DEPARTMENT OF OCEAN SCIENCE

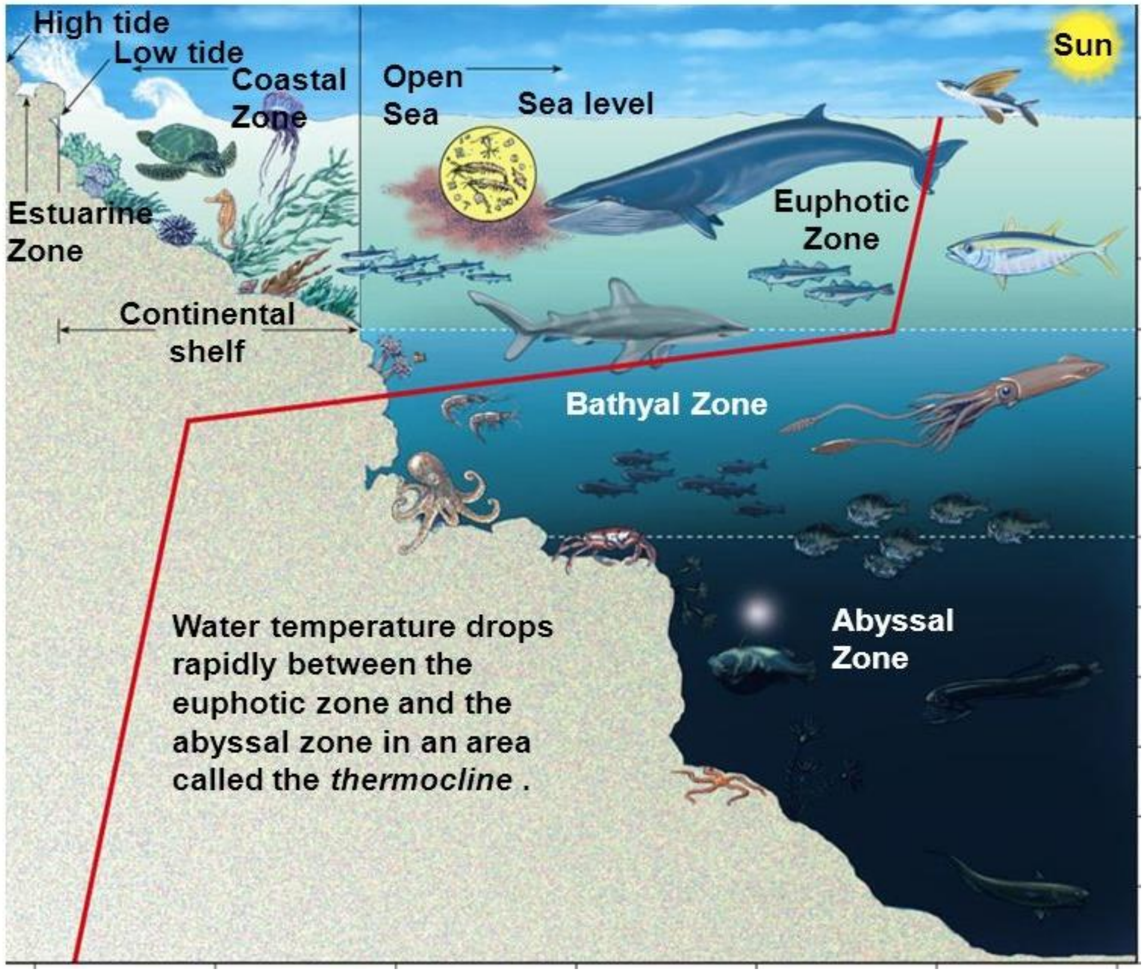
Overview:

A Glimpse of the Diversity of Marine Life – How do They Obtain Food?

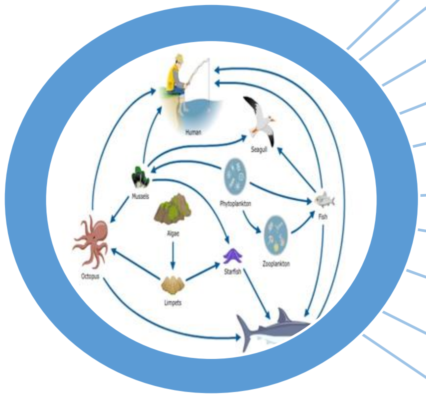
Life in the Beautiful Ocean

- Marine organisms differ vastly in size, shape and behavior
- Some live in the **surface ocean** with access to **light and ample food supply**
- Some live in the **deep ocean** where **light is absent and food supply is limited**

How do marine organisms obtain food in such diverse habitats of the ocean?



Marine Life – How do They Obtain Food?

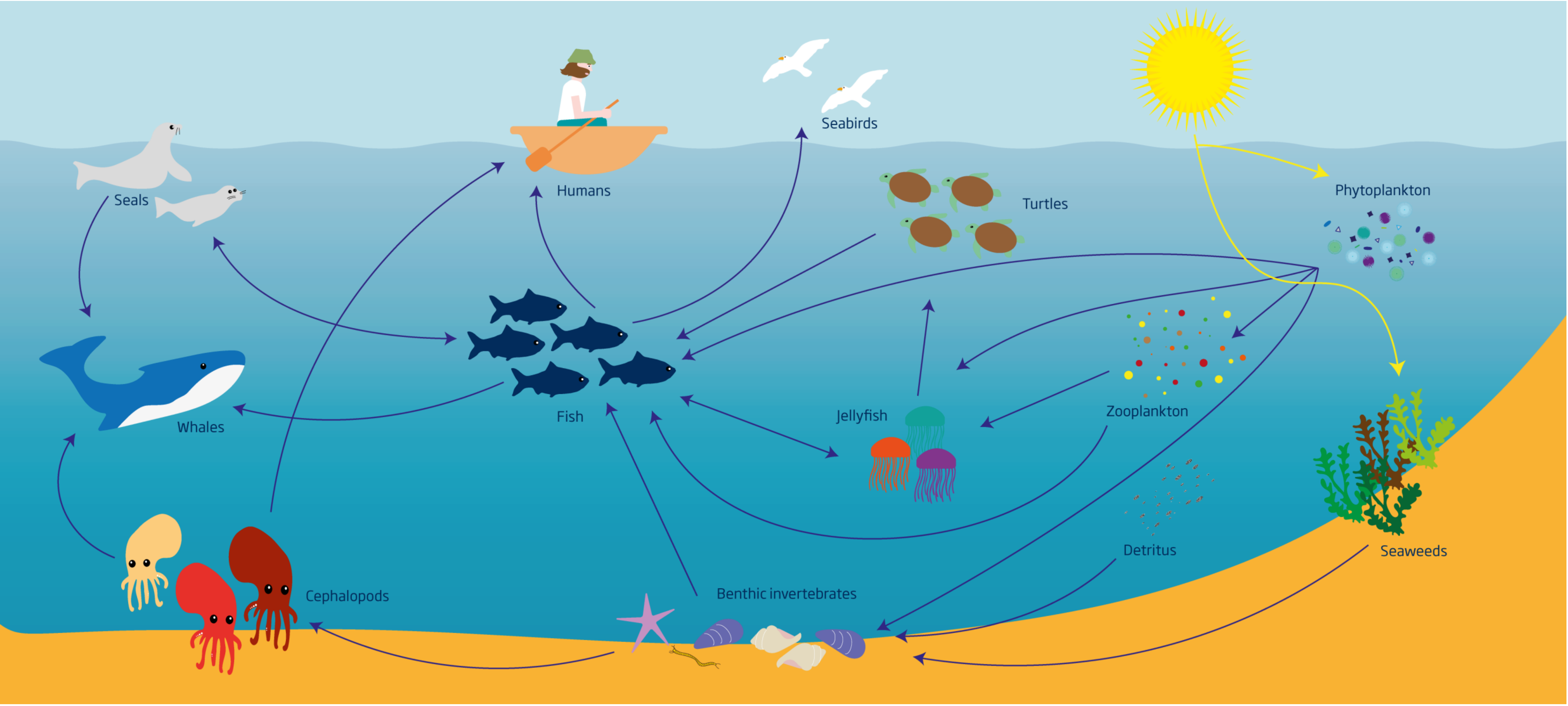


- The Marine Food Web
- Modes of Nutrition in the Marine Environment
- Photosynthesis
- Absorption of Dissolved Organic Matter
- Detritus Feeding
- Predation
- Scavenging
- Parasitism
- Proto-cooperation
- Mutualism

Intended Learning Outcomes

After this module, you should be able to understand:

- The **marine food web** provides pathways for nutrients and energy to flow through a marine ecosystem
- The **diversity of food acquisition strategies** in relation to the environmental characteristics of marine habitats
- The **interdependence between marine organisms** in food acquisition



DEPARTMENT OF
OCEAN SCIENCE

The Marine Food Web

Overview – The Marine Food Web

- Every organism requires the intake of **nutrients and energy**

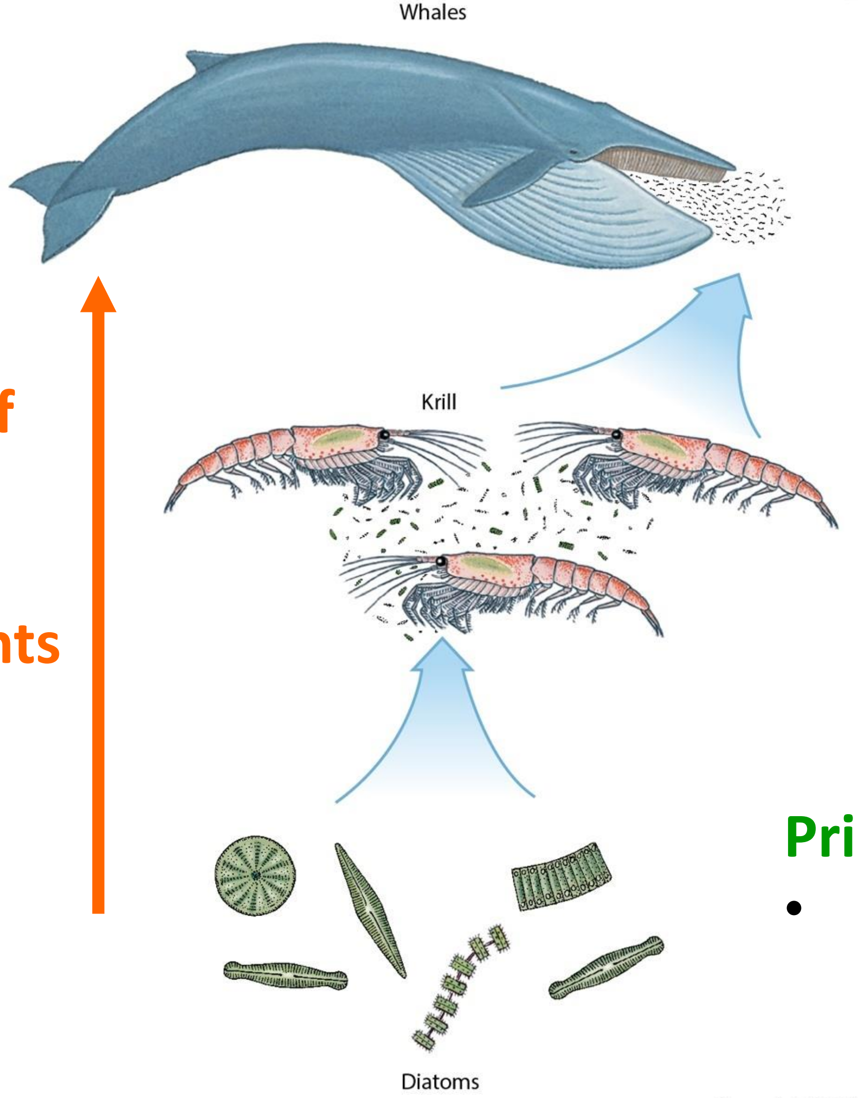
- Important to understand the **ecological role of each species** and **how energy and nutrients flow** through an ecosystem

Key Terms you will learn in this segment:

- **The Marine Food Chain**
  - Primary producers
  - Primary consumers
  - Secondary consumers
  - Decomposers

- **The Marine Food Web (the feeding relationships between species)**
  - Bottom to upper trophic levels

Food Chain – Producers, Consumers, and Decomposers



Flow of energy and nutrients

Secondary Consumers

- Feeding on primary consumers
- Carnivores (meat-eating)

Primary Consumers

- Feeding on primary producers
- Herbivores (plant-eating)

Primary Producers

- Using sunlight and CO_2 to produce their own food

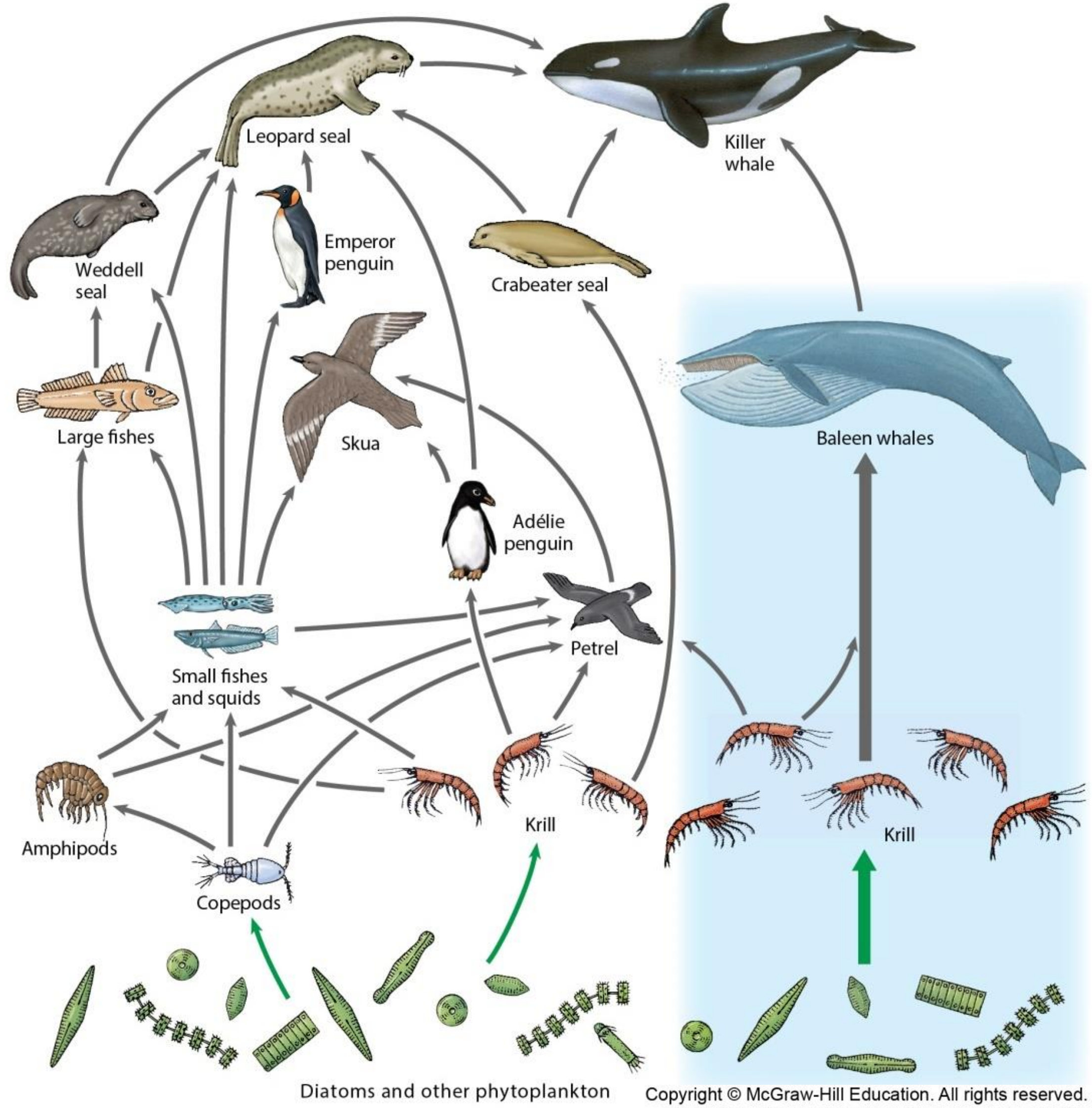
Decomposers

(e.g. bacteria, sea worms, sea slugs)

- Break down waste by feeding on dead tissues of plants and animals

Source: Bill Ober

Food Web – Feeding Patterns and Interactions



Source: Bill Ober

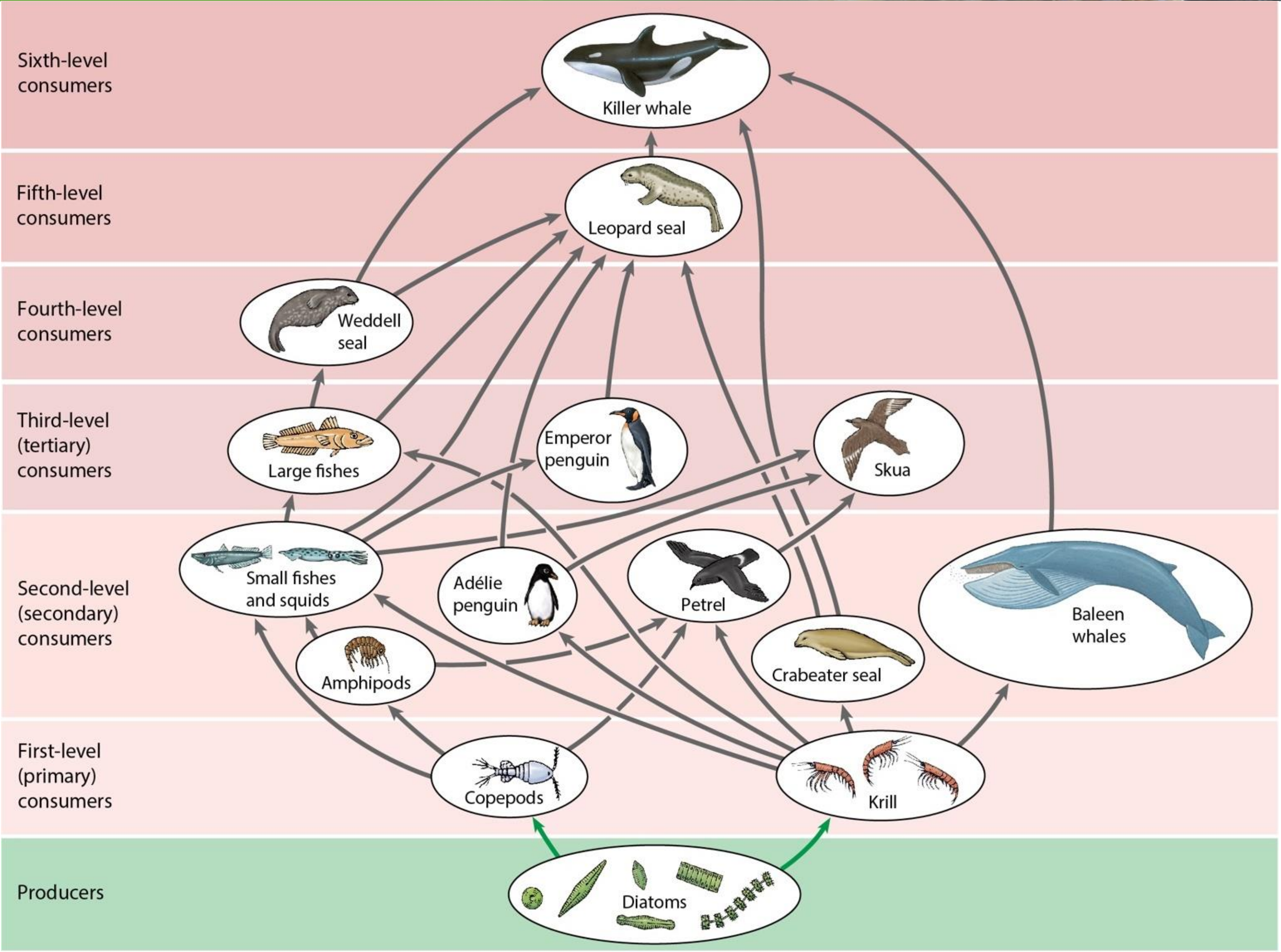
Food chains interweave and form a web-like structure

- One species of consumer can feed on more than one species of food
- One species of food item can be eaten by more than one species of consumers

A food web can help us understand

- How marine organisms interact
- Which species is more susceptible to extinction
- The ecological impacts of removing one species from an ecosystem

Trophic Levels – Steps of Energy Flow in an Ecosystem



Source: Bill Obe

The food web can be categorized into **Trophic Levels** with **primary producers at the bottom**.

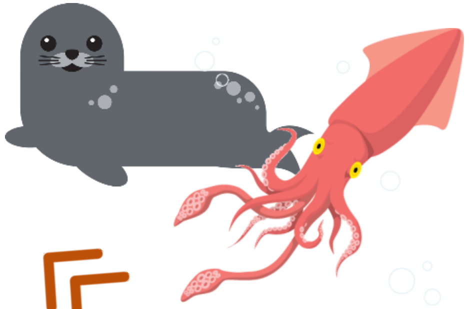
Flow of energy and nutrients

Trophic Levels – Typical Members at Each Level

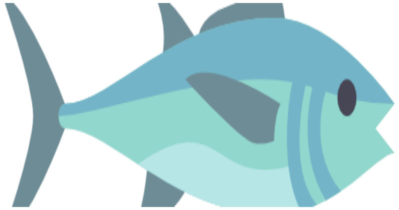
Bigger & fewer

Top carnivores
e.g. shark, dolphin

3rd level carnivores
e.g. squid, seal

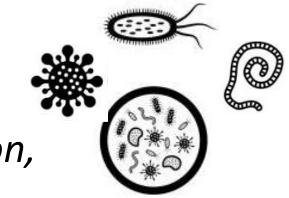


2nd level carnivores
e.g. larger fish



Smaller & more

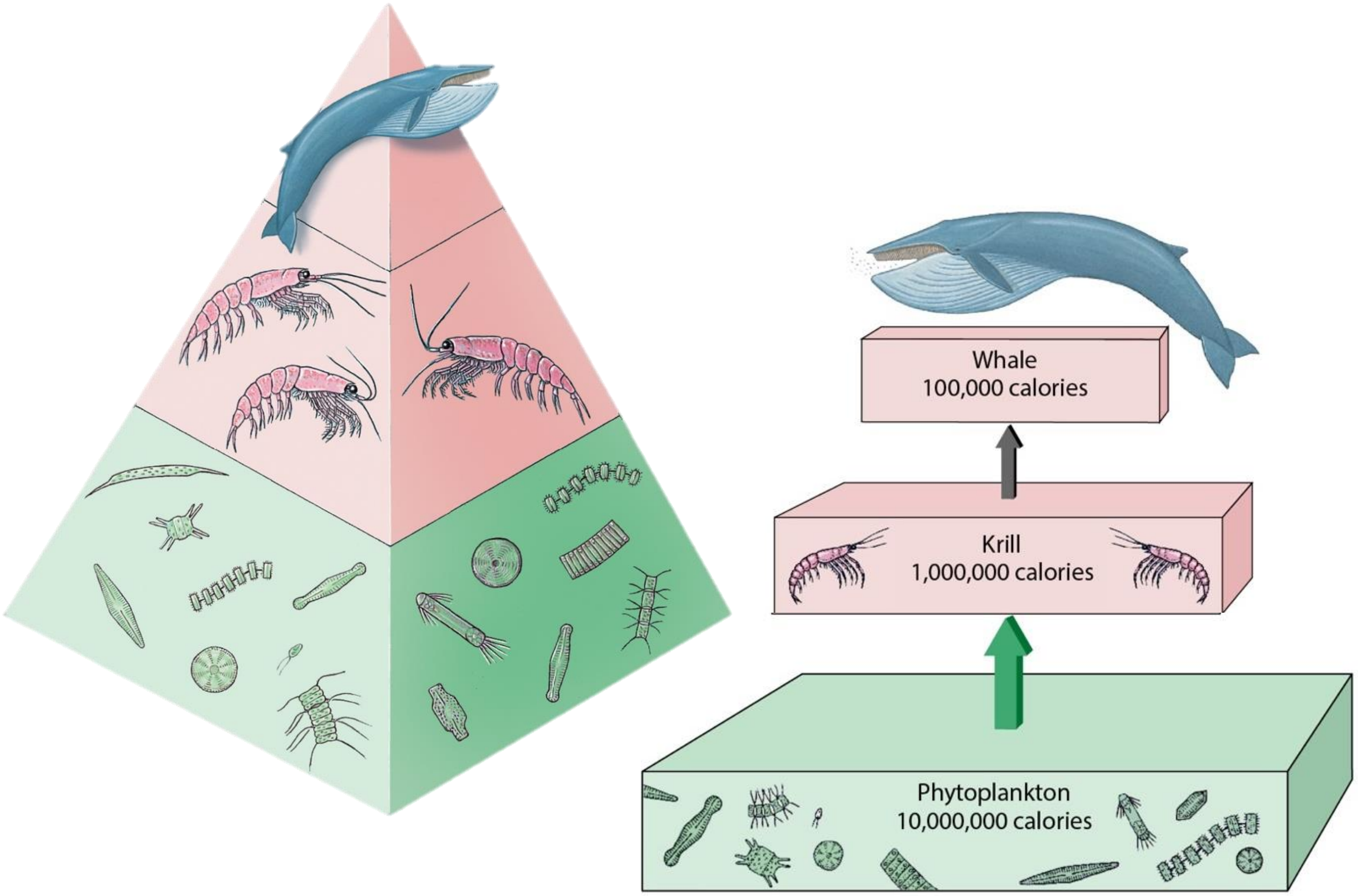
Primary Producers
e.g. phytoplankton, seaweed



Primary consumers (herbivores)
e.g. zooplankton, krill, clam

1st level carnivores
e.g. small fish, jellyfish, crustacean

Trophic Levels – 10% Rule of Nutrients & Energy Transferred



Source: Bill Ober

Certain amounts of **nutrients and energy are lost** at each trophic level as a result of **excretion and respiration**.

On average, **only 10% of the nutrients and energy is transferred** from one trophic level to the next.

As a result, the **biomass (total weight of organisms) reduces** progressively from one trophic level to the next.

Summary – The Marine Food Web

- **Food Chain: What are producers, consumers, and decomposers?**
  - **Producers:** Use sunlight and CO_2 to produce their own food
  - **Consumers:** Consume other living organisms
  - **Decomposers:** Consume dead tissue of other organisms

- **How does the ecosystem function?**
  - **Food Web:** A summary of the feeding relationships within an ecosystem
  - **Trophic Level:** The position in a food web *(e.g. primary producers, primary consumers, secondary consumers)*
  - **Energy & Nutrient Flows:** Start at bottom with producers; move up each trophic level to consumers with 10% being transferred as you go up
  - **Most Important Species:** Help devise strategies for the management of fisheries activities and the conservation of marine ecosystems

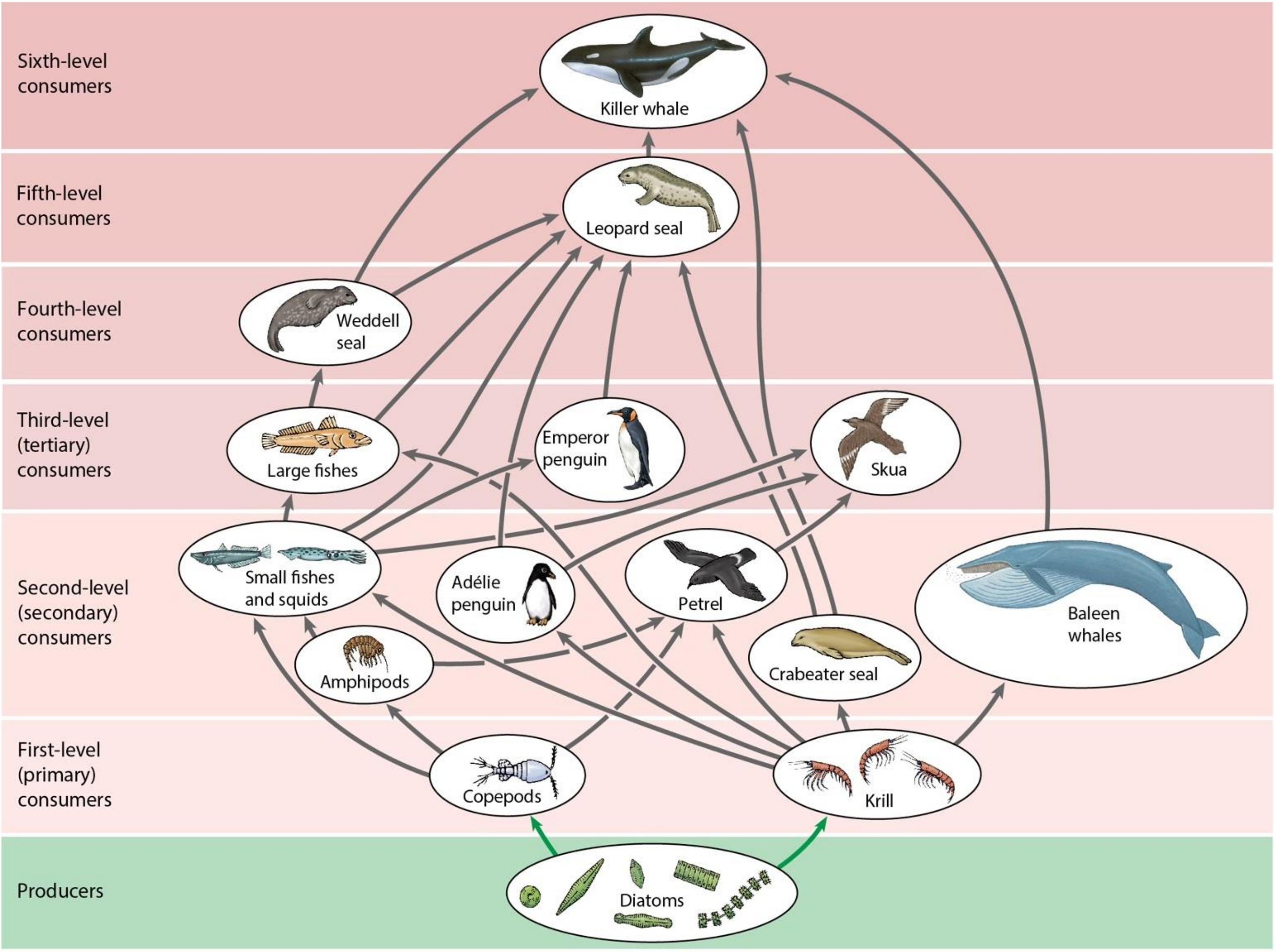
DEPARTMENT OF OCEAN SCIENCE

Modes of Nutrition in the Marine Environment

Modes of Nutrition in the Marine Environment

- Marine organisms have **different ways to acquire nutrients and energy**
- Three major modes of acquisition
  - **Autotroph** – **Production** only
  - **Heterotroph** – **Consumption** only
  - **Mixotroph** – Both **production** and **consumption**
- In this segment, you will learn
  - The **principle** of each mode of acquisition
  - The **interactions** between different modes
  - Their **importance** in the functioning of marine ecosystems

Autotrophs vs. Heterotrophs in the Ocean

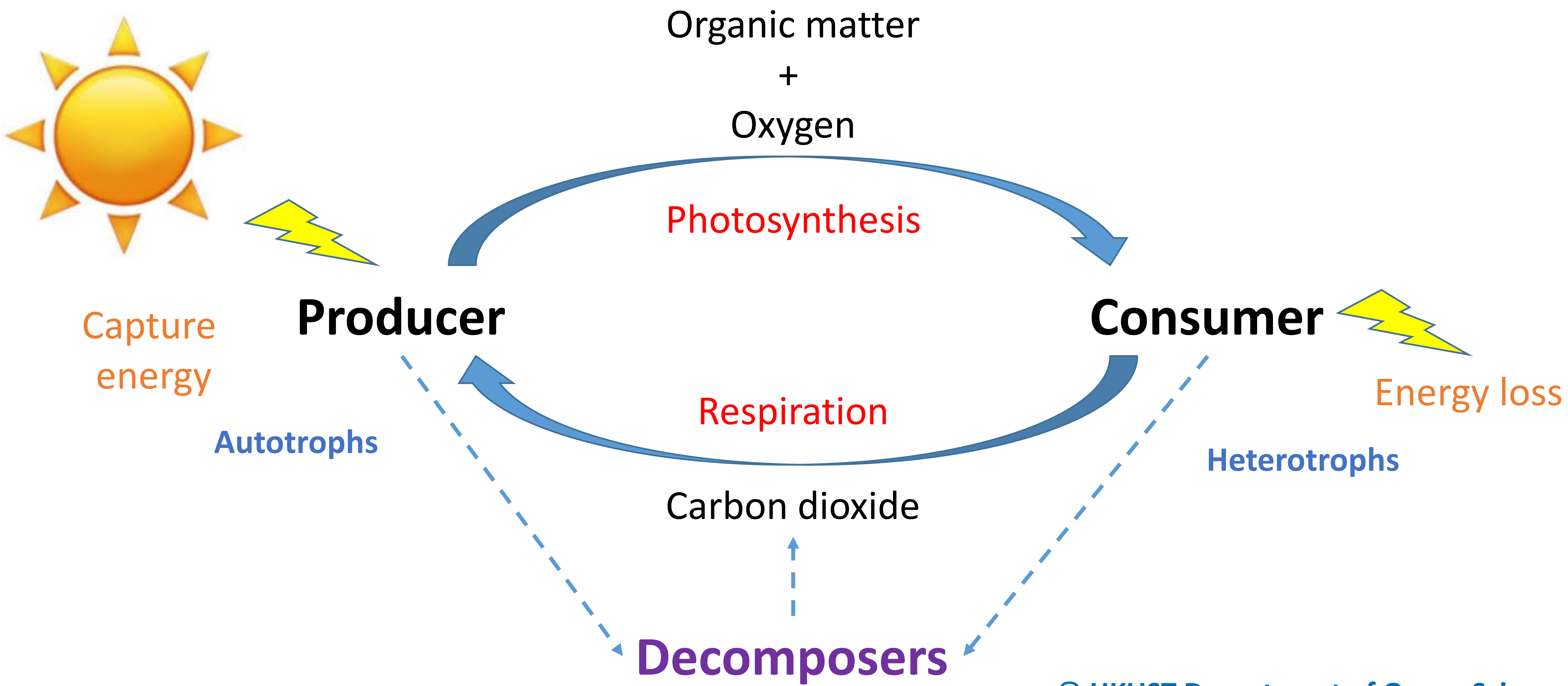


Source: Bill Ober

Heterotrophs

Autotrophs

Energy Cycle – Producers, Consumers, and Decomposers



Autotrophs vs. Heterotrophs

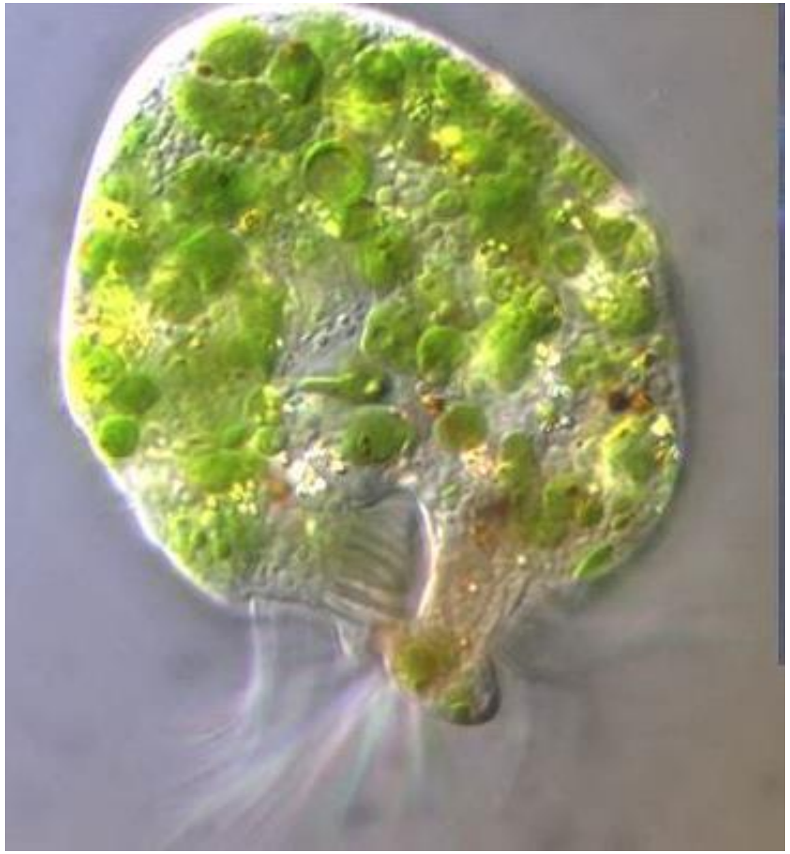
Autotrophs (or Autotrophic Organisms)	Heterotrophs (or Heterotrophic Organisms)
Producers in the ecosystem	**Consumers** in the ecosystem
Use **sunlight & CO_2** to produce organic food on their own	• Unable to produce organic food on their own • Can only utilize **organics produced by autotrophs** (directly or indirectly)
At the first **primary** level in the food chain	At **secondary**, **tertiary or higher** levels in the food chain
Plants, microalgae, and bacteria	Animals, detritus feeders, and bacteria

Autotrophs vs. Heterotrophs vs. Mixotrophs

Autotrophs (Autotrophic Organisms)	Mixotrophs (Autotropic & Heterotrophic Organisms)	Heterotrophs (Heterotrophic Organisms)
Produce their own food	Producers and Consumers	Consume other organisms
Use sunlight and CO_2 to produce organic food on their own	**Type 1:** Autotrophic & Heterotrophic equally **Type2:** Mostly Autotrophic, supplement with heterotrophic activity **Type 3:** Mostly Heterotrophic, supplement with Autotrophic activity	• Unable to produce organic food on their own • Can only utilize organics produced by autotrophs (directly or indirectly)
At the first primary level in the food chain	At the first primary level and up	At secondary, tertiary or higher levels in the food chain
Plants, microalgae, and bacteria	Bacteria and planktons	Animals, detritus feeders, and bacteria

Autotrophs vs. Heterotrophs vs. Mixotrophs

Autotrophs (Autotrophic Organisms)	Mixotrophs (Autotropic & Heterotrophic Organisms)	Heterotrophs (Heterotrophic Organisms)
Produce their own food		Consume other organisms
Use sunlight and CO_2 to produce organic food on their own	Ty… ec… Ty… w… …t Ty… su…	• Unable to produce organic food on their own • Can only utilize organics produced by autotrophs (directly or indirectly)
At the first primary level in the food chain		At secondary, tertiary or higher levels in the food chain
Plants, microalgae, and bacteria		Animals, detritus feeders, and bacteria

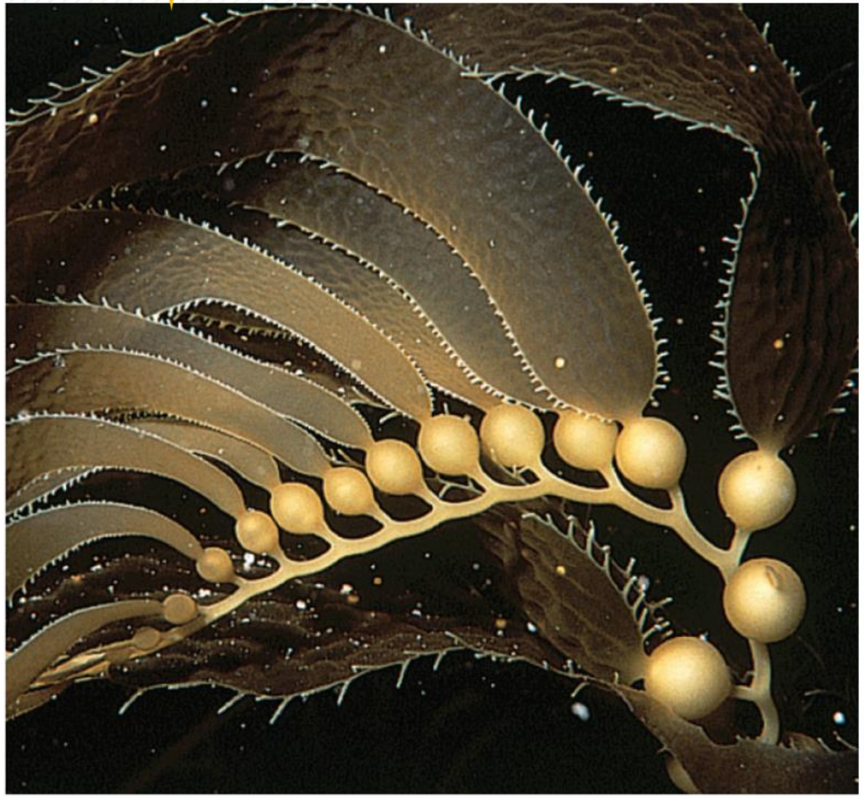


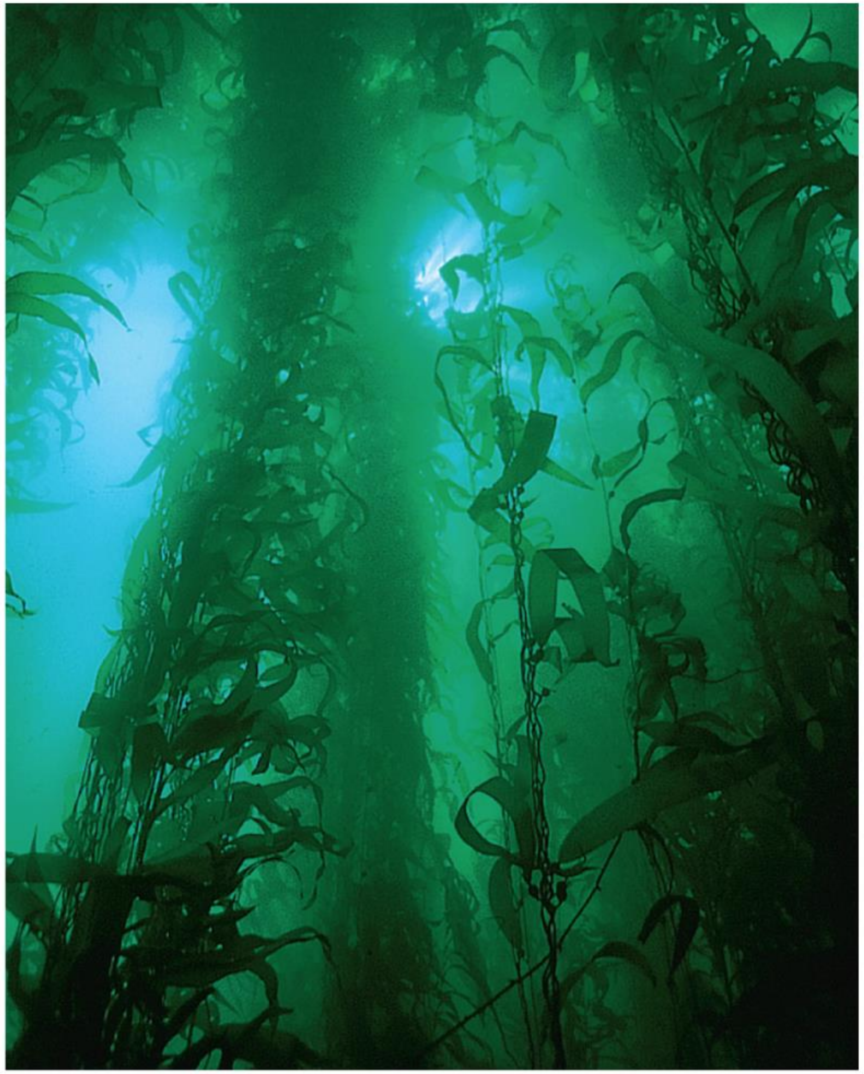
Mixotrophic ciliate in the ocean

Summary – Modes of Nutrition in the Ocean

What are the three modes of nutrient acquisition that drive the production and transfer of energy and biomass through a marine ecosystem?

- **Autotrophs:** make their own food by sunlight and carbon dioxide
- **Heterotrophs:** consume organic matter produced by autotrophs, either through
  - consuming autotrophs (**Primary Consumers / Herbivores**)
  - consuming other consumers (**Carnivores**), or both of the above (**Omnivores**)
  - consuming/breaking down dead or decaying autotrophs or heterotrophs
- **Mixotrophs:** make their own food and consume organic food produced by others





DEPARTMENT OF OCEAN SCIENCE

Photosynthesis

Overview – Photosynthesis

- **Key terms introduced in this segment:**
  - Photosynthesis
  - Photoautotrophs & Chemoautotrophs
  - Chlorophyll, ATP, glucose
  - Primary Producers, Primary Production & Primary Productivity

- In this segment, you will learn:
  - The **diversity of marine organisms** capable of photosynthesis
  - The **importance** of photosynthesis to the functioning of a marine ecosystem and provision of food to humans
  - How photosynthesis in the ocean **affects the gaseous composition in the atmosphere**

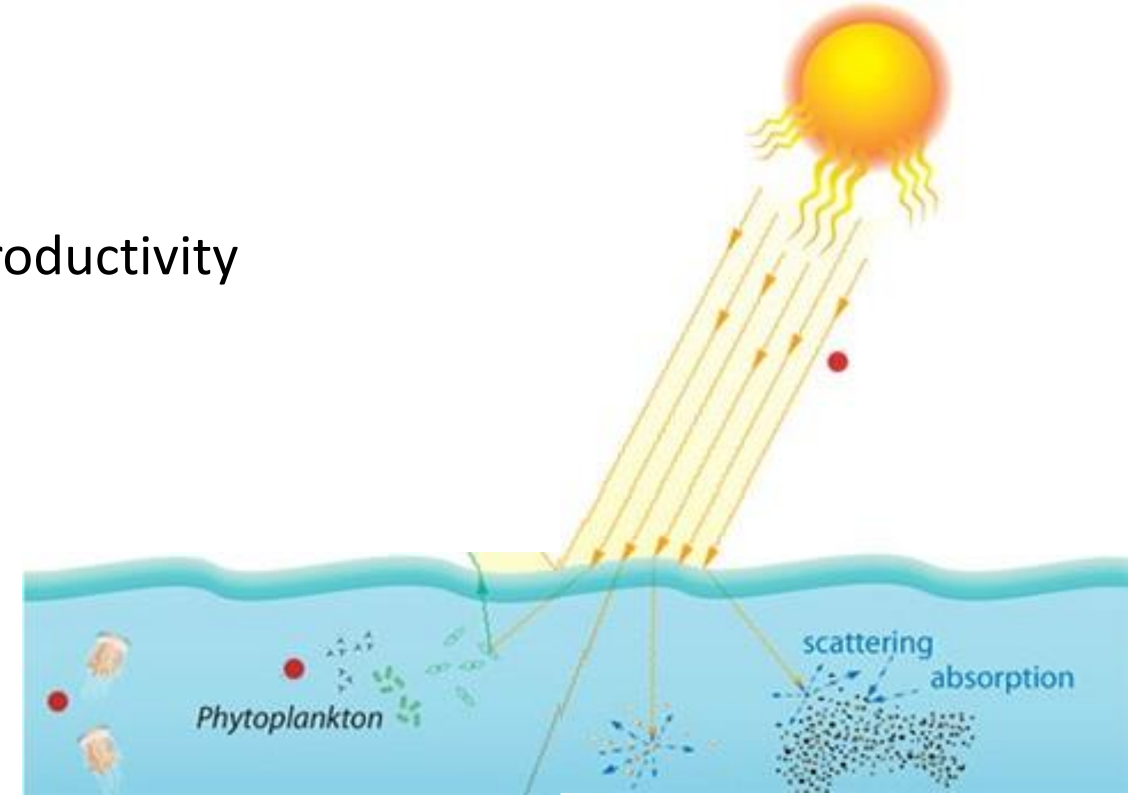


Image: Woods Hole Oceanographic institution

Photoautotrophs – Using Sunlight as Energy Source

Photoautotrophs are organisms that use *sunlight* energy to convert carbon dioxide (CO_2) and water (H_2O) into organic matter (glucose/sugar).

- Autotrophs (primary producers) are able to synthesize their own organic food using CO_2

However, the term "autotroph" does not indicate the energy source used to synthesize organic food.

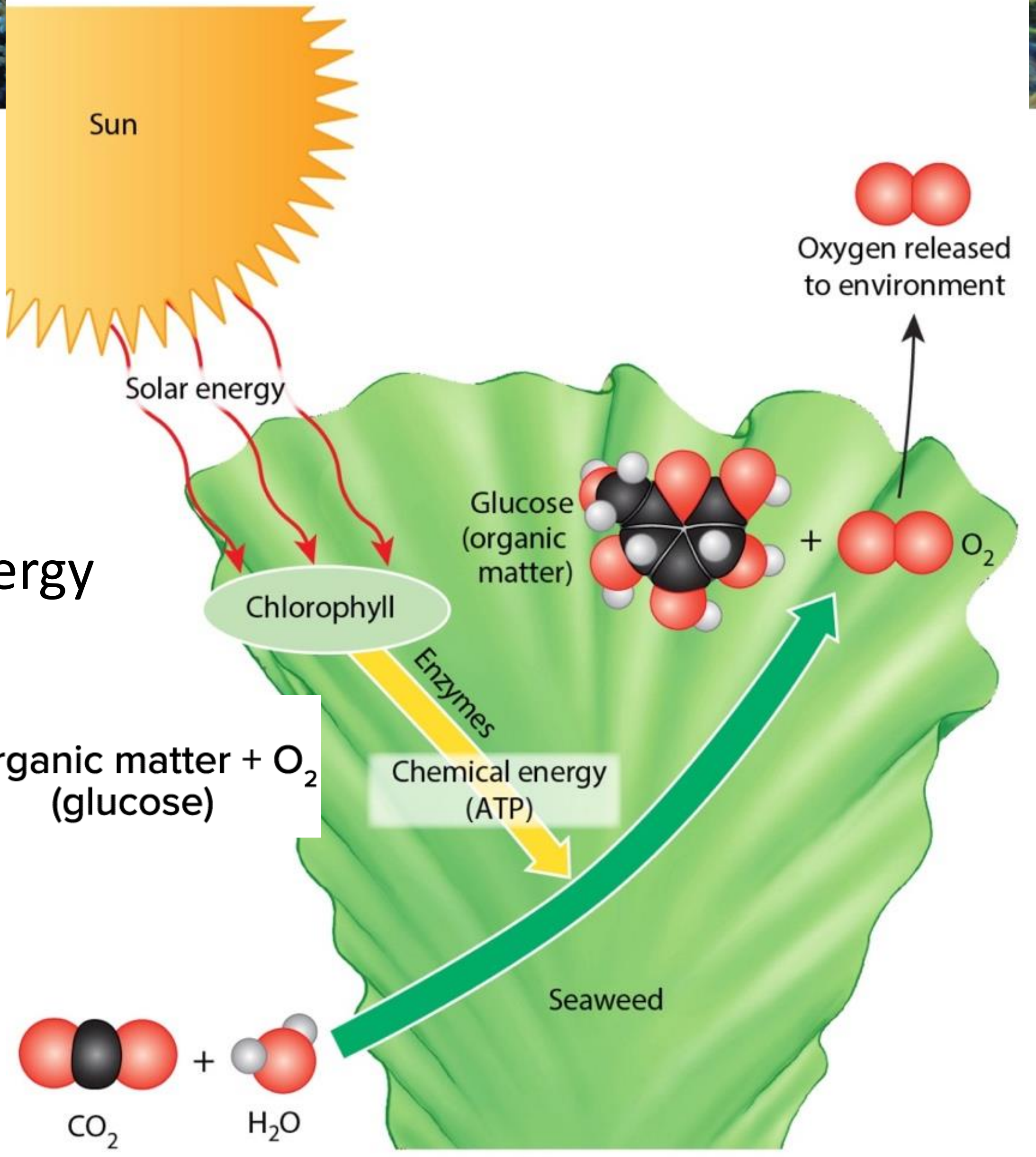
- In the surface ocean, most autotrophs use sunlight as energy source
  - **Photoautotrophs**
- In the deep ocean, where sunlight is absent, autotrophs may use energy stored in chemical compounds for the synthesis of organic food
  - **Chemoautotrophs**

Photosynthesis

Photosynthesis is the biochemical process for photoautotrophs to synthesize organic food using sunlight as the energy source.

- Needs sunlight, CO_2 & H_2O
- Chlorophyll is a pigment that receives the sun's energy
- ATP (Adenosine Triphosphate) is a chemical energy storing molecule
- Photoautotrophs use energy to turn $H_2O + CO_2$ into organic matter (glucose/sugar) to grow
- Photoautotrophs release oxygen (O_2) into the air

$$H_2O + CO_2 \xrightarrow{\text{sun energy}} \underset{\text{(glucose)}}{\text{organic matter}} + O_2$$

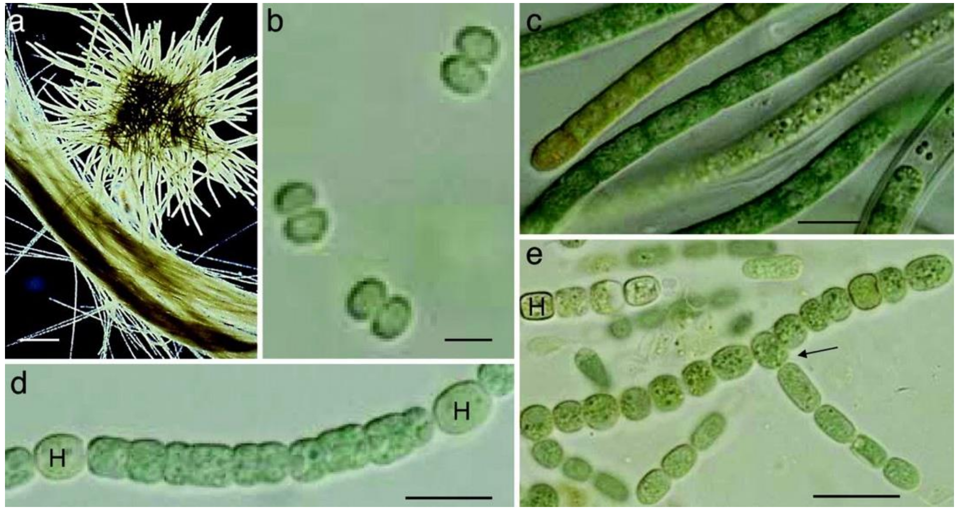


Source: Bill Ober

Marine Photoautotrophs – Examples

©Bob Barnes/Alamy Stock Photo

©James Lynch, USGS

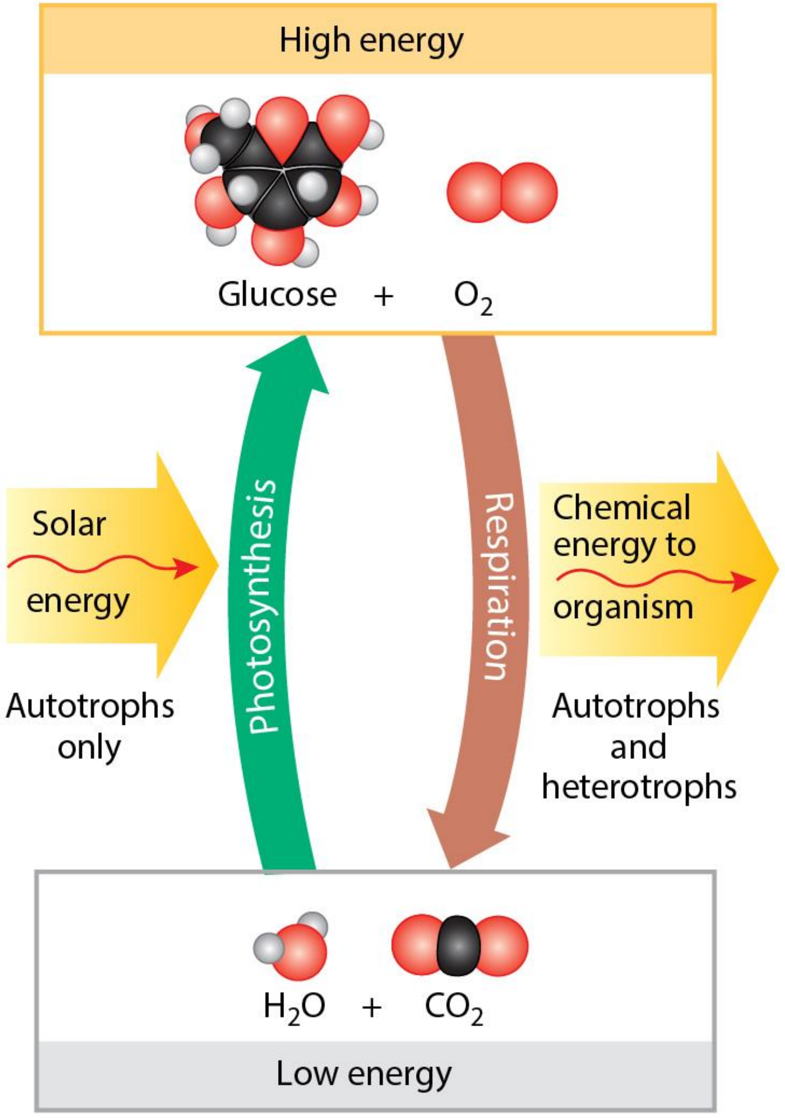


Cyanobacteria

©Peter Castro

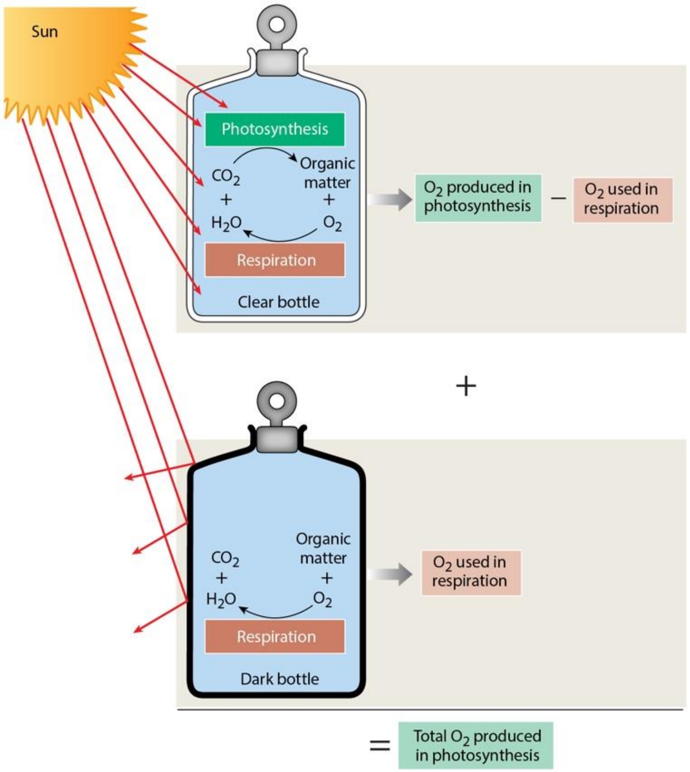
Photoautotroph – Primary Production

- **Photoautotrophs are Primary Producers**
- Part of the organics produced through photosynthesis provide energy to fuel other life sustaining processes
- The remaining organics are accumulated in the photoautotrophs for production of biomass (i.e. growth)
  - Gain in biomass (growth) = **Primary Production**
  - Rate of primary production = **Primary Productivity**

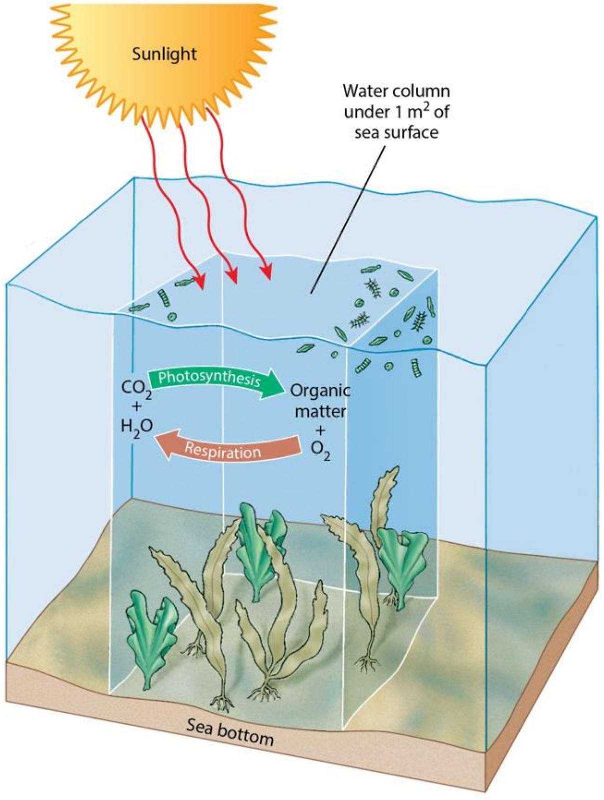


Source: Bill Ober

Photoautotroph – Primary Productivity



Source: Bill Ober



Source: Bill Ober

- Since **primary production supplies biomass to the food chain**, it is important to determine **primary productivity (rate)** for a marine ecosystem.

- **Calculate net gain of biomass**
  Subtract amount of oxygen produced in sunlight jar vs amount utilized in no sunlight jar

- Data of **primary productivity are important** not only for **scientific understanding** of the ocean but also for **management of fisheries resources**.

Importance of Primary Production in the Ocean

Because the ocean occupies 70% of Earth's surface, the total primary production in the ocean is greater than that on land.

- The primary producers contribute 50% of the oxygen gas in the atmosphere
- They also drive a biological pump that uses the sun's energy to move carbon from the atmosphere to the ocean interior, bringing down the atmospheric levels of carbon dioxide

The Primary Producers give oxygen for us to breathe & remove greenhouse gases from the air.

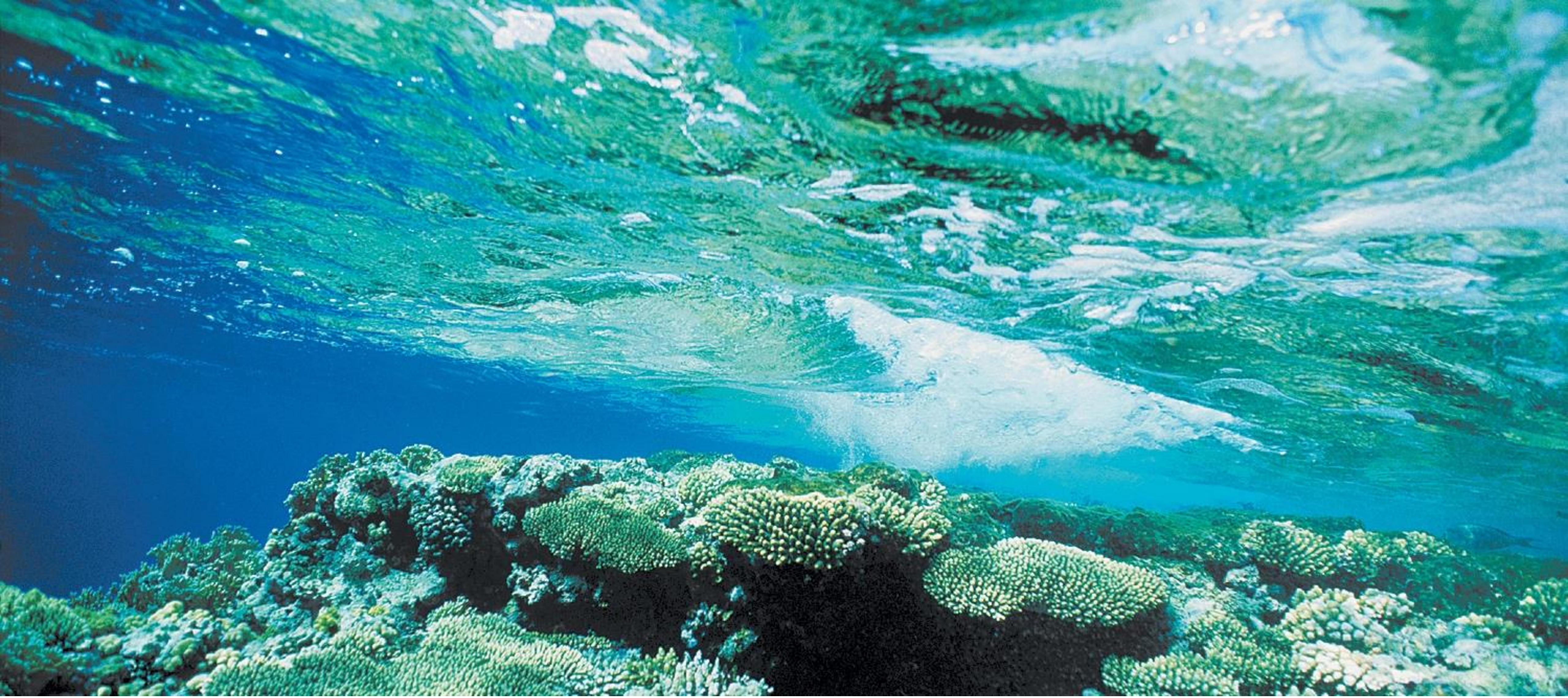
Table 10.1
Typical Rates of Primary Production in Various Marine Environments

Environment	Rate of Production (Grams of carbon fixed/m^2/y)
PELAGIC ENVIRONMENTS	
Arctic Ocean	<1–100
Southern Ocean (Antarctica)	40–260
Subpolar seas	50–110
Temperate seas (oceanic)	70–180
Temperate seas (coastal)	110–220
Central ocean gyres*	4–40
Equatorial upwelling areas*	70–180
Coastal upwelling areas*	110–370
BENTHIC ENVIRONMENTS	
Salt marshes	250–2,000
Mangrove forests	370–450
Seagrass beds	550–1,100
Kelp beds	640–1,800
Coral reefs	1,500–3,700
TERRESTRIAL ENVIRONMENTS	
Extreme deserts	0–4
Temperate farmlands	550–700
Tropical rain forests	460–1,600

*See "Patterns of Production," in 15.3, Epipelagic Food Webs.

Summary – Photoautotrophs in the Ocean

- **Photosynthesis:** A biochemical process used by photoautotrophs to produce organic matter
- **The organic matter after respiration is the biomass available to the consumers in the food chain**
    - Primary production
    - Fuels the marine ecosystem
    - Provides fisheries resources to human
- **Total primary production in the ocean is greater than that on land**
    - Generates O_2 and removes CO_2
    - Regulates the gaseous composition in the atmosphere



DEPARTMENT OF
OCEAN SCIENCE

Absorption of Dissolved Organic Matter

Overview

Key terms you will learn in this segment:

- Dissolved Organic Matter (DOM)
- Microbial Loop
- Viral Shunt

Dissolved Organic Matter as a Source of Food

Dissolved Organic Matter (DOM) is organic waste in the seawater.

- DOM is constantly released from all kinds of life in the ocean
- DOM is an important food source for many different types of marine heterotrophs, from microbes (microorganisms) to invertebrates

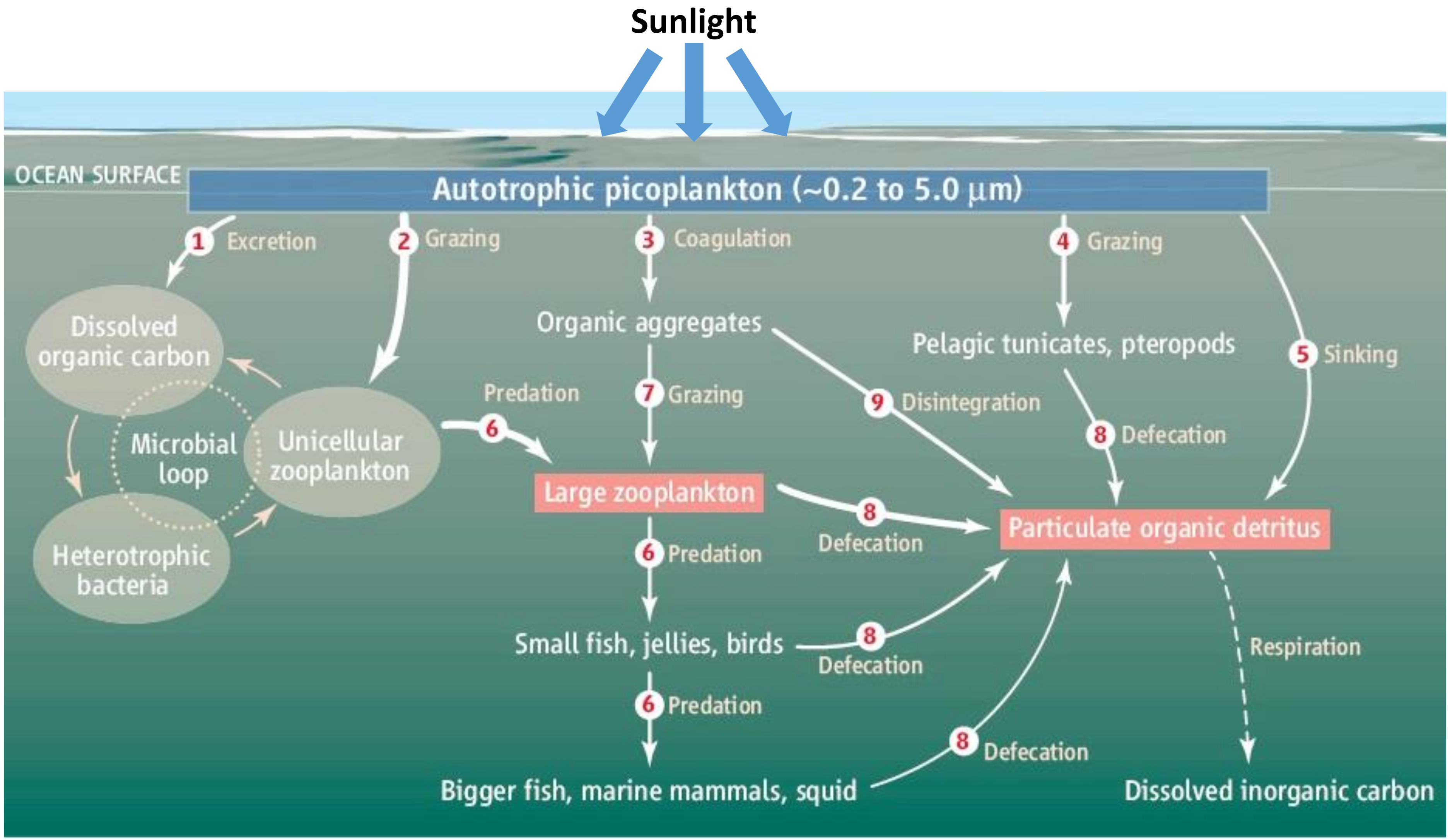
Unable to see DOM because it is dissolved in the water

Microbial Loop

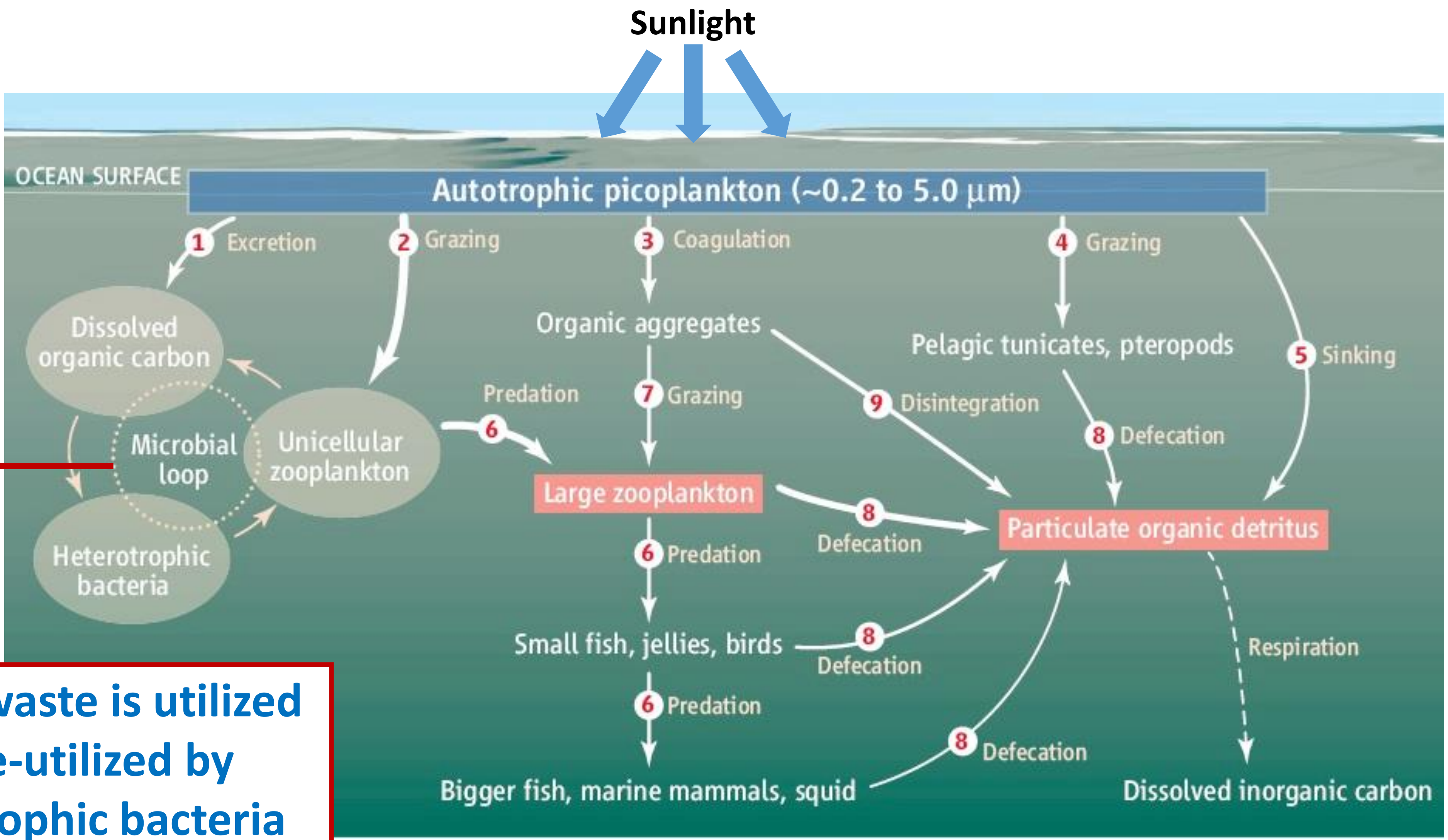
Photoautotrophs are the most important producers of DOM

- Largest biomass (the base of food chain)
- Constantly excrete organic waste into seawater
- The organic waste is immediately utilized and re-utilized by heterotrophic bacteria in the microbial loop

Microbial Loop



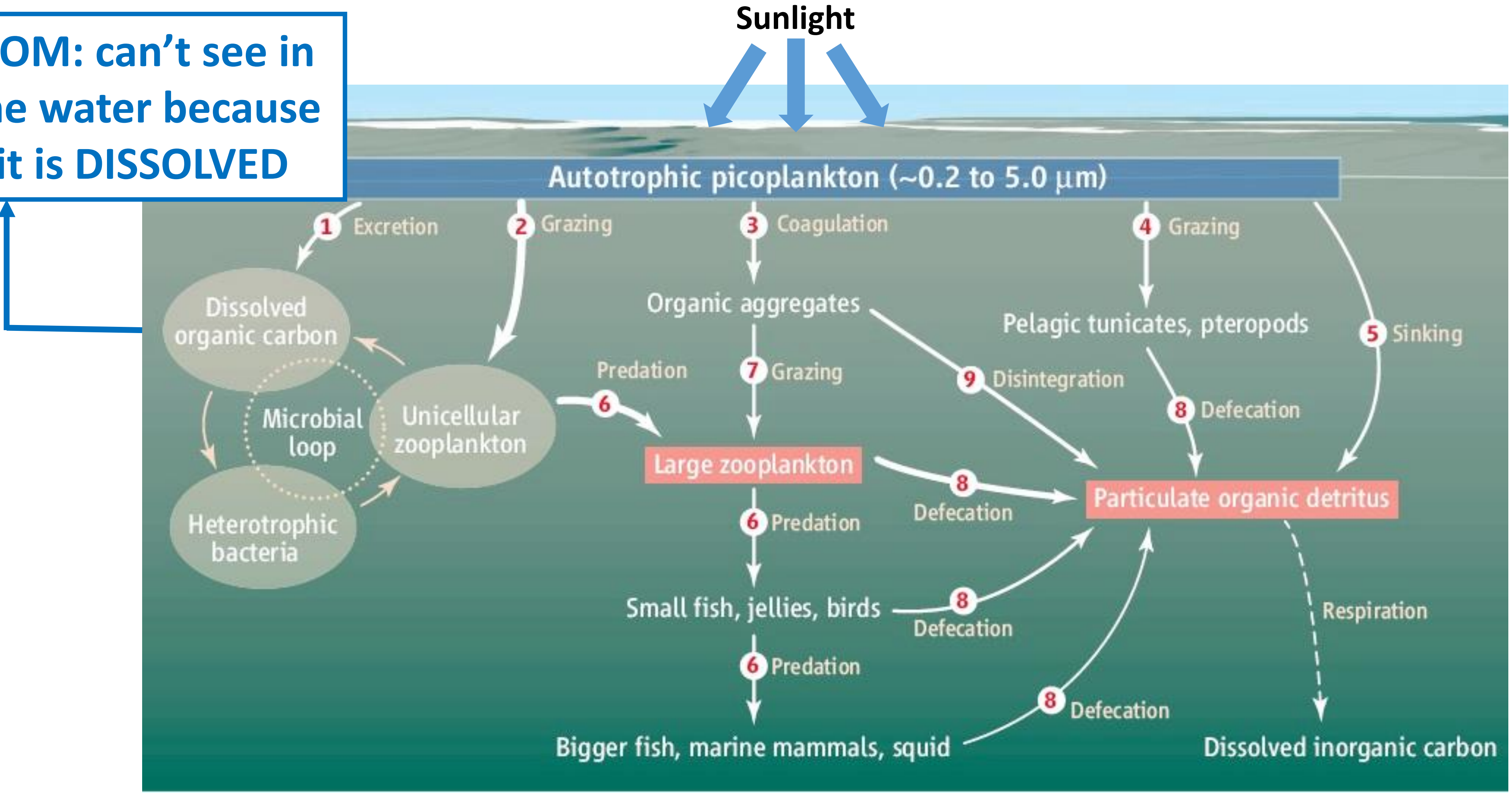
Microbial Loop



Organic waste is utilized and re-utilized by heterotrophic bacteria

Microbial Loop

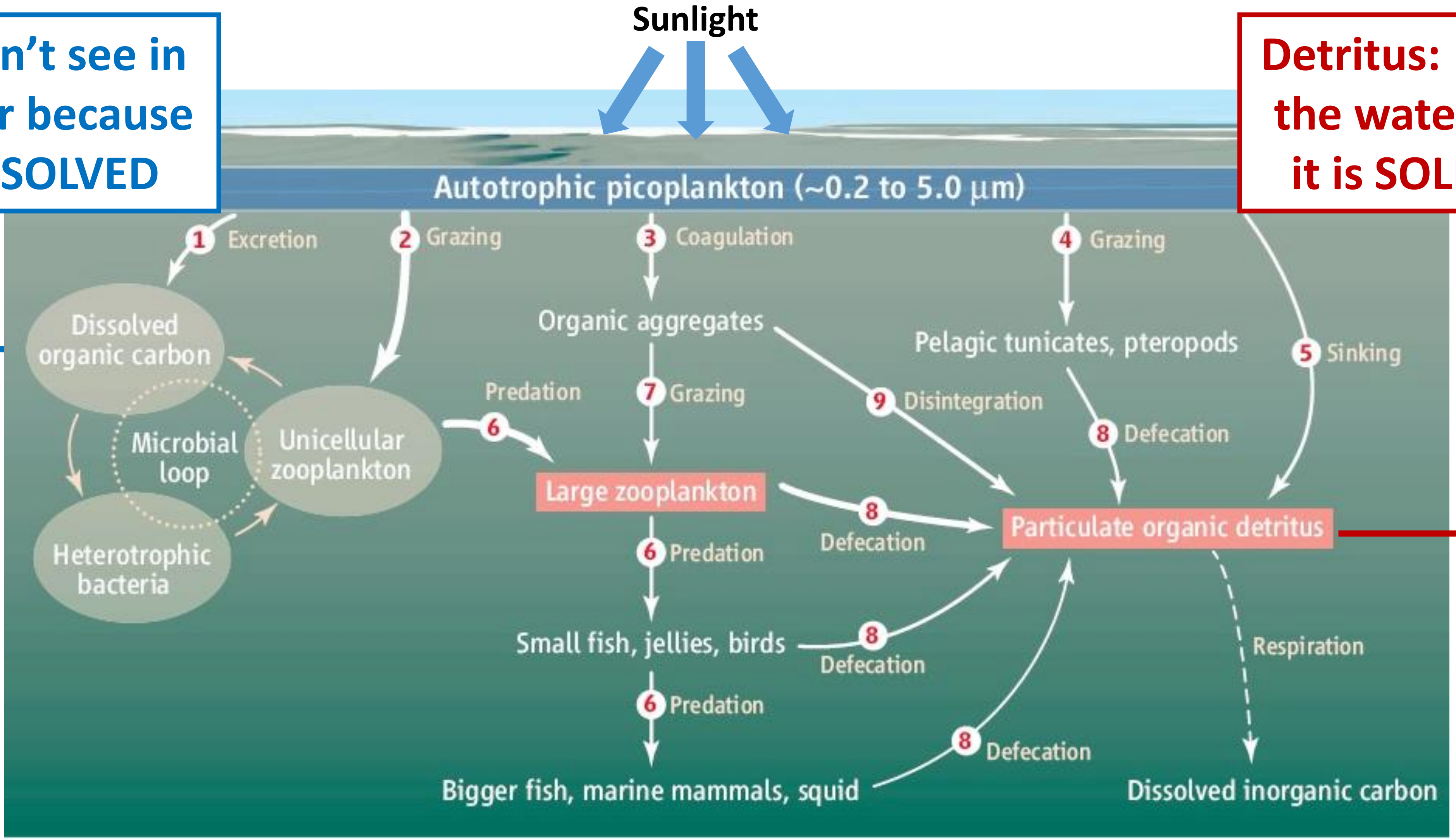
DOM: can't see in the water because it is DISSOLVED



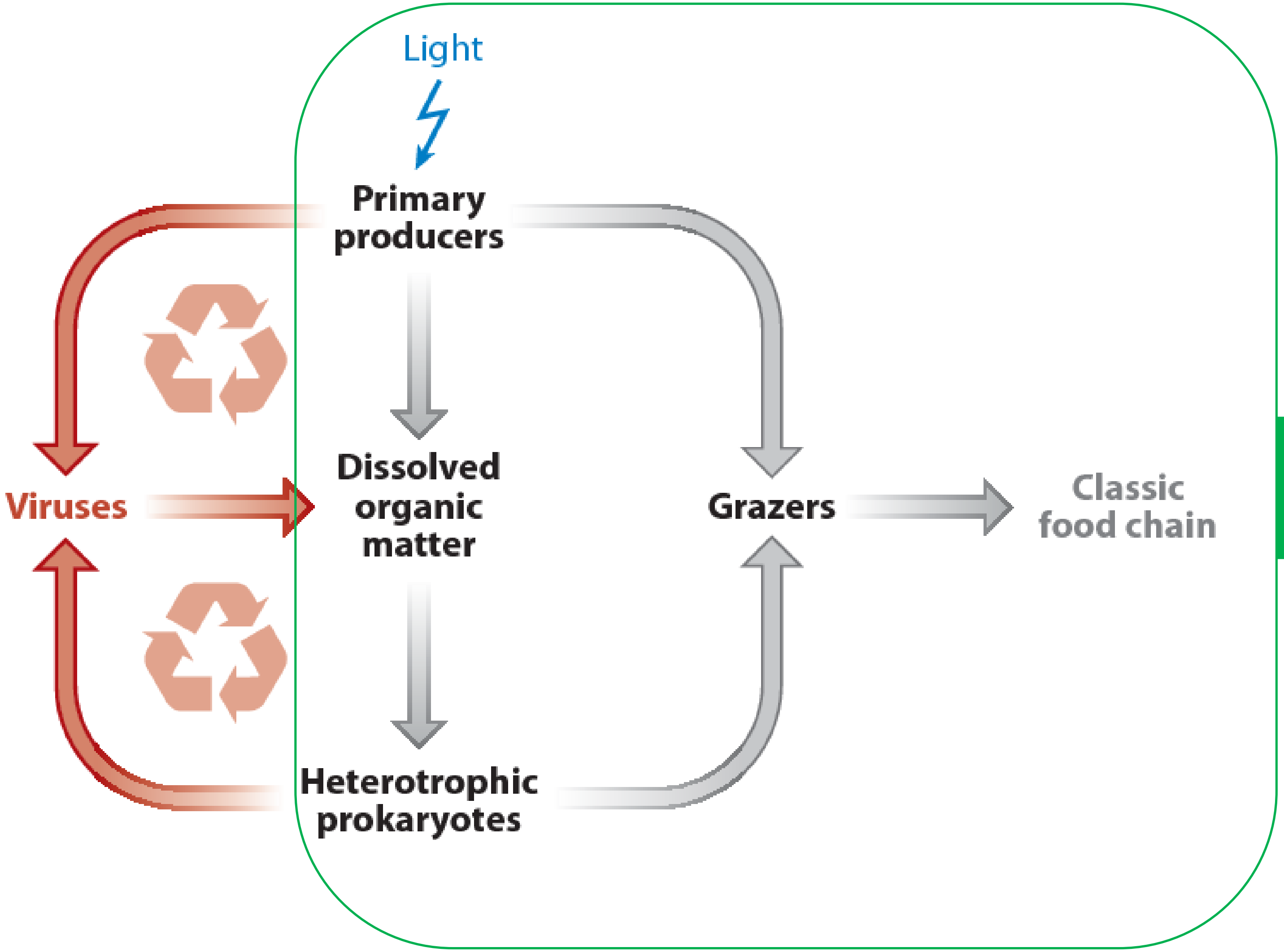
Microbial Loop

DOM: can't see in the water because it is DISSOLVED

Detritus: can see in the water because it is SOLID FORM



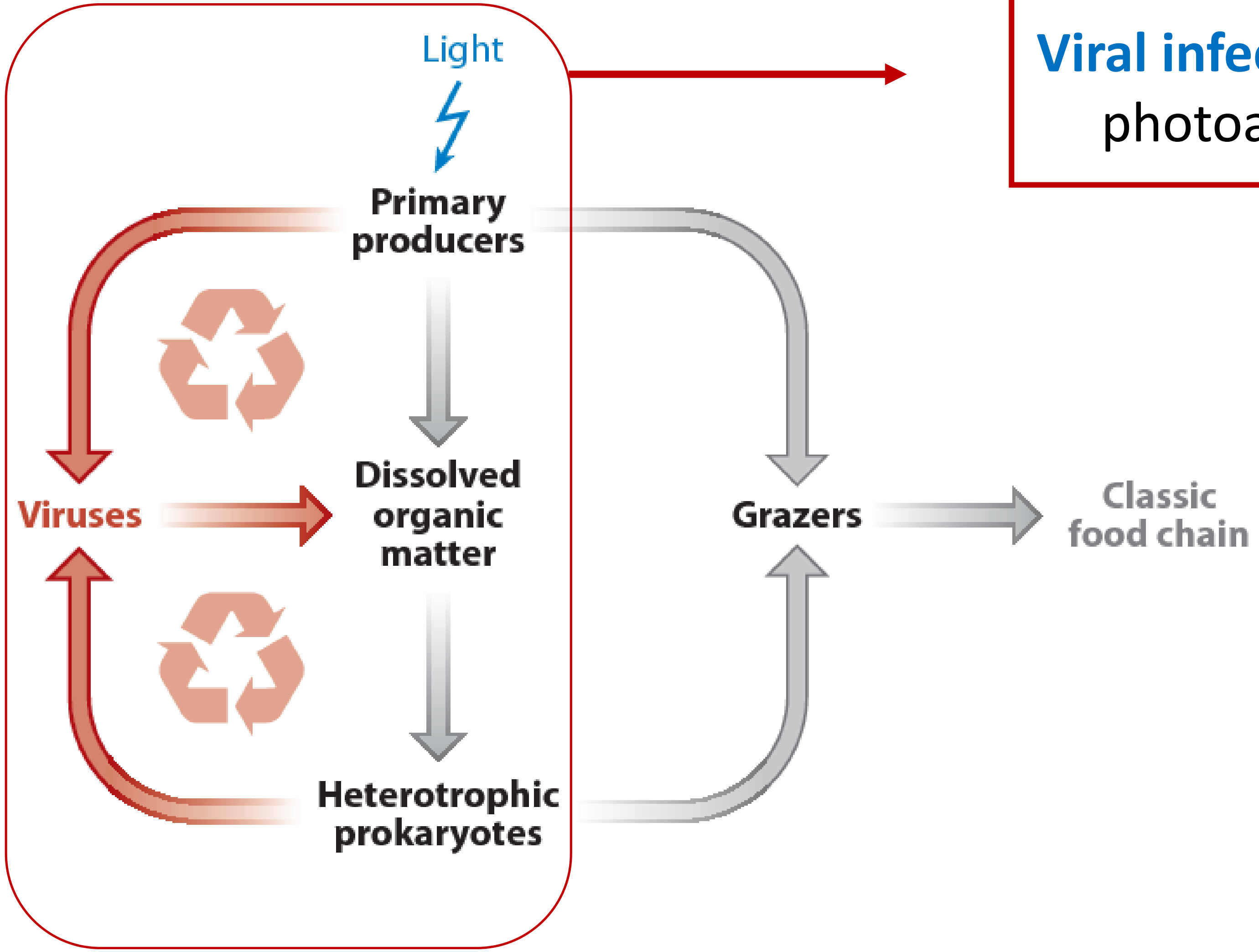
Viral Shunt – Balancing the Ecosystem



Breitbart (2012)

Normal microbial loop cycle

Viral Shunt – Balancing the Ecosystem

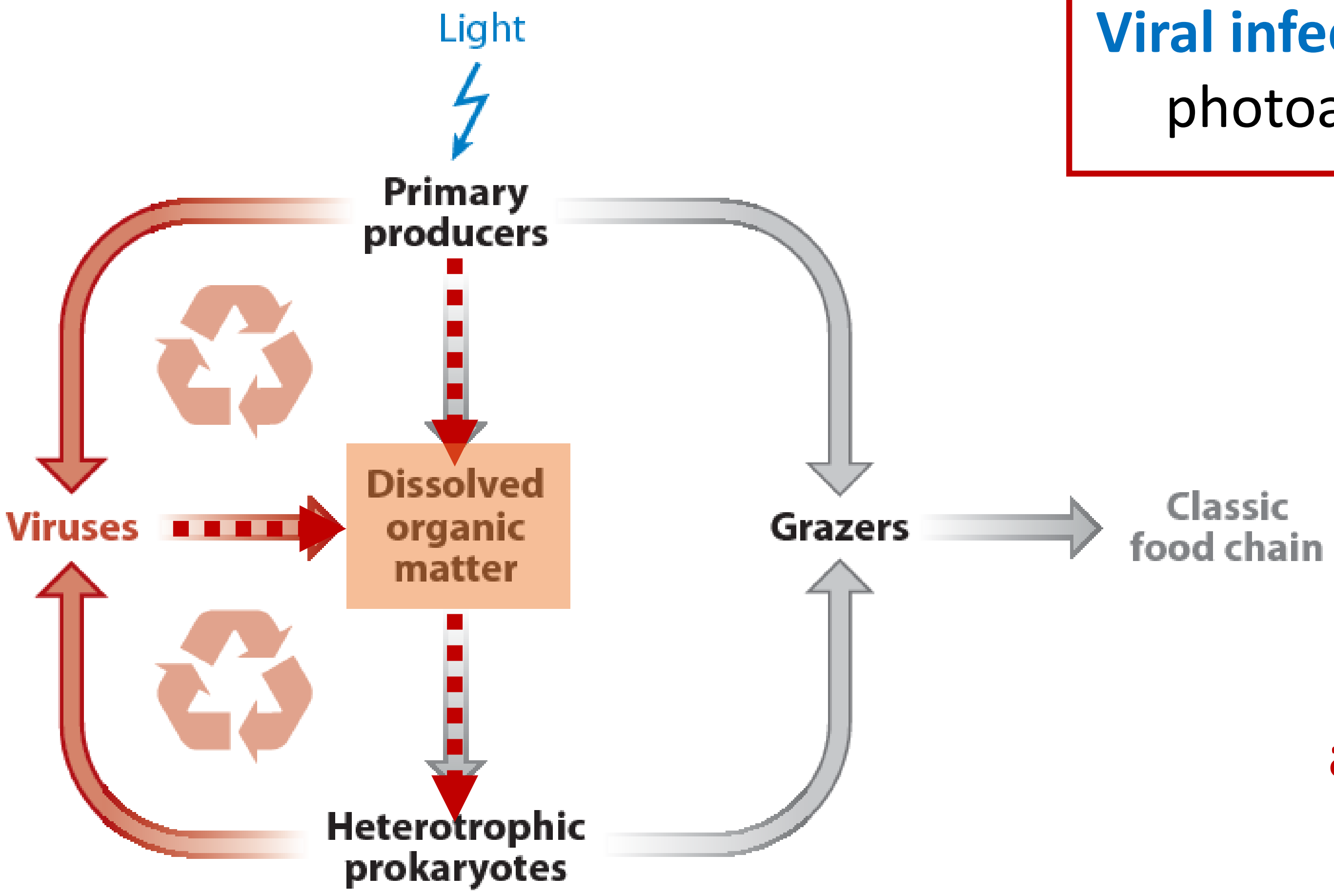


Breitbart (2012)

Viral infection accelerates the release of DOM from photoautotrophic and heterotrophic microbes

Creates a short cut in the microbial loop

Viral Shunt – Balancing the Ecosystem



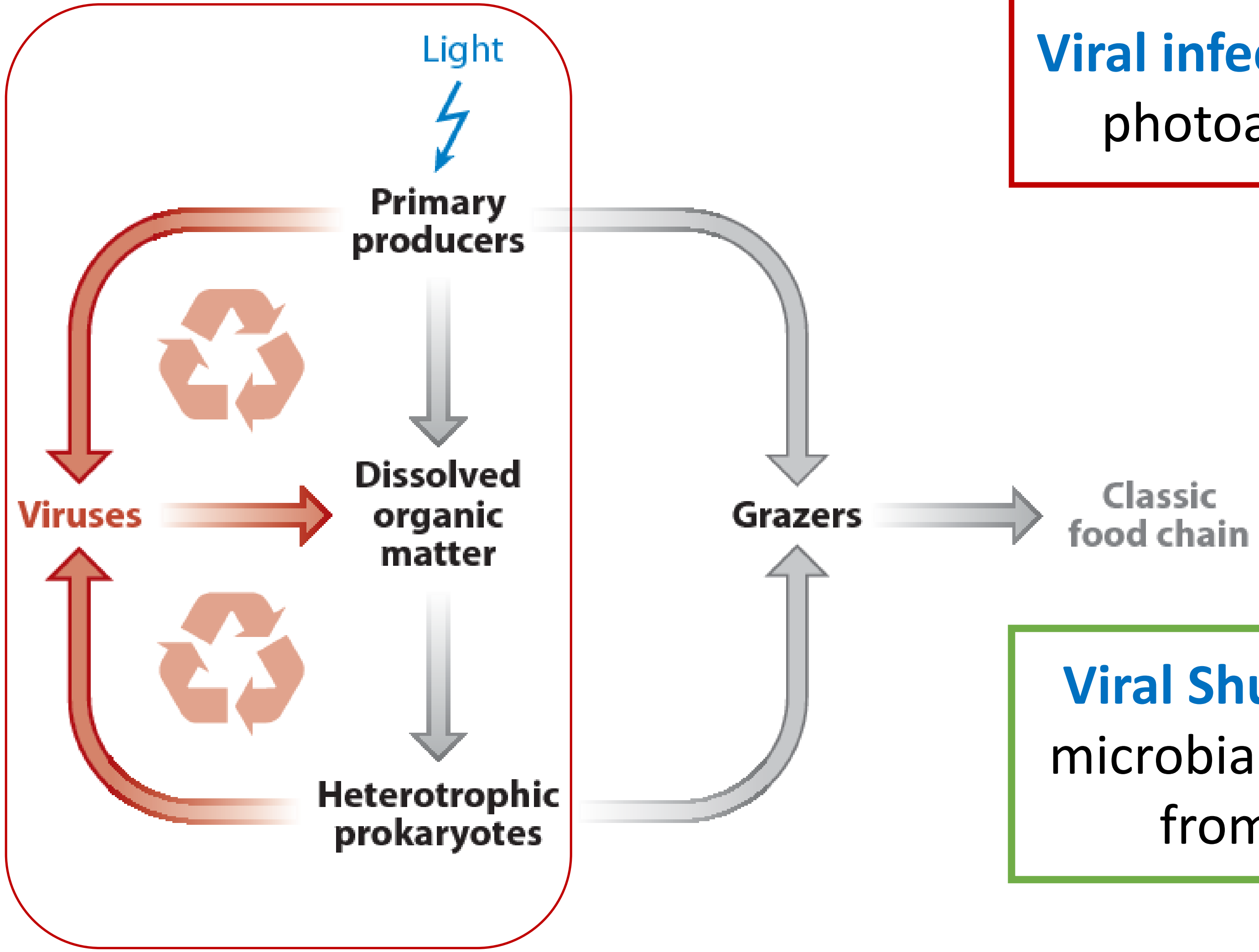
Breitbart (2012)

Viral infection accelerates the release of DOM from photoautotrophic and heterotrophic microbes

The DOM is re-utilized by heterotrophic bacteria

Creates a short cut and accelerates the microbial loop

Viral Shunt – Balancing the Ecosystem



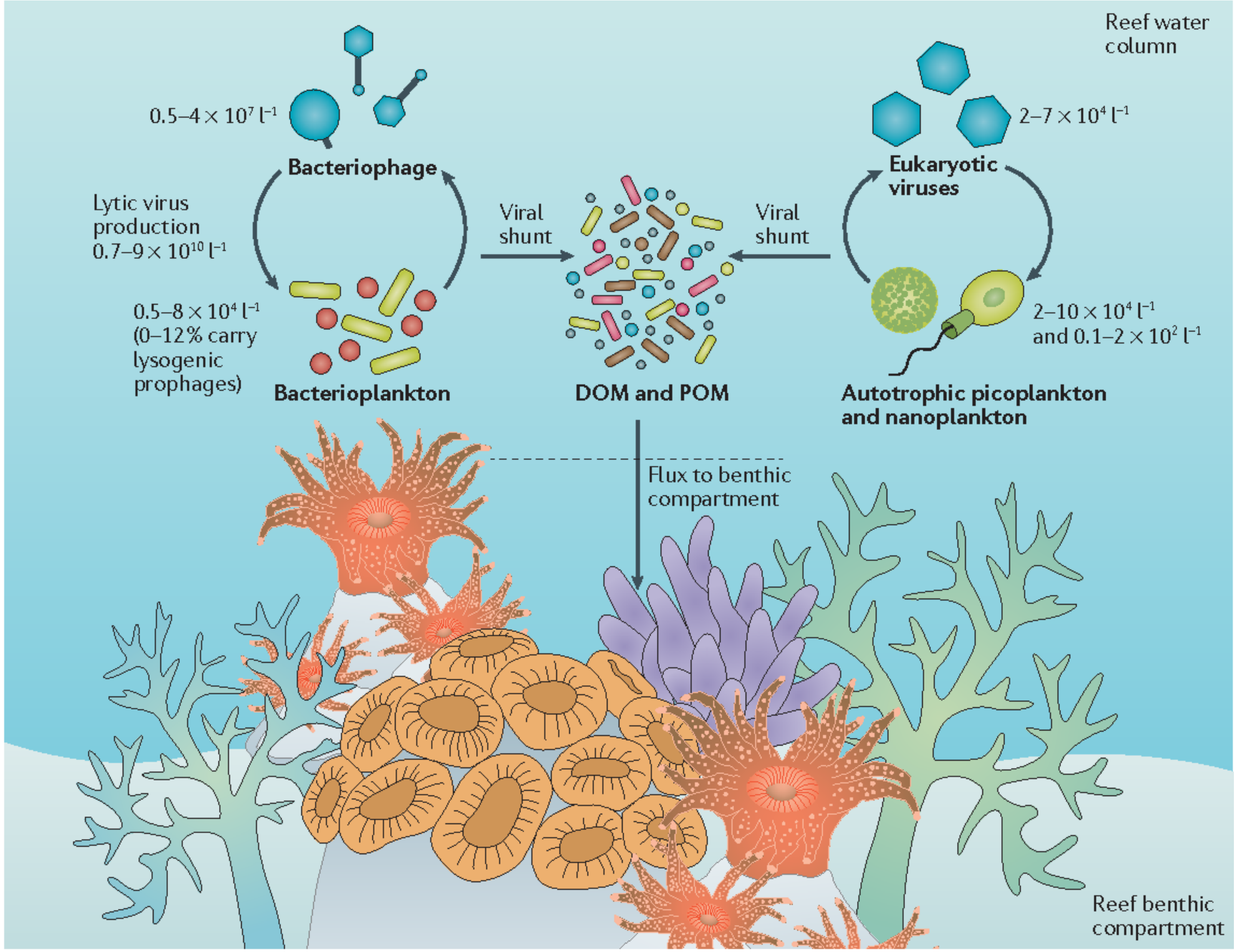
Breitbart (2012)

Viral infection accelerates the release of DOM from photoautotrophic and heterotrophic microbes

The DOM is re-utilized by heterotrophic bacteria

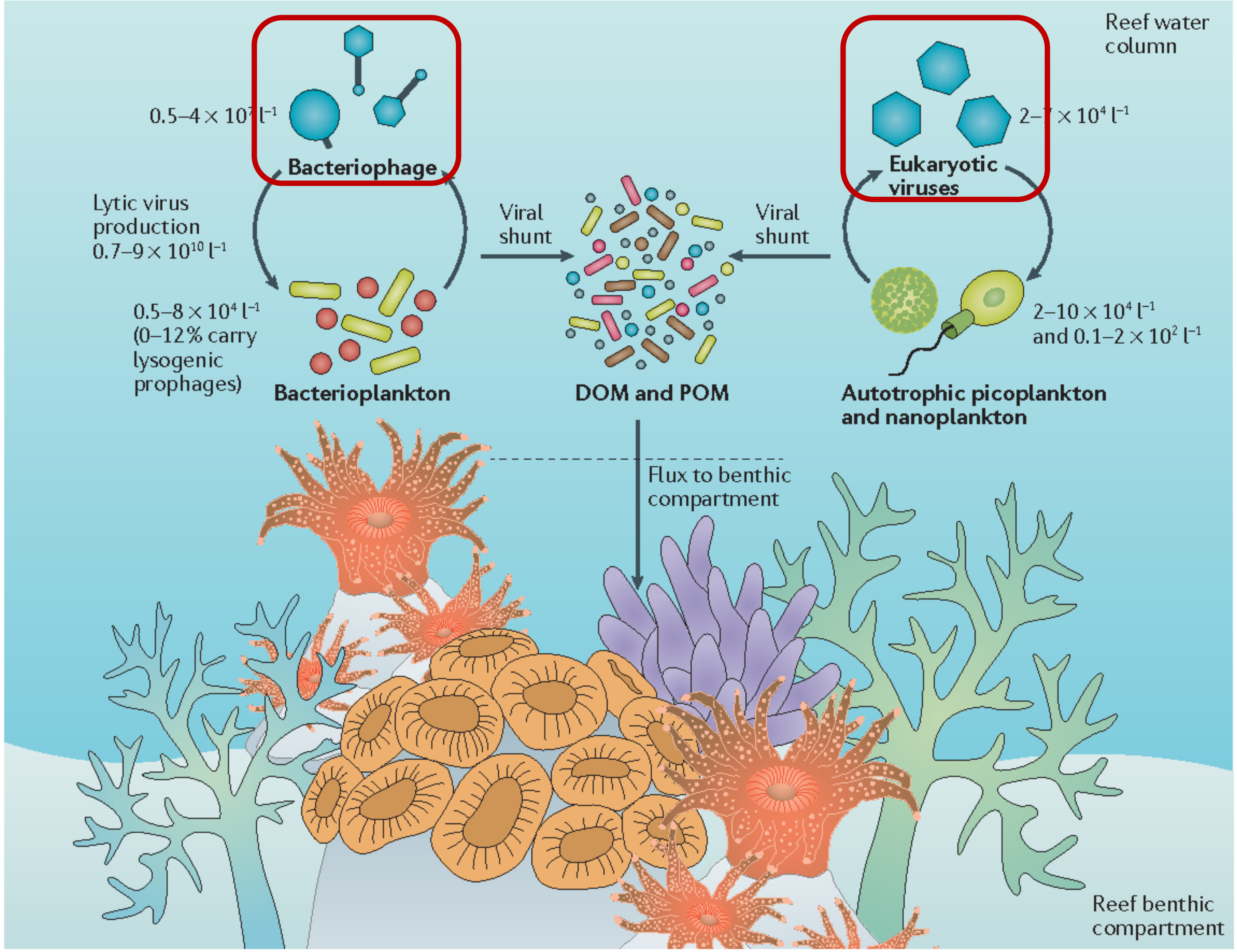
Viral Shunting helps maintain diversity within the microbial ecosystem by preventing a single species from dominating the micro-environment.

Utilization of DOM by Higher Organisms



Thurber (2017)

Utilization of DOM by Higher Organisms

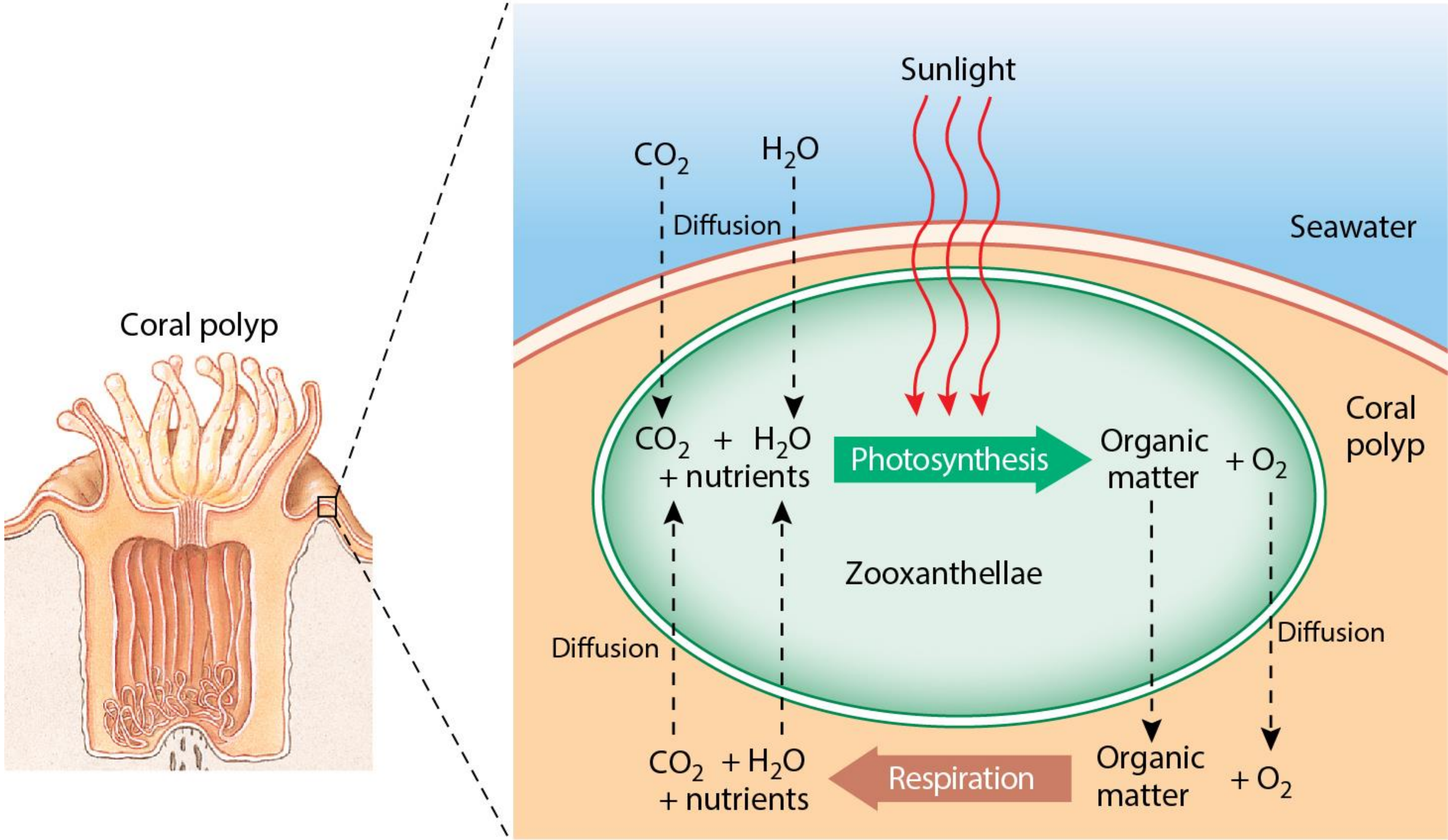


Thurber (2017)

Utilization of DOM by Corals

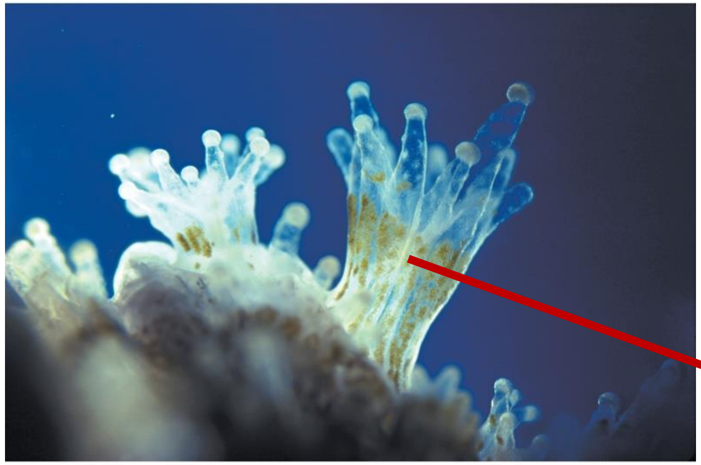
©Oxford Scientific/Getty Images

©Valerie Taylor/ardea.com



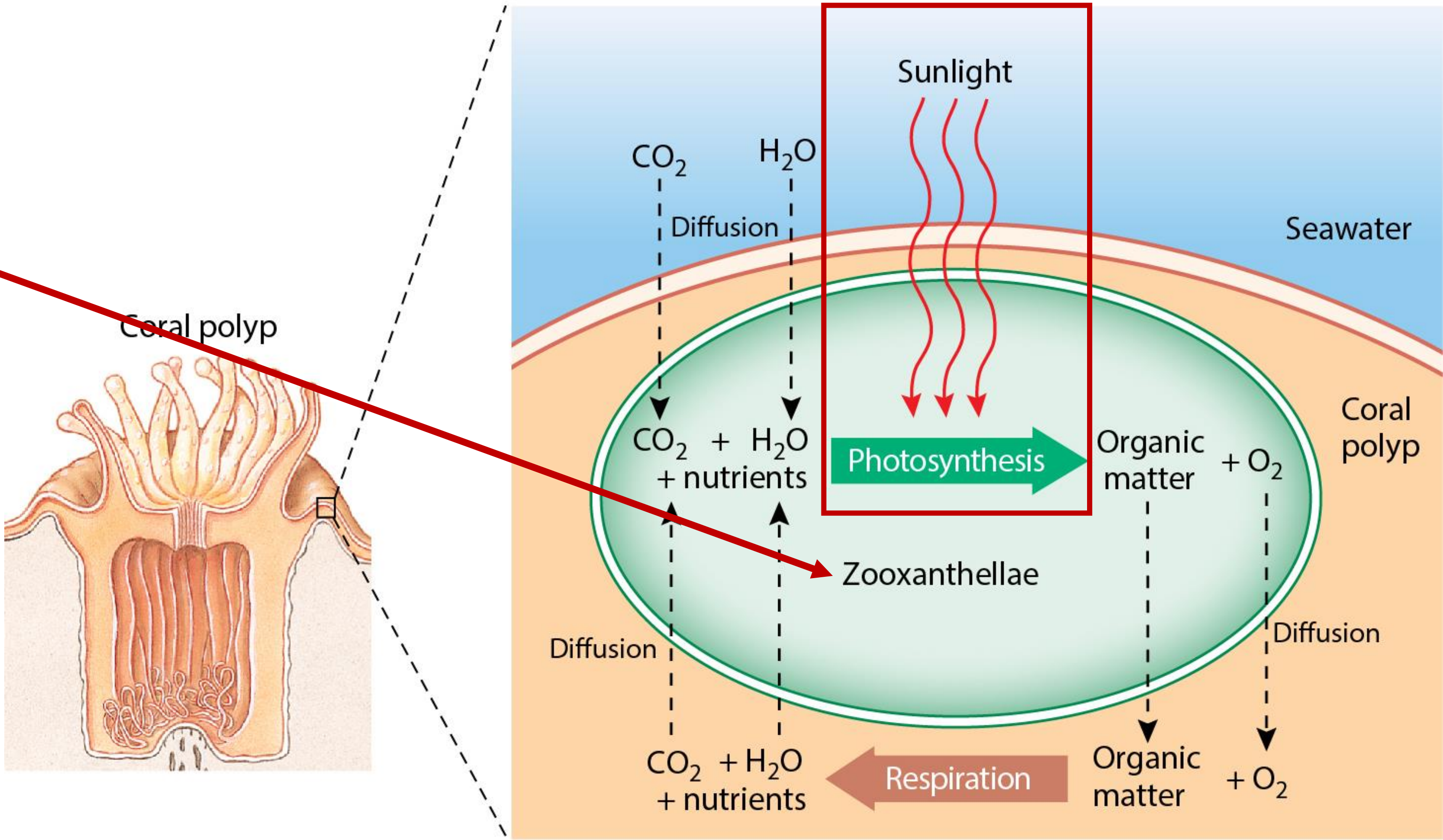
Source: Bill Ober

Utilization of DOM by Corals



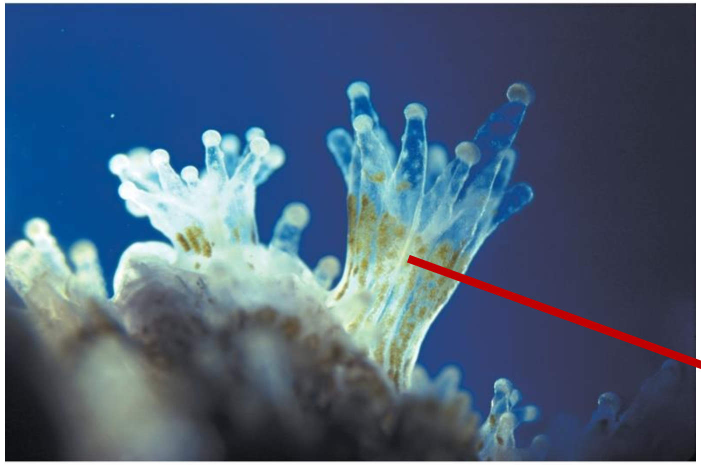
©Oxford Scientific/Getty Images

©Valerie Taylor/ardea.com



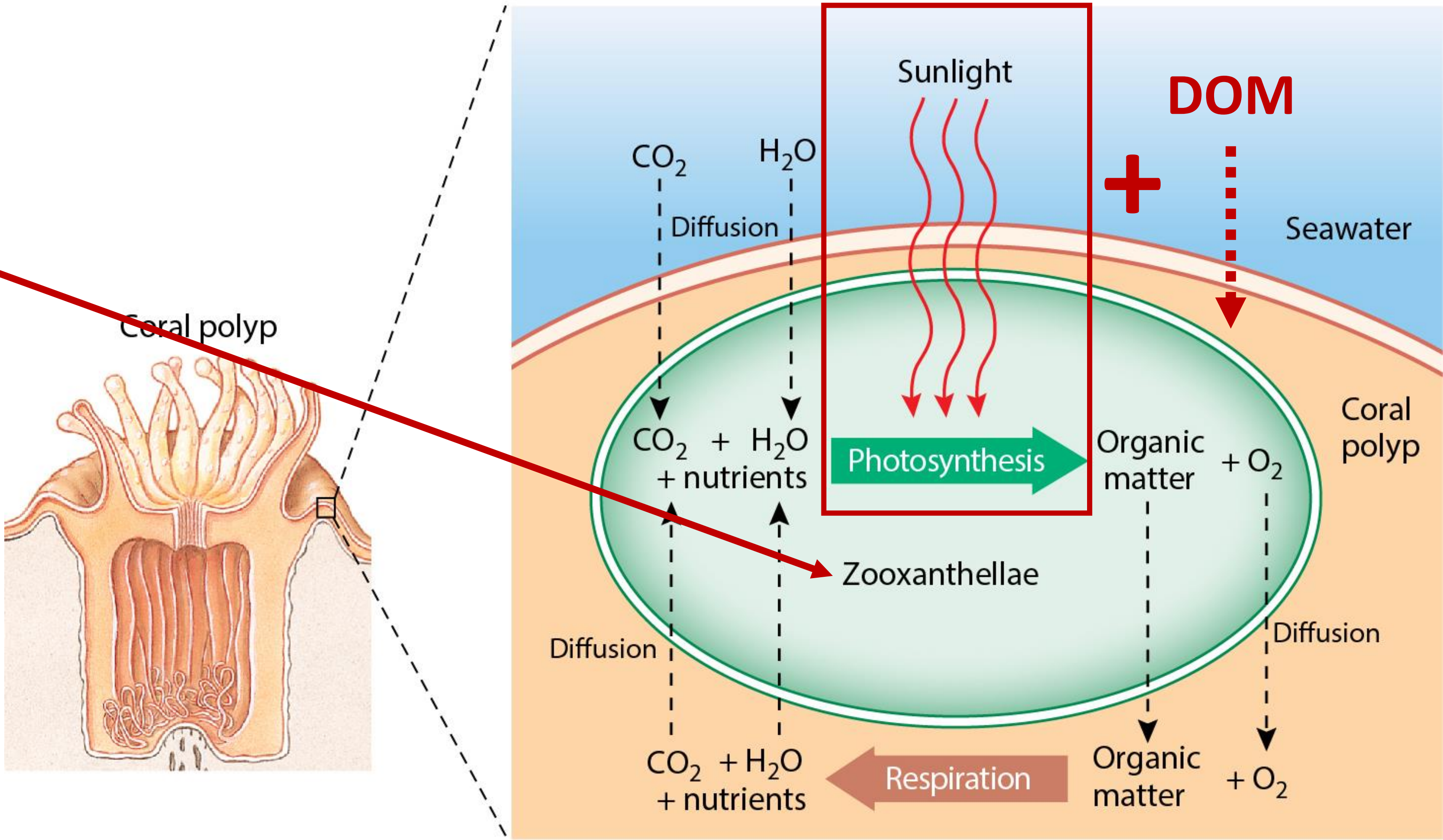
Source: Bill Ober

Utilization of DOM by Corals



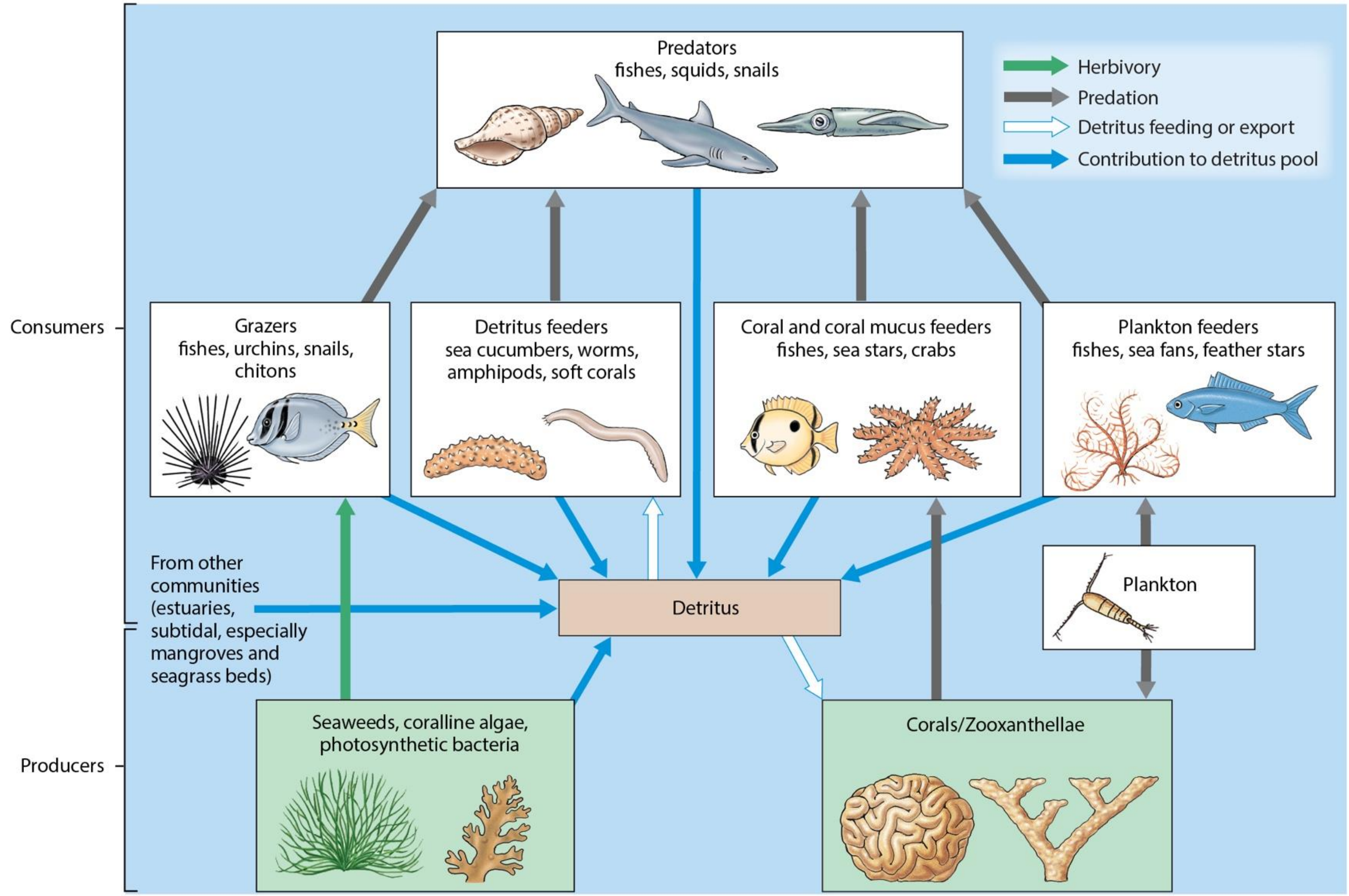
©Oxford Scientific/Getty Images

©Valerie Taylor/ardea.com



Source: Bill Ober

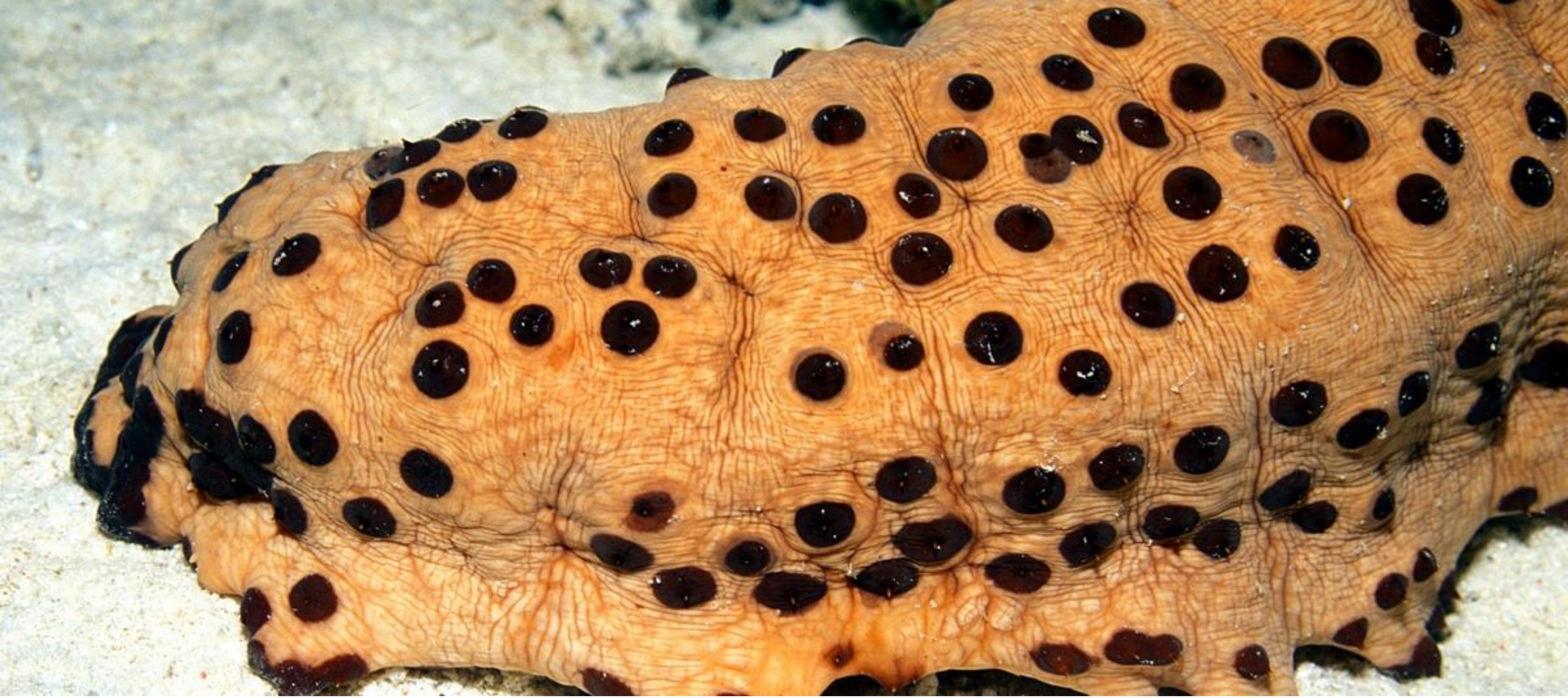
DOM Consumed by Corals to Support Ecosystem



Source: Bill Ober

Summary – Dissolved Organic Matter (DOM)

- **Microorganisms**, due to their sheer abundance, are the **most important contributor of DOM**
- A large portion of the DOM is utilized and re-utilized by bacteria, forming the **microbial loop**
- Through the consumption of bacteria by zooplankton, the DOM becomes available to the food chain
- DOM can also be utilized directly by corals, which in turn support many other marine organisms through the provision of food and shelter
- **Viral shunt** accelerates the release of DOM and helps to balance the ecosystem (avoiding dominance by certain species)



DEPARTMENT OF OCEAN SCIENCE

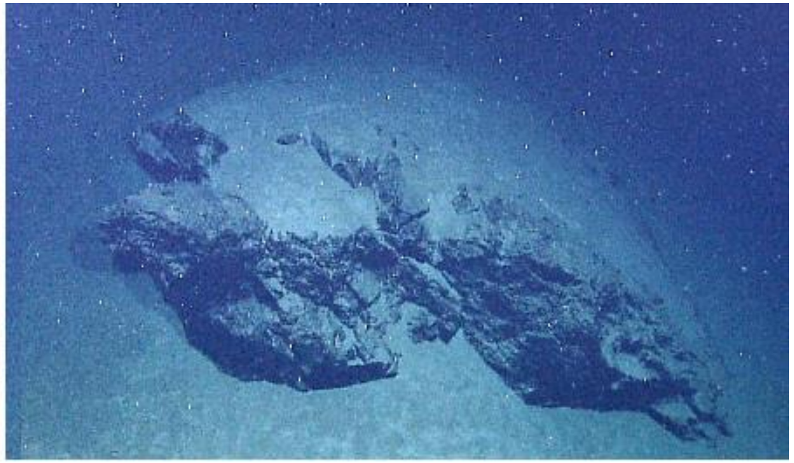
Detritus Feeding

What is Detritus?

In addition to DOM, all life in the ocean produce detritus - decaying waste or debris rich in nutrients from marine life.

- Detritus: In contrast to DOM, **detritus are organic matter in particulate form**, either **suspended** in the seawater or **deposited** on the ocean floor
- **Food source: Detritus is an important food source** for many different types of marine organisms, from heterotrophic microbes to invertebrates

Detritus (millimeter in size)

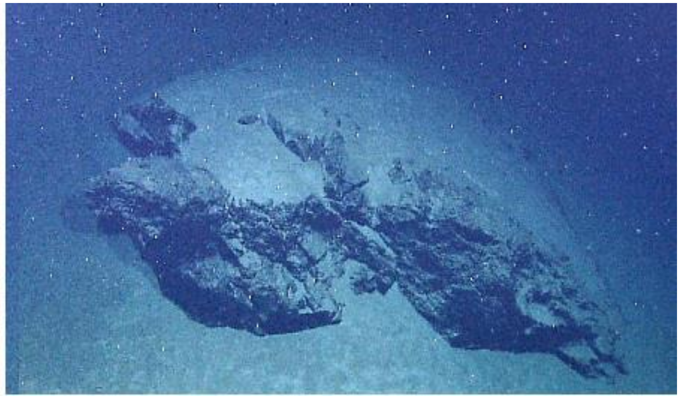


Marine Snow

Origin of Detritus

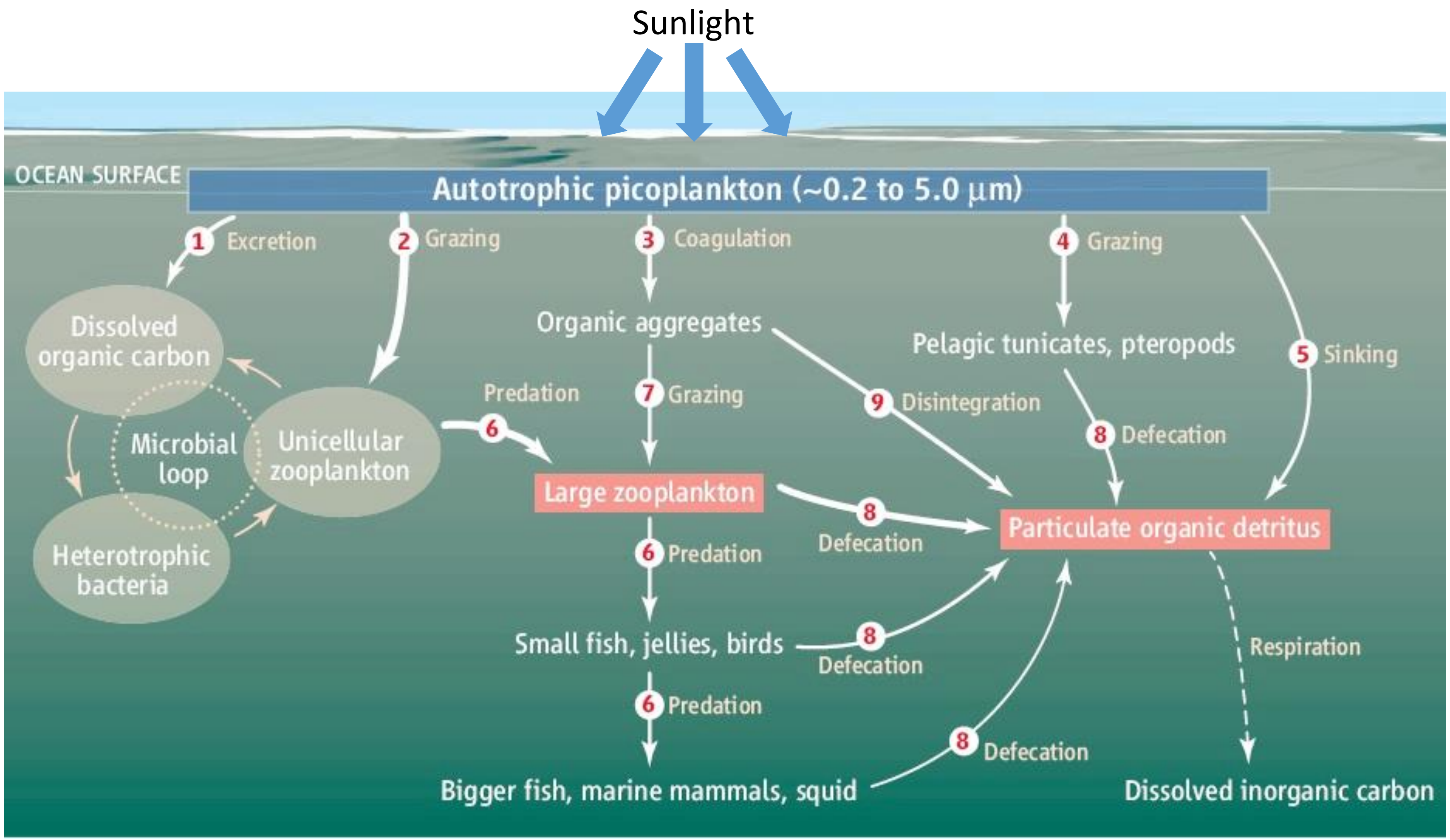
- Detritus are small pieces of organic matter derived from the decomposition of:
  - The solid waste of marine animals
  - The dead biomass of both marine plant and animals
- **DOM** is **dissolved** vs **detritus** exists in the form of **particulates**
- Detritus in the seawater column is drawn to the ocean floor by gravity, forming the so-called **Marine Snow**

Detritus (millimeter in size)



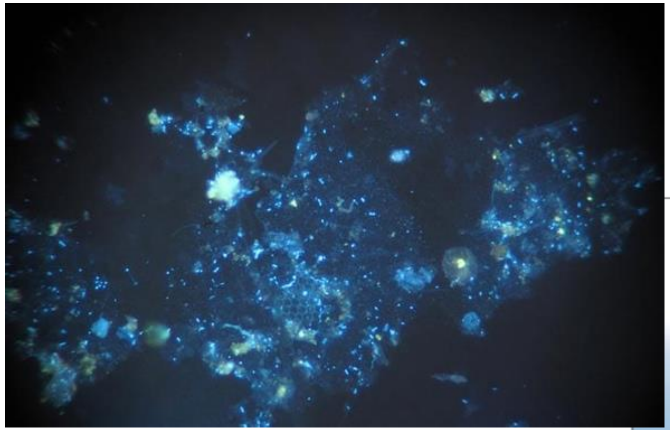
Marine snow

Origin of Detritus

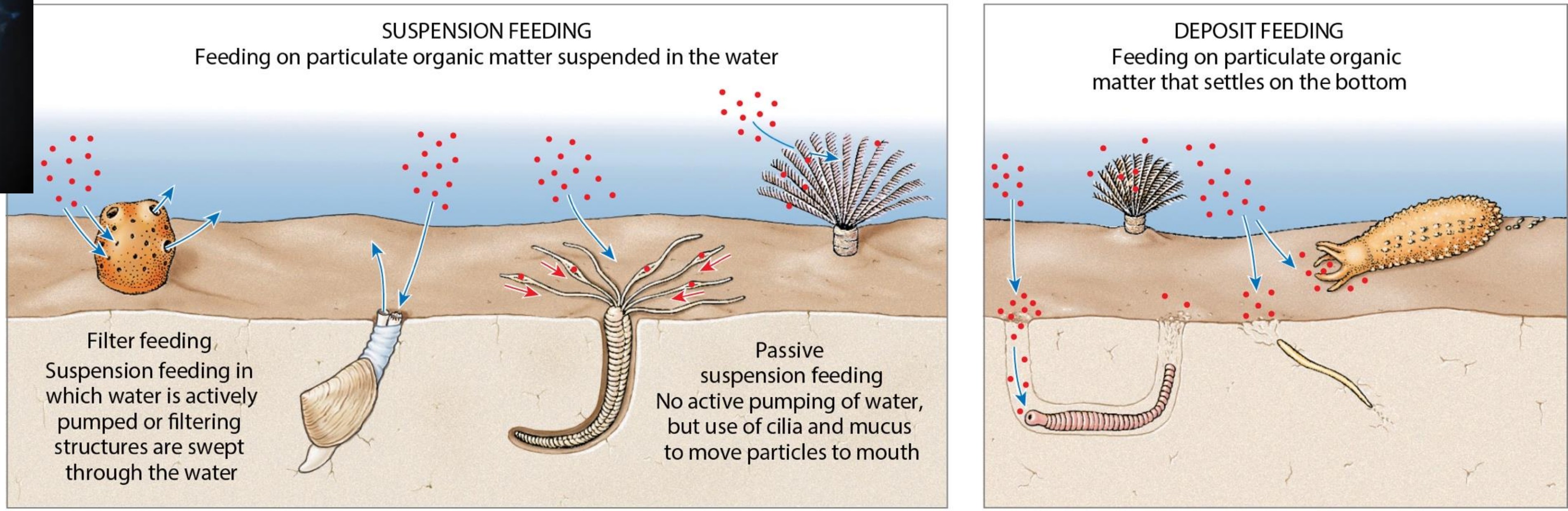


Who Feeds on Detritus?

- **Heterotrophic** (consumers) **bacteria** attached to detritus
- **Marine invertebrates** (invertebrates: animals without backbone)



Bacteria (blue dots) attached to detritus

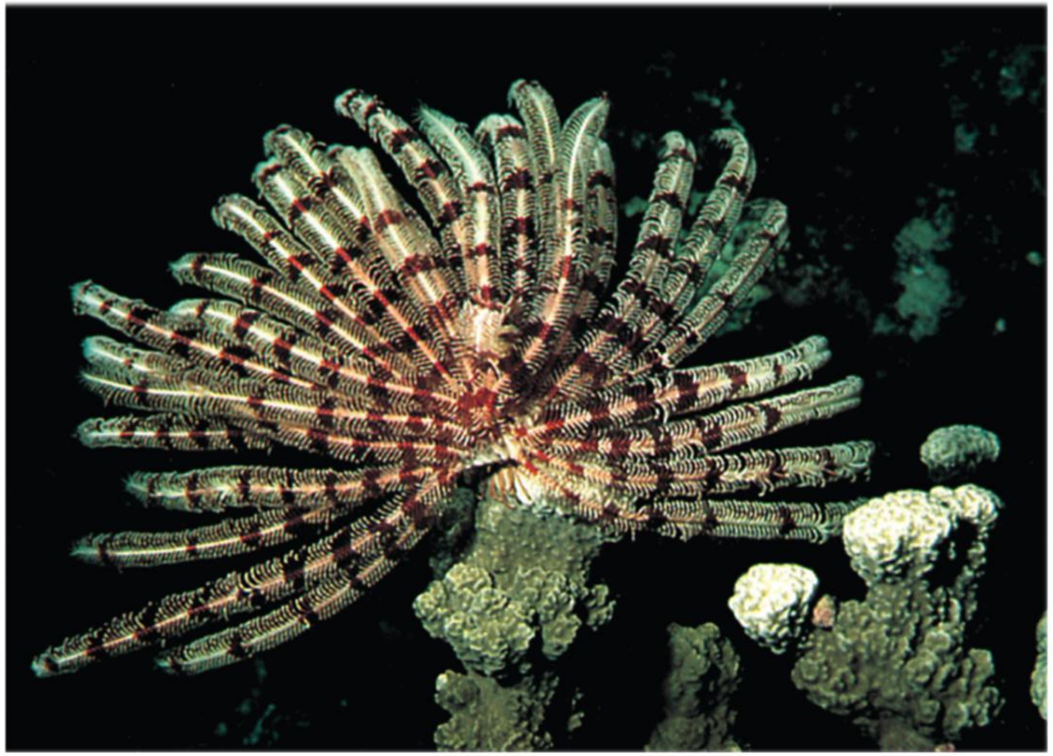


Source: Bill Ober

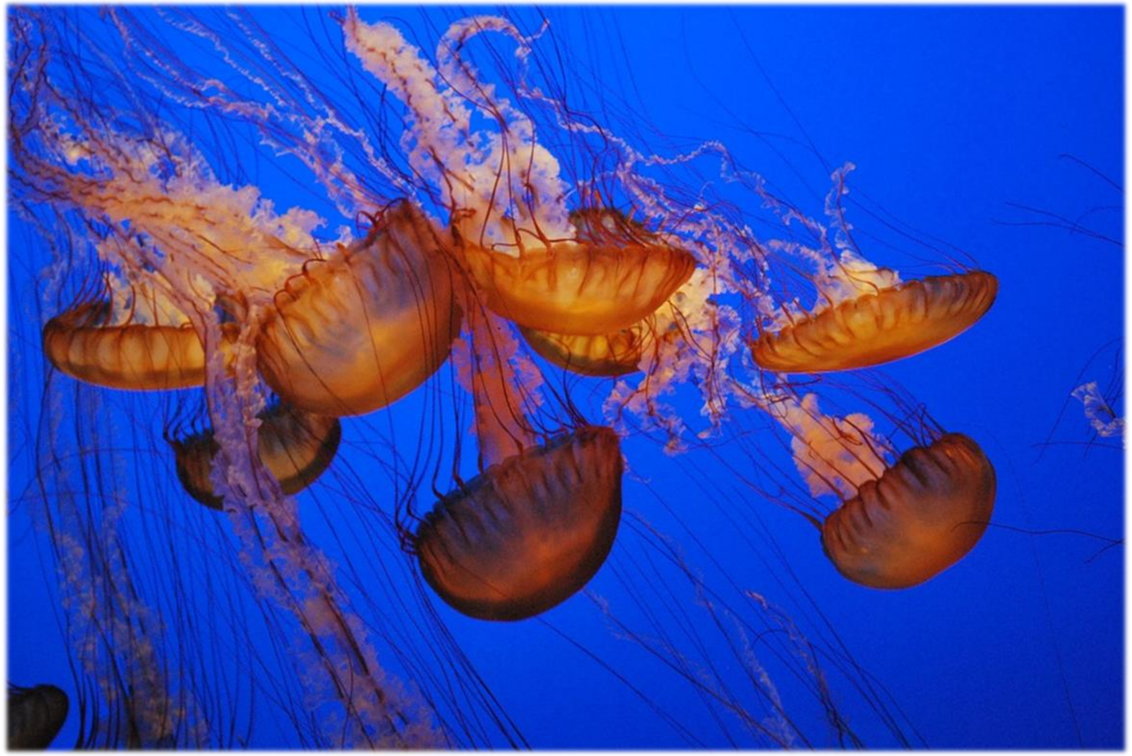
Suspension Feeders – Examples

Suspension Feeders – Animals that feed on particles floating (suspended) in the water

Feather Star



Jellyfish



Filter Feeders – Examples

Filter Feeders – Suspension feeders that actively filter food particles

Tubeworm

Tube Sponge

Clams

Image: Nick Hobgood

Deposit Feeders – Examples

Deposit Feeders – Animals that feed on organic matter that settle on the bottom

Sea Cucumber

Crab

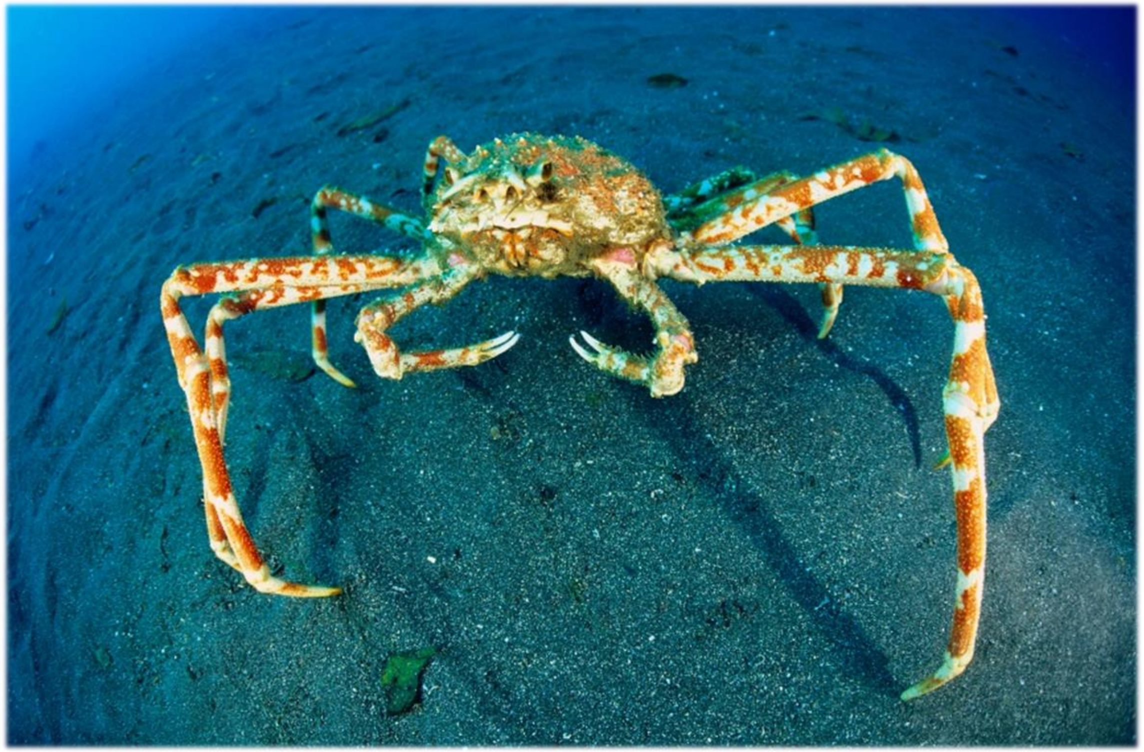
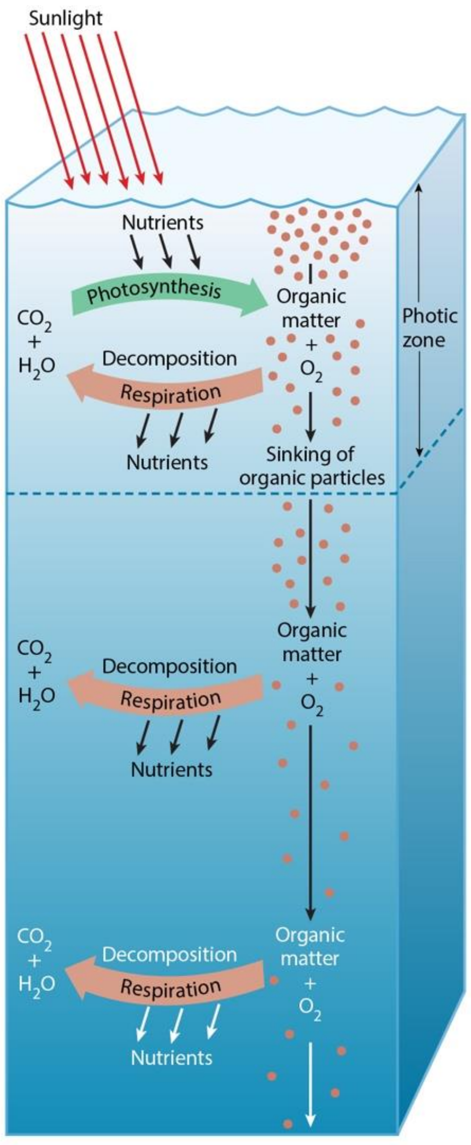


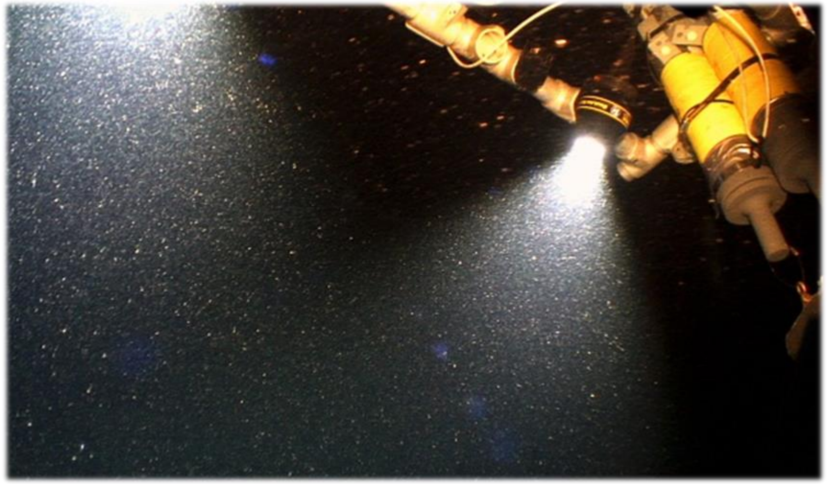
Image: Georgia Aquarium

Marine Snow

- **Detritus** falling onto the ocean floor, like snowfall
- **Heterotrophic bacteria** utilize the organic matter through respiration and produce CO_2, which can be re-utilized by photoautotrophs for photosynthesis
- A lot of **fish and zooplankton** consume marine snow
- **Unconsumed marine snow** reaches the deep ocean and serves as **important food source for the deep sea communities**



Source: Bill Ober



Marine Snow

Summary – Detritus Feeding in the Ocean

- **Detritus** – **Decaying organic matter** rich in nutrients and energy

- Its nutrient and energy return to the food chain through
  - **Active feeding** by fish and zooplankton
  - **Filter feeding, deposit feeding and suspension feeding** by invertebrates

- Detritus falls to the deep ocean as **marine snow**
  - Important food source for the **deep sea** community

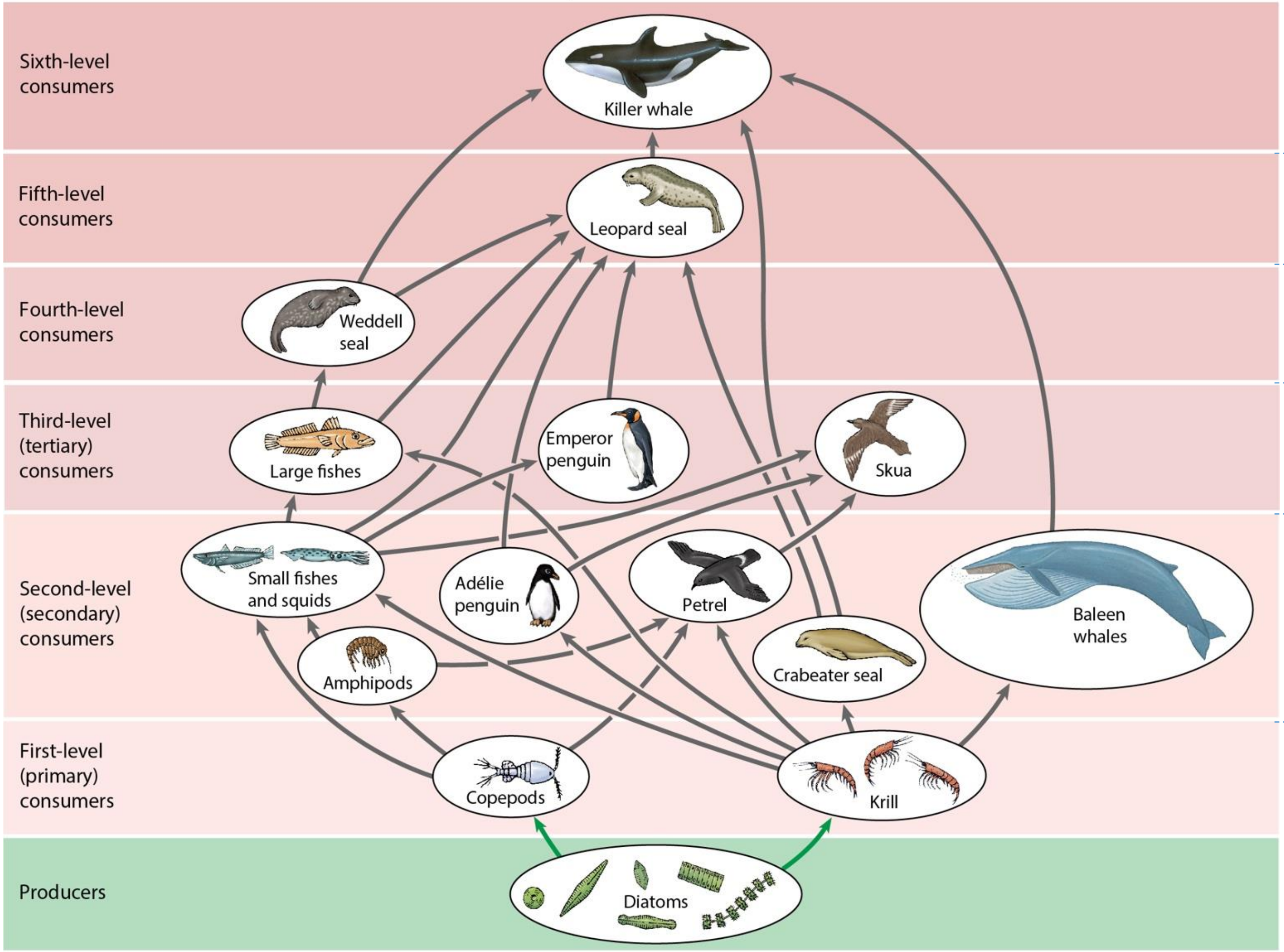
DEPARTMENT OF OCEAN SCIENCE

Predation

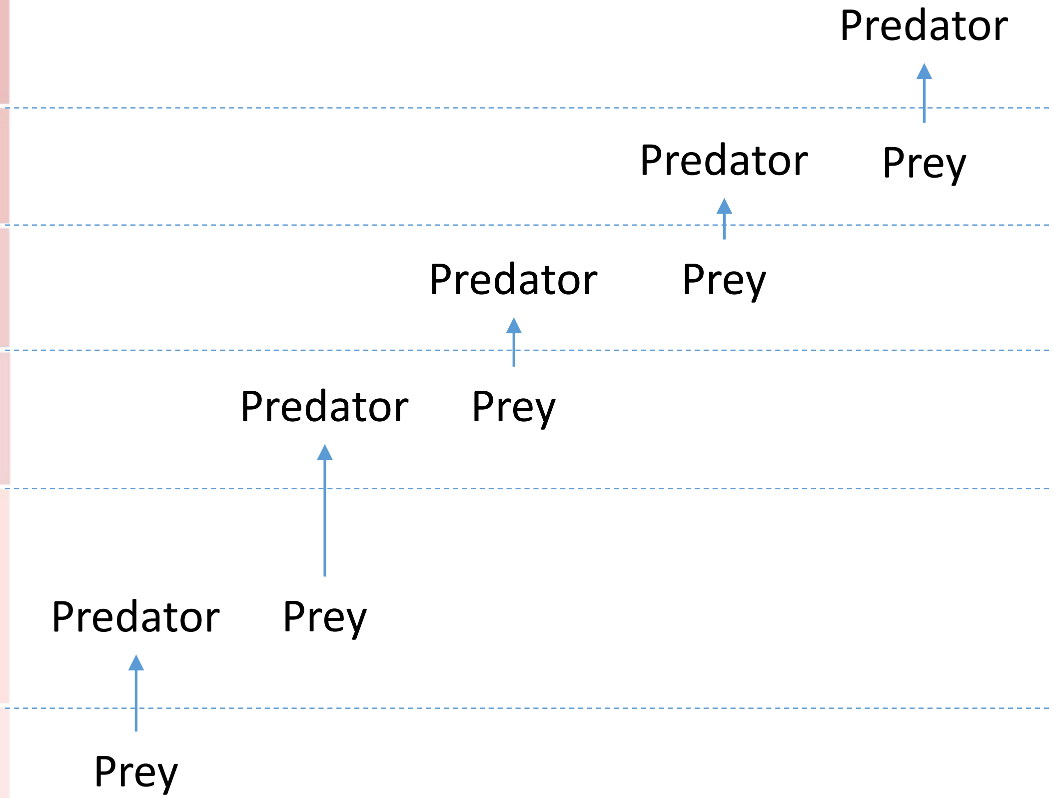
What is Predation?

- Predation is the consumption of **all or part of a living organism** by another
- It involves two parties
  - **Predator** (eating)
  - **Prey** (being eaten)
- Transfers of energy and nutrient from consumers of a lower trophic level to a higher trophic level
- Predator and prey **interact and co-evolve**

Predation



Source: Bill Ober



Predator-Prey Population Cycle

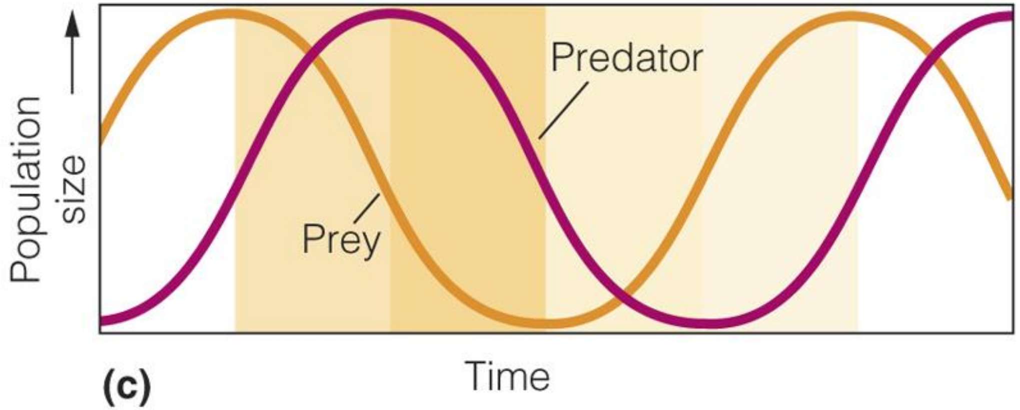
Predator

Source of mortality

Source of nutrient and energy

Prey

Predator and prey population cycle

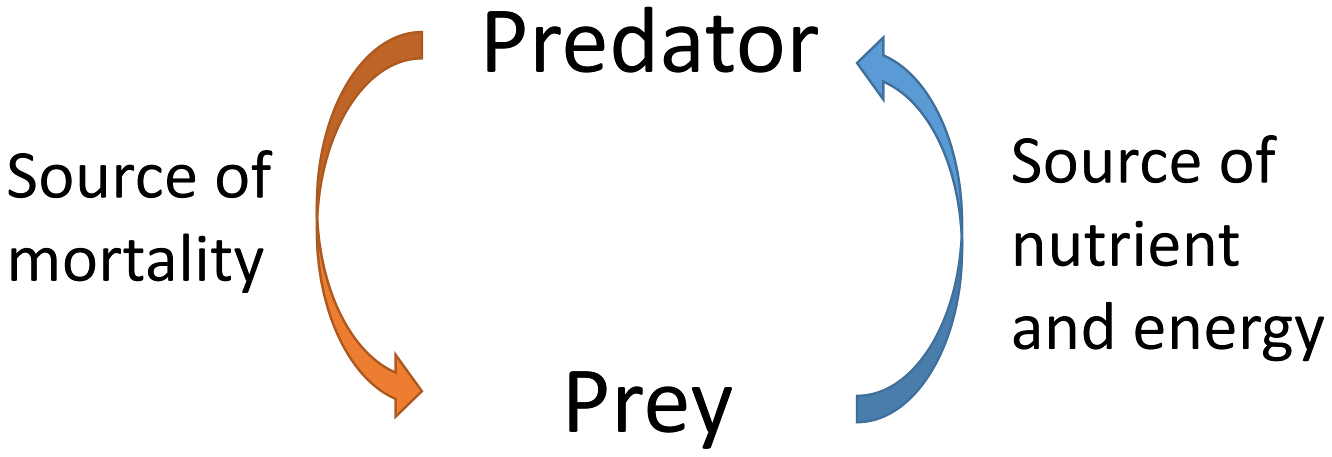


(c)

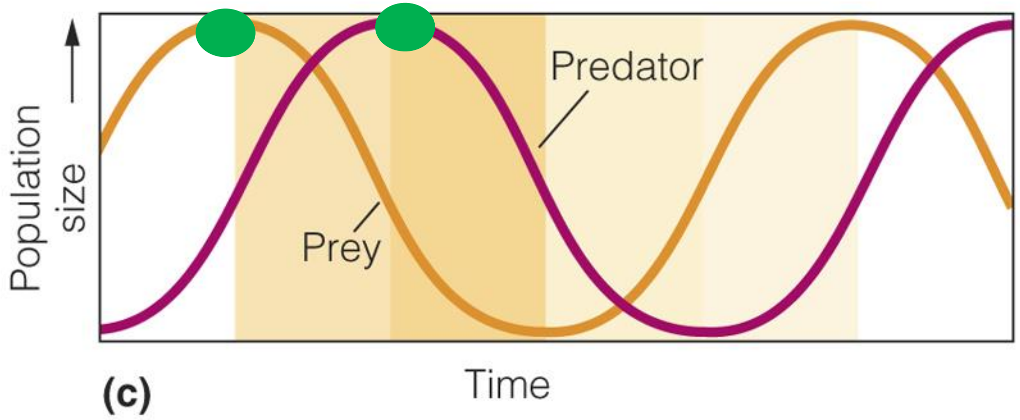
Predator and prey populations cycle through time,

- -> as **predators** decrease numbers of **prey**
- -> lack of food resources in turn decreases **predator** abundance, and
- -> lack of **predation** pressure allows **prey populations** to rebound

Predator-Prey Population Cycle



Predator and prey population cycle



Predator and prey populations cycle through time,
- -> as **predators** decrease numbers of **prey**
- -> lack of food resources in turn decreases **predator** abundance, and
- -> lack of **predation** pressure allows **prey populations** to rebound

Predator-Prey Population Cycle

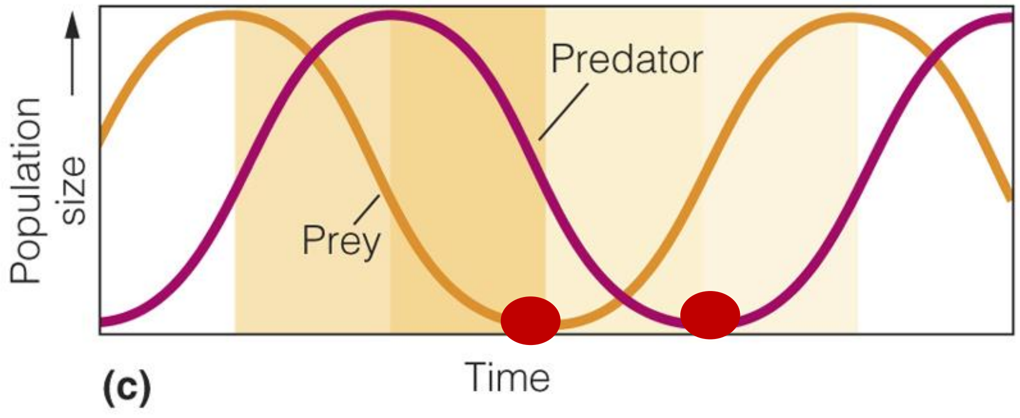
Predator

Source of mortality

Source of nutrient and energy

Prey

Predator and prey population cycle



Predator and prey populations cycle through time,

- -> as **predators** decrease numbers of **prey**
- -> lack of food resources in turn decreases **predator** abundance, and
- -> lack of **predation** pressure allows **prey populations** to rebound

Predator and Prey Co-Evolution

- **Predators exert a selective pressure on prey, and vice versa**
  - Prey species evolve ways to avoid being caught
  - Predators evolve more effective means to capture the prey

- **Natural selection – survival of the fittest**
  - Functions to preserve “smarter,” more evasive prey
  - Produces “smarter,” more skilled predators

Adaptations
e.g. run faster, camouflage

Selective pressure

Predator

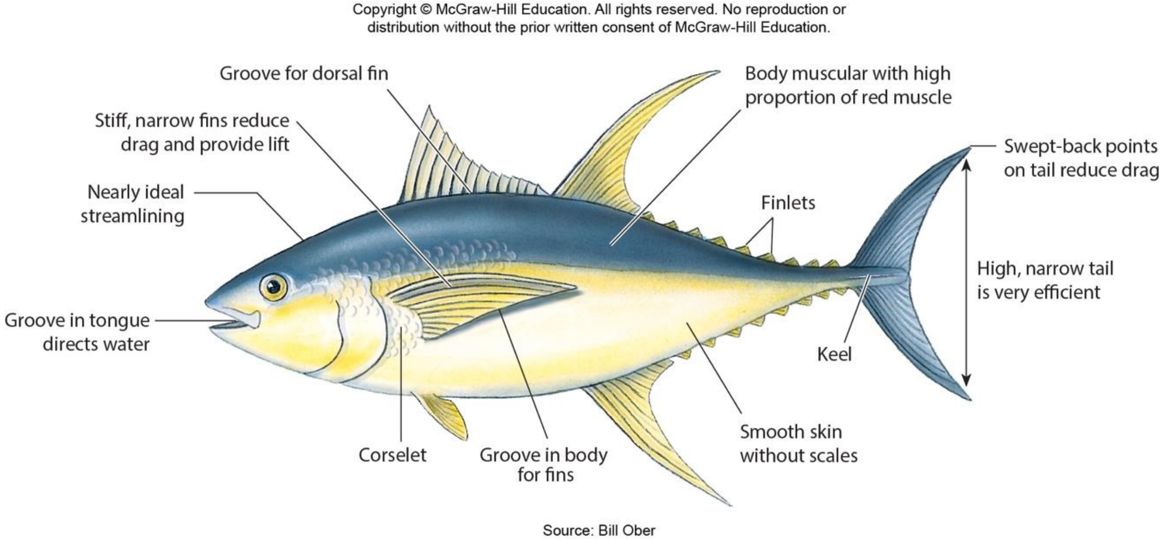
Selective pressure

Prey

Predation Tactics – Pursuit Hunting

- A direct attack by predator
- Involves a lot of chasing (high energy expenditure)

Tuna attacking a school of prey



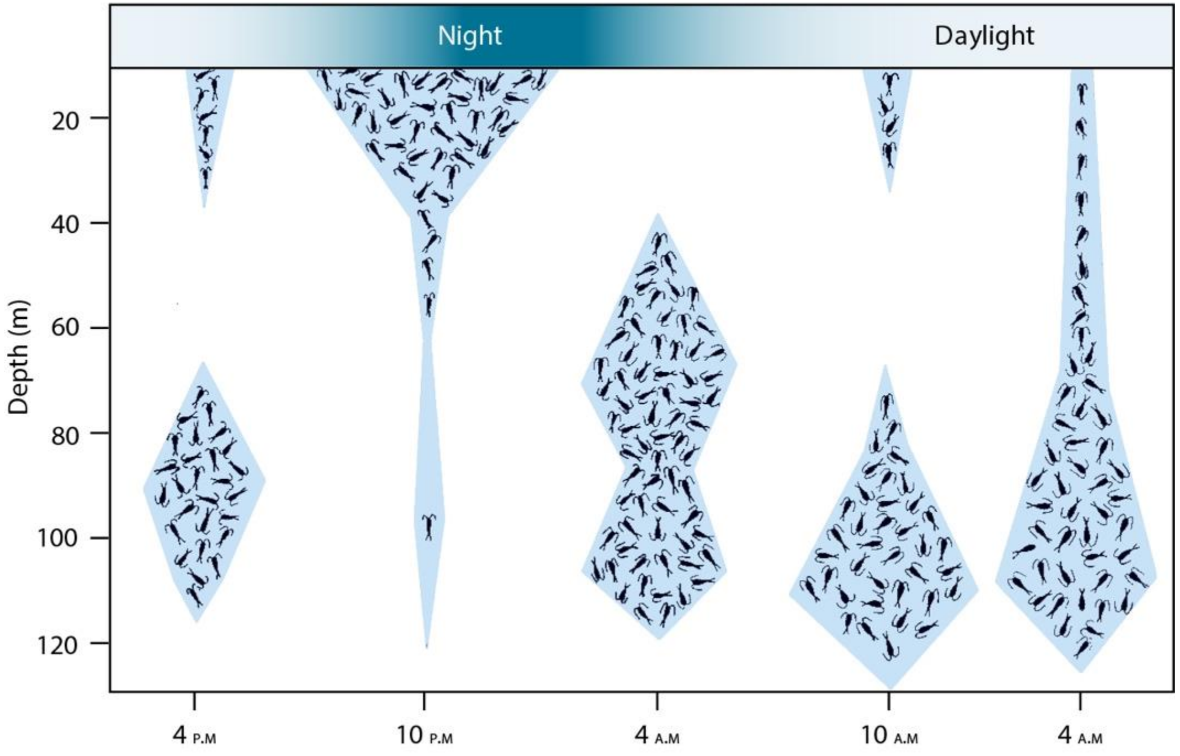
Tuna's body shape
– adapted to high speed swimming

Predation Tactics – Ambush (Sit-and-Wait)

- Predator waits motionlessly for the prey to come by
- Camouflage is often involved (change of color to match with surrounding environment)
- Waiting time can be long (low energy expenditure)

A frogfish camouflaged to match the appearance of a marine sponge while waiting for a prey

Prey's Tactics to Avoid Predators – Behavior

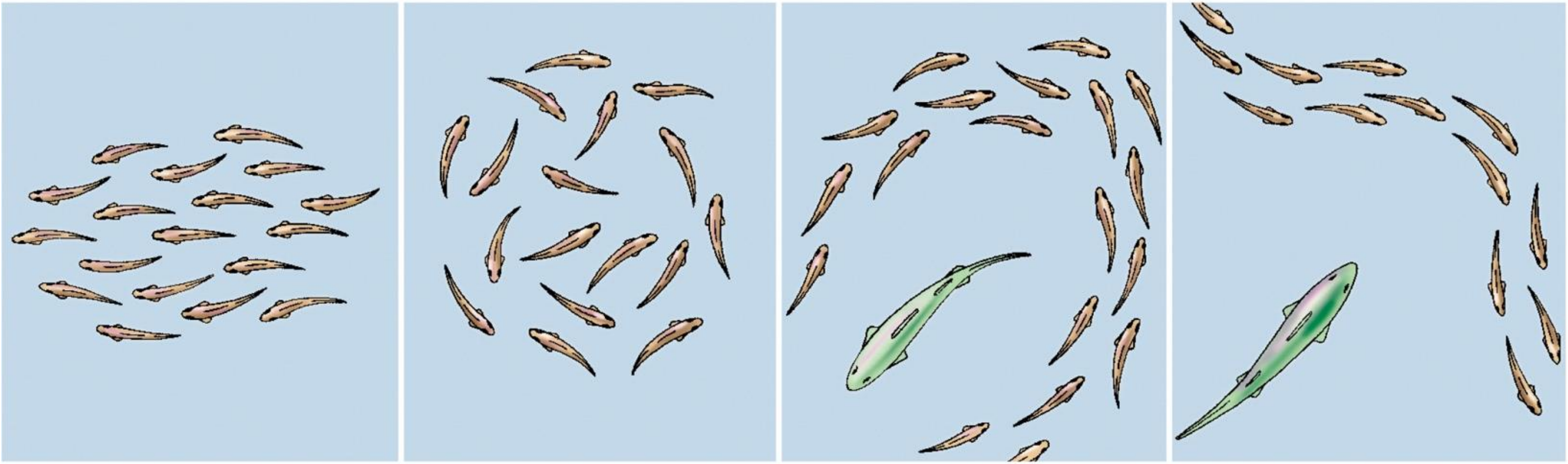


Source: Bill Ober

- Migrating up and down daily requires a lot of energy.
- Would rather spend that energy than be killed.

Daily migration of zooplanktons to avoid predators

Prey’s Tactics to Avoid Predators – Behavior



(a) Traveling (b) Feeding on plankton (c) Encirclement of predator (d) Streaming to avoid predator

Source: Bill Ober

Schooling behavior in response to the presence of predator

Prey's Tactics to Avoid Predators – Camouflage

Protective coloration - making animals or objects hard to see, or by disguising them as something else

©Paul A. Zahl/Getty Images

(a)

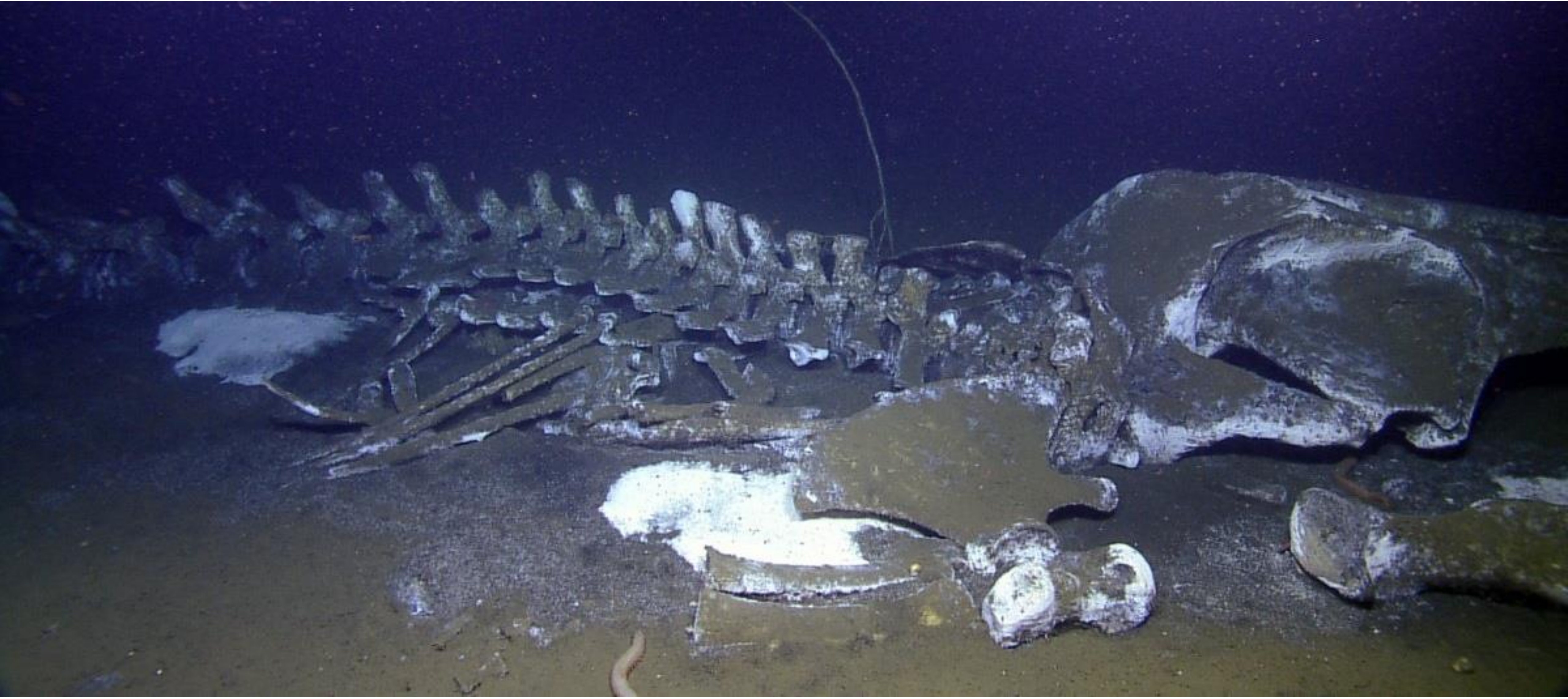
©Fred McConnaughey 2000/Science Source

Summary – Predation in the Ocean

- A marine animal consuming another marine animal
  - The transfer of nutrients and energy from the consumer of one trophic level to the consumer in another trophic level
  - **Tactics**: Active pursuit hunting or passive sit-and-wait
  - **Defense**: Migration, schooling behavior and camouflage

- The population size of a predator species has strong effects on the population of a prey species, and vice versa

- The close interactions between predator and prey lead to never-ending co-evolution



DEPARTMENT OF OCEAN SCIENCE

Scavenging

Scavenging

- The consumption of the dead tissues of plants and animals for nutrients and energy
- Detritus feeders consume small pieces of decaying matter and feces
- Scavengers (clean-up crew) consume dead body parts / tissues that are much larger in scale and they do not consume feces
- Scavengers break down large pieces of dead tissues to smaller pieces (into feces) for detritivores to consume

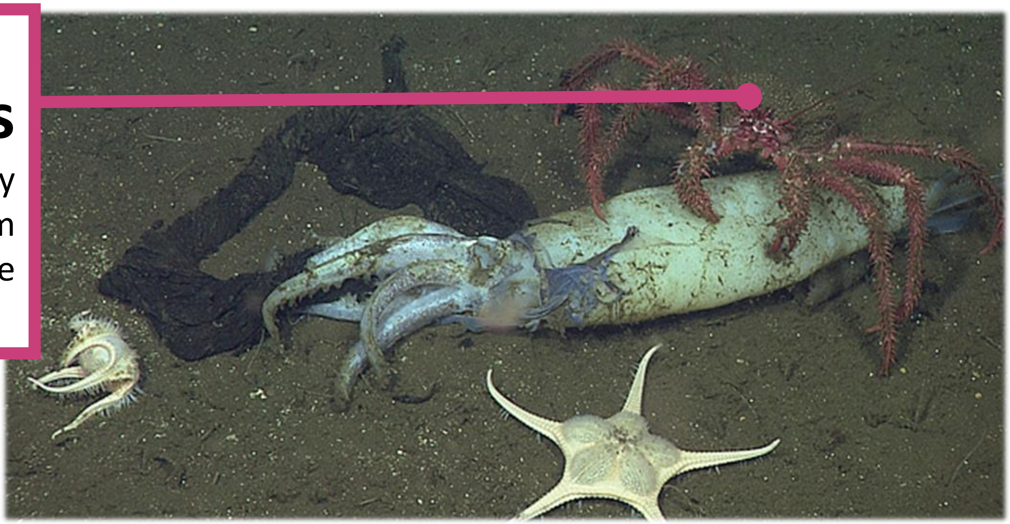
Image: Wikipedia

Scavenging

- The consumption of the dead tissues of plants and animals for nutrients and energy
- Detritus feeders consume small pieces of decaying matter and feces
- Scavengers (clean-up crew) consume dead body parts / tissues that are much larger in scale and they do not consume feces
- Scavengers break down large pieces of dead tissues to smaller pieces (into feces) for detritivores to consume

Detritus feeder

Image: Wikipedia

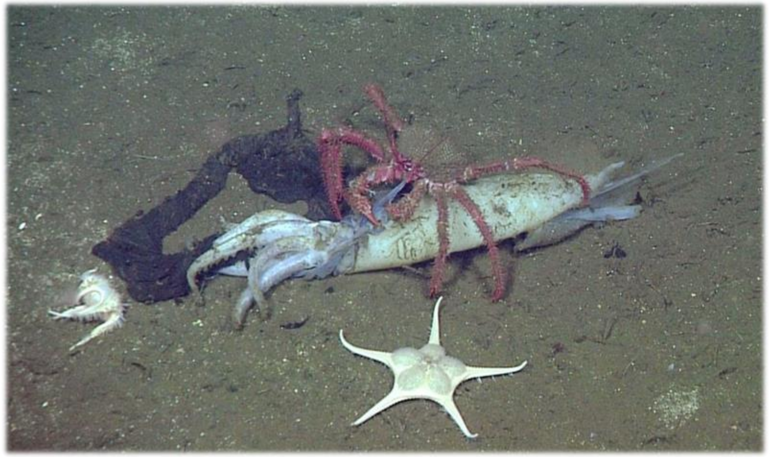


Scavengers

Image: Monterey Bay Aquarium Research Institute

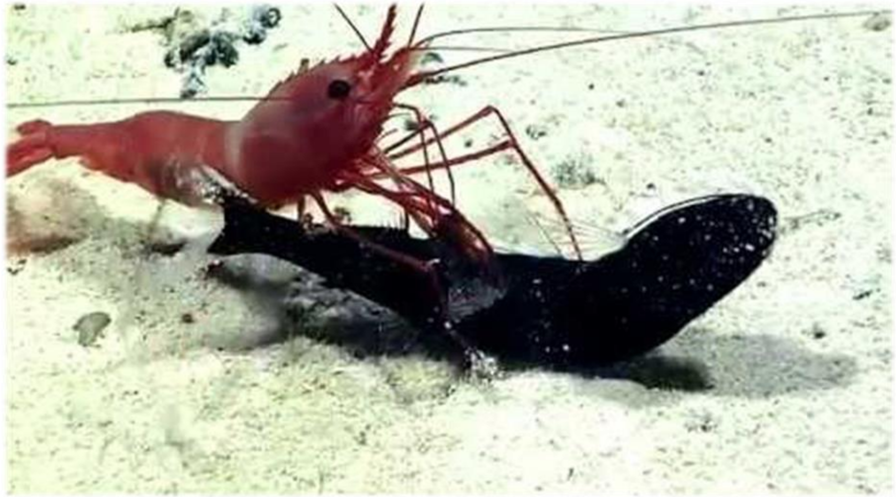
Scavengers – Examples

Spider Crab feeding on dead squid



Scavenger Shark feeding on dead whale

Shrimp feeding on dead fish



Giant Isopod – a deep-sea scavenger

Hagfish

Alamy/blickwinkel/Hartl

Hagfish: a jawless fish that eats live invertebrates and also dead animals

Hagfish uses rows of sharp teeth to pierce the tissue of dead animals, entering the body of the dead animals, and feeding from inside out

Hagfish – Fun Facts

- Hagfish can live up to months without food

- Hagfish **slime** gives hagfish a **slippery exit** when attacked by predators. A larger fish looking for a meal instead gets a mouth full of slime, while the hagfish can slide away
  https://www.youtube.com/watch?v=t5PGZRxhAyU

- Not only are hagfishes **jawless**, but they are also **boneless**. They have a skull made of cartilage and have no backbone

Summary – Scavenging in the Ocean

Every species has its own niche in the ecosystem.

- Unlike predators catching and eating live preys, scavengers’ diet is **dead tissue**
- Scavengers are important to **nutrient recycling**, through breaking down large pieces of dead tissues into smaller fragments (into feces) for detritivores
- The feces produced by scavengers are further utilized by detritivores
    - Waste of one species is the food for another species
    - **Nothing is wasted**

DEPARTMENT OF
OCEAN SCIENCE

Parasitism

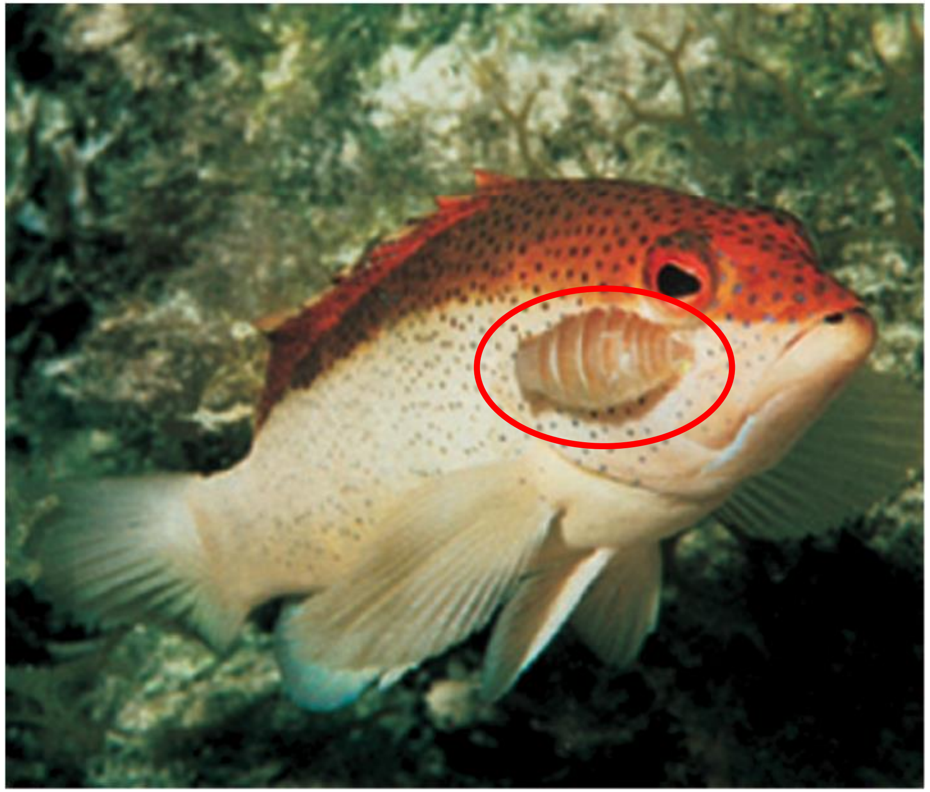
What is Parasitism?

- Involves organisms of two different species
  - A **host** and a **parasite**
- Parasite derives nutrients and energy from the host
  - The host is **harmed but not killed** (i.e. not predation)
  - However, the **host may die from other causes** associated with parasitism
- Similar to predation, parasite and host undergo continuous **co-evolution**

Parasitism

- A parasite obtains nutrients and energy by "stealing" from the host
  - This is the only way a parasite gets nutrients
  - **Highly species-specific**
- Very often a parasite also uses the host's body as **living habitat** and **site for reproduction**
- **A parasite does not intend to kill the host**
  - Otherwise, a parasite will lose its only source of nutrients and habitat
- However, host may suffer from disease, reduced growth, sterility or even death due to **secondary infection (by bacteria or viruses)**

Parasitism on Fish – Examples



©Charlie Arneson

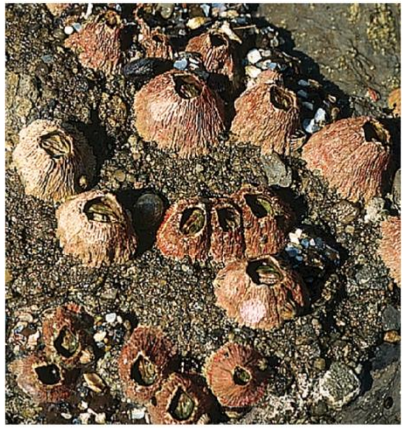
An isopod (parasite) sucking blood from a fish (host).

White spot disease caused by protozoa parasite. Infected fish often die from secondary infection.

Parasitism on Whales – Examples

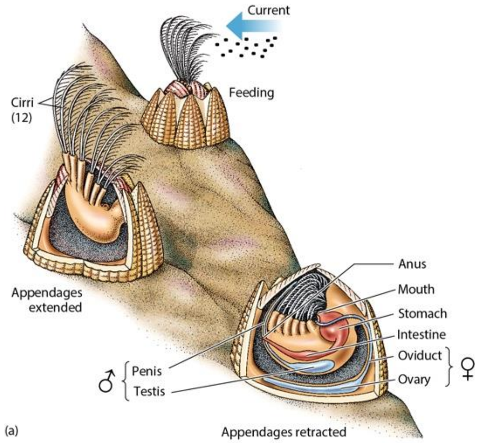
©Michael Poliza/Getty Images

Barnacles are filter feeders. They themselves can be parasites of whales.



(b)

©Peter Castro

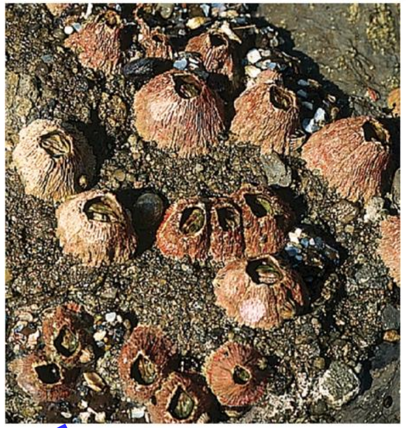


(a)

Source: Bill Ober

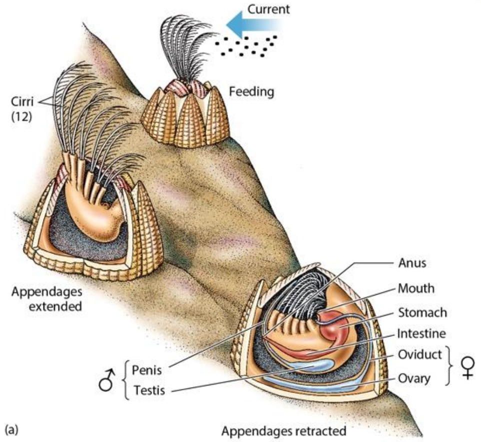
Defense against Parasitism on Whales – Examples

©Bill Ober



(b)

©Peter Castro



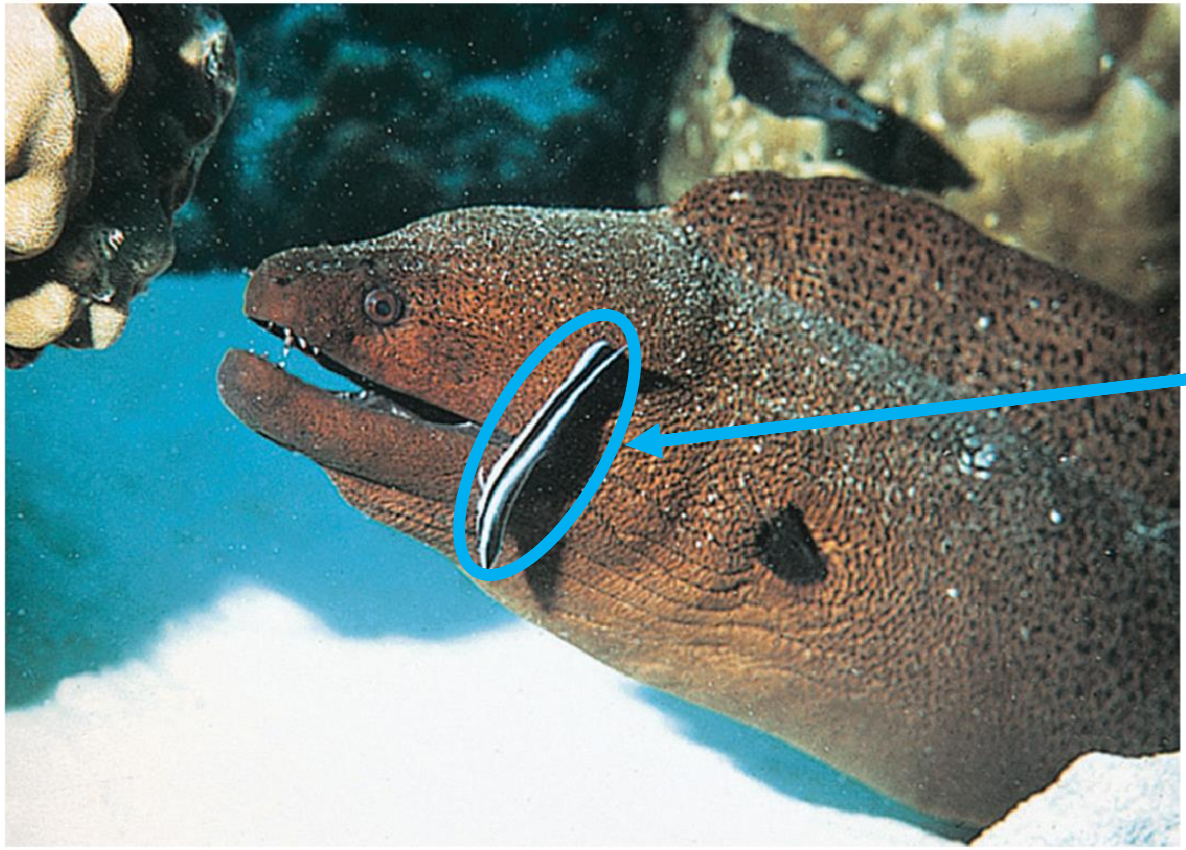
(a)

Source: Bill Ober

Aerial display is believed to be a behavior to **dislodge (get off) parasites** from the surface of marine mammals.

However, this behavior **costs energy**.

Examples of Defense against Parasite



©Bill Ober

A small fish is picking parasites off the skin of a moray eel.

Parasite and Host Coevolution

Needs to balance the **cost of defense** and the **loss of nutrients** to parasite

Host

Defense

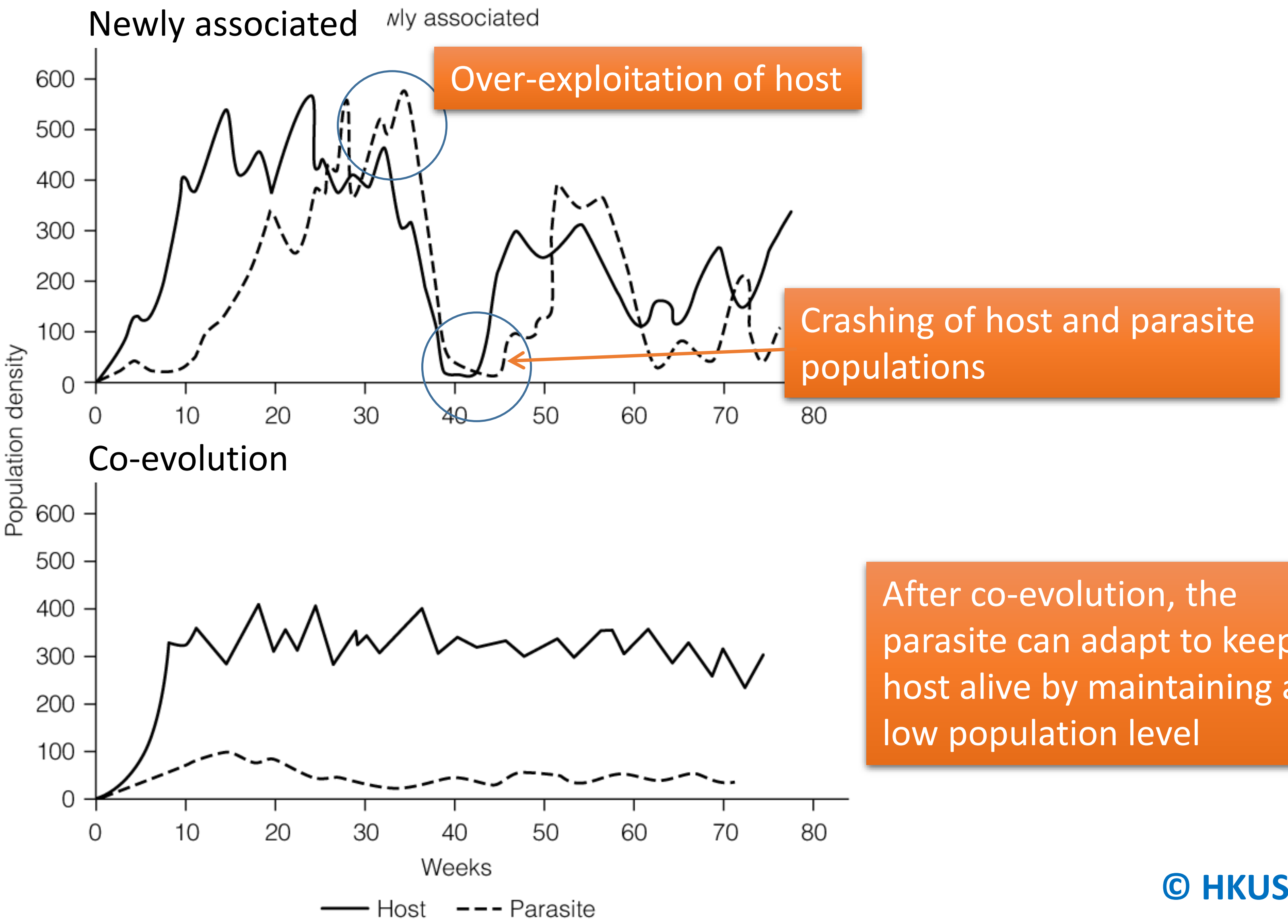
Co-evolved to keep parasitism to low levels

Source of nutrients, energy and shelter

Parasite

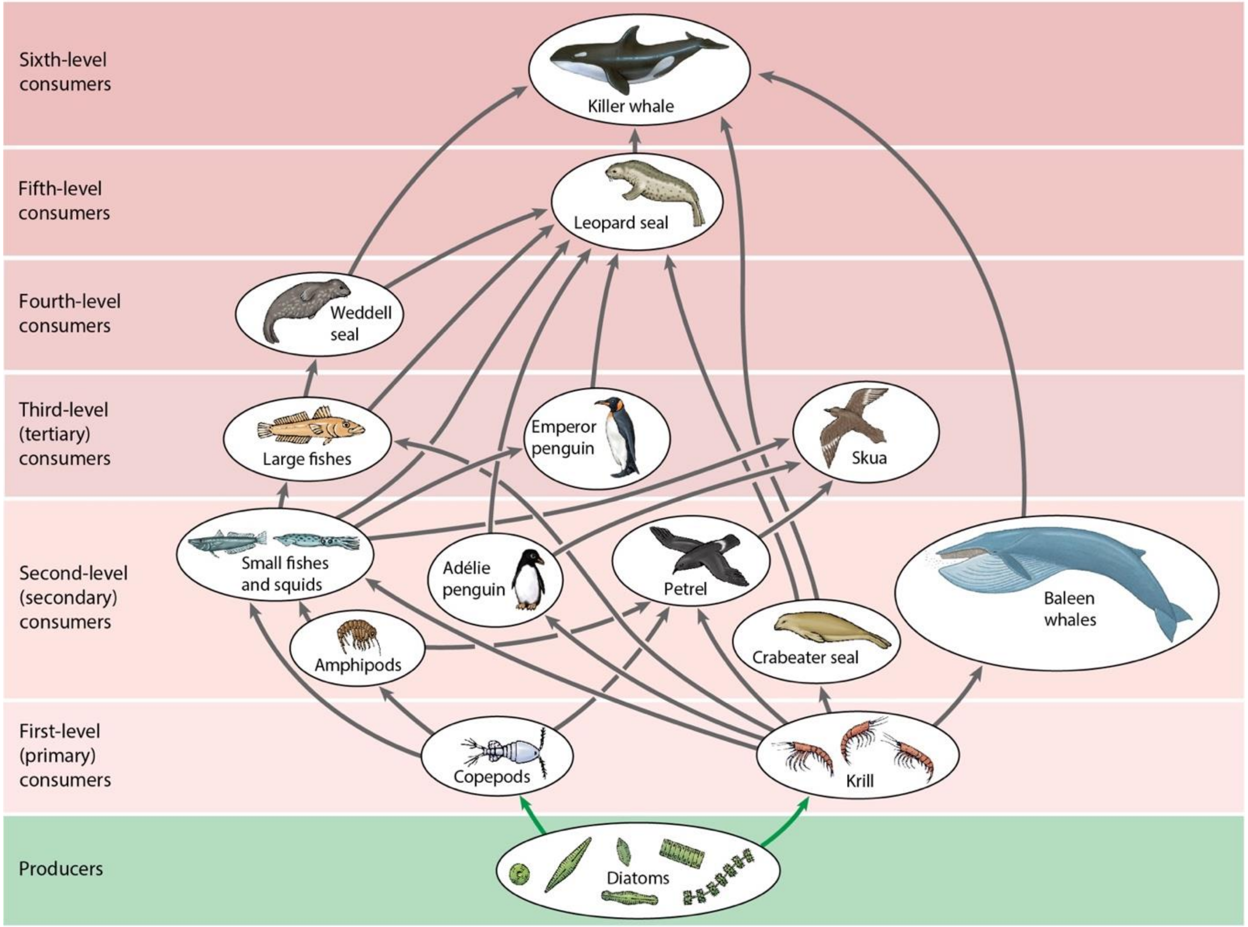
Needs to learn to **avoid host defense** and take advantages from the host **without stressing it to death**

Host and Parasite Balance in Ecosystem



After co-evolution, the parasite can adapt to keep the host alive by maintaining a low population level

Parasitism in the Marine Ecosystem



Source: Bill Ober

- Parasitism is **very common** in the marine environment
- Each species in the food web can be infected by **one or multiple** species of parasites
- The **total biomass of parasites** in a food web **can be larger than that of the top predators**

How do Parasites Fit into the Food Web?

- However, **parasites are not shown in the food web** and their **effects on the food web remain poorly understood.**

- Researchers tend to compile data on the **easy-to-observe species** in ecosystems. Small, cryptic or non-free-living organisms, such as prokaryotes, soil organisms and parasites, are generally absent from food webs. This is partly attributable to a lack of disciplinary integration.

Summary – Parasitism in the Ocean

- Parasitism is **very common** in the marine environment
  - However, its effects on the food web remain largely unknown

- A parasite derives benefits from the host **without the intention to kill the host**
  - Host's death is an **unintended consequence** (a parasite will lose its only source of nourishment (nutrients) and habitat). **The parasite harms the host** but does not kill it.

- Complex **co-evolution** occurs between host and parasite
  - A successful parasite should cause **"unnoticeable" adverse effects** to the host

DEPARTMENT OF OCEAN SCIENCE

Proto-Cooperation

What is Proto-Cooperation?

- Over a very long period of time, the co-evolution of a host-parasite relationship may lead to **Commensalism**
  - A relationship between two species in which **one gets an advantage from living closely with the other** and **the other is not affected** by it
- The impacts of a parasite to the host has been reduced to an **unnoticeable level**
  - Parasite gains benefits **without harming** the host
- A **further co-evolution from commensalism** will lead to **Proto-Cooperation**
  - A relationship that **benefits both parties**
  - **Non-obligatory**

Intimate Relationships

- **Parasitism** – one-sided benefit, parasite **harms the host**
- **Commensalism** – one-sided benefit **without harming the host**
- **Proto-cooperation** – **mutual benefits** and **non-obligatory**
- **Mutualism** – **mutual benefits** and **obligatory**

Parasitism $\xrightarrow{\textit{co-evolution}}$ **Commensalism** $\xrightarrow{\textit{co-evolution}}$ **Proto-cooperation** $\xrightarrow{\textit{co-evolution}}$ **Mutualism**

Symbiosis / Asymbiosis

Proto-Cooperation – Example

Sea anemones on the shell where a hermit crab lives in

Sea Anemone (parasite) gains benefits of mobility by getting a lift on a **Hermit Crab (host)** and it can take food from the hermit crab.

The Hermit Crab seems to be adversely affected

- Losing food
- Carrying the weight of the sea anemone costs energy

However, the Hermit Crab can gain protection by the Sea Anemone from predators *(e.g. octopus).*

The two parties can live separately. But this **non-obligatory** association provides benefits, given that the **benefits gained > the costs**.

Click to watch: https://www.youtube.com/watch?v=dYFALyP2e7U

Summary – Proto-Cooperation in the Ocean

The result of the continuous co-evolution between a host and a parasite.

- First, the parasite's harm to the host is reduced to an unnoticeable level (commensalism).
- Then, the "**host**" **finds benefits of the association by cooperating with the "parasite".**
- Nonetheless, proto-cooperation is **non-obligatory**; it is maintained as long as the **benefits out-weigh the costs**.

DEPARTMENT OF OCEAN SCIENCE

Mutualism

What is Mutualism?

- Mutualism is the result of **continuous co-evolution from proto-cooperation**
- Unlike the non-obligatory proto-cooperation, mutualism is **strictly required for the survival of the two parties**
  - The two parties are **unable to live apart**

Intimate Relationships

- **Parasitism** – one-sided benefit, parasite **harms the host**
- **Commensalism** – one-sided benefit **without harming the host**
- **Proto-cooperation** – **mutual benefits** and **non-obligatory**
- **Mutualism** – **mutual benefits** and **obligatory**

$$\underbrace{\textbf{Parasitism} \xrightarrow{\textit{co-evolution}} \textbf{Commensalism} \xrightarrow{\textit{co-evolution}} \textbf{Proto-cooperation} \xrightarrow{\textit{co-evolution}} \textbf{Mutualism}}_{\textbf{Symbiosis / Asymbiosis}}$$

Examples of Mutualism – Lichen

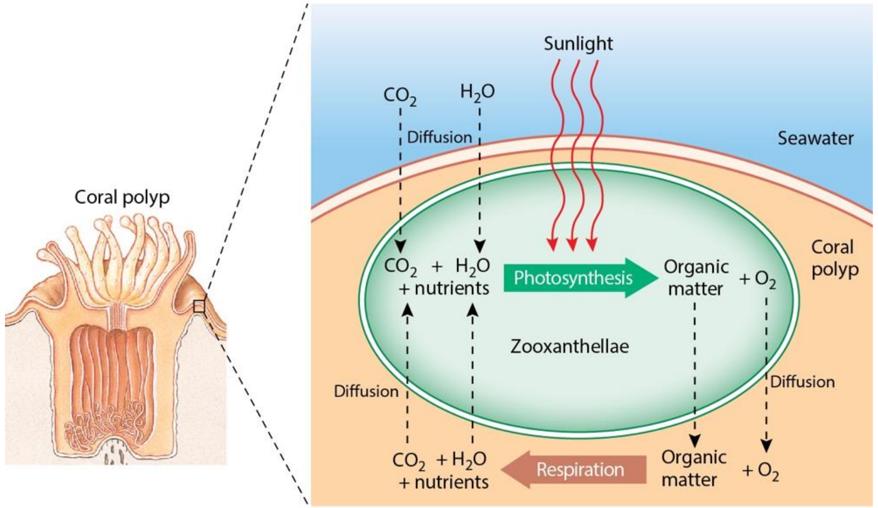
Lichen

- An association between **fungi** and **cyanobacteria** (algae)
- The fungi absorb and store water during high tide
- The cyanobacteria uses photosynthesis to provide nutrients to the fungi
- Without this association, the cyanobacteria could not survive the dryness during low tide and the fungi could not have nutrients

Lichen living on rock surfaces near the shore

Examples of Mutualism – Corals and Zooxanthellae

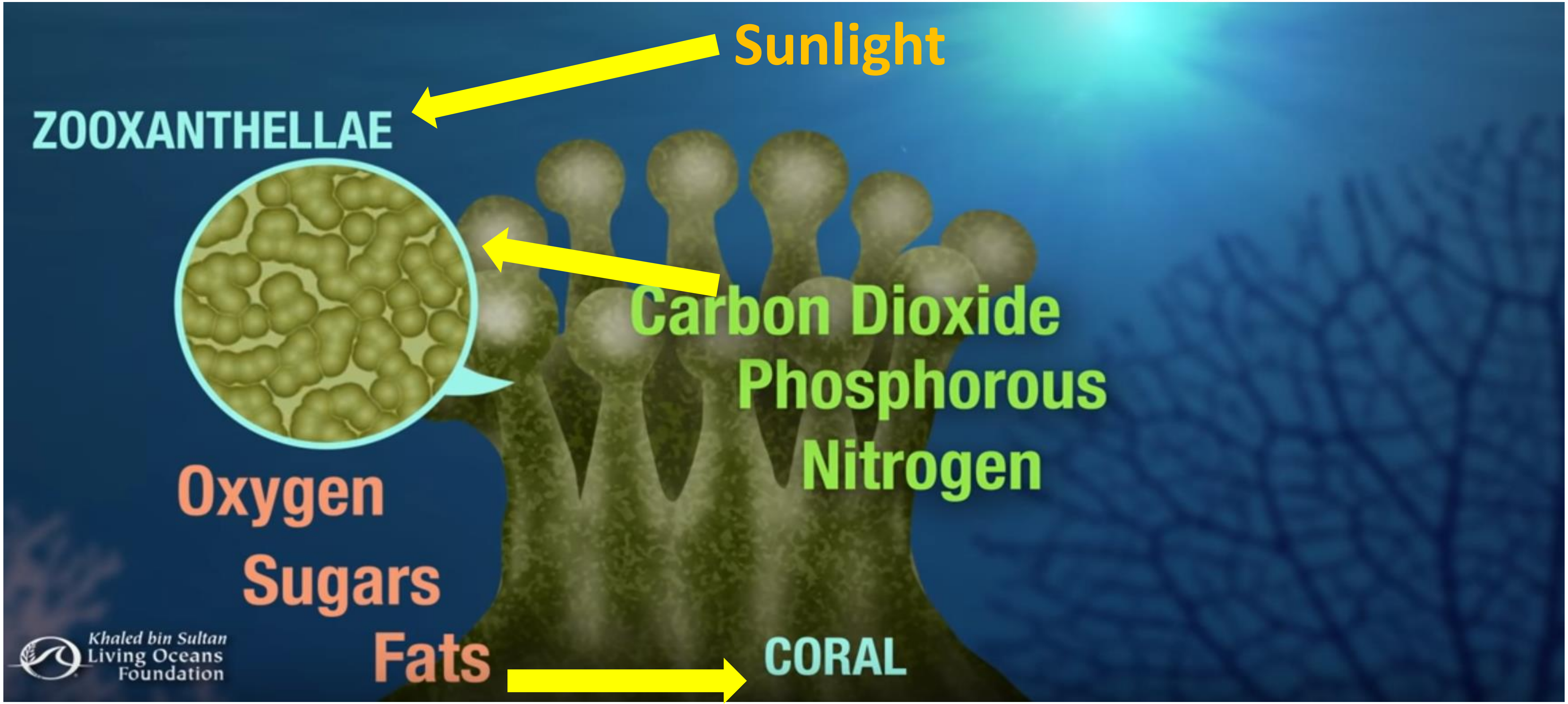
- **Zooxanthellae**: photoautotroph, able to undergo **photosynthesis**
- They provide organic food to corals
- The corals utilize the organic food for respiration and produce CO_2 to zooxanthellae for photosynthesis



Source: Bill Ober

©Oxford Scientific/Getty Images

Examples of Mutualism – Corals and Zooxanthellae



Click to watch:https://www.youtube.com/watch?v=tZuxZdG6TfM

Summary – Mutualism in the Ocean

- An **obligate** association/relationship between two species

- However, the association/relationship is **not without a cost**
  - One provides nutrients to the other party in exchange for shelter or other nutrients

- There is always a **conflict of interest** between two parties
  - Cheating: getting benefits without reciprocation
    - Essentially a host-parasite relationship

- Continuous co-evolution is necessary

DEPARTMENT OF OCEAN SCIENCE

Summary:

A Glimpse of the Diversity of Marine Life – How do They Obtain Food?

Relationships of Marine Life

- **Food Chain** – Producers, consumers and decomposers
- **Food Web** – transfer 10% of energy and nutrients from lower to higher trophic level
- **Photoautotroph** – undergoes photosynthesis (sunlight, CO_2 & H_2O)
- **DOM and Detritus Feeders** – important part of the food web by recycling organic matter
- **Predation vs. Scavenging** – predators hunt prey; scavengers consume dead tissues, providing nutrients through feces for detritivores
- **Parasitism, Proto-cooperation, Mutualism** – intimate associations between two species for nutrients and energy acquisition

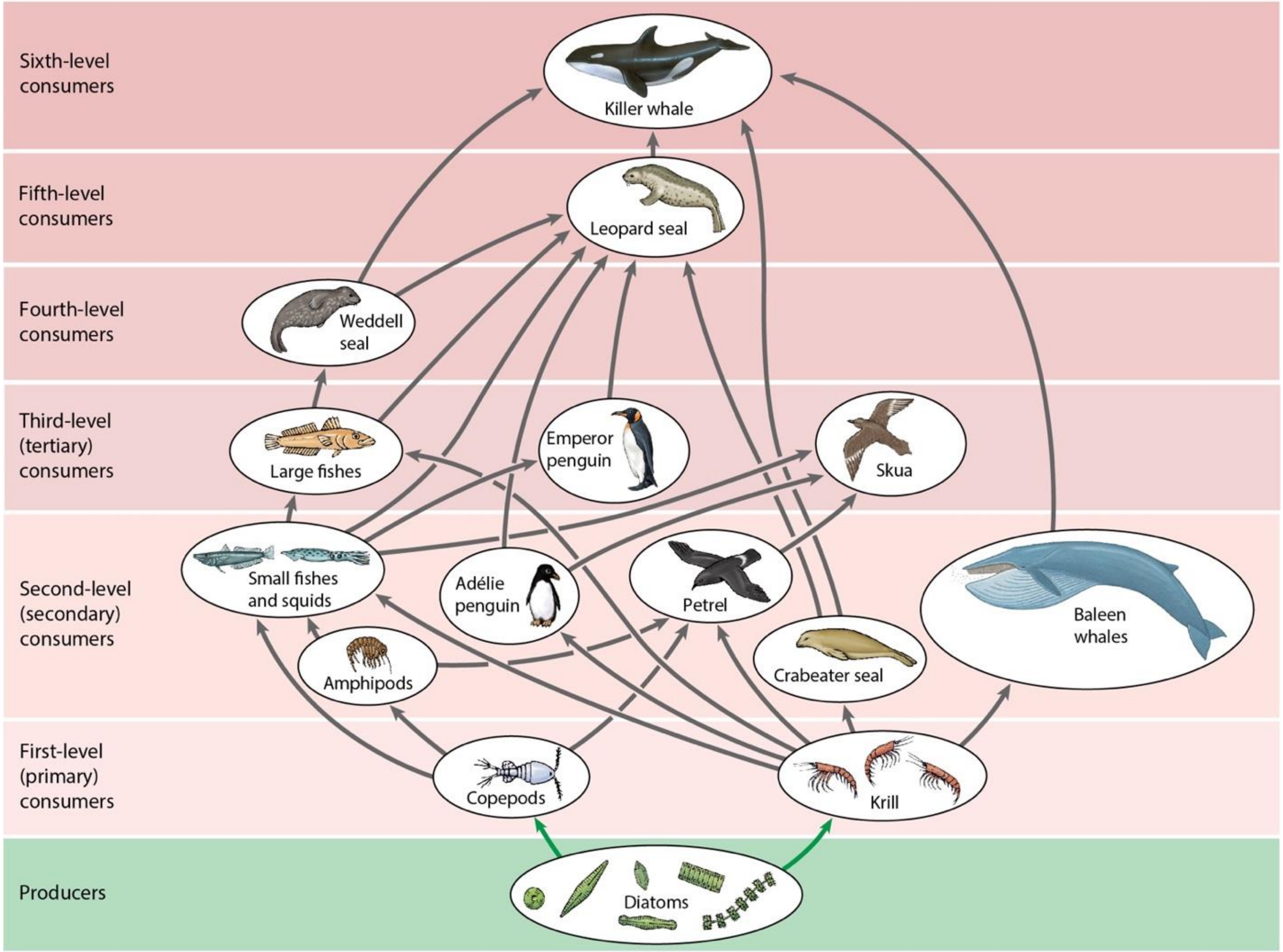
Intimate Relationships

- **Parasitism** – one-sided benefit, parasite harms the host
- **Commensalism** – one-sided benefit without harming the host
- **Proto-cooperation** – mutual benefits and non-obligatory
- **Mutualism** – mutual benefits and obligatory

Parasitism $\xrightarrow{\textit{co-evolution}}$ **Commensalism** $\xrightarrow{\textit{co-evolution}}$ **Proto-cooperation** $\xrightarrow{\textit{co-evolution}}$ **Mutualism**

Symbiosis / Asymbiosis

Intimate Relationships



Source: Bill Ober

Summary and Outlook

- In this Module, you have learned how different marine organisms are connected to each other and to the environment through the **transfer of nutrients and energy in the food web**.
- Such transfer is the **foundation of an ecosystem**.
- However, our understanding on certain components of the food web (e.g. parasitism) is still **limited**.
- **More research will be needed** to elucidate precisely how the change in the population size of a given species in the marine environment, as a result of climate change, pollution or over-harvesting, would impact an ecosystem as a whole.