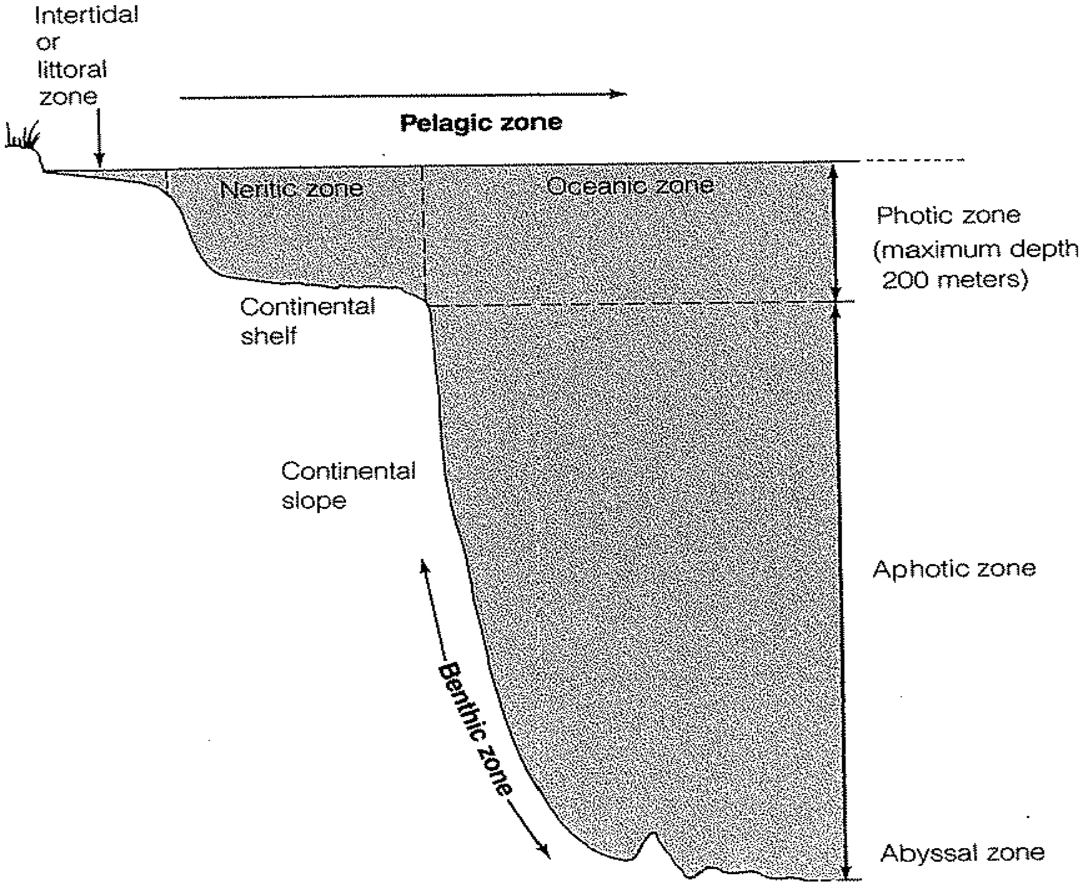
INTRODUCTIONTO MARINE ECOLOGY

- RELATIONSHIPS - "ecology"
  They can be biotic to biotic, or biotic to abiotic, even abiotic to abiotic
- Habitat- physical location of a organism

•Niche- role or function in the habitat
•Continuing with the ecosystem (observer defined)
•Ecosystems are often named according to the dominant species in the area
•BEECH/ MAPLE FOREST, OAK/HICKORY FOREST,
•CORAL REEF,
•MANGAL

ZONATION ABIOTIC

.1water ocean bottom


Intertidal
or
littoral
zone
Pelagic zone
Neritic zone
Oceanic zone
Photic zone
(maximum depth
200 meters)
Continental
shelf
Continental
slope
Aphotic zone
Benthic zone
Abyssal zone

•

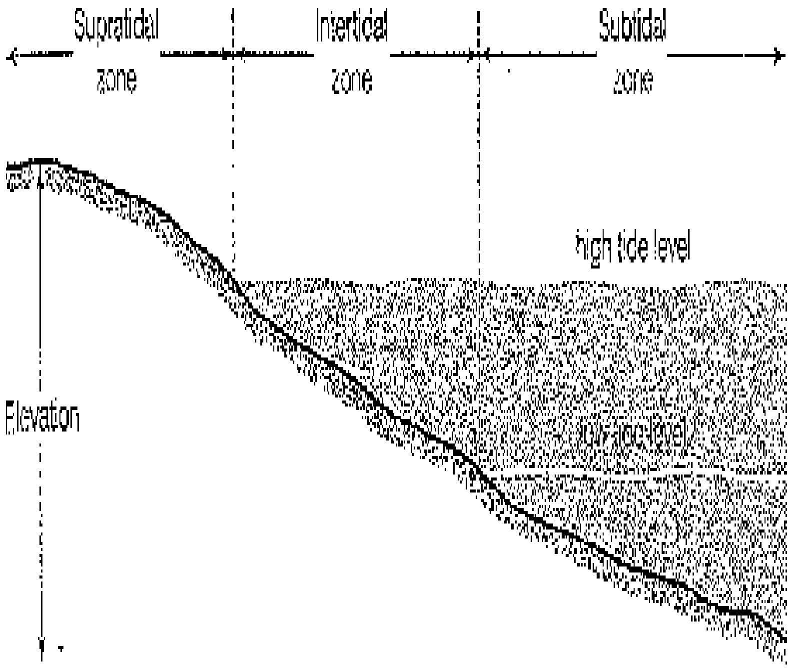


FIGURE 8-4

Typical zones along the seashore, which are the result of fluctuating tides. Supratidal, intertidal, and subtidal zones are compared to elevation.

- Tidal areas (trace here) (lumpers and splitters)

ZONATION BIOTIC

- **Pelagic**

•plankton- drifters phyto/zoo

•nekton- swimmers

•**Benthic**

•demersal- swim and rest- flounders, shrimp

- epifauna- live on the surface corals, anemones, star fish

•infauna- live in the benthic muds- tube worms, cucumbers

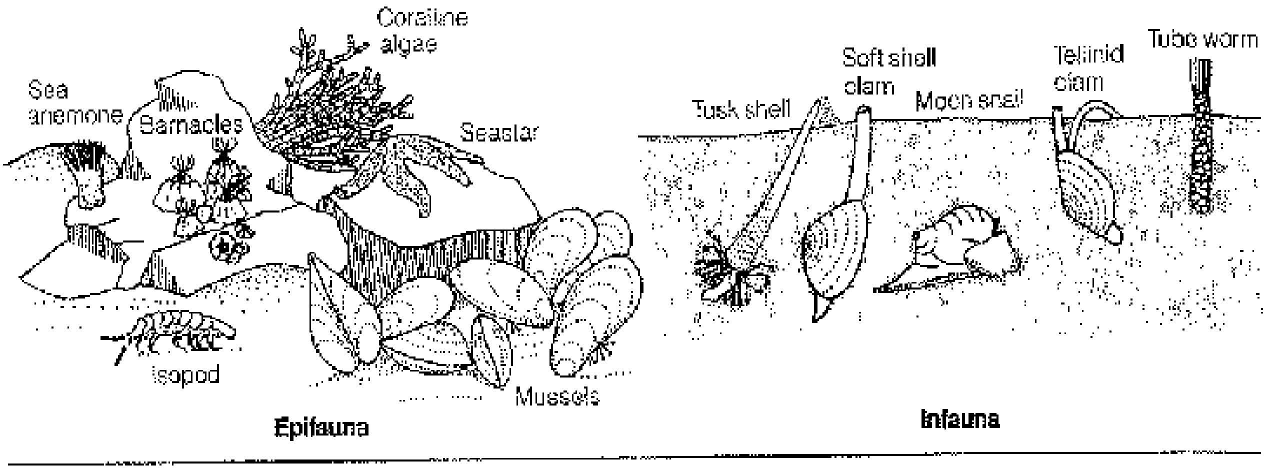


FIGURE 8-5
The benthic style of life. The epifauna live on or above the substrate; animals living within the substrate are the infauna.

Pelagic organisms

- Organisms that live in the pelagic **(liquid)** environment:

–Live suspended within the water column

–Can float or swim

–Have adaptations that allow them to stay above the ocean floor

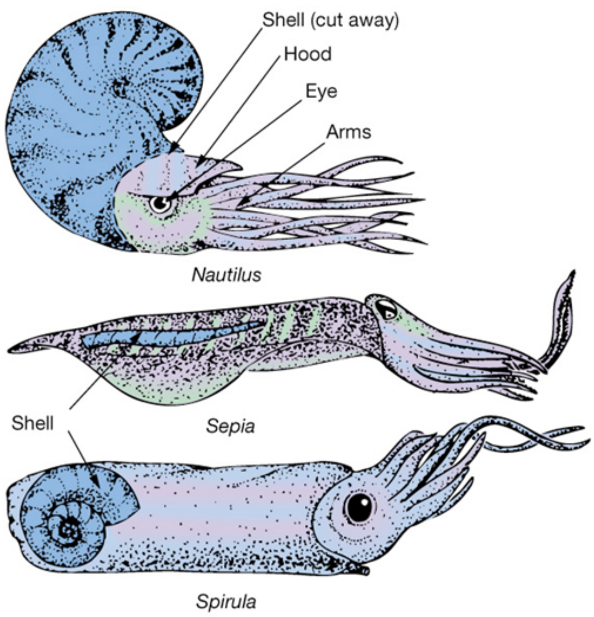
Staying above the ocean floor

- Adaptations for staying above the ocean floor:

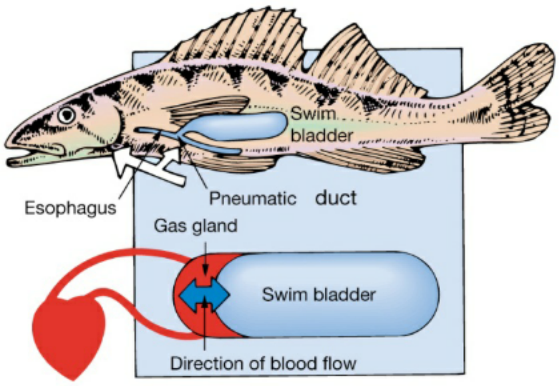
–Rigid gas containers

–Swim bladder

–Ability to float



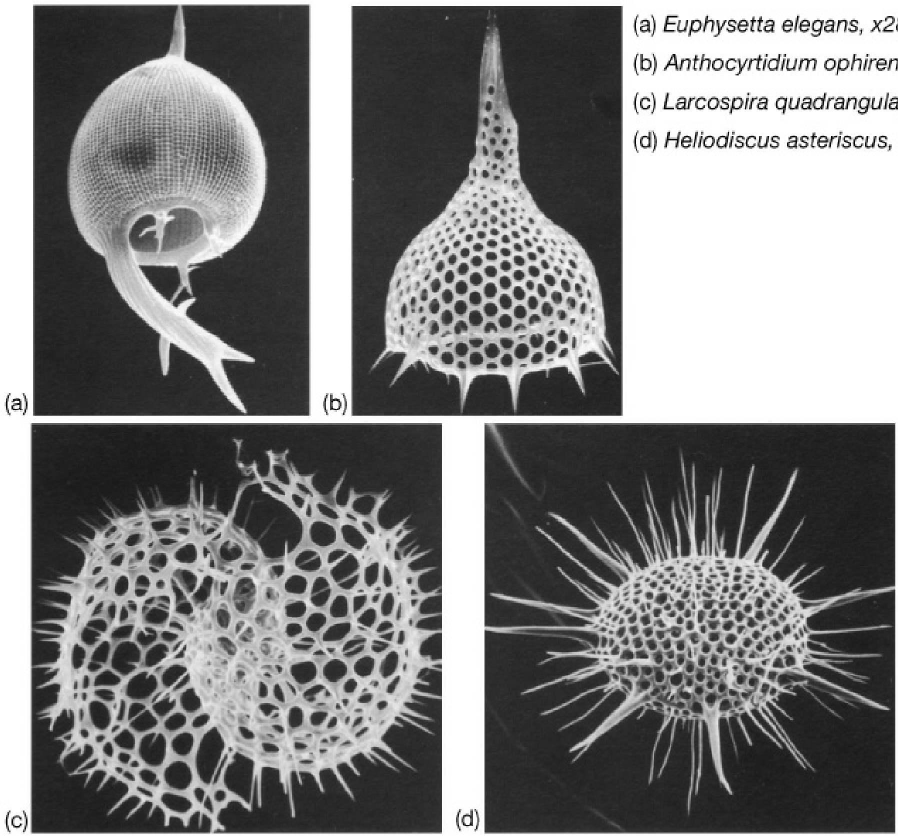
Gas containers in cephalopods



Swim bladder

Microscopic floating organisms: Radiolarians

- Radiolarians produce a hard test composed of silica
- Tests have projections to increase surface area



(a) *Euphysetta elegans*, x280
(b) *Anthocyrtidium ophirense*, x230
(c) *Larcospira quadrangula*, x190
(d) *Heliodiscus asteriscus*, x200

Microscopic floating organisms: Foraminifers

- Foraminifers produce a hard test composed of calcium carbonate

•Test is segmented or chambered

Microscopic floating organisms: Copepods

- Copepods have a hard exoskeleton and a segmented body with jointed legs

•Relatives of shrimp, crabs, and lobsters

Macroscopic floating organisms: Krill

- Krill are related to copepods but are larger in size

•Abundant in Antarctic waters, where they are a favorite food of the largest whales

Macroscopic floating organisms: Coelenterates

- Coelenterates are soft-bodied organisms including:

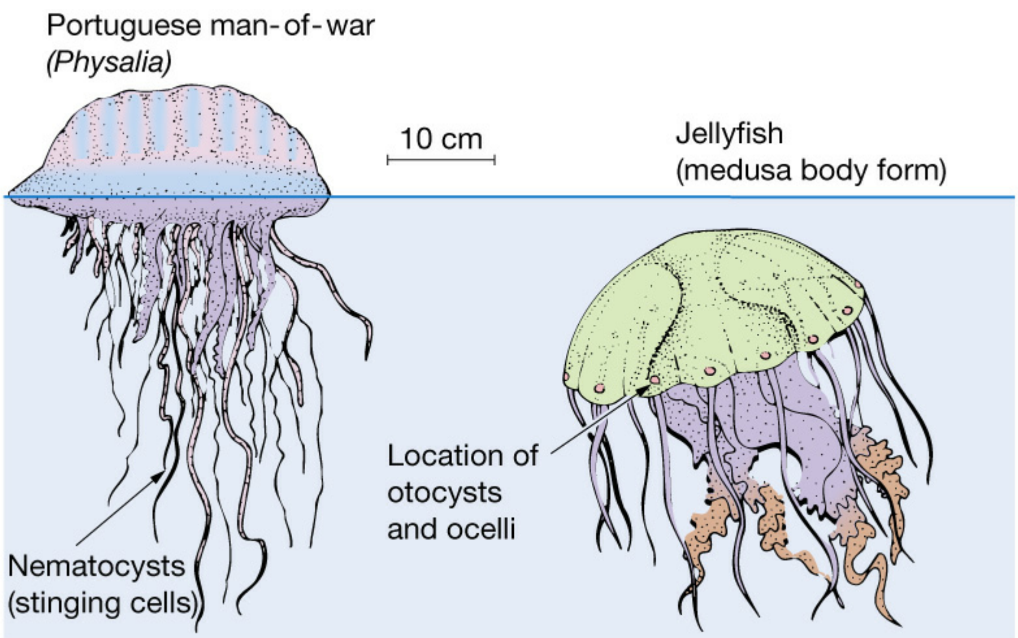
–Siphonophores (Portuguese man-of war)
Scyphozoans (jellyfish

Swimming organisms **(nekton)**

- Larger pelagic organisms can swim against currents and often migrate long distances

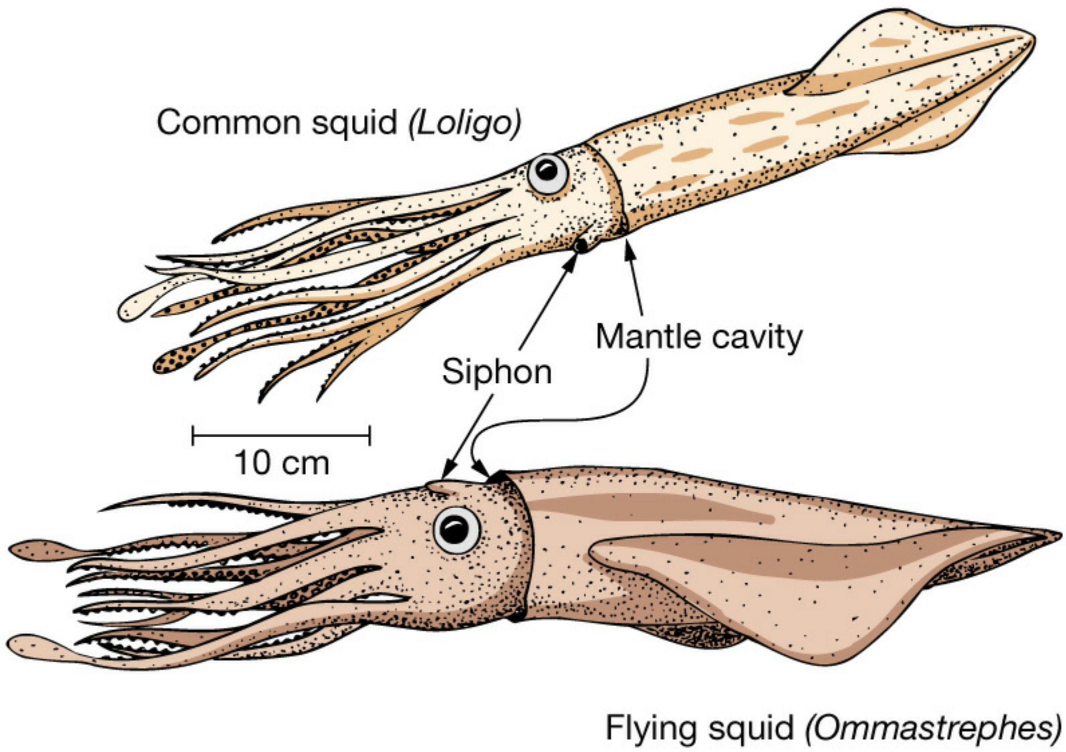
•Nektonic organisms include:
–Squid
–Fish

– Marine mammals

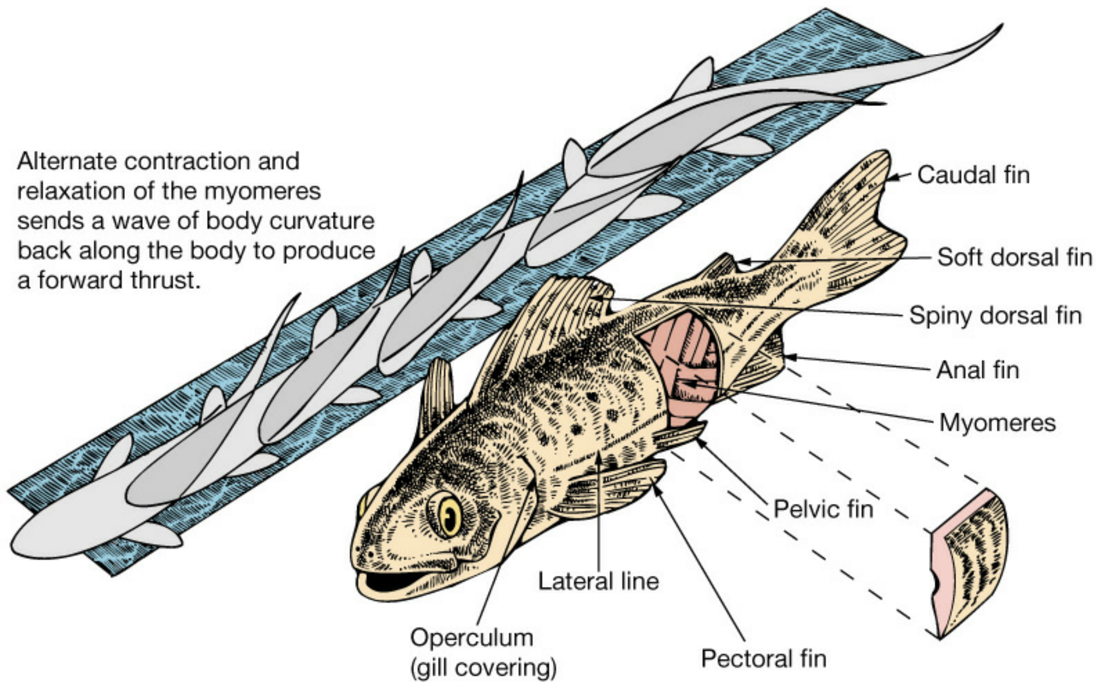


Squid

- Squid are **invertebrates** that swim by taking water into their body cavity and forcing it out through their siphon



Fish: Swimming motions and fins



Fish: Adaptations

- **Feeding styles:** Lungers versus cruisers

–Lungers sit and wait for prey to come close by

–Cruisers actively seek prey

•**Cold-blooded versus warm-blooded**

–Most fish are cold-blooded

–A few active fish are warm-blooded

•Many fish **school** to avoid predators

Fish: Deep-water nekton

- Adaptations of deep-sea fish:

–Good sensory devices

–Bioluminescence

–Large, sharp teeth

–Large mouths and expandable bodies

–Hinged jaws

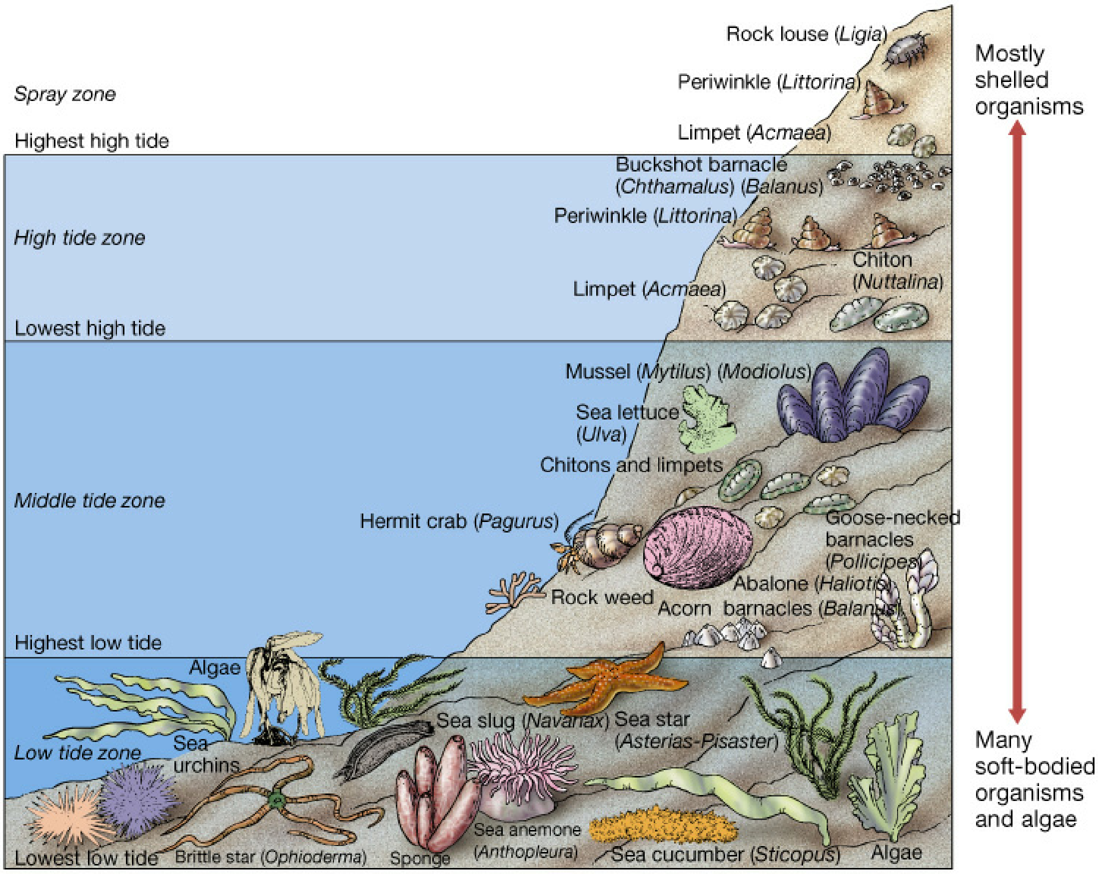
Benthic organisms

- Benthic organisms are those that live in or on the ocean floor

•More than 98% of known marine species are benthic

•The vast majority of benthic species live within the shallow continental shelf

Rocky shores: Intertidal zonation and organisms



Sea anemone

- A vicious predator cleverly disguised as a harmless flower but armed with stinging cells

Sediment-covered shores

- Most organisms burrow into the sediment (**infauna**)

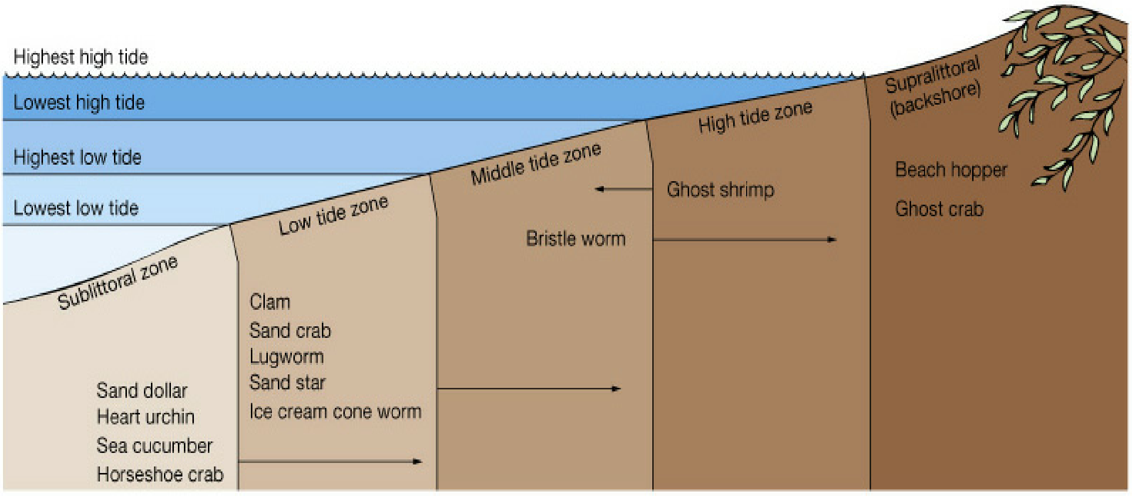
•Sediment-covered shores include:

–Beaches

–Salt marshes

–Mud flats

Sediment-covered shores: Intertidal zonation and organisms



Shallow offshore ocean floor

- Extends from the spring low-tide shoreline to the edge of the continental shelf

•Mostly sediment-covered but contains rocky exposures

•Includes:

–Kelp forests

–Coral reefs

Kelp forests

- Kelp forests are found on rocky bottoms and provide habitat for many organisms

•Gant brown bladder kelp *Macrocystis* has a strong holdfast and gas-filled floats

•*Macrocystis* can grow up to 0.6 meter (2 feet) per day

Coral reefs

- Coral reefs are hard, wave-resistant structures composed of individual coral animals (polyps)

•Individual coral polyps:

–Are about the size of an ant

–Are related to jellyfish

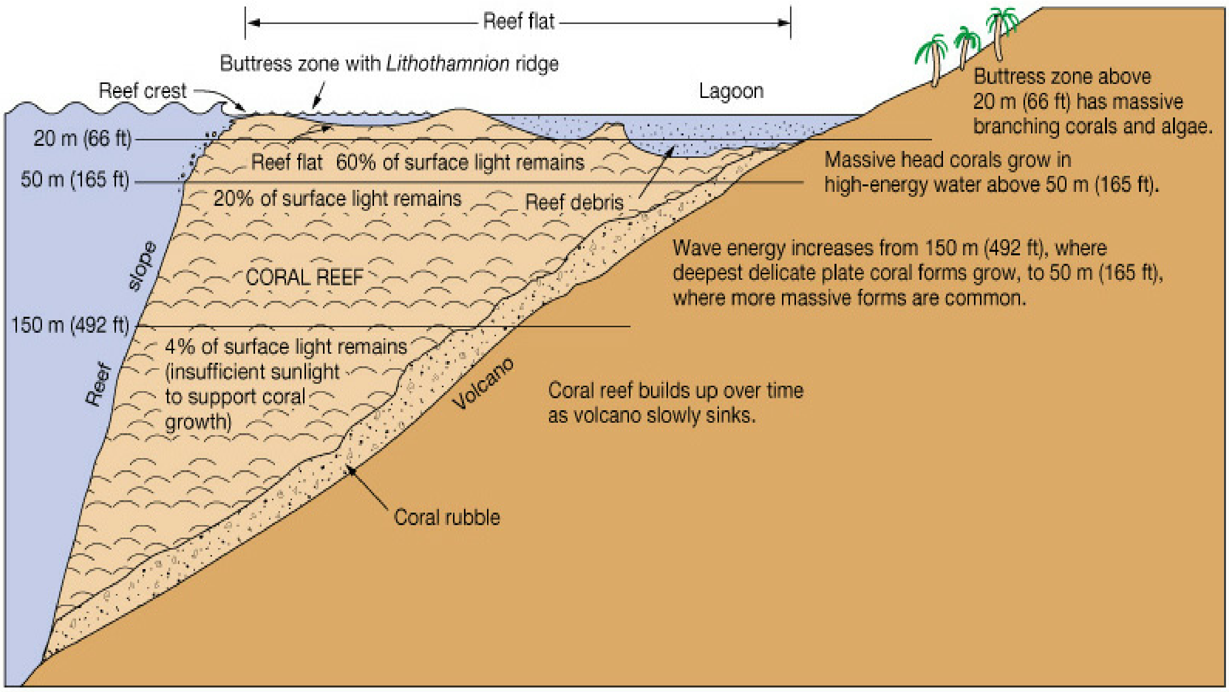
–Feed with stinging tentacles

–Live attached to the sea floor in large colonies

–Construct hard calcium carbonate structures for protection

– Contain symbiotic photosynthetic zooxanthellae algae

Coral reef zonation

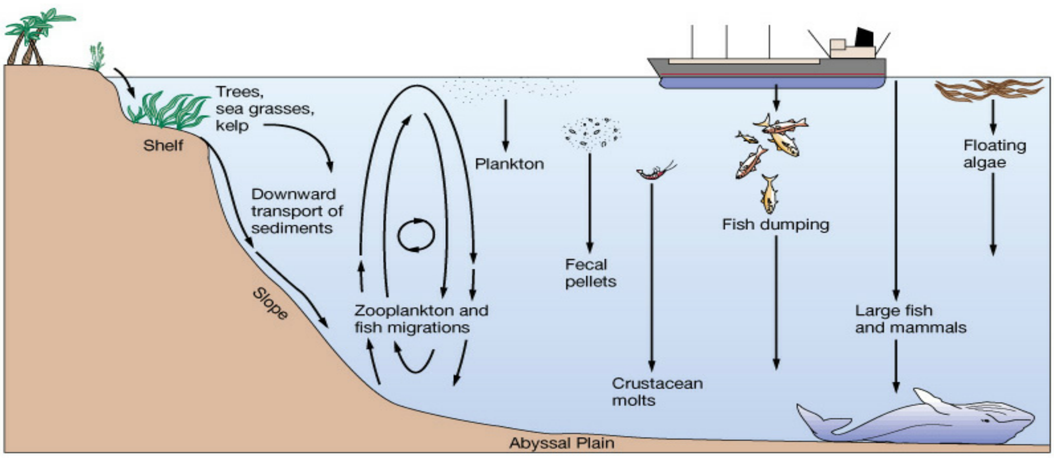


The deep-ocean floor

- Characteristics of the deep ocean:

–Absence of sunlight
–Temperatures around freezing
–Average salinity
–High dissolved oxygen
–Extremely high pressure
–Slow bottom currents (except abyssal storms)
–Low food supply

Food sources for deep-sea organisms



Deep-sea hydrothermal vent biocommunities

- Found in deep water near black smokers along the mid-ocean ridge
- Do not rely on food from sunlit surface waters
- Organisms include:
  - Tube worms
  - Clams
  - Mussels
  - Crabs
  - Microbial mats

How are vents created?

The vents tend to be located deep in the ocean. For example, in the Atlantic ocean, some 7000 feet beneath the surface, hydrothermal vents are associated with underwater mountain chain called the Mid-Ocean Ridge. This ridge is geologically active with an upwelling of hot magma and volcanic activity. The tectonic plate movements cause faulting and seawater that then enters the cracks is superheated by the molten magma. The superheated water and steam and spews out through hydrothermal vents

Hydrothermal Vents

1. cold seawater sinks down through the crust

2.O2 and K are removed from the seawater.

3 .Ca, SO4, and Mg are removed from the fluid.

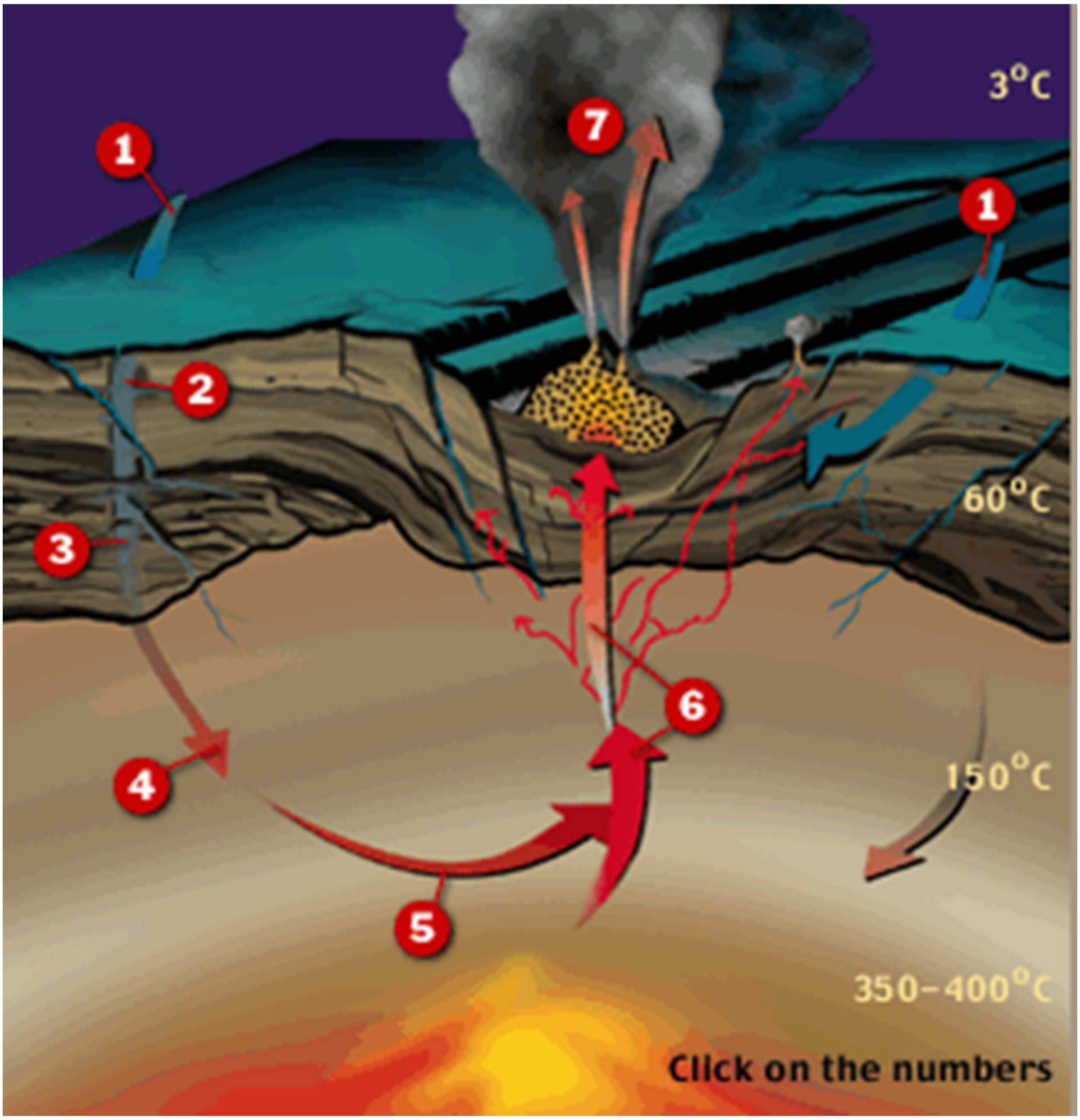
4 .Na, Ca, and K from the crust enter the fluid.

5. Highest temperatures (350-400 oC), Cu, Zn, Fe, and H2S from the crust dissolve in the fluids.

6. Hot & acidic fluids with dissolved metals rise up through crust.

7. The hydrothermal fluids mix with cold, O2-rich seawater. Metals and sulfur combine to form metal-sulfide minerals:

MnO_2, $FeO(OH)$,…



Do Vents Affect the Entire Ocean?

The world's oceans contain many chemicals other than water and salt. Where do these chemicals come from? Rivers carry some of the chemicals into the ocean. Hydrothermal vents supply others.

When seawater seeps down into the ocean crust and is heated by the magma, it undergoes lots of chemical reactions.

When the fluid rises up through the seafloor, it carries many new chemicals with it, such as copper and zinc. These chemical reactions also remove chemicals from the seawater, such as oxygen and magnesium. Here is a look at some of the many chemical reactions that take place.

1 .Cold seawater sinks down through cracks in the crust

2 .Oxygen and potassium are removed from the seawater .

3 .Calcium, sulfate, and magnesium are removed from the fluid .

4. Sodium, calcium, and potassium from the surrounding crust enter the fluid.

5. The fluids have reached their highest temperatures. Copper, zinc, iron, and sulfur from the crust dissolve in the fluids

6 .Hot fluids carrying dissolved metals rise up through crust .

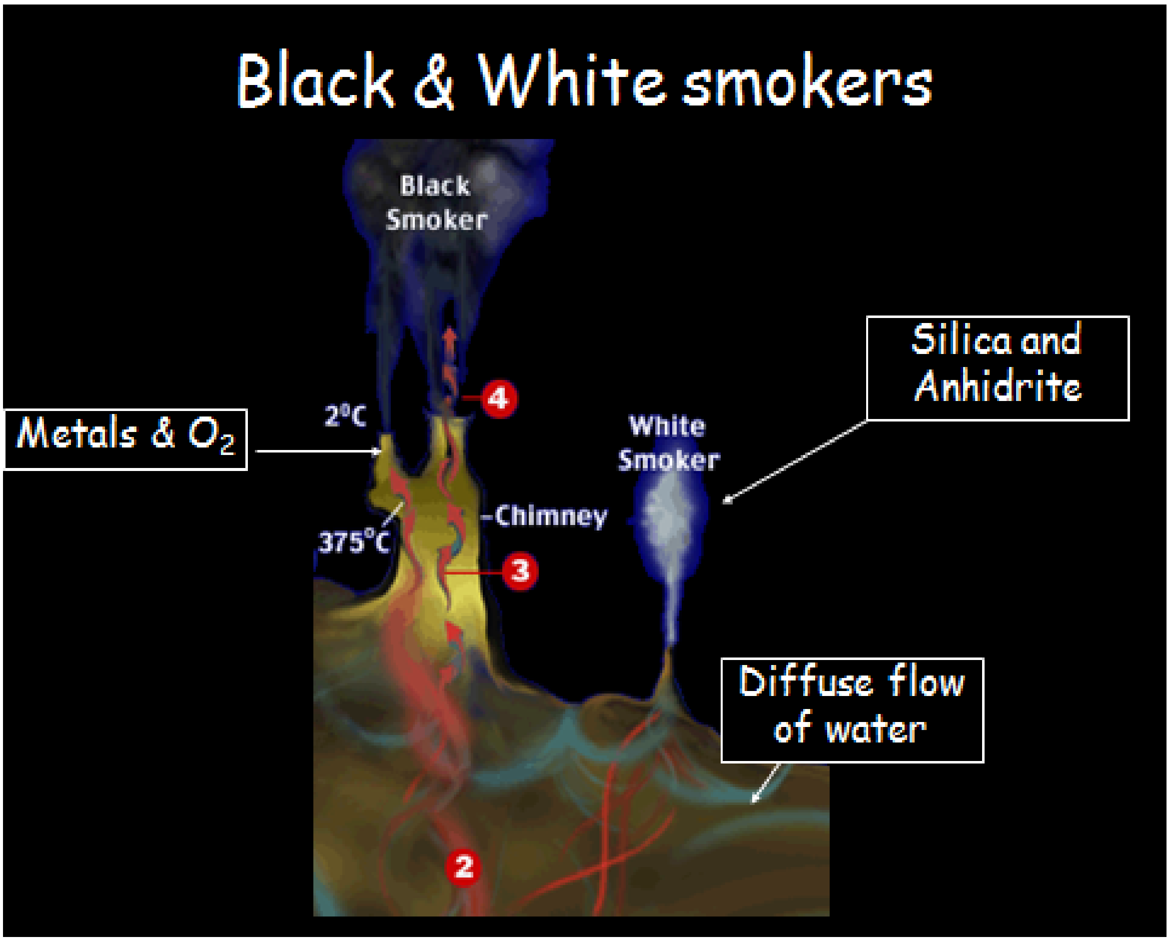
7. The hydrothermal fluids mix with cold, oxygen-rich seawater. Metals and sulfur combine to form black metal-sulfide minerals

***Some vents, known as "black smokers,"** spew out a black-colored mixture of iron and sulfide. **"White smokers**" spew out a whitish mix of barium, calcium, and silicon.

* The material that emerges from hydrothermal vents is extremely hot (up to 750° F [398.89° C]) and is very rich in minerals such as sulfur. The minerals can precipitate out of solution to form

f a chimney can occur quickly

Black & White smokers



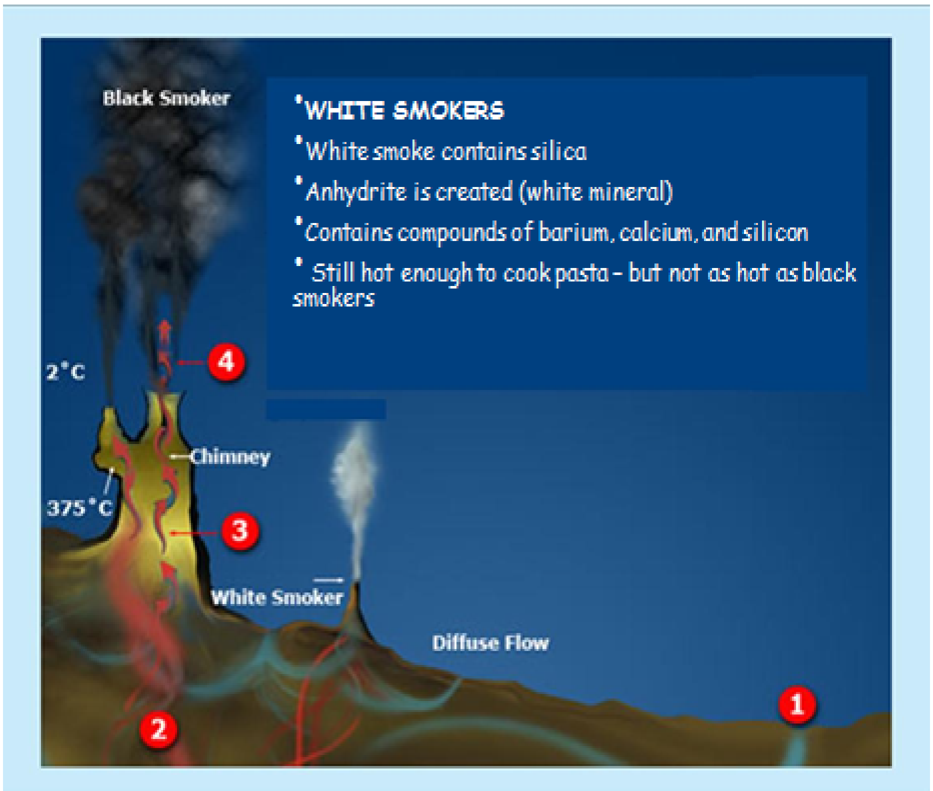
2. The seawater continues to seep far below this point in the ocean crust. Energy radiating up from molten rock deep beneath the ocean floor raises the water's temperature to around 350-400°C. As the water heats up, it reacts with the rocks in the ocean crust. These chemical reactions change the water in the following way:

- All oxygen is removed. It becomes acidic. It receive dissolved metals, .including iron, copper and zinc. It picks up hydrogen sulfide.

3. Hot liquids are less dense and therefore more buoyant than cold liquids. So the hot hydrothermal fluids rise up through the ocean crust just as a hot-air balloon rises into the air. The fluids carry the dissolved metals and hydrogen sulfide with them.
4. The hydrothermal fluids exit the chimney and mix with the cold seawater. The metals carried up in the fluids combine with sulfur to form black minerals called metal sulfides. These tiny mineral particles give the hydrothermal fluid the appearance of smoke. Many factors cause this reaction. One factor is the cold temperature of the seawater. A second equally important factor is the presence of oxygen in the seawater. Without oxygen, the minerals would never form.
- In white smokers, the hydrothermal fluids mix with seawater under the seafloor. Therefore, the black minerals form beneath the seafloor before the fluid exits the chimney. Other types of compounds, including silica, remain in the fluid. When the fluid exits the chimney, the silica precipitates out. Another chemical reaction creates a white mineral called anhydrite. Both of these minerals turn the fluids that exit the chimney white.

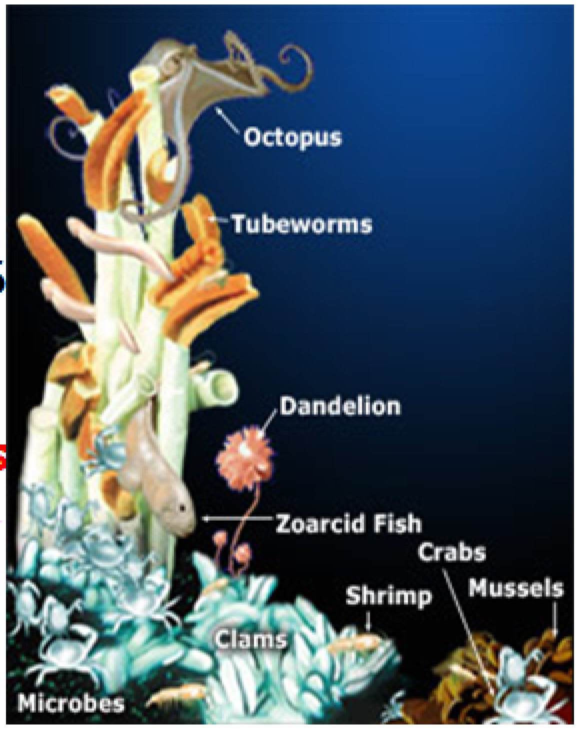
To accomplish the conversion of sulfur to energy in a process that does not utilize sunlight called chemosynthesis. The energy is then available for use by the other life forms, which directly utilize the energy, consume the bacteria, or consume the organisms that rely directly on the bacteria for nourishment. For example, the tubeworms have no means with which to take in or process nutrients. Their existence relies entirely on the bacteria that live in their tissues.

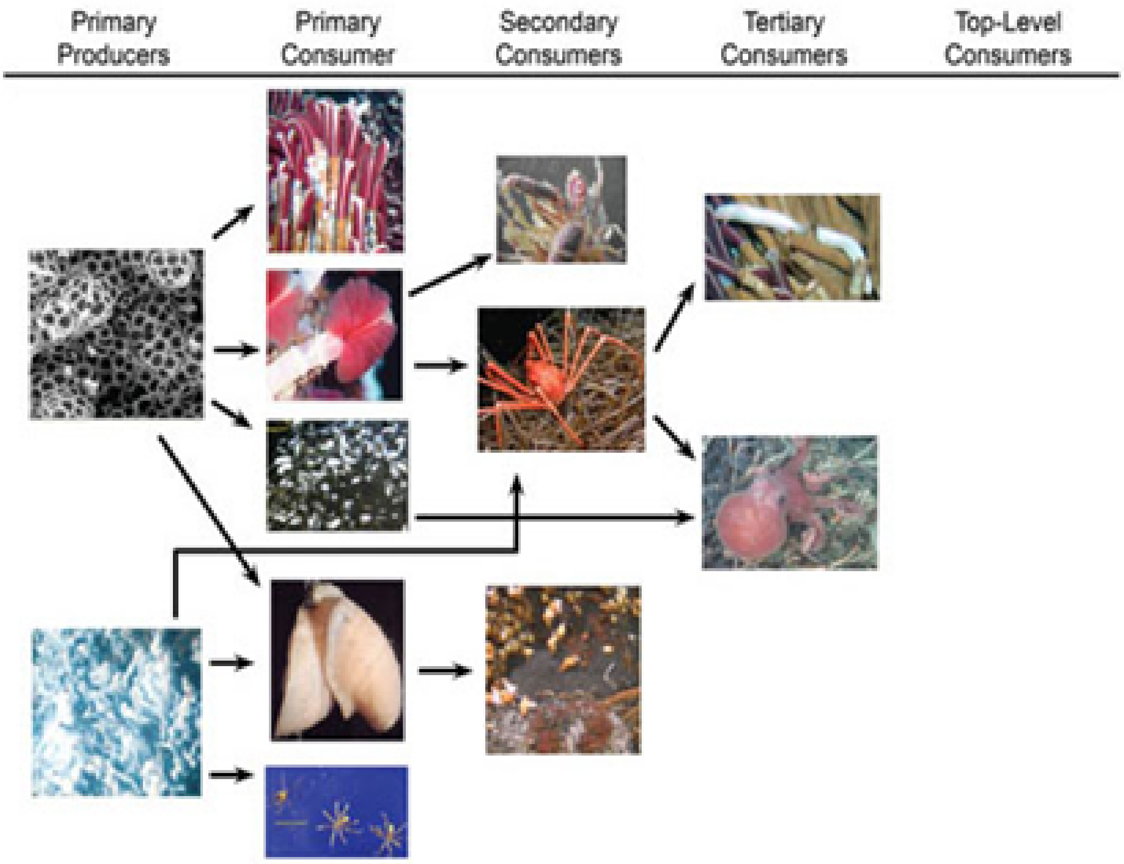
They spew mostly iron and sulfide, which combine to form iron monosulfide. This compound gives the smoker its black color.



HYDRO-THERMAL-VENT COMMUNITIES

With no sunlight, what is the base of the food web?

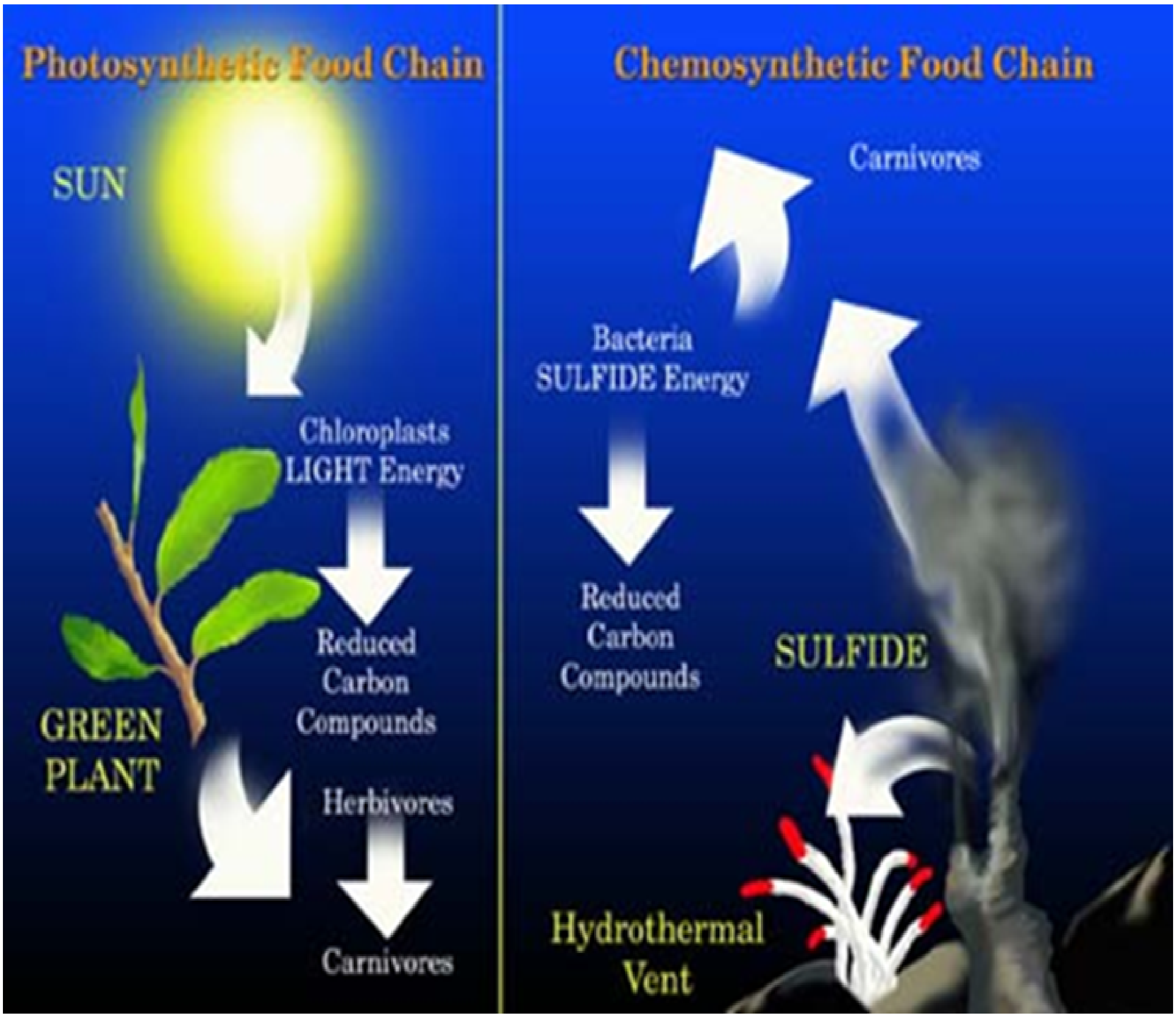




Hydrothermal energy source

$$H_2S + O_2 \rightarrow SO_{4\ +}^{} + H^+ + ATP$$

- Chemosynthetic (sulfur oxidizing)
- Thermophilic Bacteria (up to 120°C)
- Hot, anoxic, sulfide rich water mixes with Cold oxygenated water
- Hydrothermal Vents as origin of Life?

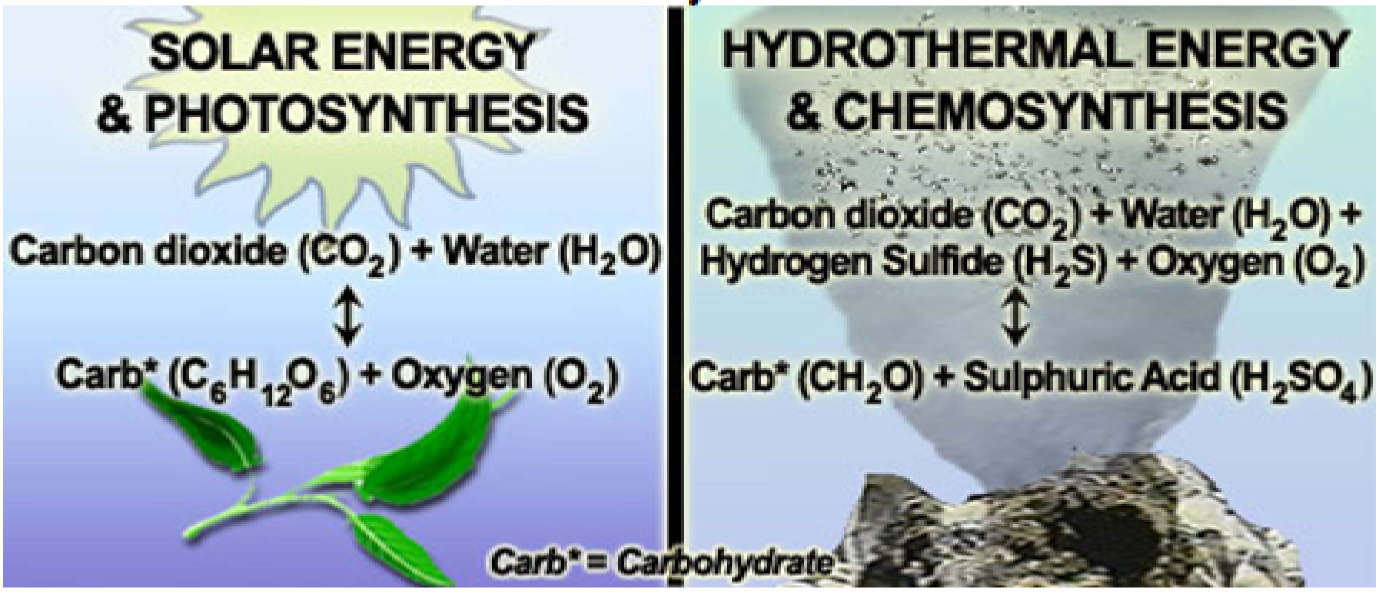


Invertebrate food sources

Food chain based on sulfur-oxidizing bacteria

- Symbiosis with Bacteria
  - Vestimentiferan tube worms
  - Vent Mussels and vent clams
- Ingestion of Bacteria
  - Grazers (gastropod limpets and snails)
  - Filter Feeders (vent shrimp, polychaete worms, amphipods, anemones)
- Predators
  - Ventfish, octopus
- Scavengers
  - Crabs

The goal is to create a carbohydrate.

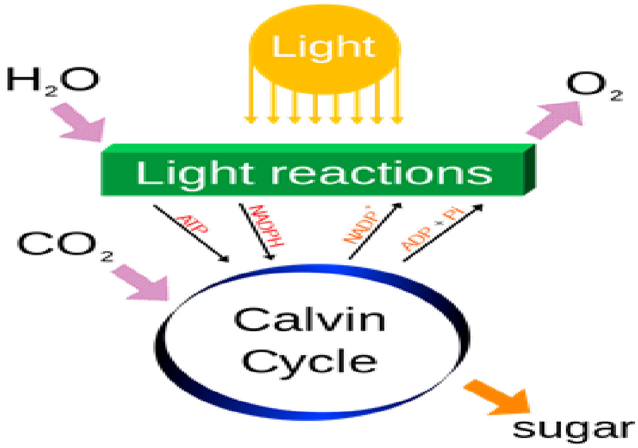


Photosynthesis: How does it work?

1) Capture light as photons

2) Generate electrochemical energy (aka 'light reaction')

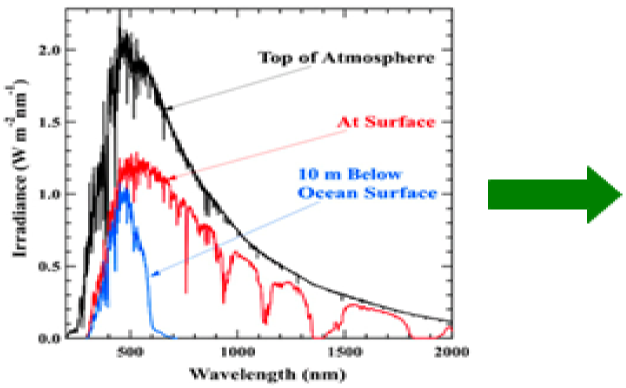
3) Fix CO_2 using electrochemical energy (aka 'dark reaction')



Photosynthesis: How does it work?

Idealized formula for oxygenic photosynthesis:

$$nCO_2 + 2n \cdot H_2O + \lambda\ (\text{light}) \rightarrow (CH_2O)_n + nO_2 + nH_2O$$



CH_2O: formaldehyde
$C_2H_4O_2$: glycoaldehyde/formate/…
$C_3H_6O_3$: glyceraldehyde/lactate/…
$C_4H_8O_4$: threose/…
$C_5H_{10}O_5$: ribulose/ribose…
$C_6H_{12}O_6$: glucose/galactose/fructose/…

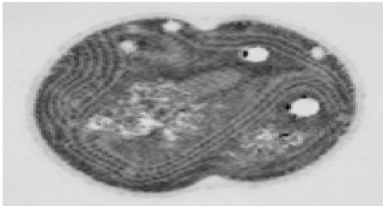
Photosynthesis: Where does it happen?

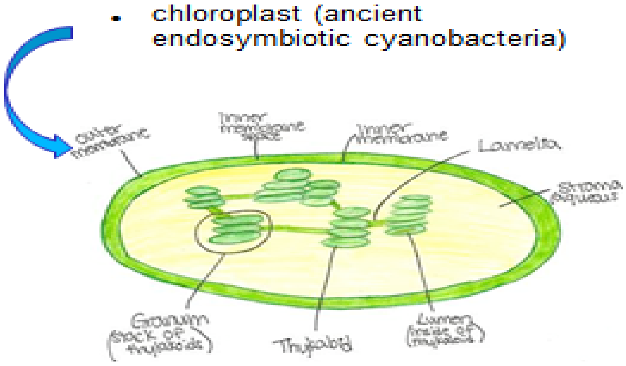
Cyanobacteria

- thylakoid membrane

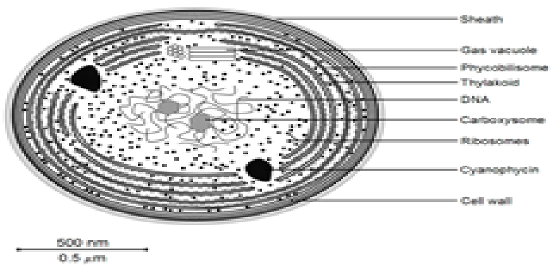
Eukaryotes

- chloroplast (ancient endosymbiotic cyanobacteria)



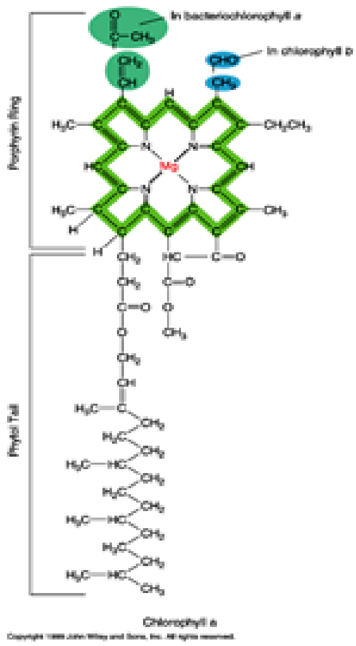


Cross-section through a cyanobacterial cell



PS Step 1: Capture Photons

- Many light-absorbing *pigments* are found in nature
- Different pigments absorb at different wavelengths
- Separate lineages have evolved different pigments
- Converts light energy to excited electrons



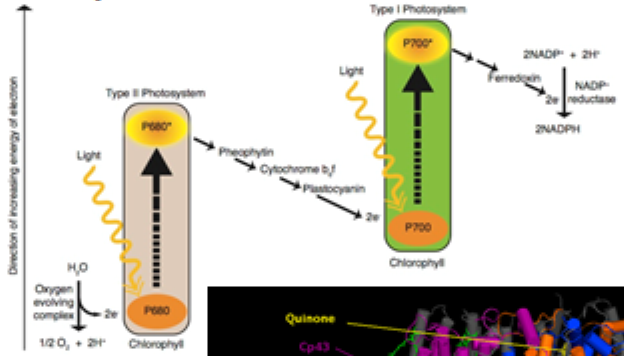
Step 2: Light-dependent Reaction

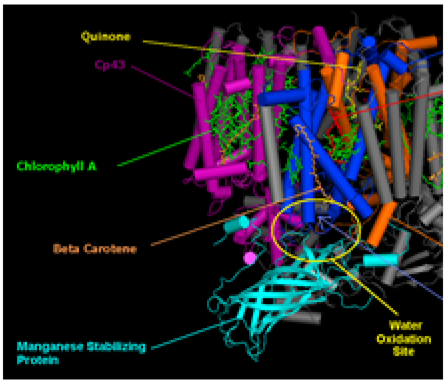
"Z-Scheme"

Production of ATP and NADPH

Transfer of absorbed light energy into chemical energy

Release of O_2 as a byproduct via *oxygen evolving complex*





Accessory Pigments: Cyanobacteria

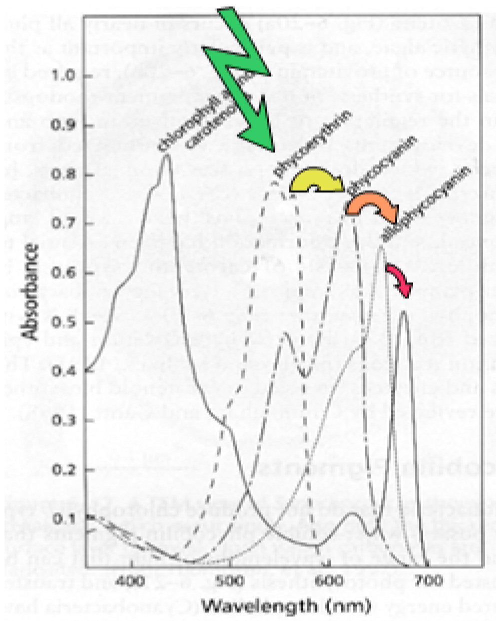
- Phycobilins absorb where chlorophyll *a* can't
- Energy passed down via fluorescence to longer wavelengths

phycoerythrin →

phycocyanin →

allophycocyanin →

chlorophyll *a*



Step 3: Light-independent ("dark") Reaction

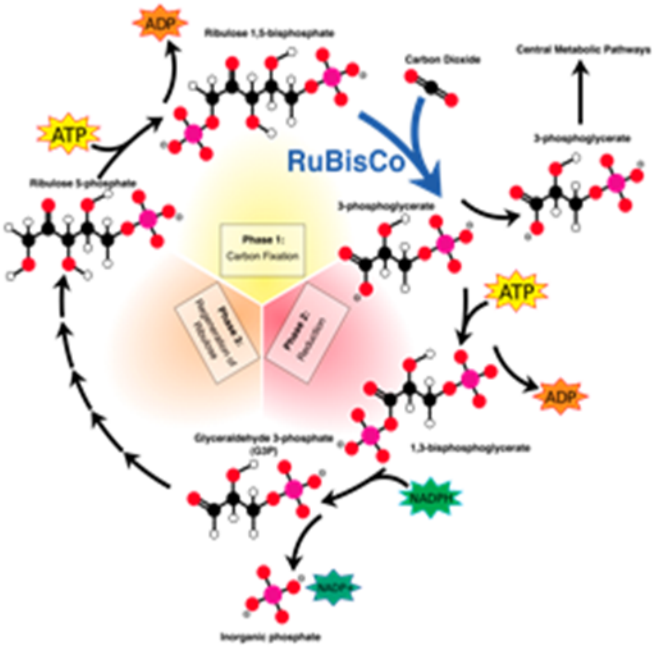
Calvin-Benson Cycle
(not limited to "dark")

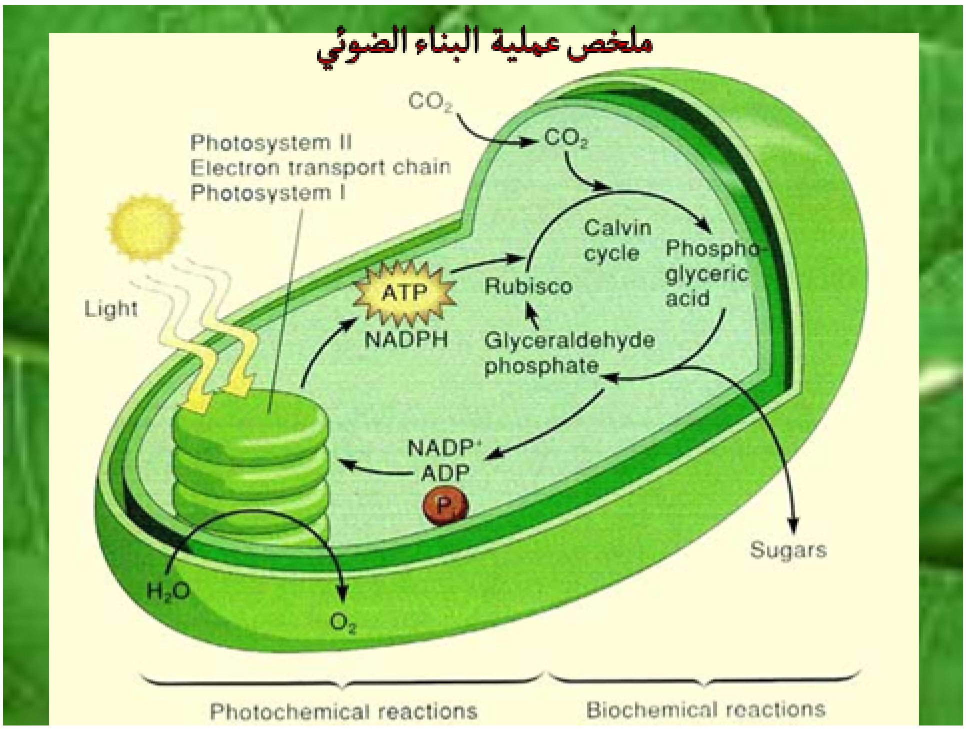
Phase 1: Carbon fixation
requires most abundant enzyme on earth: *RuBisCO* ribulose-bisphosphate-carboxylase

Phase 2: Production of organics
(~glucose via 3-PG)

Phase 3: Regeneration

Carbon-concentrating mechanism





البناء الضوئي (أو التمثيل أو التخليق أو التركيب الضوئي) (باللاتينية: Photosynthesis) : عملية كيميائية معقدة تحدث في خـ يا البكتريا الزرقاء وفي صانعات اليخضور (الصانعات الخضراء) أو الكلوروبـ ست في كل من الطحالب والنباتات العليا؛ حيث يتم فيها تحويل الطاقة الضوئية الشمسية من طاقة كهرومغناطيسية على شكل فوتونات أشعة الشمس إلى طاقة كيميائية تخزن في روابط سكر الجلوكوز وفق المعادلة التالية :

$$6CO_2 + 6H_2O + light + chloroplasts = C_6H_{12}O_6 + 6O_2$$

ومن أهم نواتج هذه المعادلة هو :

ا كسجين ; وكل جزيئة من ثاني أكسيد الكربون تدخل في المعادلة يقابلها جزيئة من ا كسجين ناتجة من التفاعل.

مركبات سكريات حاوية على طاقة عالية.

ورغم بساطة هذه المعادلة في وضعها السابق ولكنها تتم في خطوات معقدة، وتتم هذه المعادلة في دورتين:

ا ولى تسمى تفاء ت الضوء (بالإنجليزية: Light reactions) وهي تفاء ت تعتمد على وجود الضوء وتعمل عليه.

الثانية تسمى تفاء ت الظ م (بالإنجليزية: Dark reactions) أو تفاء ت دورة كالفن وهي تفاء ت تعمل ليـ وفي الظ م استغ ً للمنتجات النهارية التي أنتجت في الضوء.

وقد سميت تفاء ت الظ م باسم مكتشفها كالفن، وتعمل تفاء ت دورة كالفن في النباتات ذوات الفلقتين أو وهي مركبات ثـ ثية الكربون ولذلك تسمى دورة الكربون الثلاثي. وهناك دورة هاتش سـ ك (Hatch slak) وهي تعمل في النباتات ذوات الفلقة الواحدة (Monocotyledon) أو

Monocot).

عملية البناء الضوئي تبدأ بسقوط الضوء على مجموعة من الخـ يا النباتية المتجاورة مكونة لنظام ضوئي داخل البـ ستيدات الخضراء.

عندما تسقط فوتونات الضوء على جزيئة الكلوروفيل يصطدم الفوتون بألكترون من الكترونات الكلوروفيل عندها يصبح ا لكترون في حالة تهيج ويقفز من مداره ا صلي، وهذه حالة غير ثابتة فيميل للعودة إلى مداره ا صلي (خـ ل جزء من الثانية) وأثناء عودته يطلق الطاقة التي اكتسبها , يمكن أن تنطلق طاقة ا لكترون على شكل حرارة أو ضوء أو فلورة، اما في التمثيل الضوئي فانها تعمل على تسيير تفاعل كيميائي.

ـ الطاقة الكيميائية تختزن في المركبات العضوية الغنية بالطاقة خاصة ا دينوسين ث ثي الفوسفات (ATP) ; ويتم ذلك بوجود (ADP) والفوسفات كما في المعادلة : ADP + P + Energy = ATP

ـ تنتقل بعض هذه الطاقة ا لكترونية عبر جزيئات (+NADP) منخفضة الطاقة ليعطي (NADPH) مرتفع الطاقة وبذلك يتكون مركبان مرتفعا الطاقة هما (ATP) و(NADPH).

حيث NADP تمثل " ثنائى فوسفات اميد النيكوتين ثنائى النيوكليوتيد "

و ATP تمثل "ادينوسين ث ثي الفوسفات"

ـ يستغل جزء من الطاقة الضوئية المنتقلة من ا لكترونات في شطر جزيئات الماء (H2O) إلى ايونات الهيدروجين وأيونات الأكسجين.

ـ يدخل أيون الهيدروجين في العمليات الحيوية التالية، وينطلق ا

كسجين

ـ ولذلك فإن مصدر ا كسجين الناتج في عملية البناء الضوئي ناتج من الماء المشطور، أي أنه أكسجين الماء بعد نزع الهيدروجين منه،

ـ حيث أننا نتنفس أكسجين الماء، وتتنفسه الكائنات الحية هوائية التنفس (Aerobic respiration) ع وة على وظائف الماء الحيوية ا خرى في أجسام الكائنات الحية.

العوامل التي تؤثر في التمثيل الضوئي

يتأثر معدل البناء الضوئي بعوامل عديدة، داخلية تتعلق بالنبات وخارجية تتعلق بالبيئة.

العوامل الداخلية:

تركيب الورقة : ويشمل سمك القشيرة والبشرة، وجود ا وبار على سطحها، تركيب النسيج المتوسط، موضع الجسيمات في الخ يا ,حجم المسام وتوزعها.

نواتج التمثيل الضوئي : عندما يزداد تركيز نواتج التمثيل الضوئي في الخ يا الخضراء يقل معدل العملية وبخاصة إذا كان انتقال تلك النواتج بطيئا.

حالة المادة الحية البروتوب زم وا نزيمات وبخاصة جفاف البروتوب سم واضطراب عمل الانزيمات.

العوامل الخارجية:

تشمل العوامل الخارجية : الحرارة، الضوء وشدته، تركيز ثنائي أكسيد الكربون، الماء، العناصر

المعدنية. وكل عامل يؤثر بعملية التمثيل الضوئي ويتأثر بالعوامل الأخرى.

عمليات دورة كالفن

دورة كالفن هي إحدى الدورات الحيوية المهمة في عملية تثبيت الطاقة خاصة في النباتات ذوات الفلقتين (Dicot plants) وفيها يتم تثبيت الكربون الموجود في ثاني أكسيد الكربون لتكوين أول مركب كربوهيدراتي ثابت يمكن فصله يسمى 3-فوسفوغليسيرات.

ـ وفيها يتم استغ ل الطاقة سابقة التخزين في التفاء ت الضوئية في عم ت الطاقة من جزيئات (ATP) و(NADPH).

ـ يبدأ ذلك باتحاد ثاني أكسيد الكربون (CO2) مع ريبوليز ثنائي فوسفات وإنتاج مركب وسطي يتفكك تلقائيا إلى جزيئتي حمض فوسفوغليسيرك ويتوسط هذه الخطوة أنزيم ريبيولوز ثنيائي الفوسفات كاربوكسيلاز.

ـ يمكن استخدام (PGAL) لتخليق الجزيئات العضوية مثل الجلوكوز (Glucose) ويتحول (NADPH) إلى (NADP+).

ـ كما يتحول (ATP) إلى (ADP).

ـ وبذلك تخزن الطاقة الضوئية في الروابط الكيميائية بين ذرات المركبات الكربوهيدرائية الناتجة، ويثبت الكربون الموجود في ثاني أكسيد الكربون الجوي، كما يثبت الهيدروجين الموجود في الماء، وفي النهاية يتكون الجلوكوز (Glucose) الذي ينتقل إلى دورات تحرير الطاقة لتعاد دورة العناصر والمركبات والطاقة من جديد.

ـ أهم شيء في هذه الدورات هو تثبيت ثاني أكسيد الكربون لتكوين الجلوكوز، وهذه العملية تتم في عمليات معقدة يمكن تيسيرها فيما يلي.

ـ تتفاعل كل ست جزيئات من ريبولوز-1،5-مضاعف فوسفات (RUBP) مع ست جزيئات من ثاني أكسيد الكربون (CO2) وست جزيئات من الماء (H2O) لتكوين 12جزيء (PGA) وبذلك يثبت الكربون.

ـ تستغل طاقة (12) جزيء (ATP) والكترونات وهيدروجينات (12) جزيء NADPH2 لتحويل (12) جزيء من (PGA) إلى (12) جزيء (PGALs).

ـ تستغل طاقة (6) جزيئات (ATP) عادة ترتيب (10) جزيئات (PGALs) ليتكون (6) جزيئات (RUBPs)، وبذلك تتم دورة واحدة من دورات كالفن (أي دورة تثبيت الكربون الثلاثي).

ـ وبذلك تتم أهم عملية على سطح الكرة ا رضية وهي عملية تكوين المواد الكربوهيدراتية من ثاني

أكسيد الكربون والماء وتخزن الطاقة الشمسية في الروابط الكيميائية في تلك المواد الكربوهيداتية وينطلق ا كسجين إلى الجو بعملية التمثيل الضوئي.

ـ بعد ذلك يحول النبات المواد الكوبوهيدراتية إلى مواد دهنية، ومواد بروتينية، والمركبات النباتية الأخرى.

ـ يتغذى الحيوان والكائنات الحية الدقيقة الفطرية والبكتيريا على المنتجات النباتية.

ـ ويتغذى ا نسان على المنتجات النباتية والمنتجات الحيوانية، ومنتجات الكائنات الحية الدقيقة الصالحة لـ كل البشري.

وهذه أضخم عملية في الطبيعة حيث أنها أنتجت كل كربوهيدرات ودهون ونفط وفحم العالم.
إضافة إلى ذلك، تنتج هذه العملية ا كسجين وتستهلك ثاني أكسيد الكربون الذي يعد أحد الغازات المسببة لـ حتباس الحراري.

طرق التمثيل الضوئي

تمثيل ضوئي ثـ ثي الكربون

تمثيل ضوئي رباعي الكربون: ويسمى أيضاً مسار «هاتش ـ سلاك» نسبة لمكتشفي هذه النوع من التمثيل الضوئي.

Coral Reef Ecosystems

coral reef is a “reef” made up of layers that develop of thousands of years

Layers are made of “calcium carbonate.

.Coral reefs are found off the coasts of about 100 countries

.Coral reefs are home to about 25% of all marine life

.Among the most fragile and endangered ecosystems

Over the last few decades 35 million acres of coral reefs have been .destroyed

.Reefs off of 93 countries have been damaged

If the present rate of destruction continues 70% of all coral reefs .will be destroyed . As of now 2/3 of coral reefs are dying

.10% cannot be recovered

Causes of damage:

-High temperature

-Ultra violet light

-Pollution by humans

-Destruction for industrial purposes

-Or other environmental changes

*This causes them to loose their symbiotic algal cells

*This is called coral bleaching

تبييض الشعاب المرجانية، وذلك بسبب التوتر الناجم عن طرد أو موت البروتوزوا التكافلية، التي تشبه الطحالب، أو بسبب فقدان الصبغة داخل البروتوزوا. والشعاب المرجانية التي تشكل هيكل النظم الإيكولوجية للشعاب كبيرة من البحار الاستوائية يتوقف على العلاقة التكافلية مع الوليات السوطيات وحيدة الخلية، ودعا زوزانتلي، التي هي التمثيل الضوئي والعيش داخل أنسجتها. Zooxanthellae give. زوزانتلي إعطاء المرجانية والتلون، مع لون محدد اعتمادا على cladee خاصة. تحت الضغط، قد طرد الشعب المرجانية وزوزانتلي، الامر الذي يؤدي إلى ظهور أخف أو بيضاء بالكامل، وبالتالي فإن مصطلح "ابيض".

مرة واحدة تبدأ تبيض، فإنها تميل إلى الاستمرار حتى من دون استمرار التوتر. إذا كانت مستعمرة المرجان على قيد الحياة فترة الاجهاد، وغالبا ما تتطلب زوزانتلي أسابيع أو أشهر ليعود إلى الكثافة العادية. والمقيمين الجدد قد يكون من الانواع المختلفة. بعض الانواع من زوزانتلي والمرجان وأكثر مقاومة لاجهاد من الانواع ا

خرى

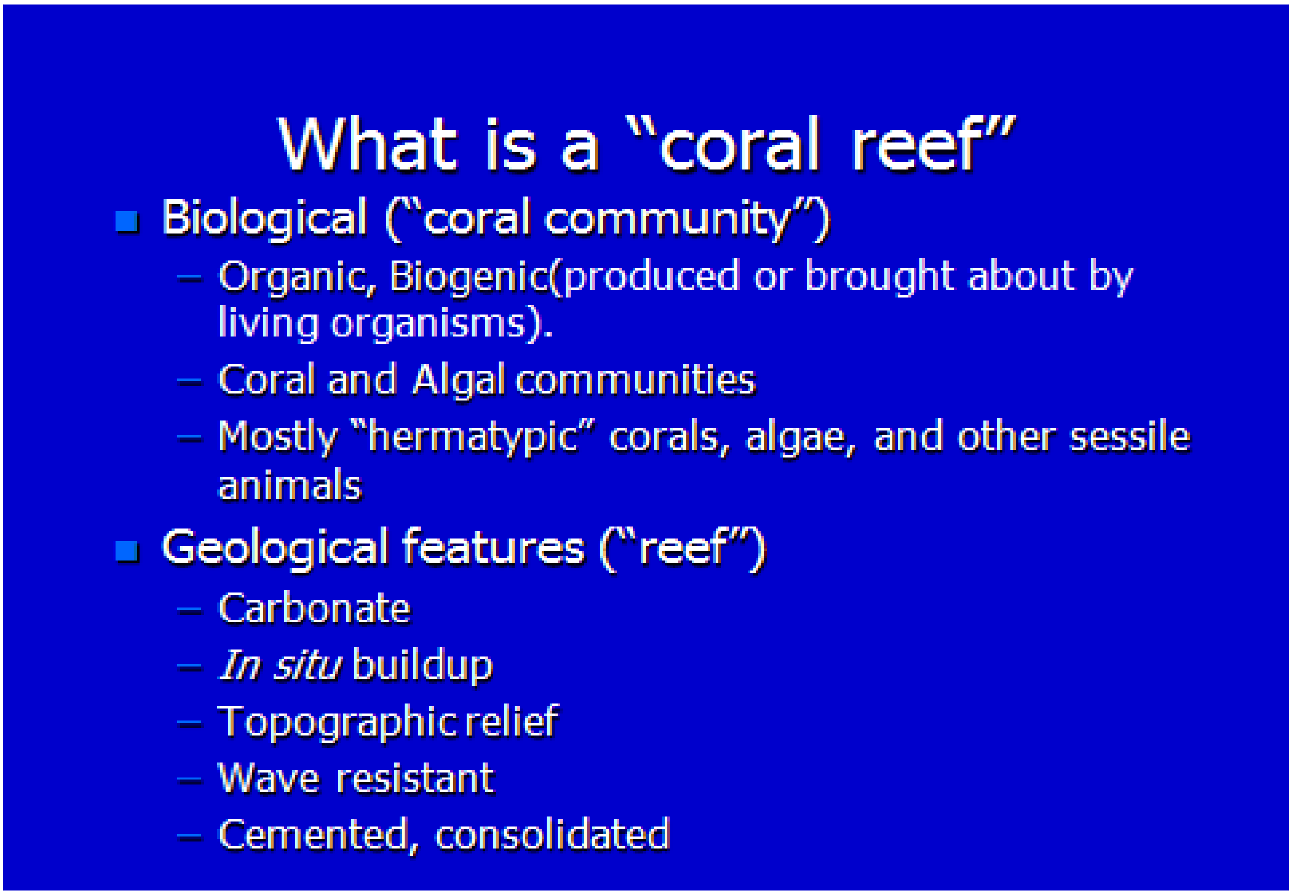
Importance of Coral Reefs

Coral reefs effect humans and organisms as shown in .figure1

.Coastal Communities are effected greatly

.Coral reefs protect them from wave and storm damage

.Provides people throughout the world with new medicines



Corals

- Phylum Anthazoa(
- Class Cnidaria
- Hermatypic (hard) corals contain symbiotic algae
- Up to 500 spp. at some sites

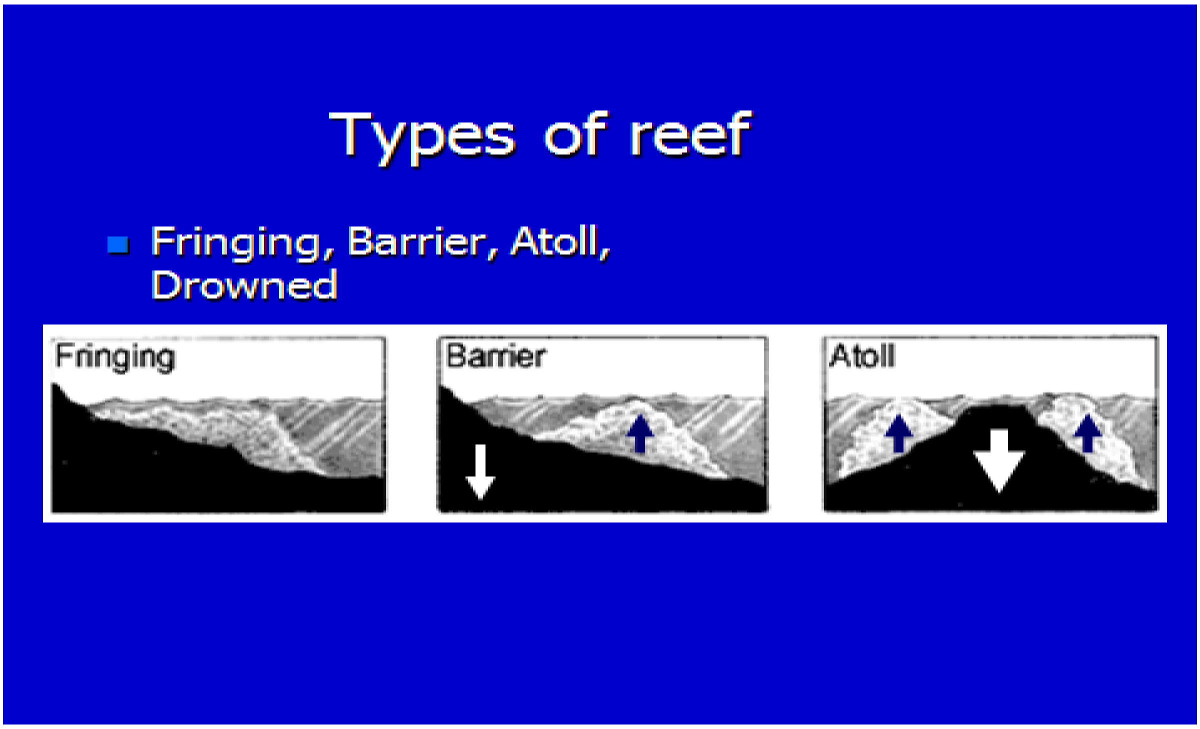
Rosen 1981

Building the reef

$CaCo_3$ addition - $CaCo_3$ loss = Accumulation

Biogenic production	**Biological erosion**	**Reef Growth**
Sediment Import	**Mechanical erosion**	
Cementation	**Sediment export, dissolution**	

Kleypas et al 2001



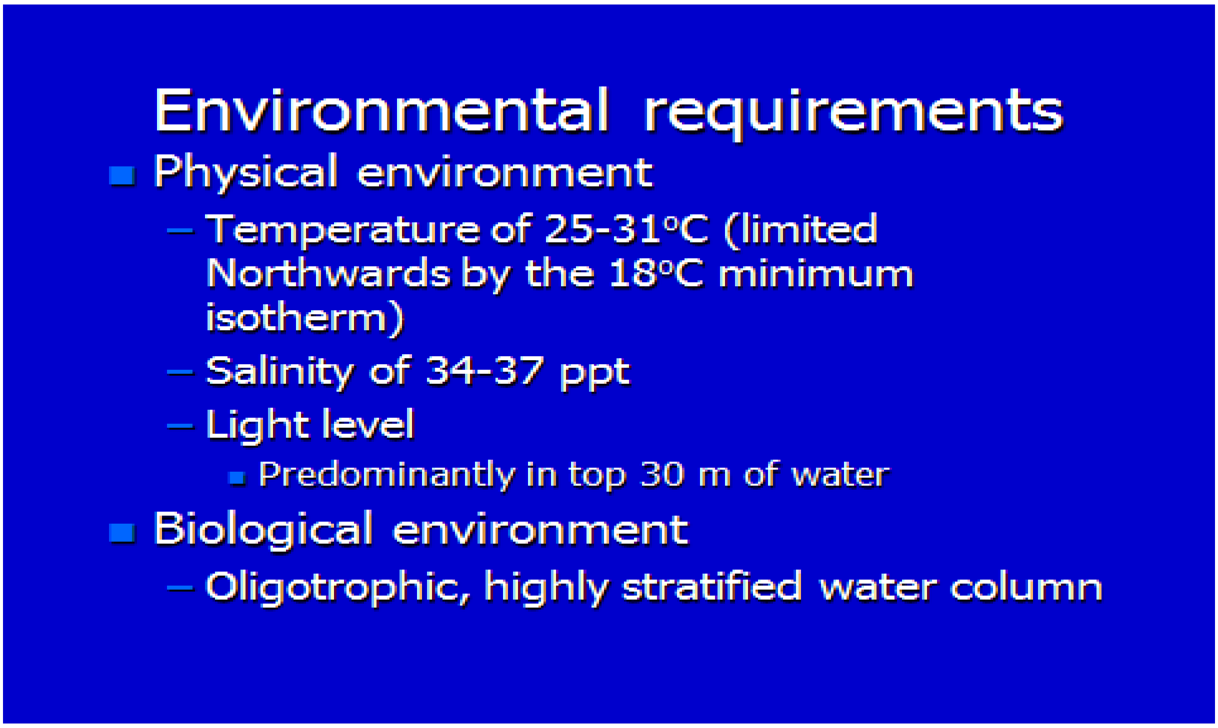
The most common type of reef is **the fringing reef**. This type of reef grows seaward directly from the shore. They form borders along the shoreline and surrounding islands. When a fringing reef continues to grow upward from a volcanic island that has sunk entirely below sea level, an atoll is formed**. Atolls** are usually .circular or oval in shape, with an open lagoon in the center

Barrier reefs are similar to fringing reefs in that they also border a shoreline; however, instead of growing directly out from the shore, they are separated from land by an expanse of water. This creates a lagoon of open, often deep water between the reef and the shore.

Coral reefs are important because they bring in billions of dollars to our economy through tourism, protect coastal homes from storms, support promising medical treatments, and provide a home for millions of aquatic species.

When corals are babies floating in the plankton, they can be eaten by many animals. They are less tasty once they settle down and secrete a skeleton, but some fish, worms, snails and sea stars prey on adult corals. Crown-of-thorns sea stars are particularly voracious predators in many parts of the Pacific Ocean.

The coral provides shelter for many animals in this complex habitat, including sponges, nudibranchs, fish (like Blacktip Reef Sharks, groupers, clown fish, eels, parrotfish, snapper, and scorpion fish), jellyfish, anemones, sea stars (including the destructive Crown of Thorns), crustaceans (like crabs, shrimp).



Threats to coral reef systems

- Overpopulation
- Unsustainable fisheries
- Coastal development
- Global climate change

Fish community

- Mainly Perciform teleosts
- 2 faunas, Diurnal and Nocturnal
- Often territorial/site attached
- Intraspecific interactions (pair bonding and harems) and interspecific mutualism (e.g. cleaning stations)
- Mostly planktonic larvae
- Estimated 4500 spp, 25% of marine total
- ~10% of world fishery landings

Coral reef fisheries

- Essential to survival of many
- Managed sustainably for generations
- Diverse ecosystem
  - Multispecies fisheries
  - Interspecies interactions may invalidate models
  - Collection of sufficient data for all species may not be practicable
  - Reduction of fishing effort to sustain all fish species wastes the productivity of most stocks

Ecosystem effects of fisheries

- Removal of predators
- Removal of algal grazers
- Change in dominance
  - Californian Sea Otters
  - Urchins
  - Crown of Thorns starfish "COTS" (*Acanthaster planci*)
- Changes in size frequency of animals

Crown of Thorns

- Eats coral by everting gut
- Aggregations can remove 95% of coral cover
- May result in collapse of remaining skeleton
- Pheromone controlled aggregated spawning
- Recovery takes at least 12 years
- Caused by loss of predators?
- Increased larval survival due to pollution?

Terrestrial impacts

- Pollution
  - Sewage
  - Agriculture
  - Aquaculture
  - Rubbish
- Sedimentation
- Eutrophication
- Construction on reef flats
- Coral mining
- Mangrove destruction

Climate change

- Potential impacts on coral communities
  - Changes in water temperature
  - Increases in CO_2 concentration
  - Changes in solar irradiation (if cloud cover changes)
  - Sea level rises leading to drowning of reefs
  - Changes in surface run-off (sedimentation)
  - Changes in land-use patterns leading to increased reef exploitation

Kleypas et al 2001

Coral bleaching

- Loss of symbiotic algae
- May cause death of animal
- A symptom of climate change?

Effects of bleaching

- Loss of symbiontic algae (Zooxanthellae) algae by:
  - Degradation *In situ*
  - Loss of algae by exocytosis
  - Expulsion of intact endodermal cells containing algae
- Resulting impacts
  - Vary between species, and even parts of the same colony
  - Loss of sensitive species (especially *Acropora* spp.)
  - Recovery slow and highly variable between sites

The Problems

- A large (and growing) number of people are dependent on coral reefs
- Management of a multispecies fishery is extremely complex, and often fails
- Terrestrial development may destroy coastal reef systems
- Global climate change may exert new pressures

How Do Oil Spills Affect Coral Reefs?

More acidic ocean. Grounded ships and heavy fishing nets. Coral reefs face a lot of threats from humans.

For these tiny animals that build their own limestone homes underwater, oil spills may add insult to injury.

But how does spilled oil reach coral reefs? And what are the effects?

How an oil spill affects corals depends on the species and maturity of the coral (e.g., early stages of life are very sensitive to oil) as well as the means and level of exposure to oil. Exposing corals to small amounts of oil for an extended period can be just as harmful as large amounts of oil for a brief time.

Coral reefs can come in contact with oil in three major ways:

1. Oil floating on the water's surface can be deposited directly on corals in an intertidal zone when the water level drops at low tide.
2. Rough seas can mix lighter oil products into the water column (like shaking up a bottle of salad dressing), where they can drift down to coral reefs.
3. As heavy oil weathers or gets mixed with sand or sediment, it can become dense enough to sink below the ocean surface and smother corals below.

Once oil comes into contact with corals, it can kill them or impede their reproduction, growth, behavior, and development. The entire reef ecosystem can suffer from an oil spill, affecting the many species of fish, crabs, and other marine invertebrates that live in and around coral reefs.

As oil spill responders, NOAA's Office of Response and Restoration has to take these and many other factors into account during an oil spill near coral reefs. For example, if the spill resulted from a ship running aground on a reef, we need to consider the environmental impacts of the options for removing the ship. Or, if an oil spill occurred offshore but near coral reefs, we would advise the U.S. Coast Guard and other pollution responders to avoid using chemical dispersants to break up the oil spill because corals can be harmed by dispersed oil.

Coral reefs can be seriously affected by leaking fuels. Spills may not affect corals directly if the oil stays near the surface of the water, as much of it evaporates within days. However, when corals are spawning, the eggs and sperm can be damaged as they float near the surface before they fertilize and settle . Also, in shallow waters the water-accommodated fraction (WAF) may disrupt reproduction . However, dispersed oil in combination with the dispersing detergents is significantly more toxic than the WAF of crude oil alone . Dispersants and WAFs plus dispersants cause larval morphology deformations, loss of normal swimming behaviour and rapid tissue degeneration.

The Deep water Horizon oil spill in the Gulf of Mexico 2010 is considered the largest accidental marine oil spill in the history of the petroleum industry. Virtually all exposed components of the marine and coastal ecosystems of the bay were damaged. In corals, the most conspicuous visual effects were tissue loss, sclerite (a component section of an exoskeleton, especially each of the plates forming the skeleton of an arthropod.) enlargement, and excess mucous production. White et al. (2012) [18] investigated 11 sites hosting deep-water coral communities 3 to 4 months after the well was covered. The impact was observed at a depth of 1,370m, 11 km from the site of the blowout. Again, oil in combination with the dispersant, in this case, proved markedly more toxic than the WAF alone .

A study into the effects of a major oil spill in the Bahia Las Minas region in the Caribbean demonstrated that three years after the spill gonad size during spawning was still reduced, and five years following the spill, the corals still showed high levels of injury measured as bleaching and/or algal covering, and reduced growth.

Produced Formation Water (PFW) is an effluent of the offshore oil and gas industry. PFWs may be toxic to marine invertebrates , and may cause bleaching through a reduction in photochemical efficiency of the dinoflagellate algae (a single-celled organism with two flagella, occurring in large numbers in marine plankton and also found in fresh water. Some produce toxins that can accumulate in shellfish, resulting in poisoning when eaten.) . When the proper cleaning procedures are being applied the bleaching is in general limited in space and time .

Chemical Fishing

Coral reefs are among the richest and most diverse fishing grounds in the oceans. The greatest driver of increased pressure on reefs since 1998 has been an 80% increase in the threat from overfishing and destructive fishing, most significantly in the Pacific and Indian Ocean . Coral fish are targeted for food, sport, and for live fish for restaurants and for aquarium fish. Cyanide fishing, which involves spraying or dumping cyanide onto reefs to stun and capture (live) fish, kills coral polyps and degrades the reef habitat . More than 40 countries are affected by cyanide fishing activities , and it is now practiced in countries from East Africa to the central Pacific. Exposure of corals to cyanide can result in a reduction or cessation of respiration, a reduction in phototrophic potential and a decrease in growth rates and fertility. The most obvious response is bleaching. Re-establishment of the symbiosis may take from six months to one year or more.

Pesticides

Virtually all rural run-off water is polluted by pesticides. Insecticides, herbicides and fungicides have been shown to affect corals at very low concentrations. For example, it has been found that the fungicide MEMC affects all life-history stages of corals. It inhibits fertilization and metamorphosis, polyps become withdrawn and photosynthetic efficiency is reduced, branches are bleached and host tissue dies. Herbicides and fertilizers used in sugarcane قصب السكرcultivation were identified as the most likely major source of the herbicide residues and nutrients found in corals .

PAM chlorophyll fluorescence measurement demonstrated a reduction in photosynthetic efficiency in Pocillopora damicornis recruits after a 2 h exposure to 1 μg l−1 diuron. The dark-adapted quantum yields also declined, indicating chronic photoinhibition and damage to photosystem II [29]. Various corals are severely bleached at 10 μg l−1 diuron, from which some may show partial or full colony recovery. Polyp fecundity was reduced by 88% in one tested species, and two species proved unable to spawn or planulate following long-term exposures to this concentration of the herbicide .

Heavy Metals, Antifouling Paints

The effect of copper on corals is of serious concern because there are numerous sources that expose corals to copper. Copper is a major component of antifouling paints, is found in sewer discharge, is a component of some fungicides and herbicides that are used on coastal agricultural crops, for wood preservation in waterworks, and in heat exchangers in power plants. Relatively low concentrations of copper can disrupt reproductive success in reef coral. Cu affected photosynthesis in zooxanthellae of A. cervicornis . Negri& Heyward (2001) found that at 17 μg l-1 copper fertilization success in Acropora millepora was reduced to 50%, and Victor & Richmond (2005) found a 12h for impaired fertilization success of 11 μgl-1 in A. surcusola. The 12h value for motility of Goniastrea aspera larvae is 21 μgl-1 [8].

Until the ban on the use of TBT in 2003, antifouling paints contained the compound as biocidal component, along with copper and zinc. As of today, high concentrations are still present in harbour and waterway sediment and around shipwrecksحطام. The latter may represent important sources of toxic substances. A good example has been described by Smith et al. (2003), who found extensive contamination of reef sediments for up to 250 m surrounding the grounding site of an oil carrier. Branchlets from adult corals exposed to sediments with a high concentration of contaminants (TBT 160 mg kg-1, Cu 1,180 mg kg−1, and Zn 1,570 mg kg−1) suffered significant mortality (38%), and Negri & Heyward (2001) showed that TBT inhibits fertilization and larval metamorphosis in A. millepora with an IC50 of 2 μg l-1.