Lecture 13:

-Deep Water Circulation

-Thermohaline circulation

-Temp-Salinity

-Abyssal circulation

-Meridional overturning circulation

-Global conveyor belt

-Thermocline

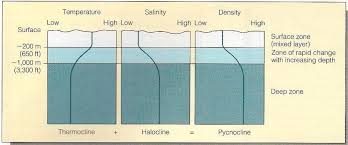
-An area of the ocean where there is a lot of change in the temperature of the ocean

-Halocline

-High salinity in the bottom of the ocean, salt has a higher density

-Pycnocline

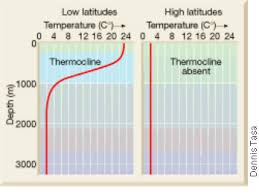
-High density at the bottom because of salinity and temperature



-Source of Deep Water

-Low latitude

-High latitude



-Warm Water acts like a lid and does not allow for mixing and deep water formation

-Driving forces: Wind cools surface water (decreases temperature), evaporated water vapor (increase salinity)

-Importance of deep water circulation

-Vertical stratification: Important in dynamics and biology

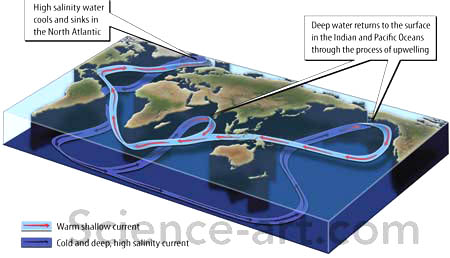
-Heat transport influences earths heat budget and climate

-It provides dissolved oxygen to the deep ocean

-Holds off the effect of climate change by being a carbon sink

Water masses: parcels of water exhibiting somewhat narrow range of temperature and salinity

-Layers of ocean currents are defined by temp. and salinity



-Two main areas of deep water production at the poles

-Very little deep water formation in the pacific because there is low salinity and lots of freshwater input

-Argo floats

-Track salinity and temperature

-Are neutrally buoyant

-Global effort

-Tracers

-Chemical, Nutrients, and radiation

-Based on when they were used you can learn about how the concentrations change in the water column

-Glacier melt

-Decreases salinity of the ocean

-Fresh water lens would stop deep water formation

Lecture 14:

-Waves are moving energy

-Most waves are wind driven

-Moving energy along ocean/ air interface

-Wind main disturbing force

-Boundary between and within fluids of different densities

-Air/ocean interface🡪Ocean waves

-Air/ air interface🡪 Atmospheric waves

-Ocean/ ocean interface🡪 Internal waves

-Splash waves: from surface disturbance/ displace

-Only effects surface of water

-Seismic wave/ Tsunami: seafloor movement

-Effects entire water column

-Wakes from boats

-Tides

-Sun and moon generated waves

-Tides

-24 hours

-Geologically generated waves

-Tsunamis/ seismic waves

-12 hours-6 minutes

-Wind generated waves

-Surface waves

-6 minuts-1 second

-Parts of a Wave

-SWL: still water level

-If there were no waves

-Crest

-Peak of wave

-Trough

-Lowest point of wave

-Wave Height

-Crest to trough

-Wave Length

-Crest to crest

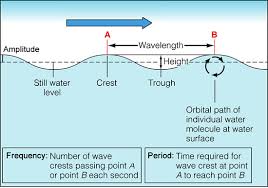
-Wave Period=T

-The time it takes for a full wave or wavelength to pass a fixed position

-Typically 6-16 seconds but can range as long as 24 hours

-Wave frequency=f

-f=1/T

-Number of waves passing a fixed location per unit time

-Water doesn’t move in a wave, only the waveform moves

-Wave Motion:

-Transmit energy

-Cyclic mortion of particles in the ocean

-up and down

-back and forth

-Body waves

-Longitudinal waves

-Push pull waves

-Particles move back and forth in a horizontal direction

-Transverse waves

-Side to side waves

-Particles move at angles to direction of energy transition

-Energy transmitted by vibration

-Transmits energy through solids

-Surface waves

-Orbital waves

-Particles moving orbital path

-Energy transmitted along interface between two fluids of different density

-Circular orbits of an object floating at the surface have the same diameters as the wave

-Wave Base

-Gets smaller as it goes down the water column

-Equal to one half the wavelength (at swl) or L/2

-Deep-water waves

-The water depth is greater then the wave base

-Water column is deep enough for the wave not to disturbed the bottom of the ocean

-Shallow-water wave

-Water depth is 1/20L or less

-Wave base interacts with bottom

-Transitional waves

-Water depth above 1/20L but less than ½ wave length

-Has some interaction with the bottom but not as much as shallow-water waves

-Wave Speed

-S= wavelength (L)/ Period (T)

-More correctly known as Celerity used only in relation to waves where no mass is in motion, just the wave

-When waves meet

-Constructive interference

-Waves in phase: crests and troughs match up🡪 results in larger waves

-Deconstructive interference

-Waves out of phase: crests and troughs to not match up🡪 results in smaller wave

-Mixes Interference

-Waves of different periods and length🡪 results in mess

-How do you build a big wave?

-Wind speed

-Duration: how long the wind blows in one direction

-Fetch: Distance it blows in one direction

-Wave development

-Capillary waves

-Gravity waves

-Waves breaking

-Wave breaks when steepness (wave height H/ wavelength L) > 1/7

-Wave Steepness= H/L

-1/7 ratio gives limitations for waves

-Biggest waves are around Antarctica because there is no land to disrupt the waves and gives perfect conditions for large waves

Lecture 15:

-Wave steepness 1/7 rule dictates maximum wave height

-7m long can only be 1m high

-14m long 2m high

-Beaufort Wind Scale and the state of the sea 0-12

-0: wind speed less than 1 knot, sea like mirror

-11: 56-63 knots wave height 11.5-16m covered by white sea foam

-12: wind speed 64 knots sea completely white with driving spray

-How big can a wind generated wave me?

-About 60 ft

-Three categories of freak waves

-“Walls of water” travelling up to 10km through ocean

-“Three sisters” Groups of three waves

-Single, giant storm waves building up to fourfold the storms waves height and collapsing after some seconds

-Draupner wave

-Single giant wave measured New Years Day 1995

-In the Open Ocean

-1 in 23 will be 2x as high

-1in 1175 will be 3x as high

-1 in 300000 will be 4x as high

-Truly big- 1 in several billion

-Wave Energy

-Fully Developed Sea

-Maximum wave height, wavelength fir particular fetch, speed and duration of the winds at equilibrium conditions🡪 they lose energy through the breaking as fast as they gain energy in wind

-Swell

-Waves preceding a storm, consistent

-Ground Swell- Deep ocean swell one that might be generated by a distant storm or earthquake.

-Wind swell not as long coming. Starts closer to shore

-As waves approach shore

-Wave speed decreases

-Wavelength deceases

-Wave height increases

-Wave steepens increases

-Wave breaks

-Brakers in surf zone

-Spilling breaker

-Water slides down front slope of wave

-Gently sloping seafloor

-Wave energy expanded over a long distance

-Plunging breaker

-Curling crest

-Moderately steep seafloor

-Wave energy expended over shorted distance

-Best for board surfers

-Surging breaker

-Breakers of shore

-Steepest seafloor

-Energy spread over shortest distance

-Best for body surfing

-Why is it better to surf on the west coast vs. the East?

-Steepness of the coast

-Wind blows toward show

-Tsunami or seismic sea wave

-What are they?

-Sudden changes in seafloor caused by earthquakes, submarine landslides, volcanic eruptions

-Effects entire water column

-Long wavelengths

-Considered shallow water waves

-Fast

-Sea level rise up to 40 m when tsunami reaches shore.

-What do they do?

-Mostly in Pacific Ocean

-Causes lots of damage

-People die

-Wave speed: square root of Gravity/Depth

-Sometimes around 540 mph

-Can be used to help evacuation and preparation

Lecture 16:

What is a Tide?

-Rhythmic rise and fall of a sea level

-Very long and regular shallow- water waves

-Caused by gravitational attraction of the Sun, Moon, and Earth

-Different tides in different places.

Tide-Generating Forces:

-Earth and moon orbit together around the Sun

-Barycenter between moon and Earth

-Earth rotation 24 hours

-Moon rotation 24.7 hours

-Gravitational pull between all objects

-Fg=(G*m*1*m*2)/r2

-G=Gravitational Constant

-If mass increase, gravitational force increase

-If distance increases, gravitational force decreases

-Zenith: closest point to mass

-Nadir: farthest point from mass

-Moon has a larger impact on tides than the Sun

-Resulting forces: differences between centripetal ad gravitational force

-Tide-Generating forces are horizontal components

-Tidal Bulges:

*-In perfect, smooth earth, no continents*

-Small horizontal forces push seawater into two bulges

-Opposite sides of earth

-One bulge faces moon

-Other bulge on other side of earth

-Two tidal bulges

-Two high tides about 12hours apart

-High tide, flood tide, seawater moves on shore

-Low tide, ebb tide, seawater moves off shore.

-Lunar Day:

-Moon orbits earth

-24 hours 50 minutes rotation

-Earth-Moon-Sun position Spring and neap tides

-Spring tides: very big tide

-New or Full moon

-Tidal range greatest

-Neap tides: very small tide

-Quarter moons

-Tidal range least

-Monthly tidal cycle

-Height of tides affected by moons location in relation to the earth

-Earth and moon are not at a perfect angle (tilt)

-Moon around earth

-Tidal range greatest at perigee

-Tidal range least at apogee (moon farthest from earth)

-Perigee - apogee cycle 27.5 days

Earth and Sun

-Tidal rage greatest perihelion (Jan) and perigee

-Tidal range least at aphelion (July) and apogee

Real tides:

-Earth not covered completely by oceans

-Continents and friction with seafloor modify tidal bulges

-Tides are shallow water waves with speed determined by depth of water

-Tidal bulges can’t keep up with earths rotation

-Instead large circulation cells in the ocean basins dictate how tides form in different oceans.

-Tidal cells in World Ocean:

-Crests and troughs of tides rotate around the Amphidromic point

-No tidal rage at point

-Cotidal lines: connect simultaneous high tide points

-Tide waves rotate every 12 hours

-Move at a speed of 1600 km/hour

-Tidal Patterns

-Diurnal

-One high tide and one low tide per day

-Tidal Period 24 hours 50 minutes

-Semidiurnal

-Two high tides and two low tides per day

-Tidal range about the same

-Tidal period 12 hours 25 minutes

-Mixes

-Two high tides and two low tides per day

-Tidal range different

-Tidal periods around 12 hours 25 minutes

Lecture 17:

-Ecology: the study of organisms at “home”

-The study of the inter-relationships between the physical and biological aspects of the environment

-How the organisms adapt and change to the environment

-What’s life?

-Adapts to their environment

-Change through time

-Capable of reproduction

-Capture, store, and produce energy

-Two marine provinces

-Pelagic Zone: water column

-Benthic Zone: bottom

-Really shallow to really deep

-Define ocean by depth

-Pelagic divisions:

-Epipelagic: surface- 200m

-Mesopelagic: 200-1000m

-Bathypelagic: 1000-2000m

-Abyssopelagic: 2000-6000

-Hadalpelagic: 6000m or greater



-Light divisions:

-Photic zone: surface-100m

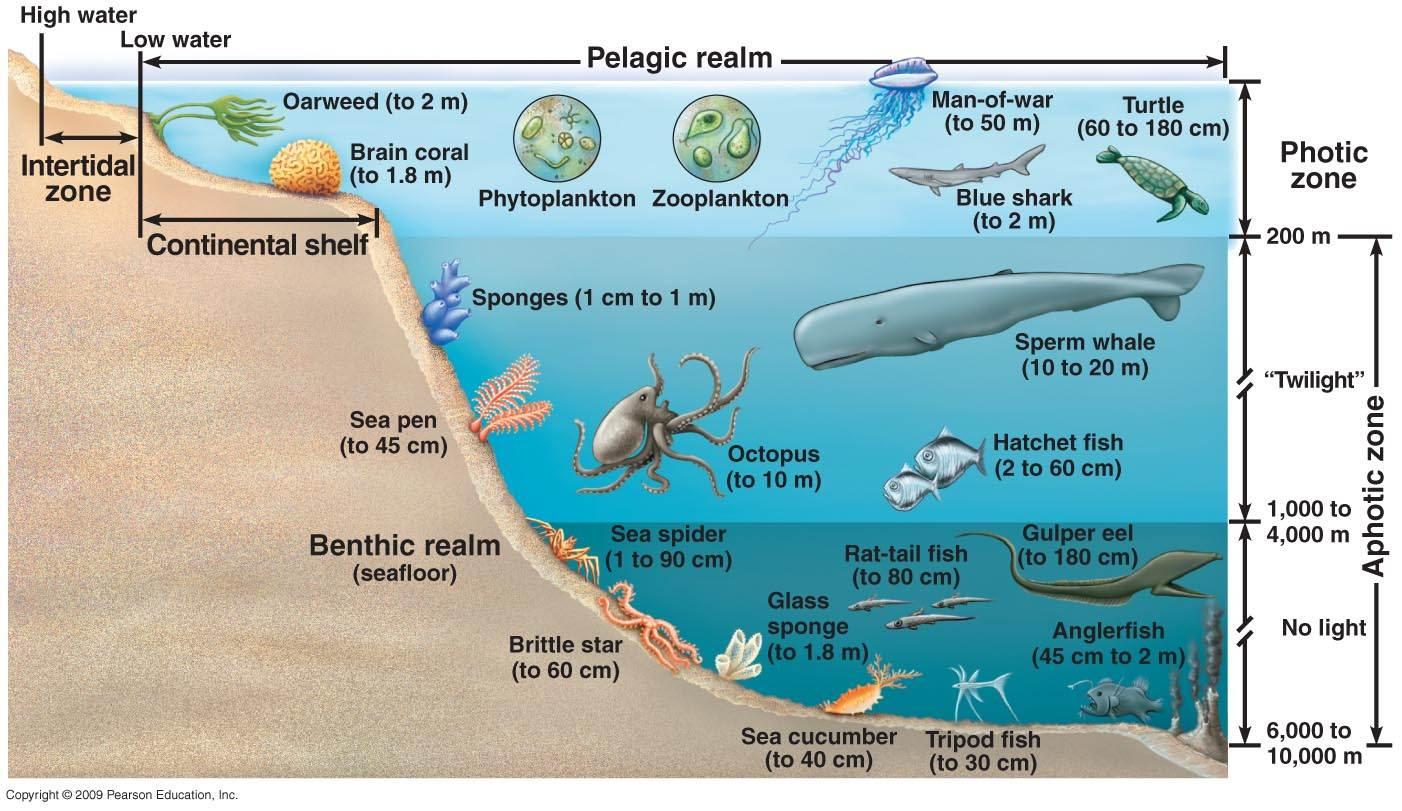
-The depth where light is sufficient for photosynthesis

-99% of photosynthesis happening here

-Dysphotic zone: 100-480m

-The depth where illumination is too weak for photosynthesis

-Aphotic zone: 480m-bottom

-The depth where no light reaches because it has all been absorbed by the water above it.

-How many species live in the ocean?

-Over 250,000

-Scientist say many many more

-In 1735 Linnaeus developed the taxonomic classification used in zoology

-Categorized from largest to smallest

-Domain

-Kingdom

-Phylum

-Class

-Order

-Family

-Genus

-Species

-The name of the species consists of the Genus and species

-Kingdoms

-Monera: bacteria, including cyanobacteria and archaea

-Protista: single or multi celled organisms with a nucleus; single celled algae (phytoplankton) or animals

-Fungi: abundant in the intertidal zone and are important in decomposition 100,000 species of molds but over all few in the ocean

-Plantae: plants free floating or attached

-Anamelea: all multicellular animals (sponges to whales)

-Domains: 3 domains

-Prokaryote: no organelles or nucleus

-Separated into Bacteria and Archaea later on

-Archaea: have a flagella structure, different ribosomal structure, type of linkage of their lipids, structure of cell covering and Eukaryote like DNA. They often are found in extreme environments.

-Eukaryote: has nucleus and membrane bound organelles

-Bacteria: unicellular organisms

-All bacteria are prokaryotes

-Normally microorganisms not visible to the human eye

-Marine Genomics

-Hot topic in marine science because you can learn a lot about how an organism is functioning

Lecture 18:

-Classification of Marine Organisms by mobility

-Plankton (floaters)

-Cannot direct their movement in the ocean

-Nekton (swimmers)

-Swim and Move actively

-Benthos (bottom dwellers)

-Pelagic Plankton

-Viruses

-Bacteria

-Phytoplankton

-Zooplankton

-Pelagic Nekton

-Squid

-Fish

-Types of Plankton

-Autotroph🡪 Phytoplankton

-Heterotroph🡪 Zooplankton (eats autotrophs)

-Most biomass on earth consists of plankton

-Phytoplankton

-Autotrophic🡪 can photosynthesize and produce their own food

-Zooplankton

-Heterotrophic🡪 relies on food produced by others

-Bacterioplankton

-Very small

-Can photosynthesize

-At least half of the oceans photosynthetic biomass

-Likely the most abundant photosynthetic organism

-Viroplankton

-Extremely Small

-Not well understood, may limit abundant of other plankton through infection.

-Holoplankton

-Entire lives as plankton

-Meroplankton

-Part of lives as plankton

-Juvenile or larval stages

-Squid’s juveniles are plankton

-Macroplankton

-Large floaters such as Jellyfish

-Picoplankton

-Very small floaters such as bacterioplankton

-Benthos

-Epifauna🡪 live on surface of seafloor/benthos

-Infauna🡪 live buried in sediments

-Nektobentos🡪 swim crawl though water above seafloor but spend most of their time on the surface of the seafloor.

-Most abundant in shallower water

-Depend on food trickling down from surface

-Many live in darkness, stillness, coldness, and under high pressure

-Ocean Primary Production

-Less in Gyres, warmer waters

-More on coastlines, freshwater deposit zones, colder water, equator, upwelling areas

-47% of Global Primary Production is from the ocean

-Only accounts for 0.2% of the earth’s biomass

-Phytoplankton🡪 Grass of the Sea

Lecture 20:

-Primary Production by Phytoplankton

-Respiration: Organic Matter +O2🡪 CO2 + NO3 + PO4 + H2O

-Consumes oxygen

-Creates nutrients

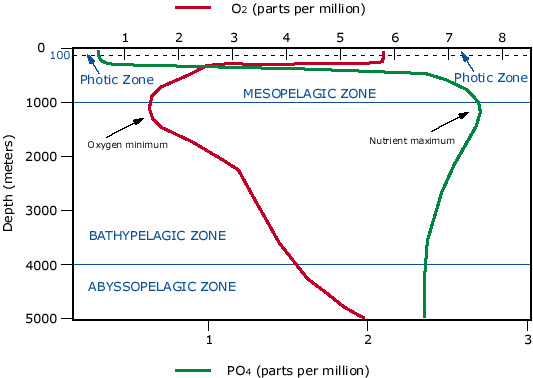
-Marine Snow

-Sinking particles

-Poop + Dead Stuff

-Contains surface CO2

-Oxygen and Nutrients



-Process of Photosynthesis happens at the surface

-Increase in oxygen at bottom because of thermohaline circulation

-100m peak driven by respiration

-Phytoplankton Bloom

-Mass abundance of Phytoplankton, noticeably larger

-Attracts larger ocean organisms

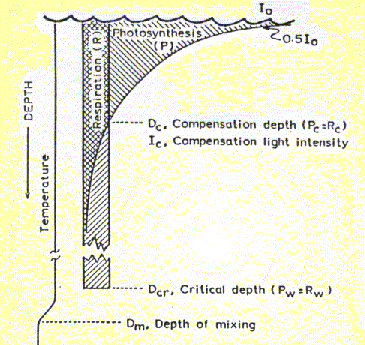
-Good for productivity at base of food chain

-Can be bad and cause dead zones

-Sverdrup’s Model of Critical Depth

-Photosynthesis exponentially decreases in light availability.

-Respiration is unaffected by light and remains constant with depth



-Compensation point: rate of photosynthesis = rate of respiration (ideal for production)

-Critical Depth point: Total photosynthesis = total respiration

-Low Latitude: strong thermocline🡪 stratified

-Hot buoyant surface layer that blocks upwelling

-High Latitude: very well mixed

-Lots of mixing and high winds

-Polar Oceans

-Nutrients are abundant due to vertical mixing

-Limited by sunlight

-Partially covered by sea ice

-Winter

-Low diatom

-Low zooplankton

-Spring

-High diatom

-Low zooplankton

-Summer

-Medium diatom

-High zooplankton

-Fall

-Low diatom

-Medium zooplankton

-Temperate Ocean

-Spring and fall blooms

-Delayed zooplankton bloom

-Nutrients fall during bloom and recover over the winter

-Tropical

-No big change throughout the year

-No bloom

-Low Primary Production as a whole

Lecture 21:

-Harmful Algal Blooms: HABS

-Nuisance bloom:

-Not harmful

-When they die oxygen levels lower

-When abundant

-Shading which blocks sunlight which means no photosynthesis

-Oxygen depletion from excessive respiration

-Mechanical irritation, damages fish gills

-Dinoflagellates

-Main algae in most cases

-Single celled

-Bioluminescent

-Harmful

-2 flagella

-6-8 million /L

-Red Tides

-Extreme Fish kills

-Toxic

-Brevetoxin: neurotoxin shellfish poisoning

-Domoic Acid: amnesic shellfish poisoning

-Cyanobacteria Toxins: Lots of different toxins that cause sickness.

-Pre 1972 vs Post 1972

-We look for it more

-Farm Runoff

-Sewage Runoff

-The Birds: Alfred Hitchcock

-Inspired by birds gone wild care in California in the 1960s

-Sea Birds vomiting and running into things

-Sooty Shearwaters

-Eat Anchovies that eat phytoplankton

-Pseudo-nitzschia bloom at the time

-Produce Demotic Acid

-Another Case in 2011

-Demotic Acid Biomagnification

-Energy flow in marine ecosystems

-Solar energy converted to chemical energy by Producers

-Consumers eat producers and other consumers

-Herbivores

-Omnivores

-Carnivores

-Decomposers eat the left over organic material

-Energy doesn’t cycle

-Nutrients do cycle

-Nutrient Cycle

-Nutrients Cycled from one chemical form to another (Fixing)

-Biogeochemical cycling

-Nutrients can be recycled through upwelling

-Trophic Levels

-Biomass decreases as you go from Producers 🡪 carnivores

-Energy and nutrients are lost as you go though feces, respiration, and death

-Chemical energy is transferred from producers to consumers

-Only 10% of energy is transferred from one level to the next

-Very inefficient

-Food Chain

-Primary Producer🡪 Herbivore🡪 One or more Carnivores

-Food Web

-Branching Network of many consumers

-Consumers are more likely to survive with alternative food sources

-“Back up Plan” design, more options if something changes in the environment

-Biomass Pyramid

-Producer🡪 carnivore = Large biomass🡪 Small biomass

-1(killer whale)🡪 10xmass (bonito)🡪 100xmass (anchovies)🡪 1000xmass (zooplankton)🡪 10000xmass (Phytoplankton)

Lecture 22:

-CO2 Concentration over time in the atmosphere

-Increases overtime

-Over 400ppm as of 2015

-Photosynthesis and Respiration

-Over the course of a year there is a high CO2 point and a low CO2 point because of the use of carbon throughout the year

-50x more inorganic carbon in the global ocean than in the atmosphere

-Solubility pump

-Thermohaline Circulation

-Gases go with the water

-Gas gets tapped in deep ocean water

-Gas exchange allows CO2 to enter ocean

-Flux depends upon air-sea CO2 difference

-Solubility increases in cold water (polar regions are sinks and equatorial regions are sources)

-Sinks and sources are not uniform in location

-Biological Pump

-Carbon gets trapped in phytoplankton

-When they die they travel to the bottom

-Photosynthesis happening on the surface

-Lots of recycling

-Particles slowly fall to the bottom and carry nutrients and CO2

-Pathways for rapid Carbon sequestering

-Turn off Biological Pump would increase atmospheric CO2 by 200 ppmv

-What Controls Carbon Export?

-Primary Production high

-Carbon flux on sinking particles 100m (decade) 5-14%

-Carbon flux 1000m (centuries) 1%

-Carbon flux at bottom (millennium) 0.1%

-What controls phytoplankton?

-Temperature

-Light (solar angle and mixing)

-Major Nutrients (Carbon,Nitrogen, Phosphorus, Silica)

106-16-1-16🡪 C-N-P-Si

-Grazing

-Minor Nutrients (Iron, Zink, other)

-High Nutrient, low chlorophyll

-Water Profiles show if elements are being biologically processed

-“Give me half a tanker of iron, and I will give you an ice age.”—John Martin

-More Photosynthesis and sequester carbon which would lower the temperature of the earth.

-Neat Experiment

-High nutrient Low chlorophyll zones got pumped with iron

-Stimulated growth at first

-Equator stimulated carbon flux

-Southern Ocean did not stimulate carbon flux, may have made it worse

-No definitive results found

Lecture 23:

-One certainty of life?

-Death

-What if that’s wrong?

-Jellyfish???

-What are Jellyfish?

-Radiata: include cnidarians and ctinophora

-Body symmetry is in a circle

-Ctenophora:

-Cone Jellies

-1-10 cm in length

-NO stinging cells

-Eat Copepods and small fish, have a real gut

-Largest organism to use cilia for movement

-Cnidaria:

-Hydra, Jellyfish, Box Jellies, Sea Anemones, Coral

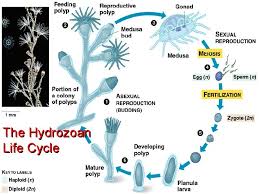
-Two body forms:

-Polyp: stationary

-Tentacles and mouth at top

-Medusa: mobile

-Tentacles and mouth at bottom

-Many exist in one or the other form primarily

-Corals are just polyps

-Jellies are just medusas

-Have stinging cells

-Cnidoblasts

-Contain nematocyst

-Box Jellies: One of the deadliest animals in the world

-Active hunter: stalks prey

-24 fully functioning eyes

-Carnivores

-Up to 10ft long 10in across

-Group of jellies are smacks or fluther

-Sea turtles eat Box Jellies

-Turritopsis dohrinii: “The Immortal Jellyfish”

-Used to be found only in the Caribbean but now found all over the world because it is transported by ballast water

-All of them are the same genetic clones

-Does backwards life cycle

-Injured or diseased, settles onto ocean floor

-Cellular transdifferentiation

-Somatic cells retain ability to change from one form to another.

-Sea Urchins can also do this

-Why do we care?

-Could we do this?

-Could we use this to make organs?