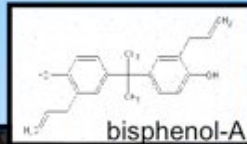


The Ecology, Biology & Chemistry of MARINE DEBRIS



PRESENTATION OVERVIEW:

This presentation provides an overview of marine debris: what it is, how it gets into the ocean, and how it is transported throughout the ocean. An introduction to the effects of this marine debris on seabirds and other marine animals follows. As far-ranging top predators, seabirds are valuable biological indicators

of climatic and human-related changes to marine food webs because they are long-lived, and have an expansive range in marine ecosystems. For these reasons, seabirds are also valuable indicators of plastic pollution in coastal and oceanic waters. The end of the presentation reviews the physiological effects of toxic chemicals found in or adsorbed* to plastics on organisms.

*adsorb: to undergo or cause to undergo a process in which a substance accumulates on the surface of a solid forming a thin film

Marine debris is found:

- on beaches
- floating on the water surface
- mixed in the water column
- on the bottom of the sea

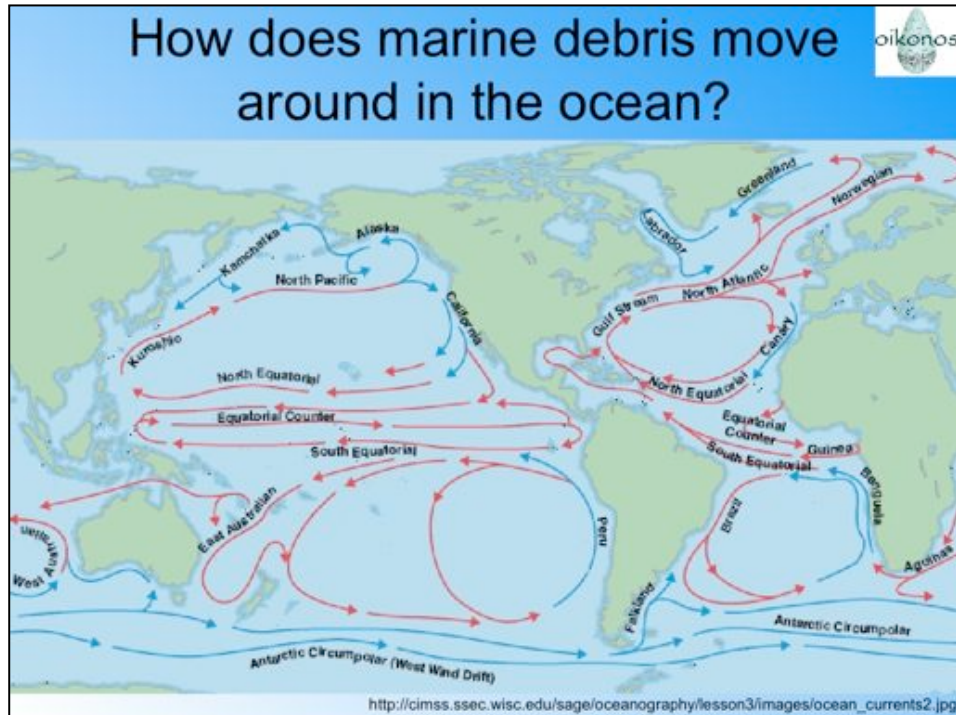


- As marine pollution increases worldwide, impacts to seabirds and other wildlife are expected to increase.
- Marine debris is found everywhere in the ocean and affects many ecosystems and organisms, from those that live near the bottom (benthic) to those that live in the water column (pelagic).
- Pictured here on this slide is a sea turtle tangled in a fishing net, a piece of plastic wrapped around a coral head, and a large accumulation of debris washing ashore in Hawaii.

Plastics are a global problem



- This is a composite satellite photo of the Earth at night. Yellow are human-caused lights. The squares represent far-away islands, where breeding seabirds are ingesting large amounts of plastics.
- The point of this slide is to highlight that marine debris reaches the farthest points of the planet, even Inaccessible islands where plastic is not directly littered by humans.
- This raises the question....how does plastic move from very human populated areas to these far-away islands?



- Marine Debris moves from high human population areas to far-away, remote islands by surface currents of the ocean. You can see the major ocean surface currents on the map above. The arrows point to the direction where they are moving to and the color denotes whether the main waters of these currents are warm or cold. (Example: The California Current is mainly cold water moving south from the Alaska area along the west coast of the USA, whereas the Gulf Stream is mainly warm water moving north from the equator along the east coast of the USA.)

-Below is a further explanation of how ocean surface currents form, move, etc. (this is more information, but not necessary information):

- + Because of solar heating temperature differences occurring between the tropics to the polar regions. The equator is warmer (closer to the sun) than the poles. The various heating and cooling of the earth's atmosphere moving from the equator to the poles causes temperature differences creating wind!!!

- + These prevailing winds 'push' the ocean. This 'push' can reach down to 400m in depth. Because the winds move in consistent directions, so does the ocean.

- + However, due to earth's rotation (Coriolis Effect), the water does not move in straight lines, instead it 'curves' and forms large circular patterns called gyres. (You can see these large gyres, circular cells in the map on this slide.)

- + These move in specific directions depending on the hemisphere. Each gyre is driven by approximately 4 major currents, and there are 5 major gyres (N. Atlantic, S. Atlantic, Indian, N. Pacific, S. Pacific) in the world's oceans.

-Surface currents are extremely important for transporting water and they have a large effect on the climate of the coastal areas nearby.

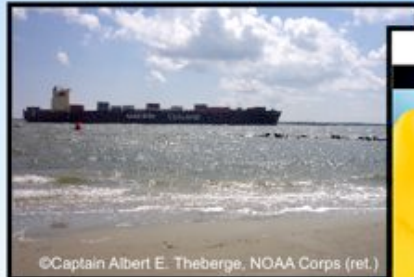
- + Example: Scotland, Ireland, and England are further north than Maine, Vermont, etc. However, in the United Kingdom and Ireland, the climate is much milder compared to the northeast of the United States. This climate difference is due to some of the warm Gulf Stream Waters transporting heat to this area.

-These currents do not only transport heat, but also animals, nutrients, and any floating marine debris and pollutants.

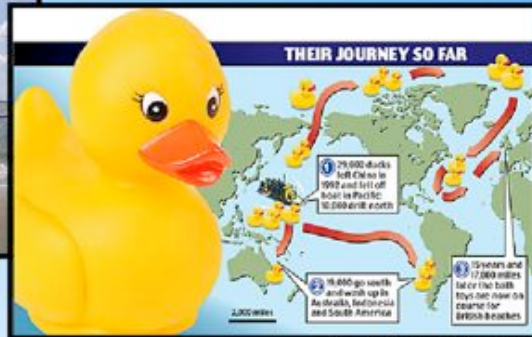
Rubber Ducky Transport



- 1992: 29,000 plastic toys spilled
- 1993: Washed up in Alaska
- 1995: Washed up in Hawaii, Japan and the USA
- 2000: Some are observed near Maine, USA
- 2007: Found on the shores of the United Kingdom



©Captain Albert E. Theberge, NOAA Corps (ret.)

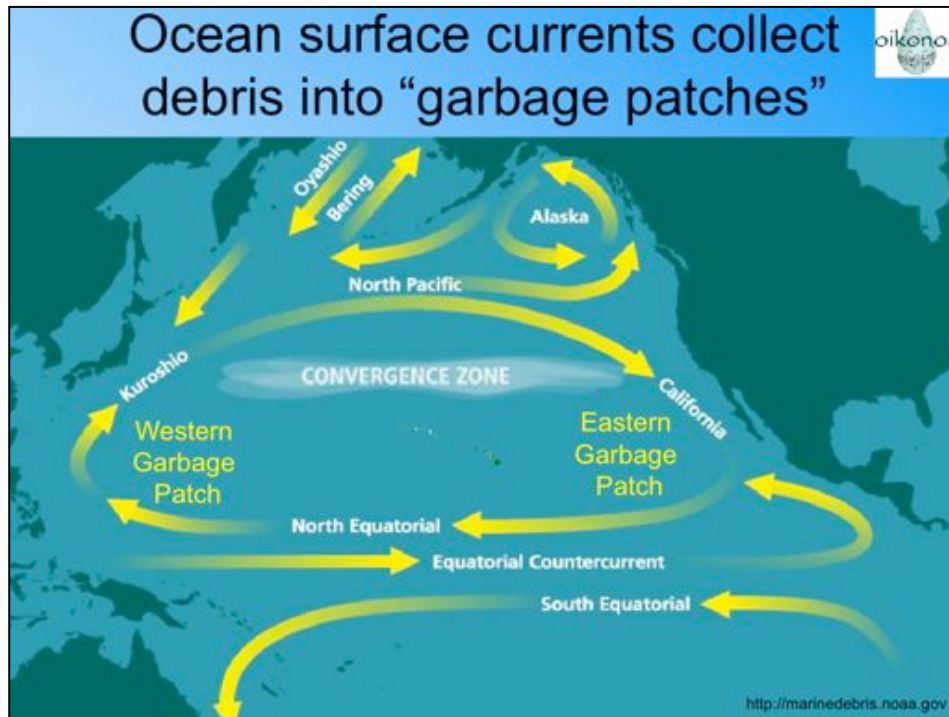


<http://www.thisislondon.co.uk>

-Cargo ships, such as the one pictured here move large amounts of sellable items across ocean basins. Occasionally, during large swell (waves) the bins of cargo fall overboard and the items begin to float where the ocean currents take them.

-This is an example of how objects floating in the ocean can move around in the ocean surface currents. In 1992, there was a rubber ducky spill, actually it was bath toys of various animal shapes (turtles, elephants, duckies, etc.)

- These toys were found washed up in coastal areas on various continents and countries over more than a 10-year period. These rubber duckies moved by surface currents. Scientists could predict where they would wash up next by observing and analyzing surface currents.



- This is a different map of ocean currents. The Yellow Arrows are denoting the major ocean surface currents in the Pacific Ocean.

- Notice the areas where there are not strong currents. This does not mean the surface ocean doesn't move at all, but it moves at a much much much slower rate. Things in these slower areas tend to accumulate in these regions.

- For example, the middle of the N. Atlantic gyre (not pictured on this map) is called the Sargasso Sea because Sargassum (free floating algae that lives on the surface ocean) accumulates in large patches in this region because of slow ocean movement.

- To think about this, imagine throwing a handful of confetti in a barrel of water, then stirring the barrel. Where does the confetti end up? It goes to the middle of the whirlpool, just like debris in a gyre.

-The Eastern Pacific Garbage Patch (EPGP) is located between Hawaii and California. The EPGP is estimated to be the size of Texas -- 3 million tons of debris. Garbage in the patches includes discarded electronics, children toys, and plastic. The plastic is very abundant, not biodegradable, and consists of mostly small, translucent, broken down microscopic pieces making it difficult to 'clean-up.'

- Many more garbage patches exist in the world's oceans. In the North Pacific, two more garbage patches exist. The Western Pacific Garbage Patch spreads from the east of Japan to the west of Hawaii. In the northern portion of the N. Pacific ocean. Also plastic and debris accumulates in the Alaskan gyre, but this garbage patch is smaller than the WPGP and the EPGP.

Biological Indicator Species



A species whose health status and abundance can be used to monitor the condition of an ecosystem or the environment.

These species can be monitored for:

- biochemical changes
- physiological changes
- behavioral changes



Example

- Tubifex (sludge) worms presence indicates water with low oxygen, a common feature of polluted water!



- All this plastic floating in areas far away from shore may have impacts on the organisms living and feeding in these regions.

- Scientists have a way of measuring the biological impact of this plastic, which can release toxic chemicals into the water as it breaks down.

- *Organisms whose status and abundance can be monitored to determine the health of an ecosystem or an environment are known as **BIOLOGICAL INDICATOR SPECIES.***

- Fish can be used as indicators of whether pollutants/toxins are in the water they live in by examining: changes in gene or protein expression, changes in organ function or appearance, or changes in reproductive behavior or swimming ability.

- Invertebrates can also be used as indicators (Tubifex worms presence in an area, shows that the water in that area is low in oxygen, which happens in a polluted water area. Therefore, when these worms are present, it is a sign that the water may be polluted.)

More information on bioindicator species used by the Environmental Protection Agency (EPA): <http://www.epa.gov/bioiweb1/html/indicator.html>

Seabirds are **Biological Indicators** of plastic pollution

oikonos

- Adult birds ingest plastic when foraging and capturing food
- Adults then feed plastic to young
- An increasing number of species affected by plastic debris and incidence of plastic

TEACHER NOTES:

*If you want more seabird information please see the Oikonos website:
<http://www.oikonos.org/projects.htm>*

- Seabirds are a biological indicator of plastic pollution.
- Seabirds are top predators on marine food webs, and forage across large areas of the world's oceans where plastic is present. Therefore, seabirds provide a way to monitor plastic pollution in the world's oceans. They are also charismatic and therefore are a good "mascot" for the problem of marine plastic debris.
- Seabirds ingest (eat) plastic – not intentionally, but most likely because it looks like their usual food items of squid and fish.
- Similar to other birds, seabird adults forage for their young and then bring this food back to their young and feed items (including plastics, mistaken for food) to their young on their breeding islands. The adult birds regurgitate whatever it has collected at sea in an oily slurry, into the chick's mouth. This may affect chick survival and health because they are being fed some plastic in place of real food items.
- Several groups of scientists have noted an increase in the proportion of plastic being ingested and overall total number of seabird species ingesting plastics.

What is this?

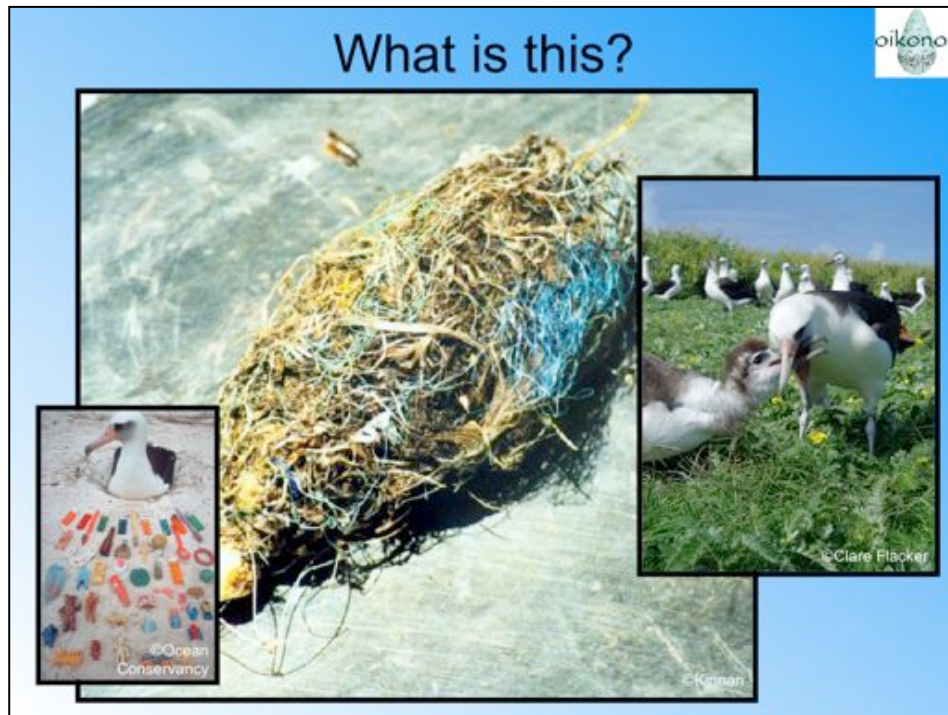


Teacher's Note: *Having students guess what this is an option here. The information below is listed on this slide and the next.*

-This is the seabird equivalent to an owl pellet, which is dissected in many classrooms. (For some owl species, when they ingest small animals they then regurgitate the inedible parts (bones, stones, etc., grass, dirt) into a ball known as an owl pellet.)

- Seabirds do the same thing, but it is called a bolus. Adult albatross do this many times at sea and these boluses are lost to the ocean. However, albatross chicks are found on breeding islands, where they regurgitate these boluses. Therefore, the boluses can be recovered and studied by scientists.

- Boluses are a compacted mass of indigestible materials that should only contain contain fish parts, squid beaks and hard parts of crustaceans. However, many boluses contain fishing line, plastics, styrofoam from fishing buoys and other non-natural items.



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- Seabirds do the same thing, but it is called a bolus. Adult albatross (picture of albatross in bottom left corner) do this many times at sea and these boluses are lost to the ocean. However, albatross chicks are found on breeding islands, where they regurgitate these boluses. Therefore, the boluses can be recovered and studied by scientists.

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- Adults forage for their young. And then bring this food back to their young and feed items (including plastics, mistaken for food) to their young. The adult birds regurgitate whatever it has collected at sea in an oily slurry, into the chick's mouth (pictured on right side of slide). This may affect chick survival and health because they are being fed plastic and not real food items.

An Albatross Bolus!



Should contain:

- 50% fish
- 32% squid
- 5% crustaceans
- 10% stomach oil

(Harrison et al. 1983; Fry 1987; Kinnan 2000)

- This slide lists what an albatross chick bolus SHOULD contain. Plastics take up space in the stomach and can interfere with or reduce absorption of important nutrients during an early stage of life for the albatross. This can impact growth.



- Here are some examples of plastics found in albatross chick boluses:
- On the right is a picture of all the plastic found in 1 Laysan's Albatross bolus that was dissected. The person in the photo is picking up a wheel from a child's toy.
- On left is another bolus dissected, with the natural pieces found in the bolus on the left squid beaks, shell fragments, and pieces of dirt/grass. On the right, are the plastic items found in this bolus.
- Almost 100% of chick albatross boluses dissected that were collected from Kure Atoll (near the EPGP) contain plastic (non-natural items).

Short Term Effects of Plastic Ingestion

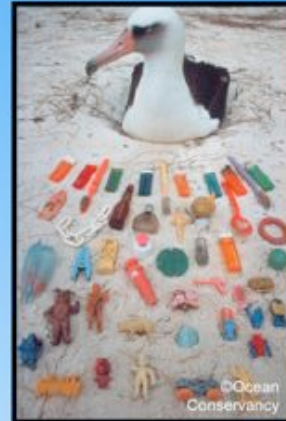
- Infection of cuts caused by plastic
- Obstruction of esophagus by plastic pieces
- Reduced food intake
- Dehydration



-Here are some examples of the short term effects of plastic ingestion by albatross chicks and adults. As mentioned a few slides before, plastic trapped in the stomach can interfere with nutrient absorption and reduce the total amount of food the chick ingests.

Long Term Effects of Plastic Ingestion

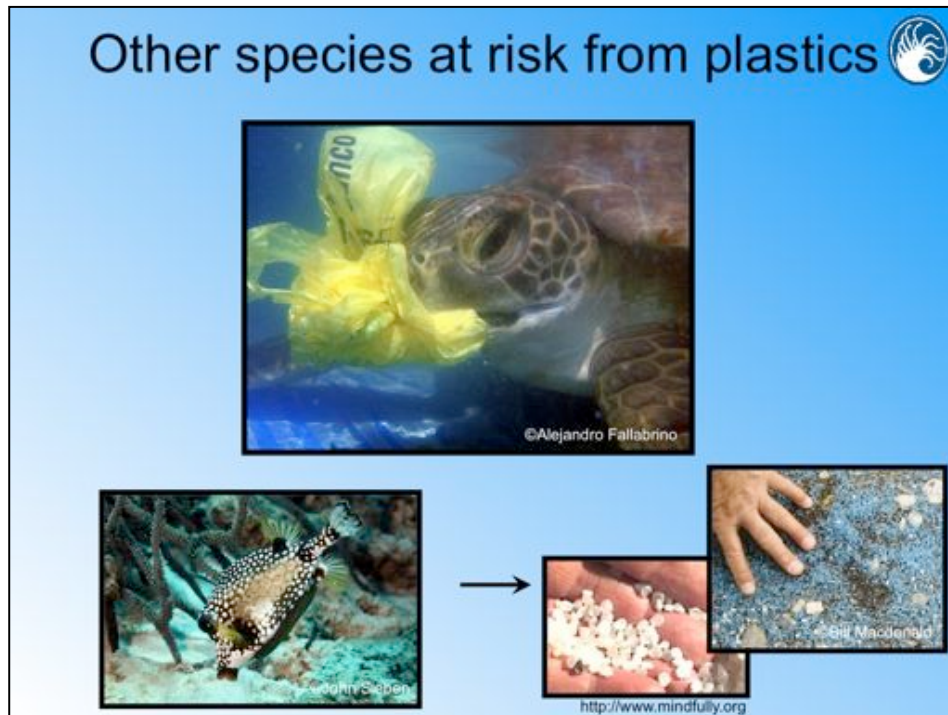
- Plastic slowly breaks down in stomach
- Plastic can leach toxic chemicals (i.e. plasticizers)
- Seabirds absorb toxic chemicals into their bodies



Important points:

- Plastic slowly breakdown in the high acidity of the stomach. Therefore, research suggests that the levels of plastic pollutants found in seabirds may be related to the amount of plastics they ingested. (Meaning, higher rates of plastic ingestions equals higher amount of plastic pollutants in albatross tissues.)
- Most of the chemicals associated with plastics (plasticizers and other persistent organic pollutants) are “hydrophobic” – meaning they prefer to associate with (stick to) plastic or sediment than remain in the water. Therefore these chemicals become concentrated on plastics and can be slowly broken down once it is ingested.
- Albatross chicks are smaller and therefore more sensitive. They do not have the same ability as adults to metabolize (detoxify) and excrete (get rid of) these pollutants, therefore the toxins accumulate more in albatross chicks.
- Chemicals associated with plastics tend to concentrate in the fat deposits of animals, where they can remain for a long time. These chemicals may be transferred to eggs from females (birds, fish, reptiles) during reproduction.

Other species at risk from plastics



These animals are also susceptible to harm by plastic ingestion:

- Certain species of sea turtles (reptiles) mistake plastic bags for their favorite food items, jellyfish or other invertebrates. These bags become lodged in their digestive system and can block it completely.

- Fish can ingest small plastic pellets floating in the water. These pellets are a by-product of plastic manufacturing. Efforts have been made in recent years to better dispose of these pellets so the amount getting into ocean waters is reduced. Fish are also susceptible to ingesting small pieces of plastic from larger items that have broken down over time.

- These marine organisms are also susceptible to the same pollutants that negatively impact seabirds. As with seabirds, juveniles (babies) are more sensitive.

Types of Plastics



Plastic type	Full name	Recycling code	Examples	Recyclable
PETE	polyethylene terephthalate	1	soda bottles	yes
HDPE	high density polyethylene	2	milk jugs, shampoo bottles, yogurt containers	yes
PVC	polyvinyl chloride	3	clear food packaging, candy wrappers, some bottles	sometimes
LDPE	low density polyethylene	4	squeezable bottles, shopping bags	yes
PP	polypropylene	5	caps, straws, some bottles	yes
PS	polystyrene	6	disposable plates & cups, CD cases	not usually
PC, other	polycarbonate	7	water jugs, sunglasses, DVDs	not usually

- Also included in the original paper, this table: summarizes types of plastics, the recycling code that can be found on the bottom, what things are made out of them and whether they can be recycled.

- This table is for use during the campus debris pick-up so students can sort what they are finding. Use the table on slide 43 to sort by the pollutant(s) associated with a certain type of plastic.

Additional information on types of plastics and their relative toxicity / environmental impact can be found at:

<http://www.thedailygreen.com/green-homes/latest/recycling-symbols-plastics-460321>

<http://www.thedailygreen.com/green-homes/eco-friendly/plastic-bottles-toxins-water-bottles-460410>

Summary of Toxic Effects



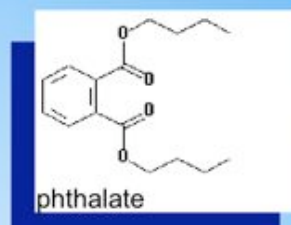
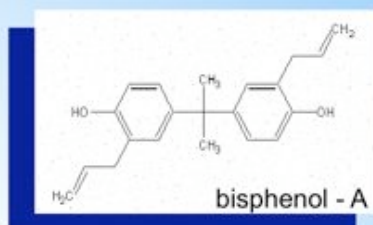
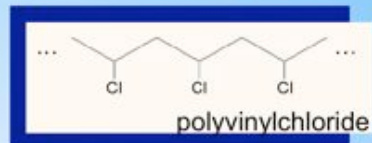
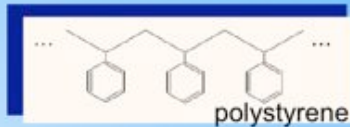
Toxic compound	Use	Effect(s)	Plastic type(s)
bisphenol A	plasticizer, can liner	mimics estrogen	PVC, PC
phthalates	plasticizer, artificial fragrances	Interferes with testosterone, sperm motility	PS, PVC
persistant organic pollutants (POPs)	pesticides, flame retardants, etc.	possible neurological and reproductive damage	all plastics
dioxins	produced in manufacture of PVC, during waste incineration	carcinogen, interferes with testosterone	all plastics
nonylphenol	anti-static, anti-fog, surfactant (in detergents)	mimics estrogen	PVC
polyaromatic hydrocarbon (PAHs)	produced when fossil fuels are burned	developmental and reproductive toxicity	all plastics
polychlorinated biphenyls (PCBs)	electronics manufacture	interferes with thyroid hormone	all plastics
styrene monomer	breakdown product	carcinogen, can form DNA adducts	polystyrene

-This table: lists the compounds that are associated with plastics, what they are used for, what their effect is, and which plastic type contains or is associated with them.

- The next slides will describe in detail some of the more common pollutants associated with plastics.

We will complete the presentation of these pollutants by summarizing again with this table.

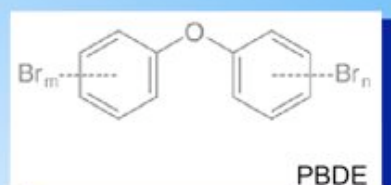
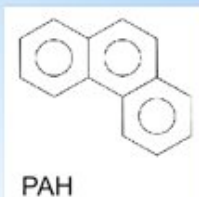
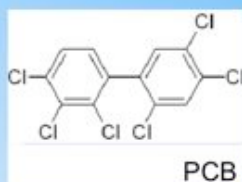
Plastics at the Molecular Level



- Plasticizers, like bisphenol-A and phthalates work by embedding themselves between the chains of plastic polymers*, like polystyrene (styrofoam) and polyvinylchloride (PVC), spacing them apart (increasing the "free volume"), and thus lowering the melting point for the plastic.
- Plasticizers make the plastic softer and more flexible. This makes it possible to make many different types of products that have different levels of flexibility.
- Picture bisphenol-A or phthalate in between each of the polymer units, pushing them apart a little bit more so there is more space between each unit.

***polymer**: a large molecule made up of repeating structural units (these units are called monomers). Polystyrene and Polyvinylchloride, pictured above, are polymers. Plastics are made by adding an enzyme that causes this chemical reaction which makes the repeating structural units to occur over and over again. Manufacturers can make the polymer chain as short or long as desired by stopping and starting the reaction. Adding the plasticizers to these polymers makes the plastics more flexible in order to make different objects of varying flexibility and shape.

Chemicals “adsorb” to plastics



- Some dangerous compounds, like pesticides and other industrial chemicals, are not added to plastics during manufacturing, but are chemically attracted to plastics because they are “hydrophobic” (defined on earlier slide). These compounds get into the water from other sources and because they are “hydrophobic” they do not remain in the water, they stick, or “adsorb” to substrates such as plastic floating in the water.

- The pollutants below can become highly concentrated on plastic pieces, which can then be ingested by animals like fish, sea turtles, or birds. These chemicals then may leach into the organism and become concentrated in fat tissue (lipids).

- PCB (polychlorinated biphenyl) - used in electrical appliances until the 1970s, banned but still persist

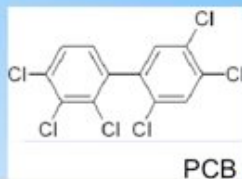
PBDE (polybrominated diethyl ether) - flame retardant used in consumer products such as upholstered furniture

PAH (polyaromatic hydrocarbon) - byproduct produced when burning fuel (also big problem after oil spills, such as the one that occurred in the Gulf of Mexico in 2010)

DDT - pesticide used in the U.S. until the 1970s, now banned in U.S. but still used in the developing world.

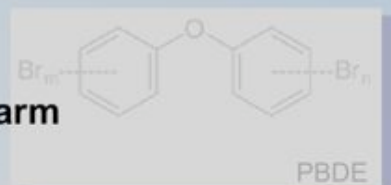
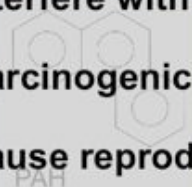
Newer chemicals – new pesticides and other industrial chemicals (i.e. nonylphenol) that are hydrophobic also have the potential to bind to plastics.

Chemicals associated with plastics



Why are these chemicals harmful to organisms?

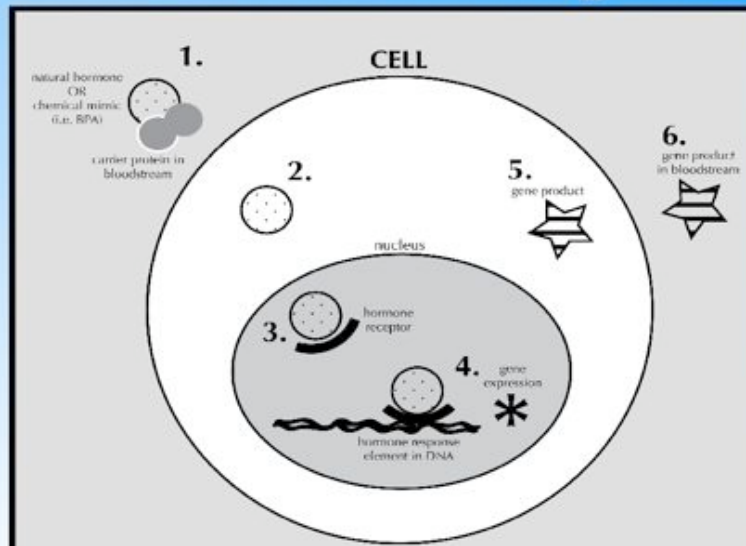
- Interfere with hormones
- Carcinogenic
- Cause reproductive harm



- In addition to their tendency to concentrate in fat tissue, these compounds are harmful to organisms in a number of subtle (sublethal) ways. We will go into more detail on each of these points in the next few slides.

1. Chemicals that are used in the manufacture (BPA, phthalates) or that adsorb to plastics can interfere with hormones such as estrogen. They can mimic or block the effects of estrogen. This is called “endocrine disruption.”
2. Some of these chemicals are carcinogenic, meaning they may cause mutations that lead to a tumor.
3. Both endocrine disruption and the formation of tumors can interfere with reproduction. Eggs produced may decrease if a tumor forms in the organism’s gonad or mating behavior may be altered.

How can plastics interfere with cell functioning?



- This is a diagram of how a plasticizer or other plastic-associated compound may cause “endocrine disruption.” Plasticizers (BPA and phthalates) can mimic or block the natural hormone estrogen from performing its necessary functions in cells. This diagram goes step by step through the process of how either a natural hormone (estrogen, testosterone) or a chemical that mimics or blocks a natural hormone gets into a cell and causes a change in gene and/or protein expression.

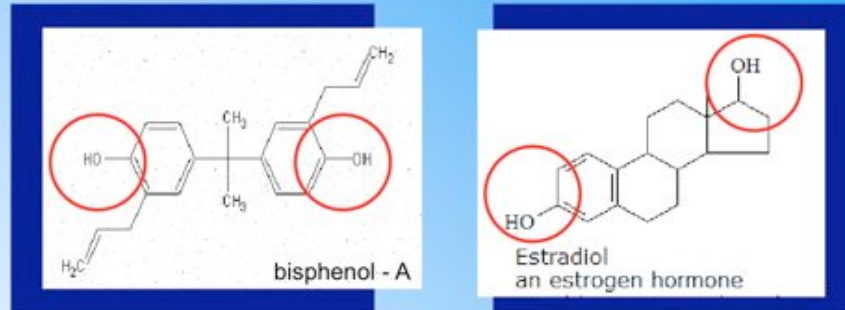
1. Natural hormone or chemical mimic (i.e. BPA) gets into organism and binds to a carrier protein in the bloodstream. Both natural hormones and chemicals that mimic hormones must bind to this carrier protein in order to be carried across the cell membrane. **The carrier protein cannot tell the difference between a natural hormone molecule and a foreign molecule that looks similar to the hormone.**

2-3. The carrier protein and molecule cross the cell membrane and then the molecule crosses the nuclear membrane. Inside the nucleus is a hormone receptor that the molecule will fit into (like a lock & key, only certain molecules fit certain types of receptors).

3-4. The hormone receptor and molecule complex form and then they bind together to the DNA, to a “hormone response element (HRE).” When it binds to the HRE a change in gene expression occurs. The genes associated with the natural hormone can be upregulated or downregulated.

5-6. A gene product (protein) may be produced once gene expression is changed. This protein then exits the cell and travels to one of the organism’s internal organs where it produces an effect. (i.e. egg development). A foreign chemical, or “endocrine disruptor” may make too much of a protein and disrupt egg development, or make a female protein that causes egg development in a male organism.

Receptor Binding (“lock & key”)

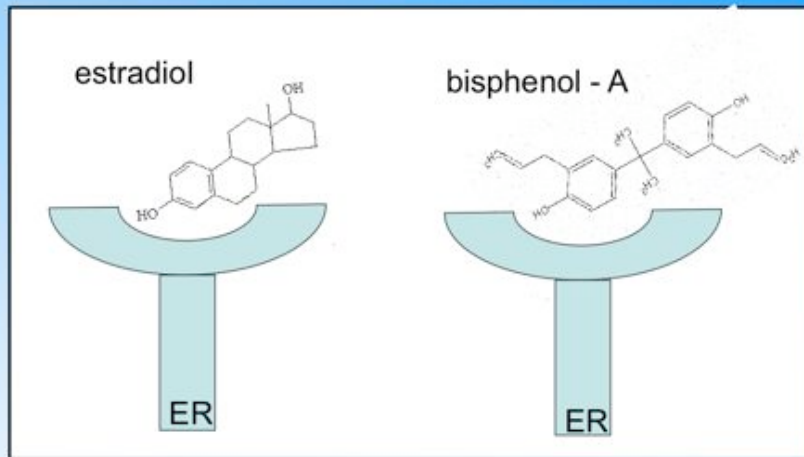


Artificially synthesized molecules can interfere with processes in the cells of organisms cells by mimicking natural molecules (i.e. hormones)

- Here are examples of two molecules that would bind to a carrier protein and then to the estrogen receptor, as shown in the previous slide. Shown here on the left is BPA, a plasticizer used in polyvinylchloride plastic (PVC) and estradiol, a natural estrogen produced by all vertebrates (birds, fish, reptiles, mammals).

- You can see that although they are very different molecules, they share some of the same properties, which make them both able to move into cells in a similar fashion. The parts of each compound circled in red are similar in structure (which is why BPA can act as an estrogen mimic, or endocrine disruptor). In addition the spacing between these -OH (hydroxyl groups) is important in that it is similar in both molecules ... so both molecules can fit in the same location in a cellular receptors. Essentially these “keys” can fit into the same “lock.”

Estrogen Receptor (in cell nucleus)



Molecule binds ER → ER binds to DNA → Gene is turned on or off

- This cartoon shows how the estrogen receptor can mistake a foreign molecule, such as BPA, for estradiol (a type of estrogen produced by the body).

-The -OH (hydroxyl) groups are placed similarly enough that they can interact with the same important amino acids in the receptor's "binding pocket." Interacting with these amino acids activates the receptor so it will then bind to the DNA response element.

Possible Impacts of Plasticizers



- Problems with reproduction
- Population reduction
- Altered male:female ratio
- Behavioral changes



-The higher-level impacts of what is happening at the cellular level are listed here. Some of these impacts are difficult to study in larger animals because they require evaluating an organism throughout its entire life cycle. Studies with fish show that behavioral changes and altered sex ratio do occur, and that longer term exposure (several years) can result in population decline.

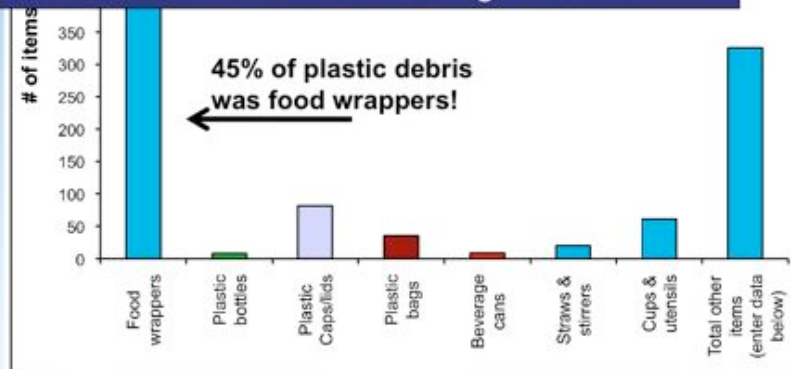
- Fish have similar receptor physiology to larger vertebrates, so impacts on fish are a good indicator of what is happening to larger animals such as sea turtles and seabirds.

Plastics on a High School Campus



Items that contain plasticizers or other harmful plastic-associated pollutants are common in litter found on high school campuses.

This graph shows amounts and types of litter collected during one afternoon at a California high school.



If you would like to split up the presentation into two halves, this would be a good place to begin on the second day.

- These plastics that could be causing problems for marine organisms in far off remote ocean locations originate in the litter found in everyday places, such as your school campus.

- This graph shows data from a campus debris collection conducted in 2009. Items were divided into different categories and the number of items from each category were tallied. Thirty students divided into groups of 3-4 each had collected from a variety of locations on campus for 15 minutes, from the quad to the football field. As you can see, food wrappers were the most common item. Many items were collected in a very short time period.

About those food wrappers ...



- Food wrappers, which were the most common items found on the high school campus shown on the previous slide, may be one of the most toxic types of plastic debris for several reasons.

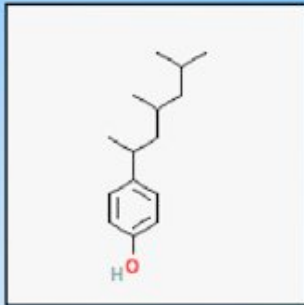
- They not only often contain plasticizers such as BPA and phthalates, but also may contain another endocrine disrupting compound, nonylphenol. (see next slide) ... These wrappers are used for many different types of food products.

About those food wrappers ...



- Nonylphenol (NP) is a surfactant used to prevent fogging of saran wrap when it is heated and to prevent static cling. You may have seen reports on the news saying not to microwave food that is covered with saran wrap. This is because NP and plasticizers can leach into the food, more so when the wrap is heated. They can also leach into an organism such as a seabird that has ingested a wrapper.

- Nonylphenol, like BPA, can act as an estrogen mimic. It can bind to and activate the estrogen receptor as shown a few slides ago.



NONYLPHENOL

- Can bind to the estrogen receptor
- Can mimic or interfere with estrogen
- Can accumulate in fish livers and cause tumors
- Bioaccumulates in prey items and effects predators

- In addition to being used for anti-fogging, NP is also used as a surfactant in pesticide formulations and other household products. One of its purposes is to keep hydrophobic compounds, such as pesticides, suspended in a liquid solution. It is now one of the most commonly found contaminants in aquatic environments.

- NP is found in high concentrations near wastewater treatment outfalls, even tertiary (3 levels of) treatment does not remove it completely.

- It does not look as much like estrogen as BPA does, but when an organism metabolizes the compound it can alter the molecule slightly to make it look more like estrogen, by adding an -OH (hydroxyl) group for example. There are enzymes in the livers of vertebrates and many invertebrates that do this. Although metabolism is meant to make things less toxic, sometimes it makes them more toxic.

- NP "bioaccumulates" because it concentrates in fat tissue. When a larger animal eats a smaller one it takes in these pollutants concentrated in the prey's tissue and incorporates it into its own fat tissue. This can then continue up the food chain.

and these candy wrappers ...



- Candy wrappers are made of a different type of plastic called polyvinylchloride (PVC). PVC contains phthalates and can also contain BPA.
- Phthalates, in particular DEHP (diethylhexylphthalate – no need to remember this word!), can bind to the estrogen receptor and activate or block it. DEHP can also interfere with testosterone and reduce sperm quality or function.
- Like other endocrine disrupting compounds that interfere with hormones, DEHP is hydrophobic and tends to concentrate in fat tissue. It can also bioaccumulate as it moves up the food chain.

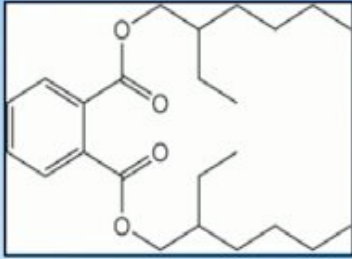


DIETHYLHEXYLPHTHALATES



- Diethylhexyl**phthalates** are used to make the PVC that these wrappers are constructed from soft and flexible enough to use as packaging material (same PVC used to make pipes).

- As described earlier, the phthalate molecule spaces the repeating plastic molecules further apart, hence changing the chemical properties of the material, making it more flexible, and increasing its versatility (one type of plastic can be made into many different types of products).



PHTHALATES

- Can interfere with estrogen receptor or block the receptor for testosterone
- May interfere with thyroid hormone function
- Possible interference with sperm motility

- Some research shows that phthalates and chemical associated with plastic, PCBs, can interfere with sperm motility. For example, fish sperm have receptors for estrogen on them, phthalates can bind to those receptors and disrupt chemo-attraction to eggs, hence reducing motility. If the phthalates are in the water this is problematic for fish, which “broadcast spawn” their gametes (sperm and eggs) into the water. If the sperm aren’t attracted to or can’t swim as quickly to the eggs that the females have broadcast spawned there may be reduced fertilization of eggs.

- Phthalates can also bind to and block the androgen receptor (testosterone), which can also impact male reproduction. The mechanism described earlier for the estrogen receptor is the same as that for the androgen receptor (carrier protein with molecule crosses cell membrane and binds to nuclear androgen receptor).

- Phthalates have recently been found to interfere with thyroid hormone function. The thyroid gland controls many processes in a vertebrate’s body, the main ones being reproduction, metabolism and growth. Therefore interference with this very important endocrine system can impact an organism in a number of ways – i.e. reduced growth, reduced gonad size, altered digestion of food, etc.

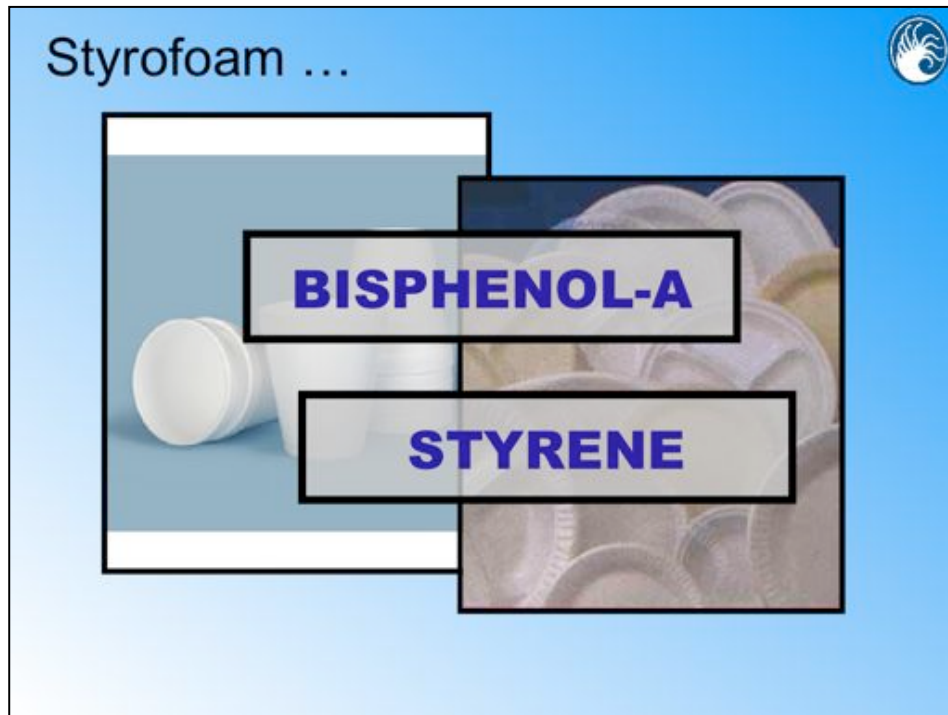
Styrofoam ...



- Another item commonly found on campuses and in litter everywhere else is styrofoam (a subtype of polystyrene). Styrofoam is also a very toxic type of plastic.

- Much of the waste produced from use of styrofoam cups and plates could be reduced by replacing these items with reusable dishware. Styrofoam is also rarely recycled, although this depends on the recycling program in your neighborhood or town.

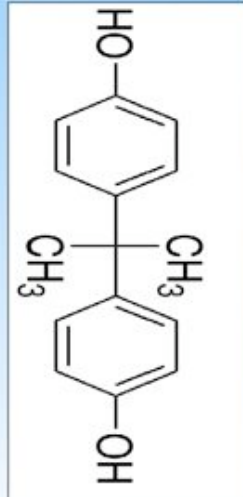
Note: **Polystyrene** isn't always styrofoam, sometimes it looks more like regular plastic – also often used as containers for food. Again, the use of BPA allows for different products to be made from the same type of plastic.



- BPA and styrene are the two contaminants of concern in Polystyrene.
- Bisphenol-A (BPA) is a plasticizer (increases plastic flexibility), and like phthalates and other compounds discussed earlier it can leach out of the container. Recently, there have been reports in the news about BPA in baby bottles (and many re-useable water bottles). Because of concerns about BPA leaching out of bottles into breastmilk or formula most manufacturers of baby bottles and other baby products that come into contact with the baby's mouth such as pacifiers have stopped using BPA.
- Styrene, the molecule that makes up polystyrene, is also toxic. It is a carcinogen, meaning that it can cause tumor growth that may lead to cancer. *In a few slides we'll describe how styrene can do this by binding to DNA.*



BISPHENOL A

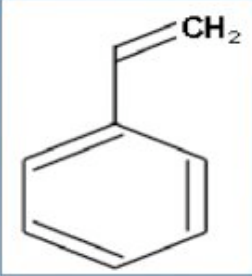


- Can bind to the estrogen receptor
- Can mimic or interfere with estrogen
- Possibly increases the risk of breast cancer

- BPA is an estrogen mimic, but depending on the concentration it can also block estrogen or interfere with its functions in the body.

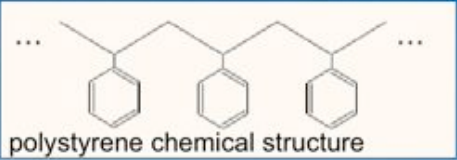
- Although evidence is not yet conclusive, many studies have suggested that BPA could be increasing the risk of breast cancer and other reproductive cancers in humans.

- Studies with fish have shown that BPA disrupts reproductive function and mating behavior.



C=Cc1ccccc1

STYRENE



polystyrene chemical structure

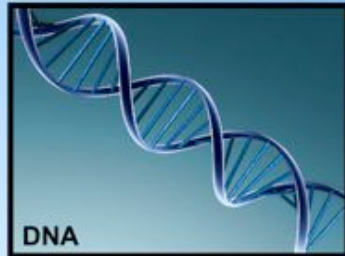
- Makes up the structure of polystyrene (Styrofoam)
- Is a confirmed mutagen
- Mutates DNA via “**adduct formation**”

- Styrene is the name of the repeating molecule (monomer) that makes up the polymer polystyrene (styrofoam), it is a confirmed mutagen*.

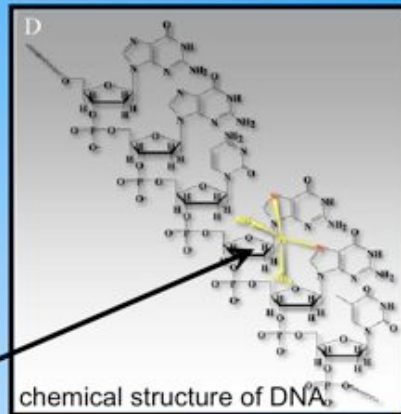
***Mutagen**: a physical or chemical agent that changes the genetic material, usually [DNA](#) of an [organism](#) and thus increases the frequency of [mutations](#) above the natural background level. As many mutations cause [cancer](#), mutagens are typically also [carcinogens](#).

Adduct formation is described in more detail on the following slide.

DNA adduct



Chemical covalently
binds to DNA backbone
(i.e. styrene monomer)



- Some contaminants, such as styrene, can covalently* bind to the DNA backbone, cross-linking the two DNA strands. When DNA attempts to replicate, the strands are unable to separate properly and strand breakage can occur. If the damaged DNA is replicated, a mutation (change in the DNA sequence) may occur. Multiple mutations can eventually lead to cancer.

*A **covalent bond** is a form of [chemical bonding](#) that is characterized by the sharing of pairs of [electrons](#) between [atoms](#), and other covalent bonds. The stable balance of attractive and repulsive forces between atoms when they share electrons is known as covalent bonding


Other Plastic Items



- These are other items commonly found as litter, such as plastic caps, bottles and straws, and they do not contain plasticizers.

- These items are made from PETE, PP, or PE plastic (see types of plastics table) and are considered to be “safer” plastics relative to PVC or PS.

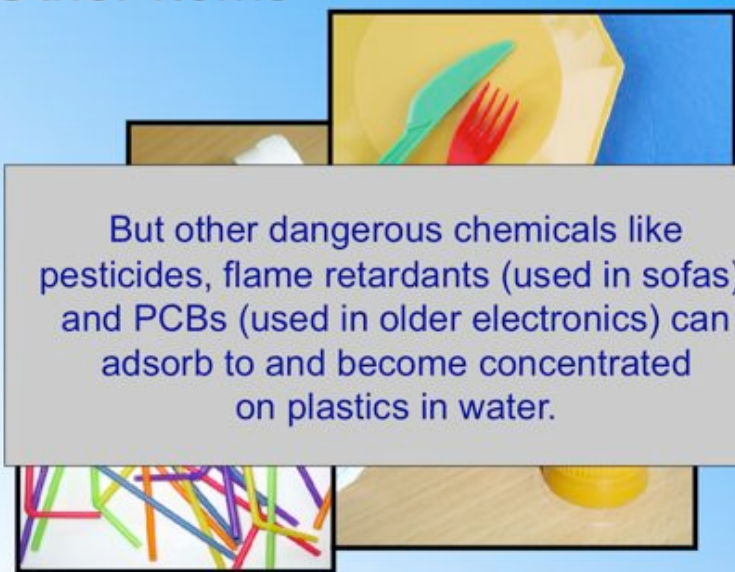
Other Plastic Items



polypropylene & polyethylene
plasticizers *not* used

-However, as *described in slides 19 and 20*, hydrophobic chemicals (such as PAHs, PCBs, PBDEs) are known to adsorb onto plastic surfaces. These chemicals can then potentially leach into an organism if the plastic is ingested.

Other Items

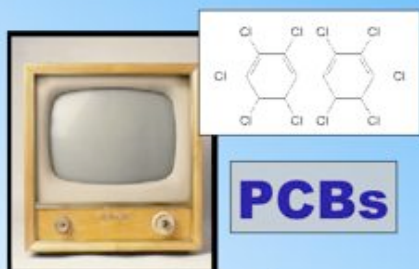


But other dangerous chemicals like pesticides, flame retardants (used in sofas), and PCBs (used in older electronics) can adsorb to and become concentrated on plastics in water.

- These chemicals are hydrophobic (do not mix well with water), so they prefer to stick to sediments or other solids like plastics. These chemicals become highly concentrated on plastics which then can be ingested by marine organisms such as birds or turtles, or fish.

- Turtles and seabirds have been found to have elevated concentrations of PCBs and other contaminants in their blood. These contaminants can also mimic or inhibit natural hormones, such as estrogen, by binding to cellular or nuclear receptors. *More information found on slide 19.*

Other Chemicals associated with Plastics



- PCBs and PBDEs are hydrophobic, meaning they do not mix well with water.

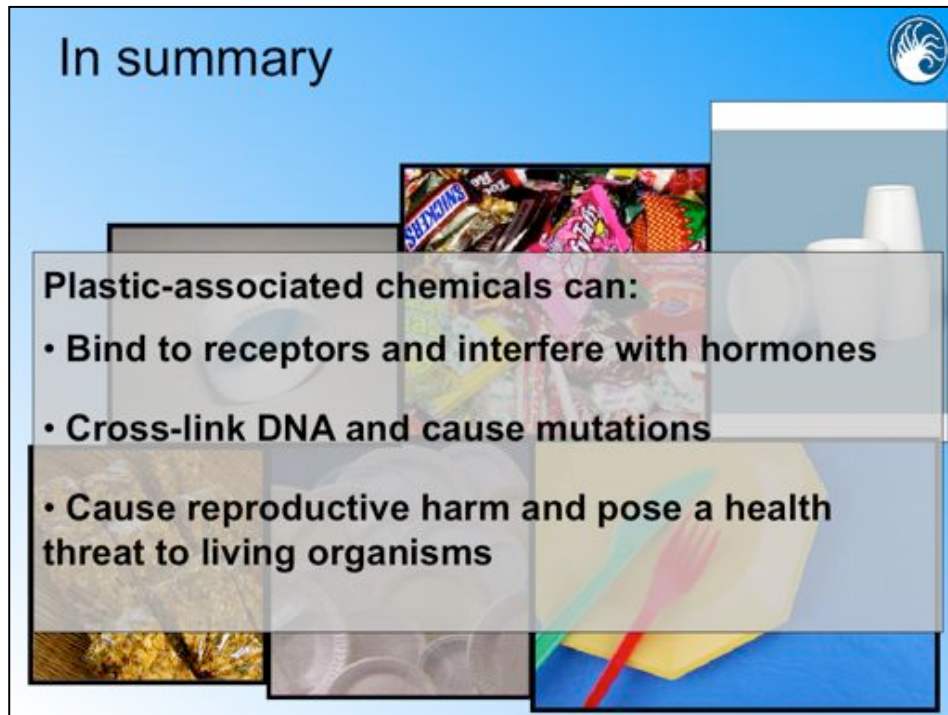


- These types of chemicals bind and concentrate on plastics in water.

- Here are two examples of hydrophobic contaminants that adsorb to plastics shown with pictures of products they are associated with.

- PCBs are no longer used but persist in the environment.
- PBDEs are currently used as flame retardants on upholstery, although much attention has recently been brought to their toxicity and endocrine disrupting potential.

In summary



Plastic-associated chemicals can:

- Bind to receptors and interfere with hormones
- Cross-link DNA and cause mutations
- Cause reproductive harm and pose a health threat to living organisms

- These impacts are more subtle than some of the more obvious problems such as mortality caused by entanglement or blockage of the digestive system, but over the long-term they are just as concerning.

- While it is impossible to do longer term studies with large animals such as albatross or sea turtles, studies with smaller vertebrates such as fish have shown that endocrine impacts at the cellular level can result in problems with reproductive function and may ultimately result in population decline.

Summary of Toxic Effects



Toxic compound	Use	Effect(s)	Plastic type(s)
bisphenol A	plasticizer, can liner	mimics estrogen	PVC, PC
phthalates	plasticizer, artificial fragrances	Interferes with testosterone, sperm motility	PS, PVC
persistant organic pollutants (POPs)	pesticides, flame retardants, etc.	possible neurological and reproductive damage	all plastics
dioxins	produced in manufacture of PVC, during waste incineration	carcinogen, interferes with testosterone	all plastics
nonylphenol	anti-static, anti-fog, surfactant (in detergents)	mimics estrogen	PVC
polyaromatic hydrocarbon (PAHs)	produced when fossil fuels are burned	developmental and reproductive toxicity	all plastics
polychlorinated biphenyls (PCBs)	electronics manufacture	interferes with thyroid hormone	all plastics
styrene monomer	breakdown product	carcinogen, can form DNA adducts	polystyrene

This table summarizes the compounds discussed throughout the presentation, it can also be found in the paper.

What can we do about the plastic pollution problem?



Suggested activity – have students get into groups to work out their own suggestions for possible solutions or improvements to the current situation.

Make a difference!



- **Limit your use of plastics**
 - reusable containers
 - avoid types of plastic with BPA, phthalates, etc.
- **Dispose of trash properly**
 - pick up litter, recycle!
- **Write to your legislators about the plastic issue**
- **Report illegal littering**



Possible answer to the question on Slide 43.



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BODEGA MARINE
LABORATORY



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