gelatinous mass (often in very shallow pools) by animals recently immersed in rising tide; after several hours in the water, the matrix of the egg mass disintegrates, liberating several thousand eggs.

DOCENT TIP:
Both checkered and eroded periwinkles are easily crushed by the weight of even a child's footstep. Eggs are often laid in very shallow pool (puddles) in the high intertidal. They are an example of why visitors should always be asked to walk where the rock surface appears to be bare and never step in a pool of water.

Nudibranchs ("naked gills")

- Gastropods without shells.
- Sea slugs with respiratory structures exposed.
- Bright colors warn predators of poisonous stings and foul taste.
- Live up to 1 year.
- Has radula and many have a jaw (no proboscis).
- Pair of rhinophores (tentacles) projecting out at anterior end. Innervated by cerebral ganglion used for smell/tasting and in some species may be retractable into sheath.



Lemon nudibranch

- Peak season to see nudibranchs (breeding season) – April to July.
- Food – Mostly carnivores, feed on hydroids, anemones, worms, bryozoans, sponges, etc.
- Predators – other nudibranchs, inexperienced fish, collectors.
- Reproduction – All are simultaneous hermaphrodites (having functional organs of both sexes), but do not self-fertilize.

DOCENT TIP:
Egg masses can be seen in lower intertidal pools by a careful observer. They appear as spiral ribbons or as a string of tiny sausage links and may contain up to 2,000,000 eggs.

Two Types

- Aeolids – have appendages called cerata on dorsal side that act as gills. Eats hydroids and anemones. Stinging cells (nematocysts) obtained from prey (e.g. anemone's tentacles) pass intact thru digestive system and incorporated into tips of cerata. Use cerata to defend itself. Can regenerate cerata. (example: *Hermissenda*)
- Dorids – lack cerata but breathe with gill like filaments that extend on the dorsal side located toward the posterior end in a feathery rosette around their anus.Gill rosette is swiftly retracted when the animal is threatened. Eat bryozoans, anemones, sponges, and tunicates.

Local Species

There are many species of nudibranchs that can be found on Duxbury. A few are listed here.

- Opalescent Nudibranch (*Hermissenda crassicornis & Hermissenda* opalescens): Common aeolid on Duxbury. Only recently (2016) were these two species distinguished from each other, so many field guides prior to that date continue to conflate the two. *H. crassicornis* has a distinct longitudinal white band along the anterior margin of each of its cerata, *H. opalescens* lacks that band. The following applies to both species: Their dorsum (i.e. their back/dorsal side) has numerous cerata besides the rhinophores. The rhinophores cannot be retracted. None of the cerata are anterior to the rhinophores. The tips of the cerata are white. Eats hydroids, but the diet also includes small anemones, bryozoans, annelids (worms), small crustacea, tiny clams, and dead animals of any sort. Will also eat other *Hermissenda* individuals. From hydroids and anemones on which it has fed, *Hermissenda* obtains nematocysts. Live less than one year. Lays an egg string in narrow coils that looks like tiny pink sausage links.

Illustration from "The Seaside Naturalist"

DOCENT TIP:
Hermissenda eggs can be found attached to surf grass and algae.

- Hopkin's Rose (*Hopkinsia rosacea*) – This small, distinctive dorid nudibranch is rose pink. Although it is a dorid it has long dorsal outgrowths that resemble cerata and almost hide its rhinophores and gill ring. Up to 3 cm long but usually less than 2 cm. Lays eggs in a narrow rose-colored ribbon spiraled counterclockwise. Low mid-intertidal.

- Sea Lemons – A yellow dorid with black dots between tubercules (i.e. bumps) on their dorsum (their backs/dorsal side). Sea Lemons get their name from their color and from the citrus smelling mucus they emit when they are disturbed. Low mid-intertidal and low intertidal.

> DOCENT TIP:
> With most visitors it is good enough that if you see a yellow dorid with black dots between the bumps to simply identify it as a "sea lemon". However, there are 3 species that may be seen at Duxbury, which you may distinguish by careful observation of the coloration on and around the bumps covering the dorsal side – Heath's Dorid (*Geitodoris heathi*) dark spots on and between low bumps on dorsal side; Monterey Sea Lemon (*Doris montereyensis*) dark spots on pointy bumps on dorsal side; and Pacific Sea Lemon (*Peltodoris nobilis*) dark spots on skin (between the bumps, not on the bumps).

- Sea Clown (*Triopha catalinae*): A dorid. The white body is opaque. Oral veil is wider than the body and has a row of short appendages from end to end. The smallest of these may be white or orange; larger ones tend to be white at the base. The rhinophores can be completely retracted. The rhinophore stalk is cylindrical and white, the tips are orange or vermillion. The dorsum has large conical or round orange tubercles, and there are flat orange patches both on the dorsum and on the sides of the body. Gill rosette is 1/3 or less from the posterior end, has 5 feathery leaves with orange or vermilion tips surrounding the anus. This is one of the largest nudibranchs able to crawl on the underside of the surface film in tide pools. It feeds on bryozoans. Tide pool fish avoid *Triopha*, and this is believed to be because of some sort of chemical repellant. The ribbon of eggs is white or cream colored is wavy and appears like a ribbon.

- Spotted Triopha (*Triopha maculate*): Dorid. Very colorful. *Triopha maculata* can, on rare occasions, grow as large as 180 mm (a little more than 7 inches) but usually the maximum length is 50 mm (about 2 inches.) The color can be a very pale and translucent yellow, or it can be a darker yellow, orange, red, and even dark brown. There are always raised whitish spots on the dorsum, hence the name maculata, meaning spotted. Lays a ribbon of eggs. Feeds on bryozoans.

Class *Bivalvia* (Bivalves)

Description

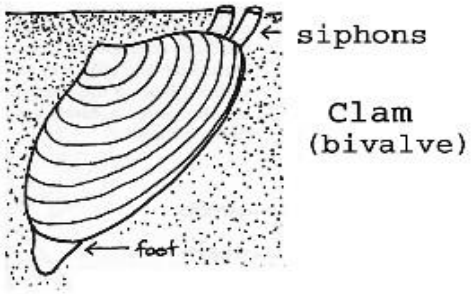


Illustration from "The Seaside

- 2 shells (valves) hinged together at top, one or two large muscles keep shell pulled shut
- Modified molluscan body plan – body is laterally compressed and enclosed in a 2–valved shell. No head, no radula.
- Some are sessile, but some use foot to dig; some swim.
- Inhalant siphon – brings water into bivalve.
- Exhalant siphon – expels water out after nutrients removed.
- Most bivalves are filter or suspension feeders. Cilia on their gills create a current, bringing water and plankton into the partially opened shell. The gills filter out the plankton, and transport it into its mouth. The gills also extract oxygen from the water.
- Food – plankton.
- Predators – sea stars, snails, birds.
- Reproduction – most dioecious (sexes separate).
- Release sperm and eggs directly into water; fertilization external.
- Life cycle: egg – larva stages – adult.

Types

- Clams
- Mussels

Clams

Local Species

- Boring Clam aka Piddock Clam (*Penitella pineta*): Like other clams, take in water and food (plankton and detritus) with an incurrent siphon, and then get rid of the water and waste through an excurrent siphon. They bore into shale at Duxbury. Much of the anterior portion of the shell – which is pointed down toward the substrata – is roughened so that the animal can rasp a hole in the rock or clay much like an augur bit. The anterior portion of the shell, while higher and more globose than the posterior portion, is not as round as other species of boring clams. The anterior portion occupies less than half the length of the valve and is separated from the posterior in a well–defined manner by a groove which runs from the dorsal to the ventral side. It is the most common species of piddock clam in the Northwest. The shape and length of the shell varies with the hardness of the rock it is boring into. It is a significant agent in the erosion of coastal shale. The clams bore 4–5 mm/year, and may burrow to depths of 15 cm. Drilling seems to be entirely mechanical. The ridges on the shell seem to be produced between bouts of rapid drilling. The animal grows as it digs deeper, so the deep portions of the hole are of greater diameter than the surface portions, and the animal cannot back out of the hole. The empty holes of piddock clams may contain anemones, small lined shore crabs, other juvenile crabs, worms, and bryozoa.

Predators include the leafy hornmouth, *C. foliatum*. In soft shale the animal may mature in 3 years, while in harder rock it may not mature until 20 years or later. Mature animals may live for many years unless the rock is broken away. They can live for months in rock that has been buried by sand.

> DOCENT TIP:
> Fun Fact for Visitors – Piddocks seem to be able to sense when their boring is approaching the burrow of another Piddock. When they approach another burrow they turn, often leaving only a millimeter or so of rock between the burrows. If the rock becomes so crowded with Piddock burrows that there is nowhere to turn the clam stops growing and remains stunted and sexually immature.

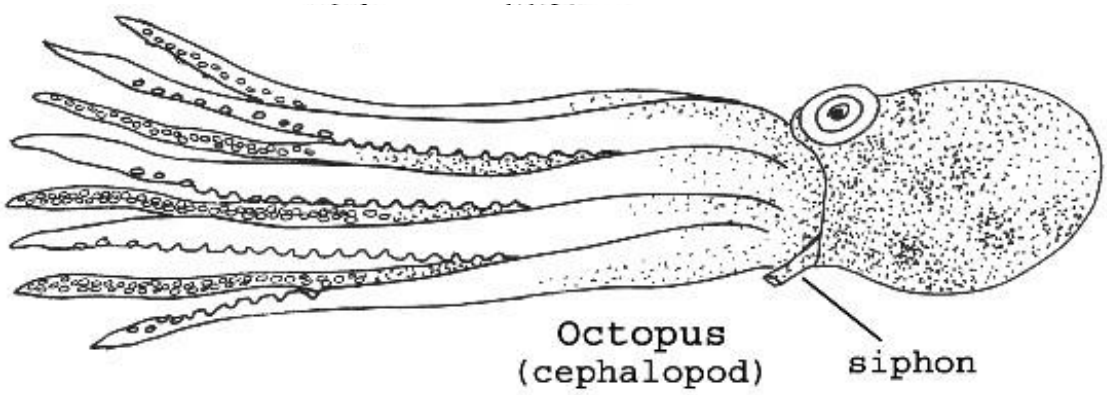
Mussels

Local Species

- California Mussel (*Mytilus californianus*): They do not colonize bare rock easily, instead preferring the shelter of pre-existing mussels and their biological filaments. Mussels attach themselves to the hard surfaces using their byssal threads. These threads are produced in liquid form by the byssal gland. If undisturbed, the shell opens slightly and the slender orange foot extends and grips the substratum. The liquid runs down a groove on the back of the foot. When the foot pulls back, exposing the liquid to sea water, the liquid solidifies into a thread. Mussels feed on plankton. Predated by the ochre star, *Pisaster ochraceus*. They reproduce by broadcast-spawning, synchronously in response to chemical cues from nearby conspecifics. Some spawning occurs throughout the year in coast mussels. In California, the peak breeding times are during July and December. They are filter feeders. When the animals are submerged, their valves open slightly and the mussels use cilia to move water through the gills. Planktonic food suspended in the water is caught in mucus, sent to the palps for sorting, and then to the mouth. Mussels consume dinoflagellates, organic particles, small diatoms, other unicellular algae, protozoa, bacteria, and detritus. Phytoplankton is the main food source.

> DOCENT TIP:
> Keep an eye out for poachers returning to the Agate Beach parking lot from the more remote parts of Duxbury where mussels are collected (out of sight from Agate Beach).

Class *Cephalopoda* (Cephalopods)



Description

- "head-footed"
- Most advanced and complex mollusks; very intelligent.
- Head pushed down toward the foot, that is modified as arms with suckers to capture prey.
- About 650 species.
- Agile and active swimmers.
- Complex nervous system.
- Reduction or loss of shell.
- Well-developed eyes – large and on side of head – can see prey.
- Body protected by thick and muscular mantle.
- Mantle encloses 2 to 4 gills.
- Water enters through free edge of the mantle and leaves thru the siphon (or funnel).
- Swim by forcing water out of the mantle cavity through its funnel. The funnel is flexible and can move around, allowing the animal to move in any direction.
- Have a radula, but use their beak as the primary feeding structure. Use the beak to tear flesh out of its prey.
- Escapes predators by rapidly changing color, squirting ink into water, and swimming away.
- Food – mostly carnivores; predators – locate food with their eyes.
- Predators – seals, sea otters, sharks, and other large fish, humans.
- Reproduction – Most are dioecious (sexes separate). Internal fertilization – male uses a modified arm to transfer a spermatophore (elongate package of sperm) to the female. Young develop externally from large yolk-filled eggs. Female octopus protects eggs until they hatch and she dies afterwards.

Types

Cephalopods include octopuses, squids, cuttlefishes, and the nautiluses. Only the octopus is found at Duxbury Reef.

Local Species

- North Pacific Giant Octopus (*Octopus dofleini*): Smaller juvenile animals are occasionally in low intertidal pools at Duxbury; larger individuals subtidal to depths of 100m. One of the largest octopus species known and the longest-lived species (5-6 years). Largest specimen had arm span of 9.6m and weighed 272 kg. They have 8 arms, sac-like body with no fins, and no shell (except internal remnant of shell). They are bottom dwellers, efficient hunters, and can emit dark fluid from ink sac to distract predators. They use crevices as homes, and come out to find food or ward off predators. Have pigment cells in skin are manipulated by muscles to alter color instantly, to match the background color for camouflage and to startle predators. Like nearly all octopus species, *O. dofleini* only reproduces one time and that occurs at the very end of its life. Eggs laid throughout year but mainly in winter. Young are pelagic for about 1 month. They eat crabs, lobsters, shrimp, clams, mussels, scallops, fish, snails, etc. To feed they grab its victim with its arms and injects venom into the prey from its jaws. It then uses its arms to bring the prey to its mouth. It uses its beak to tear flesh from its prey. Mucus from salivary glands and digestive enzymes begin to digest the prey even before it reaches the octopus' gut. It has a venomous bite and because of the anti-coagulant in the saliva, the bite could be dangerous to a child under 12 years of age. Predators include seals, sea otters, eels, sharks, lingcod and humans.

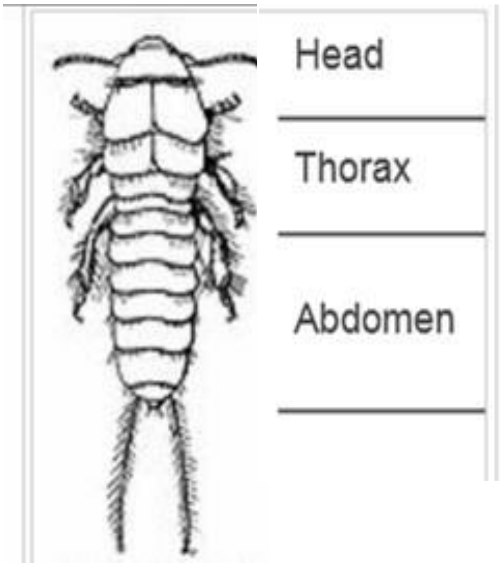
  DOCENT TIP:
  Fact for tidepool visitors – The octopus you have for dinner never had a chance to reproduce.
  Fun facts to share with visitors –
  - Octopuses are very intelligent with complex brains that can problem-solve, hold long-term memory, and show individual personality traits.
  - They can compress their body to squeeze into an opening the size of its beak.
  - They can slither out of water across exposed rocks to escape predators.

- Red Octopus (*Octopus rubescens*): white spots on the dorsal mantle and on the web in front of the eyes but no large "ocelli"/"eye" spots on the body. Arms 3-5 times the body length. The mantle length is usually less than 10 cm. They prefer to eat small crabs and hermit crabs. Females guard egg clusters intertidally or shallow subtidally from late spring through early winter in rocky areas. Peaks in breeding are in August and September. Young hatch in 6-8 weeks, spend a brief period in the plankton, and settle as juveniles in the kelp beds. Larger individuals migrate farther offshore. They mate in deep water in late spring, then move inshore again. Will be found low intertidal in kelp beds, rocky areas, under stones. One way to distinguish *O. rubescens* from small *Octopus dofleini* is that *O. rubescens* has three distinct cirri (cirri = a thin projection which may be of various shapes) below the eye.

Part 15. Phylum: *Arthropoda* (Crabs, Lobster, Shrimp, Isopods, Barnacles, Copepods, etc.)

Description

- Name means "jointed leg".
- Jointed appendages with exoskeleton (made of **chitin** – a polysaccharide (long-chain sugar molecule), often clawed.
- 1 million known species, with several million remaining undiscovered (most diverse group of animals).
- 75% of all animals belong in this phylum (insects, arachnids, crustaceans, sea spiders, and horseshoe crabs).
- Most marine species are in the subphylum *Crustacea*.
- Body divided into 3 sections:
    - **Head**
    - **Thorax**
    - **Abdomen**



Subphylum: *Crustacea*

Description

- Bilaterally symmetrical.
- About 50,000 species of crustaceans are known to science.
- Benthic (bottom dwellers), sessile (attached to the bottom), and pelagic (live in water column).
- Complete digestive tract (separate mouth and anus).
- Respiratory exchange through gills; gills isolated where legs attach to thorax.
- Open circulatory system (blood flows freely throughout body, not confined to vessels).
- Compound eyes – up to 14,000 light sensitive units grouped in a mosaic.
- Well-developed central nervous system; small, relatively simple brain.
- Keen sense of vision, smell and touch.
- Behaviorally complex – Use variety of signals to communicate with each other. Special body postures or movements are used in settling disputes or in mating rituals.
- Exoskeleton is not only protective, but gives rigid support for the attachment of muscles.
- In crustaceans, chitin is hardened with calcium carbonate.
- Exoskeleton secreted by underlying layer of tissue. Made of separate plates connected by a thin membrane. The exoskeleton does not grow, so it must be molted and regrown from time to time. Segmented exoskeleton creates joints and flexibility, allowing animal to move its body and appendages. Provides protection against parasites, injury, and predation.
- Many have claws for defense or obtaining food.
- Jointed appendages – some specialized for swimming, crawling, attaching to others, mating and feeding. Also used for gathering sensory information.
    - Antennae
    - Periopods – "walking legs"
    - Pleopods – "swimmerets"
- Molting – as animal grows, the exoskeleton does not. Molting is hormonally controlled. The old exoskeleton detaches from the layer underneath allowing a new one to grow under it. When the new exoskeleton is ready, the old one splits and the animal exits the old exoskeleton leaving it intact except at the split. The animal will take in a lot of water or air to stretch the soft new exoskeleton to enlarge the size before it hardens. The animal is easy prey until the shell hardens.
- Molting occurs less often as the animal ages.
- 3 body sections have characteristic numbers of appendages depending on the arthropod subgroup the species belongs to:
    - head – 2 sets of antennae, 3 pairs feeding appendages.
    - thorax – 5 sets of legs in most species.
    - abdomen – 5 sets of swimmerets in most species.
- Head and thorax often fused together into a cephalothorax covered by a carapace (carapace is the exoskeleton structure).
- Food – can be predators, grazers, parasites, or suspension feeders.
- Predators – birds, fish, anemones, seals, humans, etc.
- Reproduction – most are dioecious (sexes separate) – except barnacles which are hermaphrodites;

- Gametes are rarely broadcast but larvae are broadcast; male transfers sperm directly to female which broods the eggs until ready to hatch and broadcast.
  In hermaphroditic species sperm is transferred between individuals; they usually brood their eggs.
- Life cycle: egg– larvae–young adult – adult (can have up to 18 stages).
- Larval stages are planktonic.
- Can regenerate all appendages, including eyes.
- Breeding season – spring; porcelain crabs breed throughout the year.

Types

Copepods

- Important in zooplankton – food for many other animals.
- Mostly microscopic, very small.
- Although they are plankton, they can swim very small distances using their appendages.
- Use mouthparts to filter out or capture food – filter feeders.
- Female broods eggs.
- No gills – exchange oxygen or carbon dioxide with water.
- Single eye.
- Separate sexes.

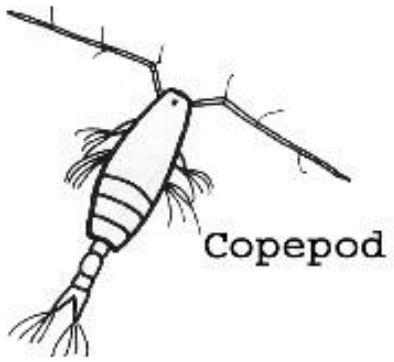


Illustration from "The Seaside Naturalist"

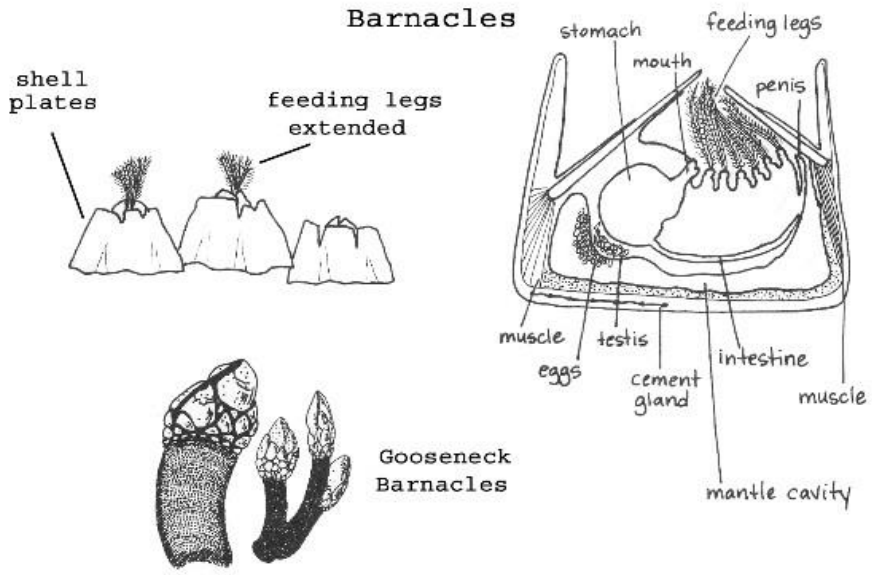
> DOCENT TIP:
> Because of their very small size, you are unlikely to observe copepods at Duxbury Reef.

Barnacles

- "Shrimp–like animal standing on its head in a limestone house"
- Attaches to surfaces (including moving ones such as whales and crabs).
- Only sessile (attached) crustaceans.
- Uses cement to anchor larvae to substrate and then metamorphoses into an adult.
- Secretes either calcareous plates (acorn barnacle) or 2 part shell (goose barnacle).
- Legs (cirri) have gills for gas exchange.
- The thin, soft cuticle covering the barnacle inside the plates is molted, but the hard plates grow larger with the barnacle.
- 'House' protects barnacles from desiccation and wave stress, but not predation
- Food – filter feeder. They use muscles to open shell plates and extends 6 pairs of feathery legs (cirri) into the water, trapping plankton and detritus.
- Predators – worms, snails, sea stars, fish, shore birds.
- Reproduction – most are hermaphrodites (has both male and female sex organs) – but must be fertilized by neighbor. A retractable tube containing sperm reaches outside the shell as far as several inches to another barnacle. Fertilized eggs develop and hatch within

the recipient barnacle's shell, where the larvae are brooded for a short time before their release. After a series of metamorphoses and molts in the plankton, the larvae settle down, attach onto a surface and grow into an adult.

- Life cycle: egg – larvae stages – adult.



Illustrations from "The Seaside Naturalist"

Local Species

- Acorn Barnacles (*Chthamalus dalli*, *Balanus glandula*, *Balanus nubulis*, etc.): There are at least 30 species of barnacles commonly called "acorn barnacles". "Acorn barnacle" is a vernacular name referring to stalkless barnacles (e.g. not a "leaf" or "gooseneck" barnacle). *C. dalli* is smaller than *B.glandula*, and can occupy higher intertidal positions than any other acorn barnacle, spending more than half their lives out of water (some living only where they are wet by splash). *B. glandula* almost equals *C. dalli* in resistance to desiccation and is found virtually as high and mixed together with *C. dalli*. Generally, where *C. dalli* and *B. glandula* both occur, the *glandula* will predominate pushing adjacent *dalli* from rocks; however, *B. glandula* is preferred by predators (whelks and the star *Pisaster ochraceus*) to *C. dalli*, and this predation makes more space for *C. dalli*. *B. nubulis*, the giant acorn barnacle, is the largest acorn barnacle, up to 110 mm in diameter; found in low intertidal. *B. nubulis* has the longest individual muscle fibers known to science and which have been used in the study of muscles.

- Leaf (or Gooseneck) Barnacle (*Pollicipes polymerus*):*P. Polymerus* occurs in wave impact areas; often mixed with mussels. Stalk ("peduncle") thick and leathery, covered with small calcareous spines ("spicules"). Capitulum covered with more than 5 plates. Feeds by directing its cirral net into currents, usually the backwash of waves. Small particles of detritus and tiny crustaceans get caught in the cirri. Predators of *P. polymerus* include the ochre sea star (*Pisaster ochraceus*) and the Glaucous-winged Gull (*Larus glaucescens*). *P. polymerus* directly competes with the California mussel (*Mytilus californianus*) and can often out-compete them, but they are more vulnerable to predation by gulls. *P. polymerus*

often grows in tight bunches (rosettes) which make them more resistant to predation. Reproduction occurs in the summer. This is a hermaphroditic species, probably requiring cross fertilization. An individual may produce 3–7 broods a year, with 100,000–240,000 larvae per brood, depending on size and age. Fully grown individuals may be 20 years old.

- Thatched Barnacles (*Semibalanus cariosus*) This is the only species at Duxbury that has the strong thatchlike external appearance created by numerous rows of longitudinal tube-like ribs; whitish grey; to 60 mm in diameter. Mid and low intertidal, usually in fissures or other protected areas around which there is much current or wave action. May live 10–15 years.

Amphipod

- Common among debris washed ashore, strong jumpers (recoil action).
- Body shape is laterally (side to side) compressed.
- Food – scavengers.
- Predators – fish, anemones, small shore birds.
- Reproduction – brooders

Local Species

- Beach Hoppers (*Megalorchestia californiana*) live on the sandy beach, often hiding within the high tide wrack of decaying seaweed or in burrows during the day. Beige or gray in color, can grow up to 2.5 cm long, have two long antennae colored pinkish or orange at the base. They mate in burrows in June–September. Females carry dark blue eggs, male fertilizes, and then she broods them under her thorax until they hatch. Predators include shorebirds, beetles and racoons.


Beach Hopper

DOCENT TIP:
You will find smaller amphipods of a variety of species taking refuge under macroalgae and perhaps swimming in tidepools. They feed on detritus and are an important food source for species like tidepool sculpin and shorebirds.

Isopods

- Flattened top to bottom (dorsoventral).
- Dull color.
- 2 compound eyes.
- Crawling legs attached to thorax.
- Legs very much alike; usually 14 legged; no claws.
- Pleopods on abdomen act as gills.
- Most are bottom dwellers – under rocks or algae.
- Can crawl or swim.
- Food – mostly scavengers or omnivores.
- Predators include fish, anemones, birds, worms.

- Reproduction – Dioecious (sexes separate).
- Females have brood pouches on bellies where eggs hatch.
- Food source for fish, crabs, shorebirds.

Local Species

- Rock louse (*Ligia pallasii*): Live high in the intertidal zone, but must stay damp to breathe with their gills. Hide under rocks to stay moist.
- Rockweed isopod (*Pentidotea wosnesenskii*)

Hermit crabs (not "true crabs")

- Long soft abdomen (vulnerable to predators) is hidden in empty shell.
- Out of the shell, it looks like a lobster.
- 1st pair of legs has claws.
- 2nd and 3rd pair of legs for walking.
- 4th and 5th pair of legs helps keep the hermit crab in its shell.
- All right handed – larger claw – used for feeding.
- While looking for food, the hermit crab is always looking for a new shell. It must change shells as it grows.
- Food – mostly scavengers, feeding on dead animals or detritus. Can filter feed plankton.
- Predators – anemones and birds.
- Reproduction –females have abdominal appendages (pleopods) for brooding eggs.
- Male will grab female with small claw and hold on to her until she is ready to mate. This way the male can use large claw to eat or protect himself in the meantime.

Local Species

- Blue Tipped Hermit Crab (*Pagurus samuelis*): Bright blue tips on its walking legs and pale blue pincer tips. The dactyls (i.e. movable "finger" on each claw) of juveniles are banded white instead of blue. Adults inactive during the day; activity picks up in late afternoon through the night until dawn. Females bear eggs from February to August. Male grips female by the edge of her shell and may carry her about for a day or more, pausing periodically to knock his shell repeatedly against hers. Mating itself, for which the animal must extend mostly out of their shells, lasts less than a second. Shell selection appears not to be learned, as animals with no prior experience exhibit the same preference for the shells of *T. funebralis* as seen in experienced crabs. Will not attempt to take shells still occupied by *T.funebralis*. Will be found in shells that it can completely retract into.

- Grainy Hermit Crab (*Pagurus granosimanus*): Most common intertidal hermit crab at Duxbury, is most easily distinguished by the light blue (white–bluish) raised dots on the chelipeds and walking legs. Active mainly in the afternoon and night. Will be found in shells that it can completely retract into.

- Hairy Hermit Crab (*Pagurus hirsutiusculus*): The legs are greenish brown with many prominent "hairs" (setae); legs 2 and 3 have white or bluish bands at the articulation points. Unlike *P. granosimanus* and *P. samuelis*, *P. hirsutiusculus* favors small shells which they cannot completely retract into.

COMMON TRAITS to all 3 hermit crab species at Duxbury – the setae on the antennules are thought to contain chemoreceptors. Opportunistic feeders, diet includes algae, mostly dead and sometimes live (e.g. whelk hatchlings) animal matter. Will steal shells from other hermit crabs but will not attempt to take a shell still occupied by the snail. Predators include sculpins, black prickleback.

Crabs

- 'True crabs'
- Folded abdomen, bodies tend to be flat.
- Decapods – 10 legs – 4 pairs walking legs, 2 with claws; move sideways.
- Uses "scare" displays.
- 2 feeding appendages – fit like doors over mouth.
- Food – mostly scavengers, but will eat live prey (some are herbivores).
- Predators – rock fish, sea otter.
- Reproduction – dioecious (sexes separate).
- Females have wide abdomen (for egg brooding), males have pencil shaped flap.
- Female stores sperm until her eggs are ready to be released. Then the sperm flows over them and fertilizes them. Eggs attach in a big mass to female's abdomen, where they are brooded until hatched.
- Life cycle: egg – larvae stages – molts – adults.

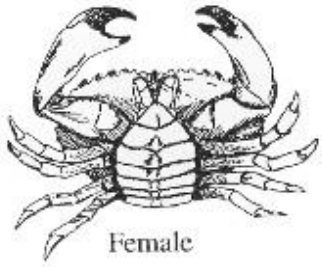
Local Species

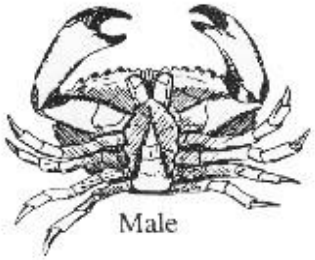
- Lined Shore Crab (*Pachygrapsus crassipes*): Brown/purple or black carapace with green stripes. Its carapace is squarish; eyes almost at corners. Spends about ½ of its time out of water, submerges periodically to wet its gills. Eats minute algae and diatoms, scraped from surface with chelae (a dense "pad" on the ventral side of the claw which is used to scrape the surface). Some large algae are also eaten, especially *Ulva*, *Fucus* and *Endocladia*. Also eat dead animal matter and occasionally limpets, hermit crabs and isopods. Can survive up to 3 days out of the water, retaining water in gill chambers. Are aggressive toward one another. Do not defend feeding territory from each other, but they may defend a food item or a crevice refuge. Mating occurs when the female molts, while she is still soft-shelled. Courtship dance precedes the act, after which the male rolls over on his back and the female walks above him. Females carry their eggs, up to 50,000, attached to underside of telson (tail). Reproduce February to October, peak in June and July. Takes at least 3 years to reach full size; this involves 21 molts for females, 18 for males.

- Kelp (Shield) Crab (*Pugettia producta, P. richii* & *P.* gracilis): The carapace looks like an old-fashioned 5-pointed police badge. Dorsal side of *P. producta*'s carpace is smooth, but has tubercles (i.e. is bumpy) on *richii* and *gracilis*. Claw tips on *richii* are white; blue or

orange on *gracilis*. Will use the sharp teeth on their carapace to "decorate" themselves, attaching algae, and bryozoans, which are sometimes later eaten. Predators include clingfish and sculpin. Mainly herbivores, however, feeding preferences can depend on season: in summer months when algae is abundant, they eat algae nearly exclusively; in winter they are more carnivorous, eating small mussels, barnacles, bryozoans, and hydroids. Their many jointed walking legs help them climb on kelp.

- Pacific Rock Crab (*Cancer antennarium*): Scavenger and predator of hermit crabs & snails (*Tegula*). Cannot osmo-regulate and, therefore, cannot tolerate brackish conditions. Captures hermit crabs by walking over them and sitting on them, or may flick them under the body using their walking legs. Inserts fingers of both pincers into the shell containing the hermit crab and chips away around the aperture until the hermit cannot retreat further. Carpace is oval, with eleven teeth from eye socket to side. The dorsal coloration is usually a deep mottled red or brown, although this can vary to shades of orange or gray. The ventral side is white, with characteristic red spotting, especially on anterior end of ventral side. The claws are black-tipped, and the walking legs are almost always hairy. The latter trait is more common in females. As with all members of the *Cancer* genus, males have a slenderer, pointed abdomen than do the females. Females carry eggs usually from November to January (a few can be found at other times). Sexual maturity attained in 2 years.

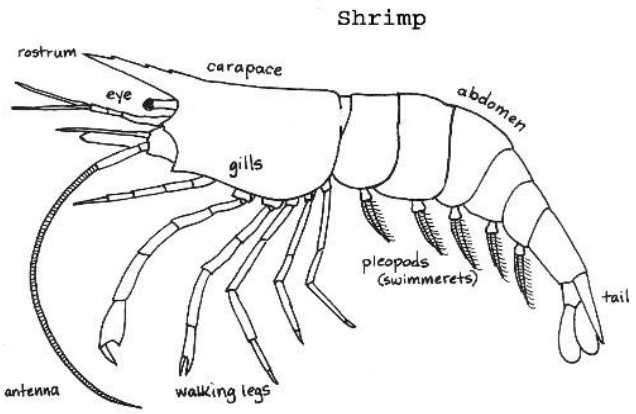

Female


Male

DOCENT TIP:
C. antennarius' close cousin is the Dungeness crab (*Cancer magister*). *C. magister's* claws are white-tipped. They are not found live in the intertidal at Duxbury.

Shrimp

- Thin exoskeleton; well-developed carapace.
- Swim using abdominal pleopods.
- Gills are where legs attach to body, hidden near carapace.
- Special appendages near mouth that beat to create water current over gills.
- Rostrum – long spine extending from front of carapace.
- 5 pairs of legs (for walking).



- First pair of legs usually has claws – used to obtain food or in defense.
- Food – some are carnivorous, some eat plankton and detritus.
- Predators – anemones, fish.
- Reproduction – egg brooders.

Local Species

- Broken-back Shrimp, aka Red-banded Transparent Shrimp or Coastal Shrimp (*Heptacarpus pictus, H. brevirostris* and *H. littoralis*): The species of this genus are the most common intertidal shrimps along the US Pacific coast. *Heptacarpus* characteristically bend their tails under and forward when swimming, thus darting backwards. Color is highly variable as is body-color patterns. The variable colors in this shrimp are mainly due to colors in the tissues rather than in the exoskeleton. Nearly all of the transparent shrimp found in rocky pools will be *H. pictus. H. pictus* is a transparent shrimp, with a pale-green form banded with red. Females mate and brood eggs more than once, molting between broods. Mating takes place rapidly, shortly after the female molts. Males attach packets of sperm to the ventral surface of the newly molted female near the oviducal apertures.

> DOCENT TIP:
> *H. pictus* are found more easily at night with a head lamp, their eyes reflecting back points of light. There is no quick/easy way of identifying the various species of *Heptacarpus*. Species which are not transparent are usually in the lower tide pools.

**This is an example of common English species names being imprecisely applied.*

Part 16. Phylum: *Echinodermata* (Sea Stars and Urchins)

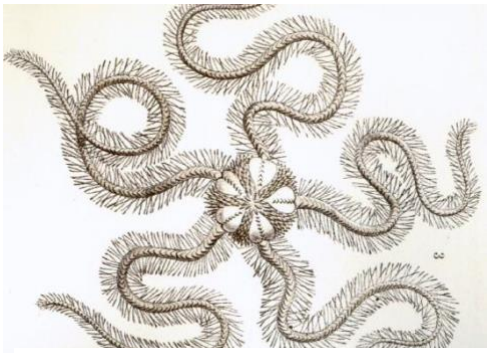
Description

- "Spiny-skinned" animals.
- About 6,000 species.

Types

- Class *Asteroidia* – sea stars
- Class *Echinoidea* – sea urchins
- Class *Ophiuroidea* – brittle stars
- Class *Holothuroidea* – sea cucumbers
- Class *Crinoidea* – feather stars (not found on Duxbury)

Anatomy



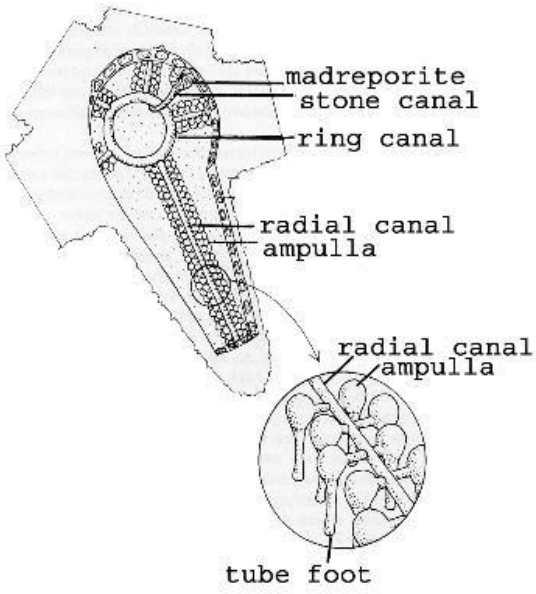
Brittle Star; *Image by Ernst Haekel: Kunstformen der Natur (1904)*

- Adults have radial symmetry (typically pentaradial – of 5 similar parts).
- Complete digestive tract (separate mouth and anus).
- Respiratory exchange thru the body surface.
- No circulatory system.
- No brain.
- Net of nerves that run throughout body.
- Skin contains thousands of neurosensory cells.
- Pedicellariae – tiny pincer like structures that keep its surface clean (some stars don't have these structures such as the leather star, bat star, and blood star).
- Internal calcareous skeleton with spines covered with skin.
- Sea stars – flexible skeleton consists of multiple small plates that move with one another
- Sea urchin – fused skeleton plates – rigid shell – empty shell is called a 'test'.
- Water vascular system – unique internal plumbing system that control tube feet. Hydraulic network of water filled canals that run throughout body, ending with muscular extensions called tube feet. By varying internal water pressure, can extend or contract tube feet.
- Tube feet used for locomotion, food collection, sensory functions and respiration.
- Tube feet have small suction cups at end.
- Madreporite – water intake hole on aboral surface that feeds the water vascular system.
- Mouth is underneath (on oral side).
- Aboral side faces up (with anal pores).
- Some have duo-glands. These 2 separate glands are paired but have different jobs. They are sometimes located on the tube feet, and sometimes on the epidermis between the tube feet. The 'adhesor' gland releases adhesive to allow the organism to stick to the substrate, and the 'releaser' gland secretes an enzyme that dissolves the adhesive. This is how an

ochre sea star 'sticks' to the rocks. It was previously thought that the suction from the tube feet caused this, but that is not the case. Tube feet are used for positioning or movement, the duo-glands allow sticking or releasing from the substrate.

- Reproduction – Most reproduce sexually; some asexually.
- Egg and sperm released into water, eggs externally fertilized.
- Some brood eggs.
- Egg – planktonic larval stages (bilateral) – adult.
- Most can regenerate lost body parts (including rays and tube feet).

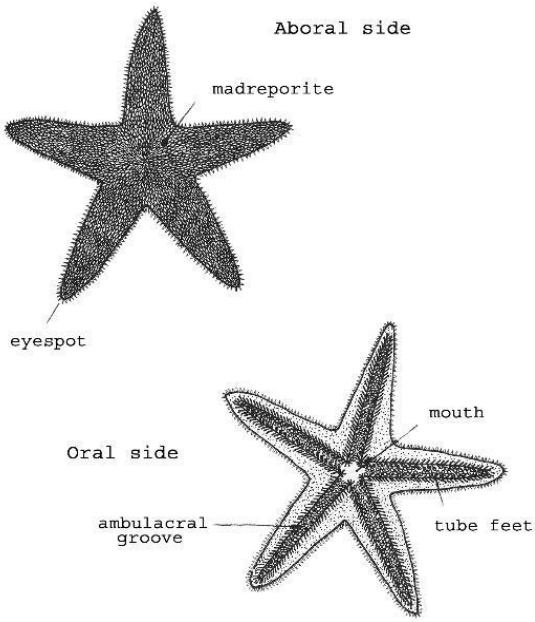
Water Vascular System



DOCENT TIP:
Explaining how the ochre stars hold on to the substrata makes a good illustration of why visitors should not pick creatures up. When a star is picked up from the substrata, the chemical bond formed by the star with the substrata is involuntarily broken and the tube feet are ripped off.

Although the tube feet will eventually regenerate, that will not happen before the next high tide. If enough tube feet are lost by picking the star up, the star will be unable to withstand wave & current forces, tumble around and probably die. Of course, not putting the organism back exactly where it was found also compounds that problem.

Class *Asteroidia* (Sea Stars)



Description

- Most have 5 arms radiating from a central disk.
- Have internal organs in both central disc and arms.
- 2 or 4 rows with hundreds of podia – tube feet (clear thread-like appendages ending in suckers) that protrude from the oral surface, radiating along the ambulacral groves (channels) on each arm.
- Move by reaching out their tube feet and pulling themselves along.
- Flexible skeleton.
- Some sea stars have pedicellaria (a minute claw-shaped appendage used for defense or keeping the body surface clean).
- Small pigment eye spot at end of each arm – sensitive to light.
- Mouth and tube feet on oral surface.
- Skin has clumps of oxygen-absorbing tissue (skin gills). Pedicellariae keep the skin breathing by keeping it free and clean from larvae attaching to it.
- 2 stomachs – most sea stars feed by everting their stomach through their mouths and into the shell of prey. They use their tube feet to pull at the 2 halves of the shells, opening it just a little once the animal tires. The sea star then secrets digestive enzymes into the shell of the prey absorbing the digested animal and returning its stomach back into its own body.

Sunflower Star

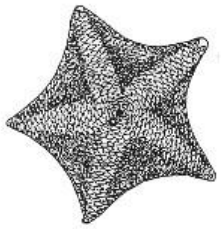
- All are predators, scavengers, carnivores.
- Food – bivalves, snails, barnacles, other 'attached' or slow-moving animals.
- Predators – human collectors, sea stars, birds.
- Reproduction – broadcast spawners.
- Life cycle: egg – planktonic larval stages – adult.
- Breeding season – spring and summer.
- Can regenerate rays and a portion of the central disk, along with tube feet.

Local Species

- Ochre sea star (*Pisaster ochraceus*): Individuals usually have 5 arms but this can vary from 4 to 7. Aboral surfaces have many small white spines (pedicallarae) arranged in detached groups or in a reticulate pattern, generally forming a star-shaped design on central part of disk. Tube feet on the undersides of arms have discs that allow them to remain attached to rock in high wave energy shore by creating a chemical bond (glue-like) with substrata. No sexual dimorphism. Broadcast spawners. Can live as long as 20 years. Can evert its stomach through its mouth and engulf its prey, liquify it with digestive enzymes and ingest the processed food. The *Pisaster ochraceus* can feed on a mussel when it opens its valves (shells) to feed and breathe. *P. ochraceus* can insert part of its everted stomach through

the narrow gap. Once the stomach is inside the mussel, digestion takes place. It is thought one sea star can consume eighty California mussels in a year.

- Bat Star (*Patiria miniate*): Arms short and triangular, usually 5 in number, sometimes 4 to 9. Arm radius (to center of disk) up to 10 cm. Web-rayed with concave margins facing center of disk. No pedicellariae. Color extremely variable, most commonly red or bright orange, coloration may be solid or mottled. Can be found in low intertidal usually among rocks with overgrown surfgrass. An omnivore and a scavenger, feeds by extending its stomach over a large variety of plants and animals, dead or alive. Occasionally eats other sea stars.


Bat Star

- Blood Star (*Henricia leviuscula*): Disk small; arms long, slender, tapering, usually 5 in number. Pedicellariae absent. Aboral surface orange-red, tan or purple, often banded with darker shades. Feeds on bacteria and other tiny particles which are captured in its mucus and swept into the mouth by ciliated tracts. May also feed by applying its stomach to the surfaces of sponges and bryozoa. Found on the protected sides of rocks, under rocks and in caves and pools, most frequently where rock is encrusted with sponge or bryozoa.

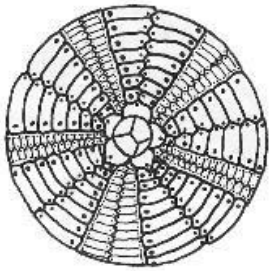
- Six Rayed Star (*Leptasterias spp.*): Two species possible, *L. pusilla* and *L. hexactis*. Very small star; female broods eggs for over a month in the winter, and doesn't eat during this time. Brooding female carries eggs in the region of the mouth, below the central disk, and cannot flatten herself against the substrata. In that humped-up position she is anchored only by tube feet at the outer parts of her arms and if dislodged by a wave (or a human), will lose her eggs. The presence of the brooding egg mass blocks the mother's mouth, and thus the females do not feed while brooding, even if food is immediately available. Carnivore which preys on littorine snails, limpets, chitons, barnacles, small mussels, alive or dead. Middle to low intertidal where exposed to surf.

> DOCENT TIP:
> *H.leviusula* and *Leptasteroas hexactis* have recently started coming back on Duxbury. Be watchful of visitors trying to pick them up thinking they are "baby" sea stars.

- Sunflower Star (*Pycnopodia helianthoides*) – not seen in Marin County; wiped out by star wasting disease, small population may be recovering but uncertain and likely not at Duxbury. In the past they were numerous at e.g. Salt Point.

Class *Echinoidea* (Sea Urchins)

Description



- Skeleton forms a round rigid "test" with movable spines (on ball and socket joints) and pedicellariae.
- Locomotion by moveable spines or tube feet.
- Spines used for defense and trapping seaweed.
- 10 sections of test – 5 sections are pierced with holes through which the tube feet protrude (called ambulacral plates). Other 5 sections are without holes and are called interambulacral plates.
- Mouth on bottom, anus on top.
- Aristotle's lantern – 5 piece jaw – used to bite off algae. As teeth wear down, they continue to grow. Teeth function as a unit. Can be extended from and pulled back into the mouth.
- They burrow into rocks by continued scraping of their spines against the rocks. Many eventually become entombed, having grown too large to exit through the opening first created.
- Mostly herbivores and sediment feeders. They snag pieces of algae as it drifts by.
- Food – graze on seaweeds and sea grasses
- Predators – sea stars, otters, crabs, fish, people, birds.
- Reproduction – broadcast spawners.
- Life cycle: egg – planktonic larval stages – adult.
- Breeding season – winter and spring.
- Can regenerate tube feet and pedicellariae.

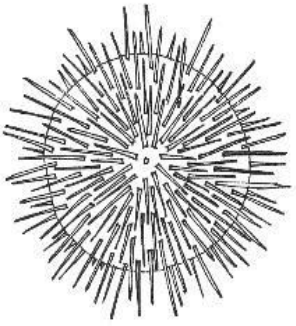
Local Species

- Purple Sea Urchin (*Strongylocentrotus purpuratus*): Commonly inhabit rounded burrows or depressions in the rock, which they may enlarge with their teeth and perhaps spines as they grow. Diameter of test usually about 5 cm, can be up to 10 cm. Broken spines are regenerated. Teeth grow out at a rate that they are completely replaced in about 75 days. Use tube feet to cling to substratum. Tube feet also used to attach algae and shell bits to the aboral surface. Become sexually mature during 2nd year. Most spawning occurs in January to March. Sexes are usually separate but hermaphrodites occasionally occur. Low intertidal, typically in areas at Duxbury where there is moderate to strong wave action. Can live to be older than 30 years. Food: variety of red and brown algae; however the kelp *Macrocystis* is first choice. Predators are sea stars (esp. sunflower stars, occasionally ochre and leather stars), California sheepshead fish, and sea otters.

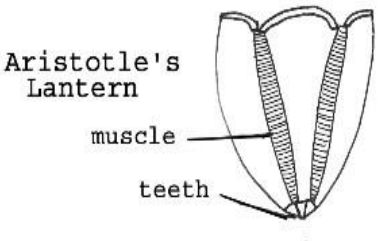
DOCENT TIP:
Some people are under the misunderstanding that removing purple urchins from the reef is a restorative practice to save the kelp. However, docents should explain that marine life on Duxbury Reef is protected. Purple urchins must remain undisturbed on the reef. Qualified urchin removal programs are occurring elsewhere on the coast in kelp bed areas under managed restoration programs.

- Red Sea Urchin (*Strongylocentrotus franciscanus*): Largest urchin in the Pacific Northwest. Test often more than 10 cm in diameter, with spines to 5 cm or more in length. Color usually red, red-brown. Feed primarily on kelp (especially *Nereocystis* or *Macrocystis*) but can eat sessile invertebrates. Often forms large subtidal aggregations in or near kelp beds. Young urchins often are found under larger individuals. A prime food for sea otters. Other predators include the sunflower star (*Pycnopodia helianthoides*), leather star (*Dermasterias imbricata*), red rock crab (*Cancer productus*), spiny lobster (*Panulirus interruptus*) and sheephead fish (in S. California), and humans. They are uncommon at Duxbury; in very low intertidal zone; most likely to see dead as a test cast ashore.

DOCENT TIP:
Fun fact that illustrates the impact by fisheries removing the large, more mature members from the general population of a species – Adult *S. franciscanus* urchins release a chemical cue that causes the young to aggregate underneath them when the adults detect the presence of sunflower stars (*Pycnopodia helianthoides*). These urchins live over 100 years, and some found near Vancouver Island that may be 200 years old. They seem to reproduce best when in dense aggregations. Aggregations from which smaller individuals have been harvested recover much faster than those from which larger individuals have been removed by harvest, indicating the loss of protective function by the older urchins impact recovery rates of the population after fishing.



Purple Sea Urchin



Class *Ophiuroidea* (Brittle Stars)

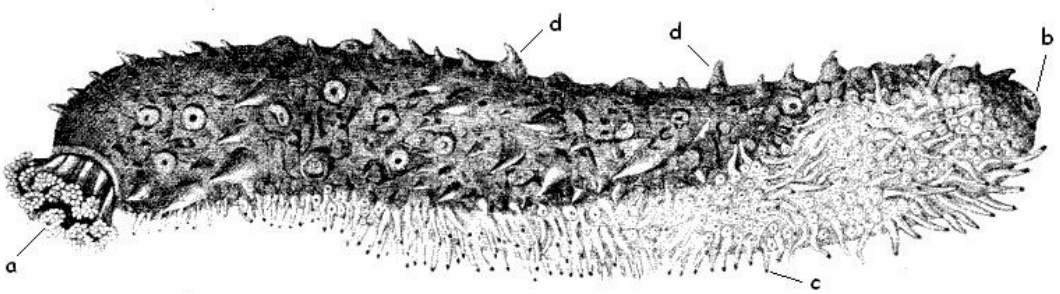
Description

- Unlike true sea stars, brittle stars do not have organs in their arms.
- Brittle stars use their thin arms to crawl along the sea floor.
- Use tube feet to catch tiny food particles and pass them to mouth.
- Food – detritus, plankton
- Predators – fish, crabs, hermit crabs, seastars.
- Reproduction – broadcast spawners and can reproduce asexually.
- In the intertidal, they're often hiding in small crevices or under rocks, with only their arms reaching out.
- *Rarely seen in Marin intertidal. Rarely seen at Duxbury.*

Species

- Long-armed Brittle Star (*Amphiodia occidentalis*): They contain a flat disc body which can measure up to 11 mm in diameter that contains their organs. Five long, segmented arms at least eight times the diameter of the disc extend from the body which are covered in flattened spines. They have tube feet but move using bilaterally symmetrical locomotion to crawl, with the center limb toward the direction of movement. They eat mainly detritus on the seafloor, but can use their tube feet to catch particles. Broadcast spawners in winter and spring.

Class *Holothuroidea* (Sea Cucumbers)



a) tube feet of mouth (for feeding), b) cloaca (containing anus and respiratory tree), c) walking tube feed, d) sensory papillae

Image courtesy of Wikipedia Commons

Description

- Sea cucumbers maintain the typical echinoderm pentaradial (5part-radial) symmetry. However, they are elongated and lay on one side, so that the mouth faces one way and the anus the other (unlike a sea urchin or sea star with the mouth on the bottom).
- Skeleton is reduced to microscopic ossicles, so they are softer than a star or urchin and can change shape more readily and squeeze into tight places.
- Most are benthic, but a few are pelagic.
- Have a respiratory tree (gill-like structure) inside their anus (or, in some cases, protruding). Gas exchange occurs by pulling water in and out of their anus.
- Some only have tube feet protruding from 3 bottom ambulacral grooves (the two grooves on the top may have vestigial or no tube feet), which makes them somewhat asymmetrical.
- Food – typically deposit feeders on detritus.
- Predators – crabs, fish.
- Reproduction – broadcast spawner.

Local Species

- Dwarf Sea Cucumber (*Lissothuria nutriens*): 1.5–2 cm long, scarlet dorsal surface or bright orange–red; ventral side pale pink, flattened; distinct feathery oral tentacles. In low intertidal on vertical rock faces and in sandy deposits among algal holdfasts, seagrass roots, sponges. At Duxbury, but quite uncommon.

Part 17. Phylum: *Chordata* (Tunicates, Fish, Marine Mammals, Birds)

Description

- With stiffening rod or backbone.
- About 49,000 species.

Two groups

- Urochordates – invertebrate (lack backbone) – example tunicates.
- Vertebrates – have backbone – example fish (sharks, rays), birds, mammals, amphibians, and reptiles.

Anatomy

- To be classified in this phylum, an animal needs to display the following traits during at least one stage in its development.
- A single, hollow nerve cord that runs along the dorsal length of the animal (spinal cord or dorsal nerve cord).
- Pharyngeal slits (openings to the embryonic digestive tube).
- A notochord – flexible rod for support that lies between the nerve cord and the gut. (Sometimes surrounded or replaced by series of articulating bone – backbone).
- Bilaterally symmetrical.
- Ventral heart.
- A tail some time during larval stage or embryo.
- Complete digestive tract (separate mouth and anus).
- Closed circulatory system (blood remains in vessels).
- Respiratory exchange thru gills or lungs.
- All major organ systems are present and very well developed.
- Remarkable locomotive abilities, with muscles that work against an internal skeleton.

Urochordates (invertebrates)

Subphylum: *Urocordata* (Tunicates)

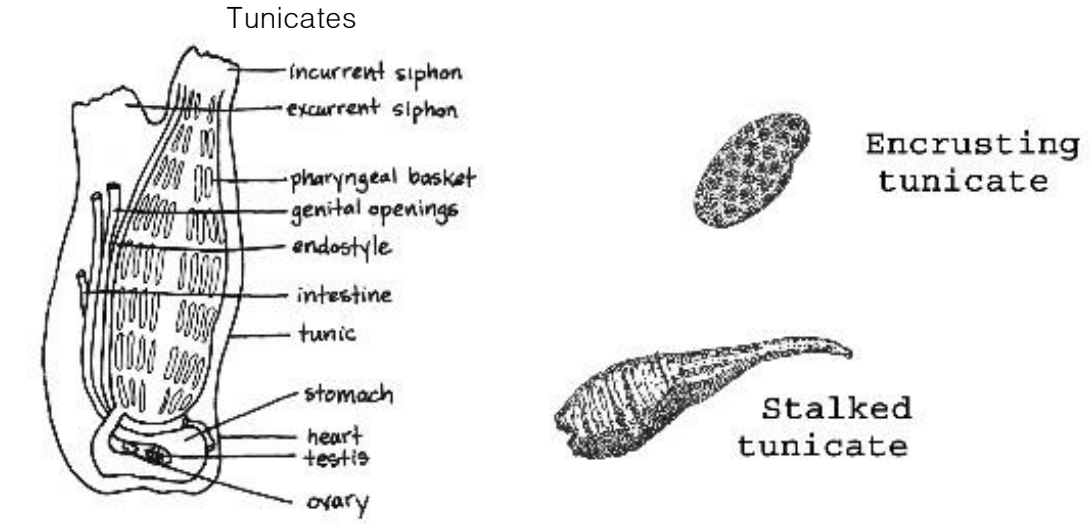


Illustration from "Exploring Tidepools"

Description

- About 1,400 marine species.
- Nicknamed "sea squirts" because when disturbed or expelling debris, it will force a jet of water from both siphons.
- Only sessile (attached) chordates.
- Saclike bodies attached or anchored in soft sediments.
- Body is protected by a tunic (a leathery or gelatinous outer covering), that provides support and protects the animal inside.
- Many species solitary; others live in simple colonies where individuals united by a chord of tissue called a "stolen."
- As larvae, resemble tadpoles and have all 3 characteristics mentioned previously under general anatomy for Phylum Chordata. It then attaches to a hard substrate with adhesive organs and reabsorbs the tail, notochord and nerve cord and changes into blob-like creature.
- Food – filter feeders. Cilia on pharynx beat to create a current. Water is sucked in through the incurrent siphon and is filtered thru the pharynx, which is coated with mucus.
- At the side of the pharynx, the endostyle rolls the sheet of mucus with food particles in it and sends it to the esophagus and stomach. Water is then passed thru the gill clefts, where oxygen is extracted, and finally exits thru the excurrent siphon.
- Food includes plankton and detritus filtered from water.
- Predators – skates, bottom dwelling fish and nudibranchs.
- Reproduction – all hermaphrodites. Both male and female sex organs are found in the tunicate, but self-fertilization does not occur.
- Breeding season – spring.
- Life cycle: larvae – metamorphosis – adult.

Local Species

- Sea Pork (*Amaroucium californicum*): Found in the lowest intertidal zone at Duxbury. Will probably be most commonly seen at Duxbury detached from substrata and deposited on the sand at the lines left by the retreating high tides. Looks a little bit like an alien organ, or a blob of rubbery industrial waste.
- Lightbulb Tunicate *(Clavelina huntsmanii)*: This social tunicate (individual zooids are attached to one another) has individual, flattened zooids which are much taller (usually 2.5cm sometimes up to 5cm) than wide (1 cm). The tunic is clear or translucent. The pharynx is not pigmented as a whole, but there are two distinct pink lines like the filaments of a light bulb up the sides of the zooid. Individual zooids form clusters up to 50 cm across.

DOCENT TIP:
The pink lines are usually visible only on very close examination – i.e. get down close to it. The margins of the atrial and oral apertures are not lobed. At Duxbury will usually be seen hanging from the landward underside of ledges in the low intertidal.

Vertebrate Chordates

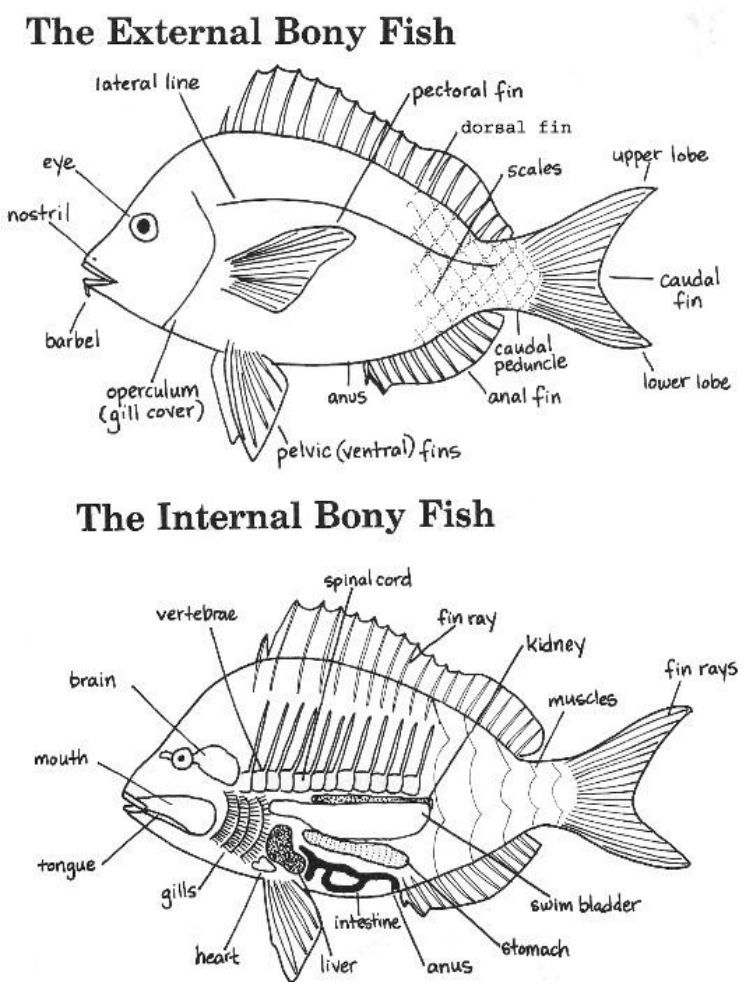
Description

- Bilaterally symmetrical.
- Backbone (vertebral column or spine) that encloses the nerve cord.
- Vertebrae enclosed and protect the nerve cord (spinal cord) which enables a complex brain and sensory structures.
- Presence of an endoskeleton.

Class: *Osteichthyes* (Bony Fishes – Cod, Tuna, etc.)

Description

- Skeleton made up (at least partially) of bone.
- Thin, flexible, overlapping scales that develop from bone.
- Scales covered by thin layer of tissue and protective mucus.
- Gill cover – a flap of bony plates and tissue protecting the gills.
- Upper and lower lobes of tail (caudal fin) are almost always same size.
- Fins consist of thin membranes that are supported by bony spines (fin rays); give fish mobility, stability, and maneuverability.
- Mouth at front of head.
- Teeth fused to jawbones.
- Barbel – used in tasting and feeding
- lateral line – made up of sensory cells that detect disturbances in the water.
- Air or swim bladder – gas filled sac above stomach and intestines which allow the fish (by inflating or deflating it) to adjust buoyancy to keep from sinking or rising (maintain neutral buoyancy).
- Fish breathe by taking water in thru their mouths. As they close their mouth, water is forced over their gills and out the operculum. Blood circulates thru the fine filaments in the gills, and hemoglobin in the blood absorbs the dissolved oxygen in the water. Water exiting from the gills contains 80% less oxygen then when entering.



Illustrations from "The Seaside Naturalist"

- Some fish have gill-rakers – screen-like structure over the gills that filter food and debris from water as it passes of the gills.
- Fish swim by flexing streamlined bodies – waves of contractions travel down successive muscle segments along the fish. These waves push the water backward, causing the fish to move forward.
- Ectothermic – regulate body temperature only by moving to warmer or colder waters.
- Food – algae, various prey.
- Predators – fish, crabs and other crustaceans, plankton, worms, mollusks.
- Reproduction – spawn gametes, some broadcast, some brood. Young hatch from eggs.
- Most reproduce thru external fertilization where egg and sperm are released in water near each other.
- Life cycle: egg – larvae in eggs – larvae – fry (young fish) – adult.

Local Species

- Tidepool sculpin (*Oligocottus maculosus*): Because oxygen content in the tide pools can be low, the sculpin can gulp air and force it into its bloodstream by compressing it with its operculum. There are 300 species of sculpins. Sculpins tend to be small, rarely growing at Duxbury over 10 cm (4 in.) in length, with compressed bodies, large fanlike fins, and an array of spines along their dorsal fins. Many sculpins carry toxins in their spines, and should therefore not be handled to prevent discomfort. Although the toxin found in sculpin spines is rarely fatal, it can cause skin irritation, sweating, nausea, or dizziness.
- Wooly sculpin (*Clinocottus analis*): Lighter in color than *O. maculosus*, without dark vertical stripes. Can breathe air and has been known to survive out of water for up to 24 hours. The diet includes mainly crustaceans, especially amphipods, as well as fish eggs and larvae, polychaetes, and mollusks. Most of its food items are light-colored or clear, suggesting that these are easiest for the fish to see against the dark background of its habitat.

> DOCENT TIP:
> Because oxygen content in the tide pools can be low, the sculpin can gulp air and force it into its bloodstream by compressing it with its operculum.

- Prickleback – Black Prickleback (*Xiphister atropurpureus*) & Monkeyface Prickleback or Monkeyface Eel (*Cebidichthys violaceus*): Sometimes called "blennies"; Blennies belong to 3 different families, but those found at Duxbury only belong to the family *Stichaeidae* (pricklebacks). Pricklebacks are mostly herbivores. Seldom travel more than 15 feet from their home. Predators are herons and egrets. *X. atropurpureus* when young are greenish black and black as adults. Up to 30 cm (12 inches) long. Lives in mid and low intertidal in the under-rock habitat, frequently in places that are merely damp or have very shallow pools when the tide is out. May remain out of water under rocks or seaweed. Breathe air and can stay out of water for 10-23 hours if kept moist. Many specimens (not all) have 3 stripes radiating backward and upward from the eye to about to about the base of the pectoral fin (which appears as a minute flap). Many *C. violaceus* also have these stripes. Fertilization is internal. After mating, females deposit non-adhesive masses of 17,000 to 46,000 eggs

under boulders set on substrata of pebbles, small rocks and shells during the winter and spring. The eggs are tended and guarded by a male. The substratum and the overlaying boulder provide the channels and pockets that this fish prefers for a snug-fitting yet well-aerated living space.

DOCENT TIP:
Pricklebacks are not eels, but an eel-like bony fish, that visitors see and will report to you as "I saw an eel". They (esp. *C. violaceus*) are commonly sought by fishermen using poke poles during the lowest tides and are now much less frequently found then 10 years ago. Some people like the taste, others find the smell of it cooking to be like rotting kelp.

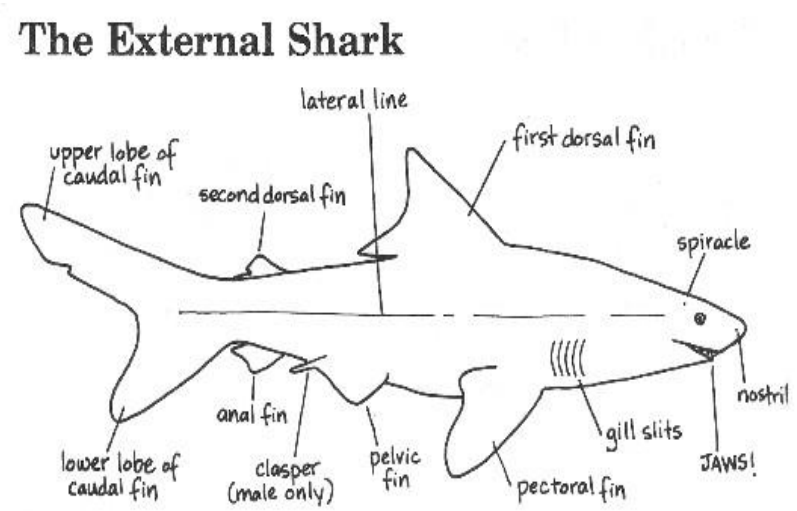
DOCENT TIP:
X. Atropurpureus provides an excellent example of why visitors should look with their eyes and not with their hands, not picking up or moving larger rock as they will cause the non-adhesive egg masses laid beneath them to be damaged or lost, injure the prickleback that has made that snug space its home or that is tending the egg mass, and cause the loss of that habitat which had the right balance of snugness and good aeration. Also, why stepping in shallow tide pools, particularly those with growths of larger algae or sea grass, is not a good practice as the prickleback hiding under those growths is killed.
C. violaceus when young are often a pale translucent olive, adults are grey with greenish, or greenish black, or light brownish. Up to 80 cm (2.5 feet) long. Lives in low tidal zone and subtidal zones close to the low tidal in under-rock, under-ledge habitat. Researchers are split on whether male, females or both tend the eggs once deposited.

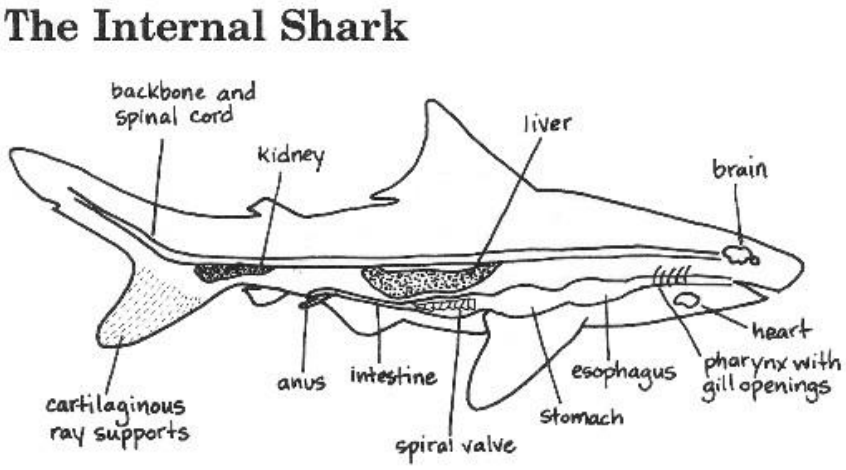
- Clingfish (*Gobiesox maeandricus*): Found in rocky intertidal zones, often in the presence of algae and kelp. A predatory species whose diet changes based on its size. The smaller Clingfish feeds on small crustaceans, isopods, and mollusks, the larger ones feed heavily on limpets attached to the surrounding rocks. The species has developed distinct morphologies that helps it obtain its food. The adhesive disk on the underside of the body is used to stabilize the fish when it finds its prey on nearby rocks. The mouth contains chisel-like teeth. It can stick with limpetlike tenacity to smooth rocks covered in algae or biofilms, however, it is more capable of sticking to rougher rocks and gravel substrates using the adhesive disk on its underside. This is a significant morphological feature as the fish have to withstand the rough waves in the intertidal zone. The adhesive disk allows the clingfish to remain in place even when the waves are pulling at a force many times larger than its own body weight. It also uses the rocks in its reproductive cycle, to make nests for its eggs. The intertidal zone makes the Clingfish susceptible to air exposure and desiccation. To survive low tide conditions, it has developed modified pectoral fins that help keep water close to the gills for respiration, even when not submerged in water. If exposed to air, the clingfish can breathe through its gills for a short period of time. They

reproduce in the spring, after the males have built nests out of rocks. Females deposit eggs and the males release their sperm and fertilize them. The males stay close to guard the eggs and soon after, many planktonic larvae hatch. They continue to develop in this planktonic state and soon are large enough to latch on to the kelp with their developing adhesive disk. They develop until they have reached their full size and are able to join the other adults in the rough, rocky intertidal area.

Class: *Chondrichthyes* (Cartilaginous fishes – sharks, rays, skates)

Description





- Have skeleton made of cartilage – lighter and more flexible than bone.
- Movable jaws, armed with well–developed teeth.
- 3 to 15 sets of replacement teeth arranged inside of jaw. They point downward, and turn up as they reach the outer edge of the mouth.
- Mouth ventral (underneath head).
- Small eyes with good vision.
- Acute sense of smell.
- Internal ear and lateral line detect impulses in water (like thrashing of sick fish).
- Ampullae of Lorenzini – sac–like pores in head sensitive to electrical impulses.
- Rough, sandpaper like skin – tiny scales same composition as teeth.
- No flap over gills (uncovered gills) – open to outside thru slits.
- Most have 5 slits per side, some have 7 slits.
- Most must keep swimming to keep breathing. Not able to pump water over their gills, so cannot hang motionless.
- Most torpedo shaped, streamlined.

- Powerful tail propels them thru the water – asymmetrical tail fin longer on top of fork.
- No rib cage to protect internal organs.
- No swim or air bladder. Large liver with low-density oil assists in buoyancy.
- Most are exothermic – body temp is controlled by moving to warmer or colder water.
- Food – mostly scavengers and carnivores.
- Predators – other sharks, seals, sea lions, humans.
- Reproduction – fertilization by copulation.
- Some lay eggs in leathery cases and babies hatch into water months later.
- Some retain fertilized eggs and babies emerge live after hatching inside.
- Clasper – on male only – clasping device used in reproduction – extends from pelvic fins. Male inserts this into female and the sperm passes along a groove in the clasper into the female.

> DOCENT TIP:
> You are unlikely to see a shark while tidepooling at Duxbury Reef unless it is dead on the beach. They are present in deeper water seaward of the intertidal area.

Class: *Mammalia*

Description

- Endothermic – regulate and maintain constant temperature.
- Hair on bodies.
- Skeletons of bone.
- Breath air into lungs.
- Bear live young. Internal fertilization, gestation and birth.
- Female possess milk producing mammary glands with which they feed their young.
- Includes marine mammals such whales, seals, and manatees.

Types

- Whales
- Sea otters
- River otters
- Pinnipeds
-

Whales

- Layer of blubber under skin insulates the whale and stores energy.
- Nose (blowhole) on top of head so it is exposed as soon as it surfaces.

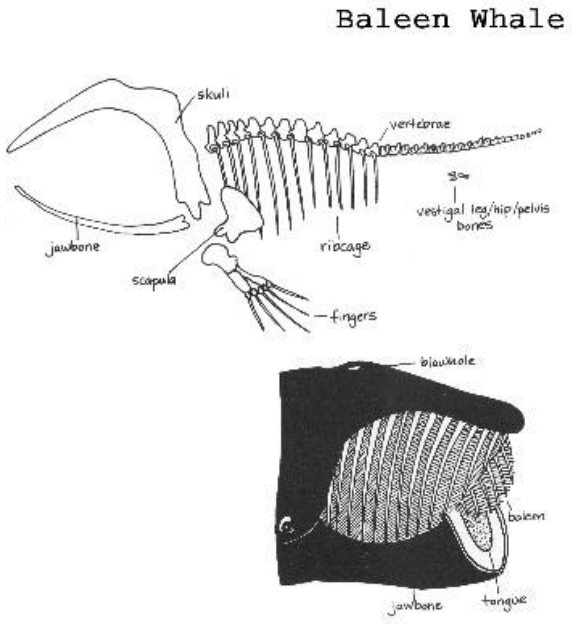
Two types of whales

Toothed whales – predators

- Examples: **sperm whale, pilot whale, orca**.
- Use teeth to capture prey and swallow whole
- **Food** – fish, squid, birds, mammals.
- **Predators** – other whales, humans.
- Massive accumulation of waxy tissue between top of head and upper jaws (melon). The sperm whale with its massive head (1/3 of their body length) was hunted for this wax-like oil (spermaceti) for lamp oil and candle wax.
- Beam sound waves thru water, can navigate thru a sonar-like process called
- Use echolocation.

Baleen whales

- Examples: **blue whale, humpback, gray whale**.
- Strain planktonic food out of water.
- Baleen – is a series of fringed flexible keratin plates that hang down from the whale's upper jaw.
- To feed – the whale opens his jaws, and water and food pour into its mouth. He closes the mouth partially, and forces water thru the baleen. Trapped food
- Inside the baleen is then wiped off with the tongue and swallowed whole.
- **Food** – krill, zooplankton, small fish.



Illustrations from "The Seaside Naturalist"

DOCENT TIP:
It is occasionally possible to see whales spouting offshore of Duxbury Reef, and unfortunately, occasionally, a dead whale may wash up on Agate Beach or the Reef. You may also see whale bones from previously washed up whales. If you observe a newly washed up whale, report it to the California Academy of Science and/or Point Reyes National Seashore.

Sea Otters

- Playful and intelligent.
- Size – to 5 ft and to 100 lbs.
- Usually live around kelp beds.
- Thick pelt – Once hunted to near extinction due to its thick pelt.
- Lacks layer of blubber. Insulation from the cold is provided by air trapped in its dense fur.
- Now protected, strong recovery of species.

- Normally seen floating on its back while eating.
- Food – shellfish, crabs, sea urchins, fishes.
- Predators – bald eagles, bears, whales.
- When the sea otter had almost been annihilated, sea urchins grew in such numbers that kelp forests could not generate. Now with otters returning south of San Francisco, the kelp forests are healthy and balanced once again.
- Vulnerable to oil spills. The waterproofing and insulating qualities of the fur are destroyed by oil.

River Otters

- Marine and freshwater streams, lakes, creeks, ponds and marshes.
- Smaller than sea otters.
- Longer and more rounded tail.
- Swims acrobatically.
- Food – fish, shellfish and prefers to eat on land rather than in the water.
- Predators – coyotes, bobcats, dogs, cougars, bears.
- Maintains a den on land near water, and temporary shelters.

> DOCENT TIP:
> Sea otters (*Enhydra lutris*) are currently not present in Marin County, north of San Mateo County. It is believed *E. lutris* populations have not recovered in this area from widespread hunting during the 19th century because of the shark population. If you observe one offshore, you can report it to the Marine Mammal Center or Point Reyes National Seashore.
>
> If you see an otter in Marin County, it is most likely a North American river otter (*Lontra Canadensis*), often mistaken for sea otters. There is a small fragile population of river otters swimming in the marine environment in Point Reyes National Seashore, which is best left alone. River otters have been seen resting at Duxbury or swimming not far offshore. However, those sightings have been rare as their presence is discouraged by both humans and dogs. You can report otter sightings to the River Otter Ecology Project's Otter Spotter Map.

Pinnipeds

- "Wing footed".
- Most live in cold water.
- Blubber – a thick layer of fat under their skin. Used as insulation, food reserve, and helps provide buoyancy.
- Have bristly hair for added protection against the cold.
- Comes up onto land or ice at breeding time.

Some Types

Seals

- To walk on land, must wiggle on belly, pulling along on front flippers. Cannot rotate rear flippers forward to walk on (like sea lions do).
- Swim by powerful stokes of the rear flippers.

Harbor seals

- Earless – no visible external ear.
- Color – white to black.
- When the tide is in, they are diving and hunting.
- At low tide, they haul out on rocky platforms to sunbathe.
- Are shy, will dive into water when approached by humans.
- Can stay submerged for long dives.
- While diving, their heart rate decreases the blood flow to extremities.
- Body is cut off to conserve heat, energy and oxygen supply.
- Food – fish, squid, invertebrates.
- Predators – orcas, northern elephant seals, great white sharks.
- Seen at Duxbury.

Elephant seals

- Named because of male's extended snout.
- Males fight – scar each–others' chest and thickened neck in process.
- Can dive to 6000 feet.
- Pup and mate at Point Reyes National Seashore.
- Migrate to North Pacific and back twice per year.
- Food – fishes, squids, octopus.
- Predators – sharks, orcas.
- Size – male: to 16 ft, 4,500 lbs; female: to 9ft, 1,300 lbs.

Sea Lions

- Eared seals.
- Loud bark.
- Sea lions easy to teach.
- Can move their rear flippers forward, so they can use all 4 limbs to walk or run on land.
- Can rotate their front flippers back to support their body, permitting the animal to sit on land with its neck and head raised.
- Swim relying mostly on broad front flippers.
- Females stay at breeding grounds on offshore islands in So. Cal year–round.
- Males move north after breeding.
- Prominent ridge on forehead.
- Flippers hairless and black. Flippers help them to swim to depths of 800 feet.
- Size – male: to 8 ft, up to 750 lbs; female: to 6.5 ft, up to 250 lbs.
- Food – fish, squid, crab, octopus.
- Predators – orcas, sharks, humans.

Fur Seals

- Were almost exterminated because of their very thick fur. Most are now protected, though some are still hunted.
- Eared seals.
- Unlikely to see at Duxbury.
- Food – fish, squid.
- Predators – orcas, sharks, humans.

> DOCENT TIP:
> At Duxbury there is a constant population of Harbor Seals with take outs at the southern and middle parts of Duxbury. They will also be commonly seen swimming a few dozen yards offshore watching people on Agate Beach. Elephant seal wieners (about 3–5 months old) will on occasion (maybe 1x/year) end up at Duxbury on the shore in March–June. They will be probably be sick or injured (or dead). Sea lions are rare on Duxbury, but not rare in these waters. The buoy about 1 mile off the southern tip of Duxbury is a favorite haul out for sea lions. See Greater Farallones website (www.farallones.org/sanctuary-wildlife/marine-mammals/) for more information on marine mammals in our area

Class: *Aves* (Birds)

Description

- Possess feathers.
- Forelimbs modified into wings.
- Hind limbs adapted to walking, swimming or perching.
- Scales present on feet, very warm blooded (101–112 degrees).
- Light skeleton, bones with extensive air sacs.
- Egg-laying (oviparous).

> TIPS FOR BIRD WATCHING:
>
> Look at the bird. (don't bury your head in a field guide)
>
> Observe the details: markings, shapes, flight speed, calls, behavior.
>
> Get to know a few common birds in the area at a time.
>
> Listen to natural sounds.

Local Species

Just a few commonly observed birds at Duxbury are included in this manual. See local bird guides for more comprehensive information on local birds in Marin County.

Bill adaptations (reflect what they eat)

Fish eaters

- Great Egret – long yellow bill, black legs, quick stabbing motions with its beak at small fish.

- Snowy Egret – long black bill, black legs, yellow feet; smaller than great egret; eats crabs, shrimp, small fish.
- Great Blue Heron – slate gray feathers, large; eats fish, snakes, rodents, frogs, small birds, insects.
- Western Grebe –slender black and white water bird with long neck and straight bill; almost entirely small fish.
- Caspian Tern – large tern, white/light gray with bright red bill and black cap; mostly fish, a diver.
- Brown Pelican – gray–brown, large; may see sitting on outer edges of reef or gliding over water in formation, plunges to catch fish.
- Double–crested Cormorant – large black water bird with long neck and tail and orange at base of bill; mostly eats fish with just a few crustaceans, insects and amphibians. They dive and chase fish underwater using powerful propulsion from webbed feet.
- Brandt's Cormorant – looks similar to double–crested but with bright blue facial skin. Diver and swimmer and similar diet to double–crested, fish and squid.

Invertebrate eaters

- Willet – worms, snails, clams
- Curlew – crustaceans
- Black Oyster Catcher – black, with bright orange bill; eats limpets, mussels, urchins, crabs.
- Black Turnstone – mostly black back and wings with white specks and white belly; eats barnacles, crustaceans, mollusks, insects. They do turn stones, exploiting a food source not used by other shorebirds, but they are by no means specialized. They toss seaweed, rifle eggs, feed on maggots under dead seals, and even climb into bushes for berries.

Scavengers

- Western Gull –White and dark gray with pink legs and feet, red spot on tip of bill; opportunistic, they eat any living or dead matter that floats on the water.
- California Gull – gray wing and back, yellow legs and feet, red and black spot on tip of bill; also, opportunistic feeders.

Funder Acknowledgement

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