Plastic Love Affair
Part 3: Impacts of Plastic

Health Impacts

- Humans
- Animals

Ecosystem Impacts

Opening Thoughts

Janus, in Roman mythology, was the god of change. Capable of simultaneously understanding the past while peering into the future, Janus represented transitions, both personal and social.

Modern society is at a pivotal moment with respect to plastics. What we know is that our lives and societies have been improved by the development of plastics.

But there is also a reckoning.

Opening Thoughts

Plastic bags kill an estimated 1 million sea creatures every year.

Plastics have been found in Arctic snow, in soil samples from Swiss nature reserves, on Mount Everest, and in the Pacific Ocean's Mariana Trench — 7 miles below the surface.

Plastics have been found in your food, in your water… and in you.

Overview of Health Impacts

"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy.“

Paracelsus (1493? – 1541)
The Father of Toxicology

Overview of Health Impacts

Toxicology is the study of the **adverse effects** of chemicals on living organisms. **Adverse effects** includes both acute (short-term) and chronic (long-term) impacts.

An Adverse Effect is simply an undesired response to stimuli, including chemical exposure or drug intake.

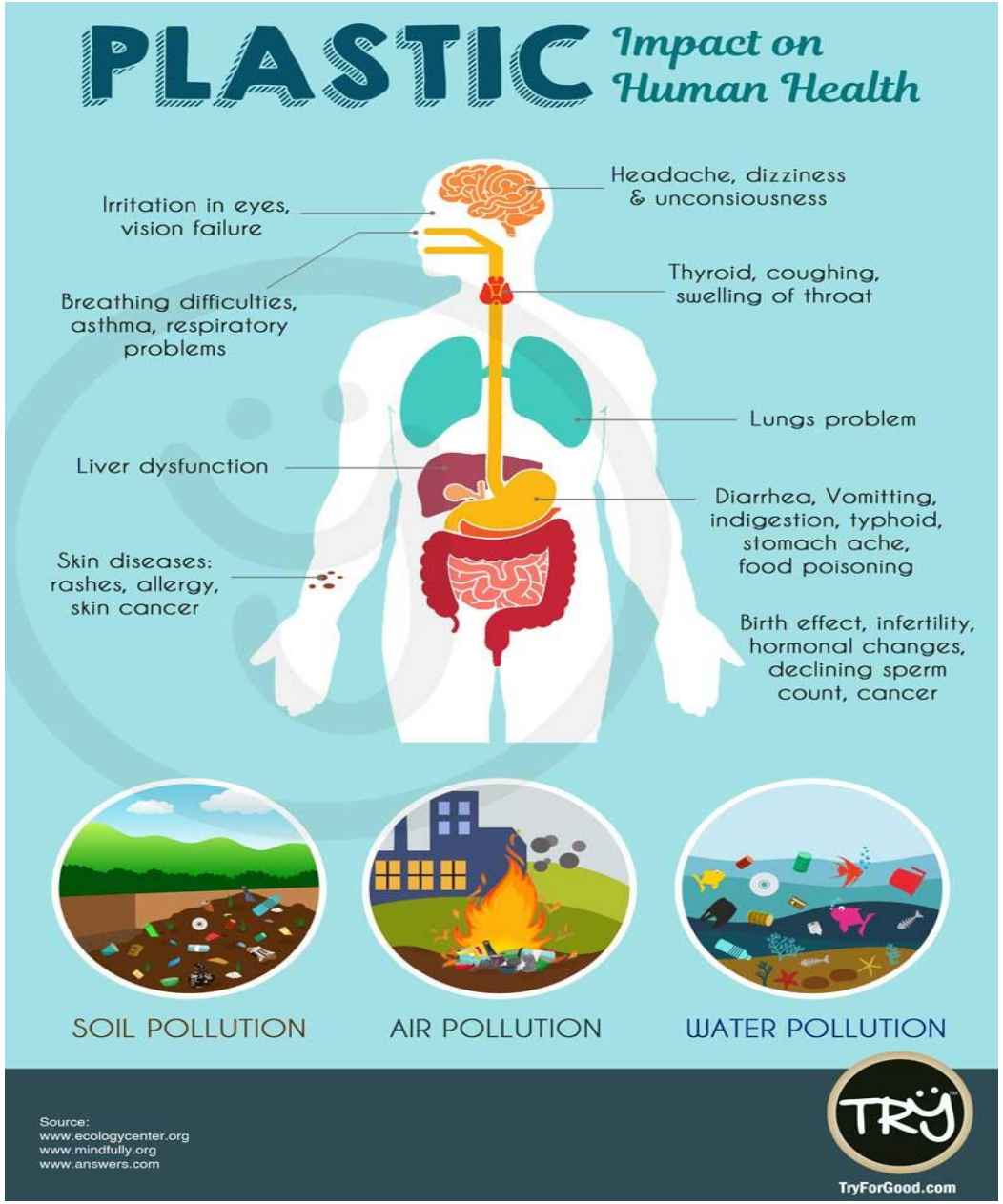
Chemicals enter the most organisms (including humans) in one of four ways:

- Inhalation
- Ingestion
- Dermal exposure
- Injection

Overview of Health Impacts

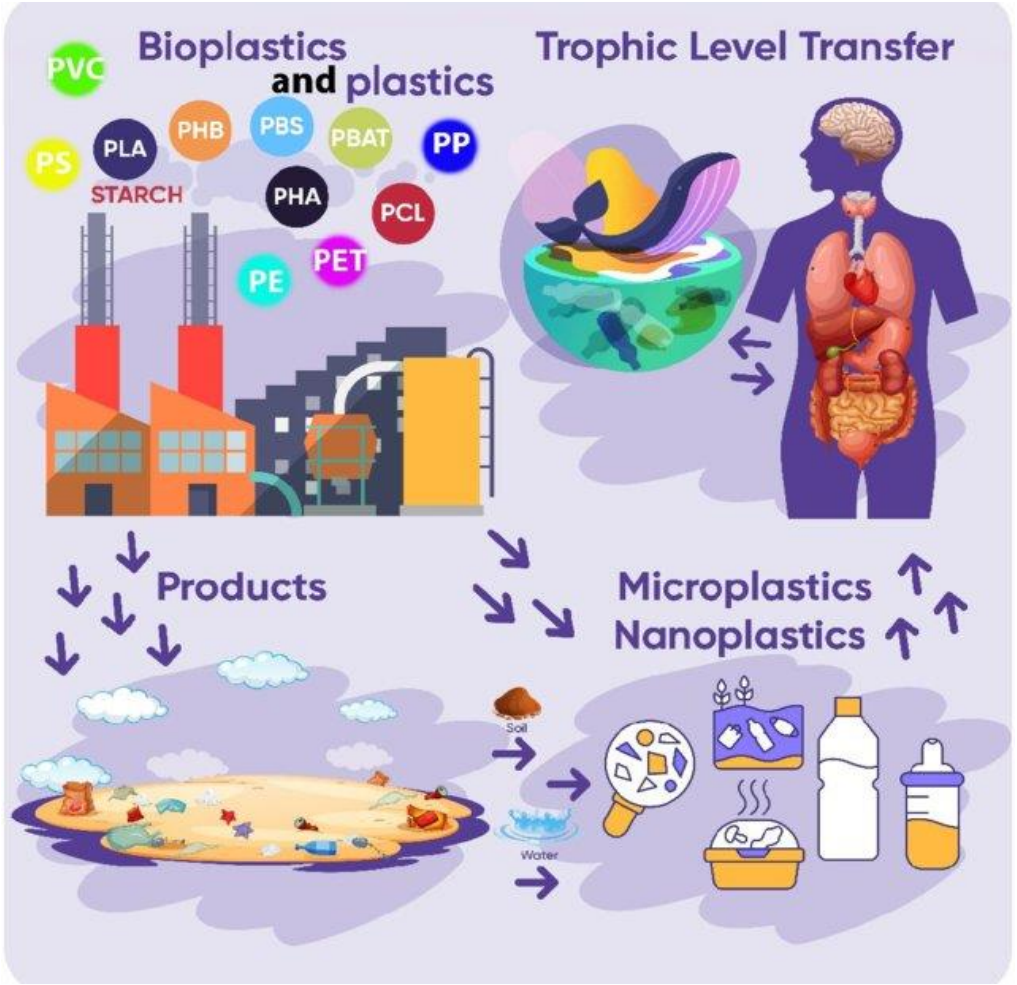
For plastics, most research supports the conclusion that the principal route of exposure is through ingestion although some inhalation is known to occur (e.g., micro-plastics in the ambient air).

A 2019 study estimated that each of us consumes 5 grams (roughly the mass of a credit card) of micro-plastics each week. A 2017 study found micro-plastics in 83% of all public water systems (over 90% in US systems).



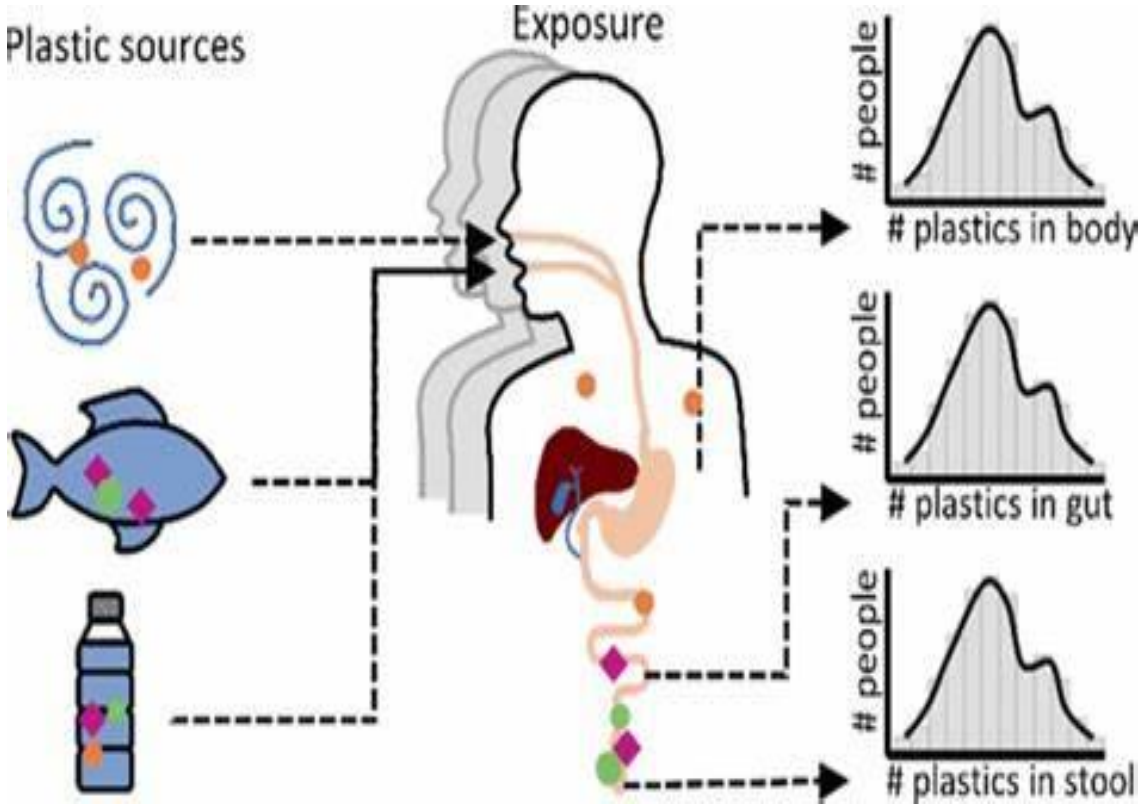
Overview of Health Impacts

One recent study reveals that most meat and even vegan alternatives contain cancer-linked micro-plastics, coinciding with toxins found in bottled water. Testing 16 protein sources, including chicken, beef steak, seafood, pork, tofu, and three-plant-based meat, scientists found 90% contained nano-plastics, posing potential health risks.



Overview of Health Impacts

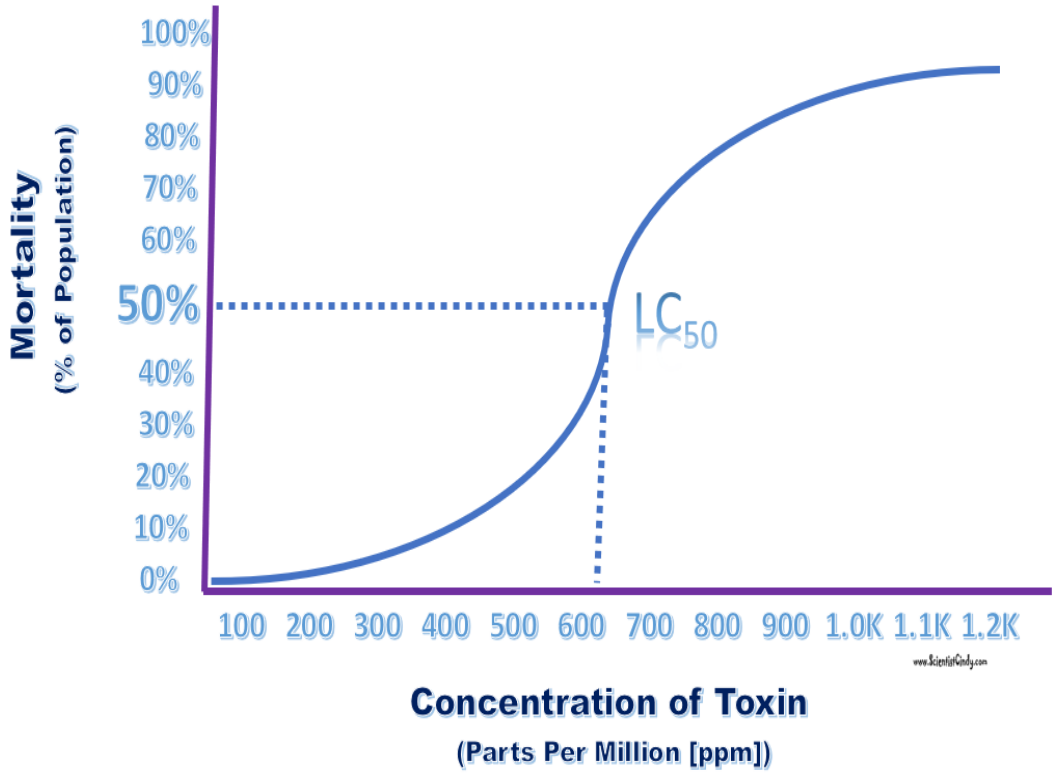
The general consensus among scientists is that plastics do not generally harm the gastrointestinal tract although some can be irritants. In general, plastics are absorbed through the lining of the GI tract and distributed via the blood to internal organs where the damage occurs.



Overview of Health Impacts

Toxicology is concerned with the relationship between doses (exposure to a compound) and physiological responses, often shortened to "dose/response".

In the most extreme relationship, lethality is calculated based on doses, the so-called LD_{50}.



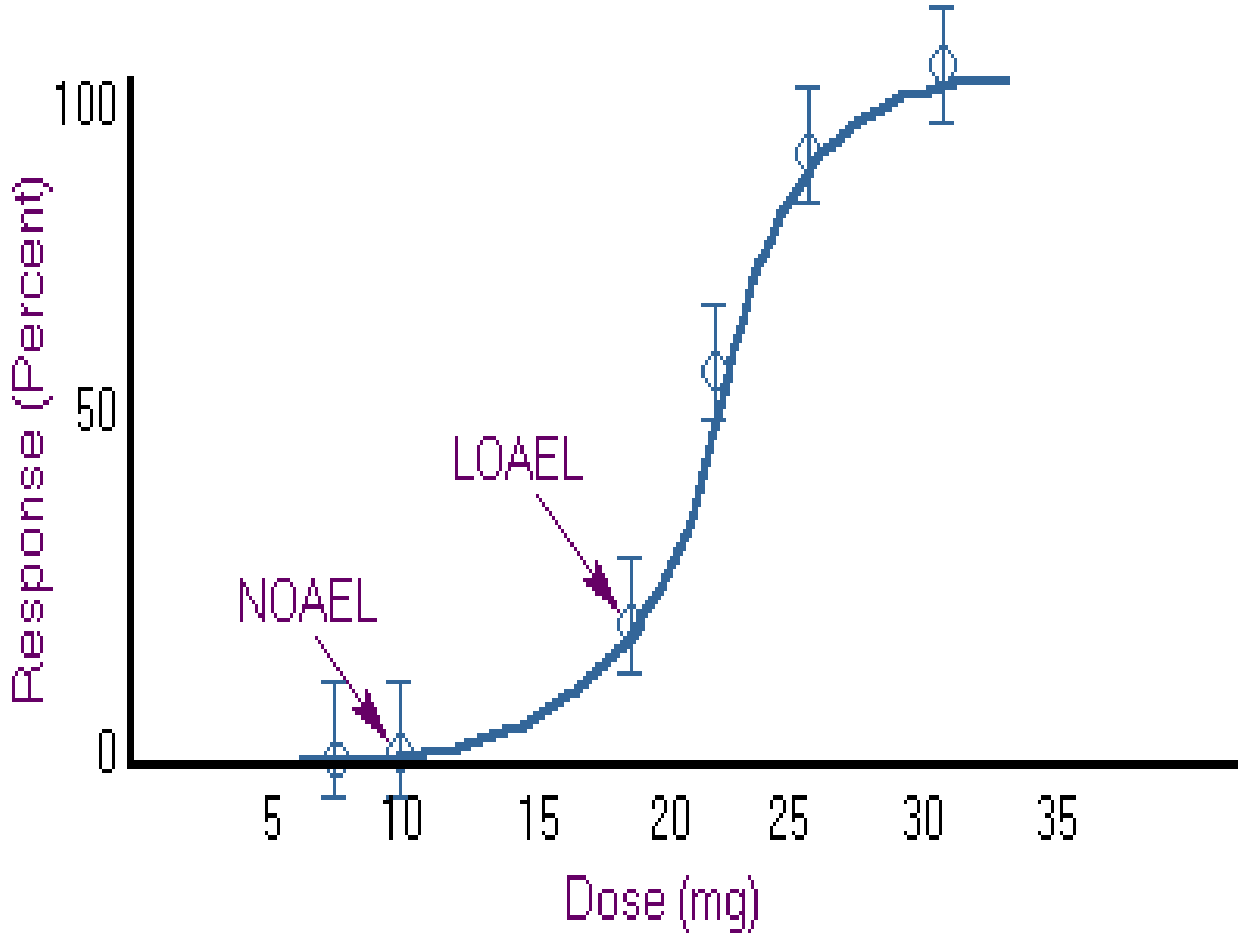
Overview of Health Impacts

But there are subtle impacts caused by a chemical, impacts that can be measured and correlated to specific doses.

The lowest levels where impacts are measured and correlated are referred to as **LOAEL, or the Lowest Observed Adverse Effect Level.**

No Observed Adverse Effect Level, or NOAEL, denotes **the level of exposure of an organism**, found by experiment or observation, at which there is no biologically or statistically significant increase in the frequency or severity of any adverse effects of the tested protocol.

NOAEL is not the same as No Impact!



Overview of Health Impacts

Effects can be:

- Mutagenic effects:

  Changes caused by a chemical in genetic material, usually DNA, thus increases the frequency of mutations above the natural background level. As many mutations cause cancer, mutagens are typically also carcinogens.

- Teratogenic effects:

  The combined consequences of consuming a harmful substance on a developing fetus; may manifest itself as an anatomical abnormality (e.g., Thalidomide deformities) and/or mental impairment (e.g. fetal alcohol syndrome).

- Carcinogenic effects:

  Chemical exposure which results in the exacerbation of cancer or in the increase of its propagation. This may be due to the ability to damage the genome or to the disruption of cellular metabolic processes.

Overview of Health Impacts

Questions:

- What human health impacts are known to have occurred in the past as a result of exposure to plastics?
- What human health impacts are associated with exposure to plastics?
- What human health impacts are associated with compounds used to make plastics?

Plastics and Human Health

The health implications of human exposure to plastics and the compounds that make up plastics are still being studied. Conclusions are often tentative and have been misrepresented on social media.

Data from various studies indicate **potential health effects** such as:

- Metabolic disruption
- Reduction in fertility
- Immune dysfunction
- Neurodegenerative diseases
- Chronic inflammation, which can lead to cancer
- Interference with hormone function

Plastics and Human Health

Any discussion about the health implications of plastics is complicated by the heterogeneous nature of plastics; simply put, plastic are not a monolithic product.

Plastics are made from different ingredients, plastics dissolve or degrade at different rates (from a variety of catalysts) and plastics intersect with human activity in different ways (exposure routes).

Human Health Impacts

And this conversation about human health is further complicated by the lack of studies defining impacts from plastics. Scientific investigations of plastics are a recent (last 20-30 years) phenomenon. Prior to that, plastics were viewed as benign.

One prominent researcher is Dr. Tracy Woodruff of UC-San Francisco. According to Dr. Woodruff, very few of the thousands of compounds used in plastic production have been adequately studied. Because of the absence of governmental requirements for such testing, less than 1% of chemicals in plastics have been studied for their human health effects (and even less for long-term health effects).

Human Health Impacts

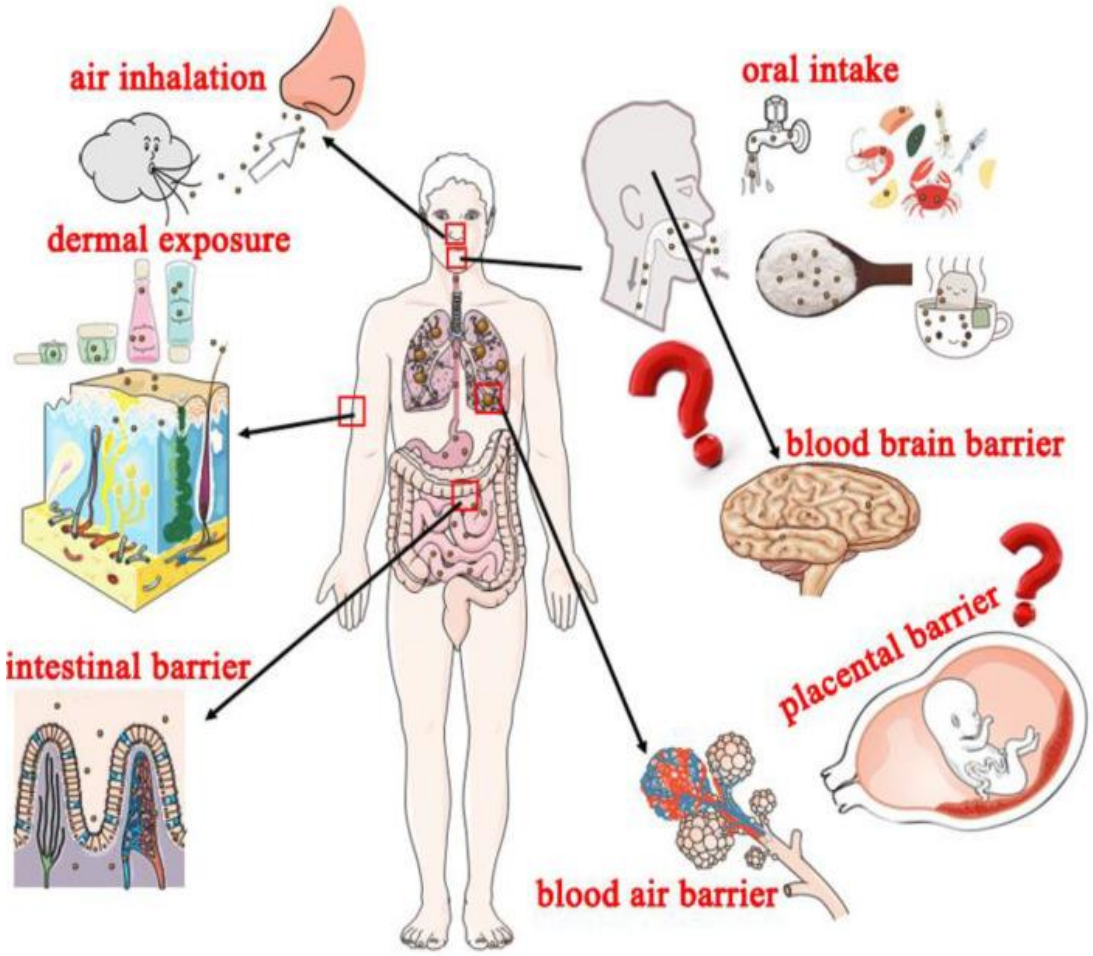
The mere presence is not a health impact; knowing that plastics are in our bodies leads to the more difficult question:

- Do plastics affect our health?
- Do plastics affect future generations?
- Are some plastics benign?
- Is there a “safe” level of plastics exposure?

Human Health Impacts

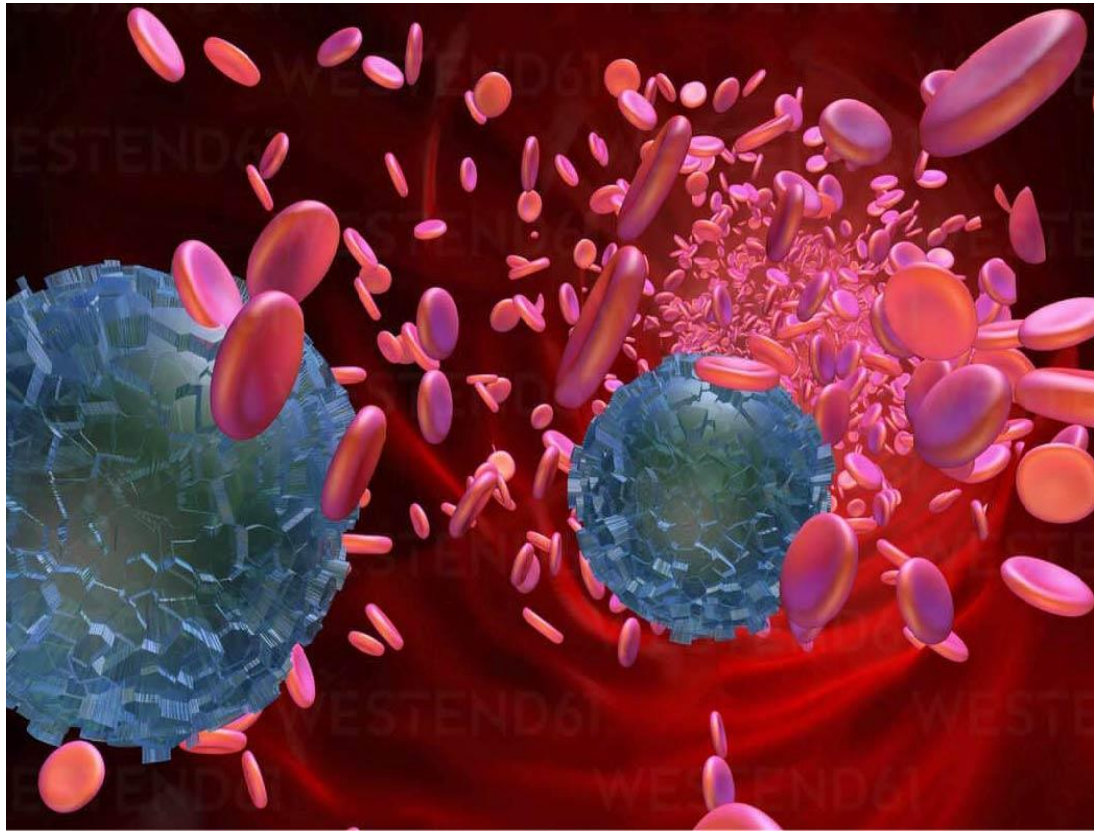
According to Harvard University (2023):

“Current technologies don’t yet enable researchers to quantify population-level micro-plastics exposures or gauge what proportion of those particles stay in our bodies. However, micro-plastics’ ubiquity in the environment, combined with preliminary findings from human cell and animal studies over the past decade, have led to urgent calls for more research and regulation.”



Plastics and Cancer

Scientists are still trying to untangle the chain connecting plastic exposure to cancer, but they've identified a few key links. When the immune system detects micro-plastics, it responds with inflammation, an all-purpose reaction to just about anything the body recognizes as foreign. And certain chemicals in plastics seem to block enzymes that your body produces to forestall the cell-damaging effects of oxidation. Oxidative stress and chronic inflammation have long been linked to cancer.



Plastics and Cancer

No definitive link has, to date, been established between plastic products and cancers.

But…

Plastics and Cancer

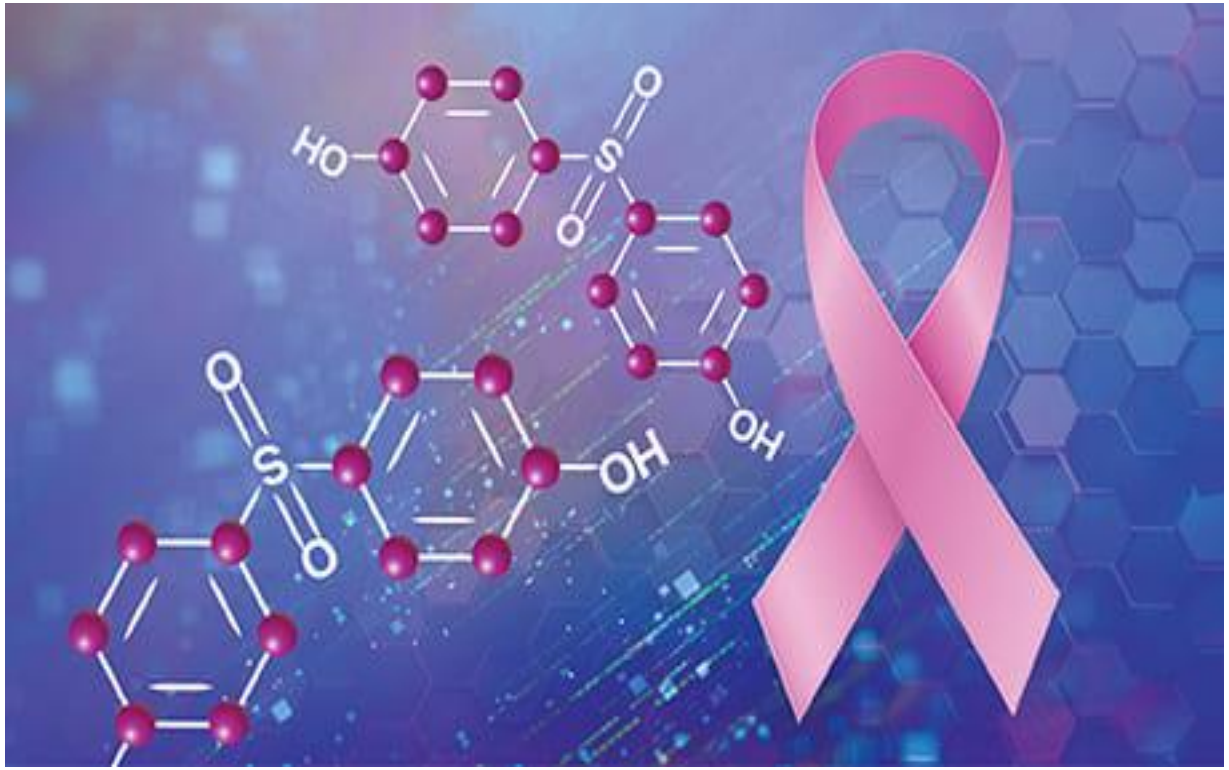
According to a 2024 Consumer Report article:

"In the areas near plastic production facilities, researchers have documented increased risk for leukemia and lymphoma, lung cancer, asthma, stroke, premature birth, and stillbirth."

….and….

Plastics and Cancer

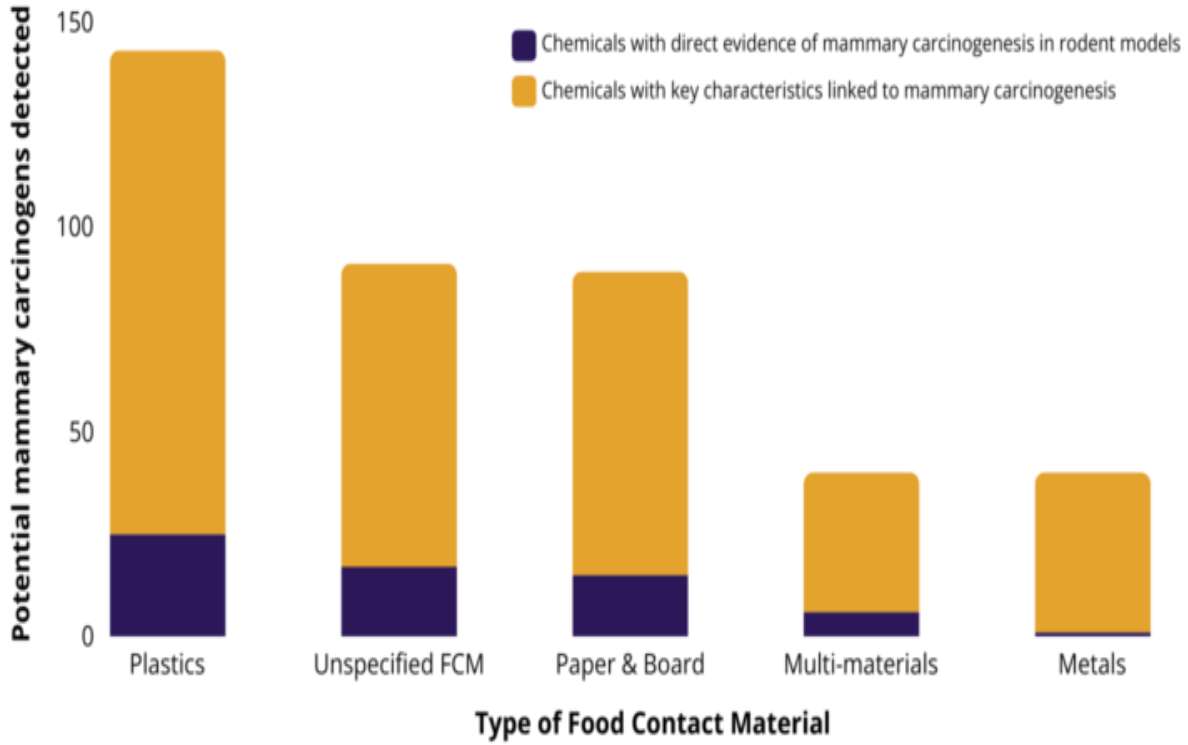
Micro-plastics have been shown to remain in the body longer than scientists previously thought. When plastics are introduced into lab-grown tumors, the presence of the micro-plastics serves to accelerate tumor growth.



Plastics and Cancer

What is clear is that compounds used to form plastics, including several phthalates as well as BPA, are known carcinogens.

Almost 200 chemicals (189) connected to breast cancer are used in the making of food packaging and plastic tableware, and the presence of 76 of those compounds was confirmed in the human body, according to a 2024 study from the Food Packaging Forum.



Plastics and Cancer

Of the compounds used to make plastics, possibly the most toxic is vinyl chloride (VC), long known for deleterious health effects including its association with many forms of cancer.

According to the NIH, vinyl chloride exposure is associated with an increased risk of a rare form of liver cancer (hepatic angiosarcoma), as well as primary liver
cancer, brain and lung cancers, lymphoma, and leukemia.

Plastics and Cancer

VC is a gas under ambient conditions and therefore its storage, transport (including through East Palestine, OH in February 2023) and use within the production of PVC is in liquid form. Since the 1930s, VC's toxicity has been well documented. Yet it has remained in widespread use for decades despite its dangers.

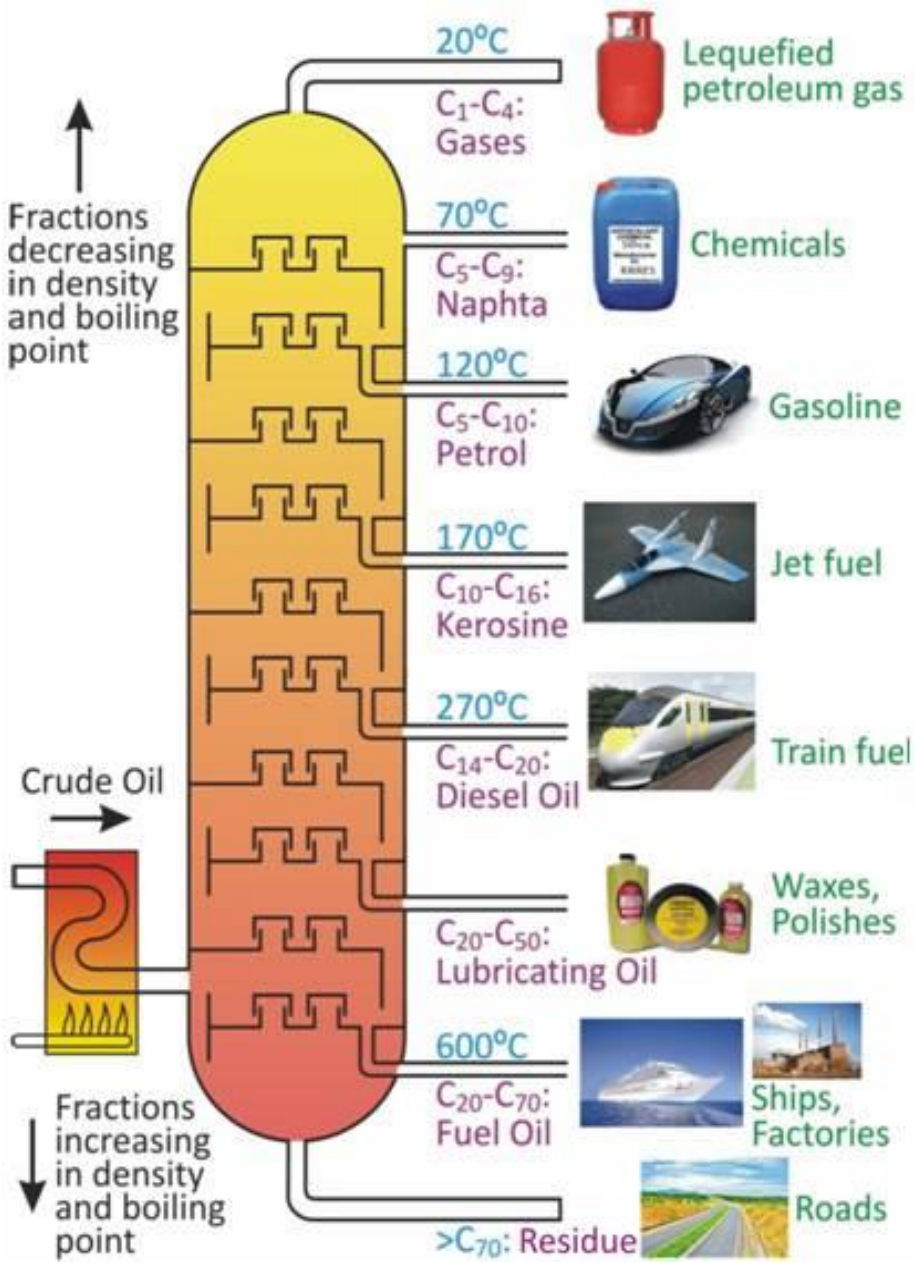
In December 2023, the U.S. EPA (finally) announced that it was considering whether to review the risks posed by VC under TSCA (VC is considered a Group 1 carcinogen by international organizations).

Plastics and Human Health

The Toxicity of Plasticizers.

Plastics are formed using one or more compounds that have been determined to be deleterious to human health.

Naphtha (a combination of ethane and propene) are used in making many plastic products. By most estimates, roughly 6% of the world's crude oil (once refined into naphtha) becomes an in-product to plastics.



Plastics and Human Health

The Toxicity of Plasticizers.

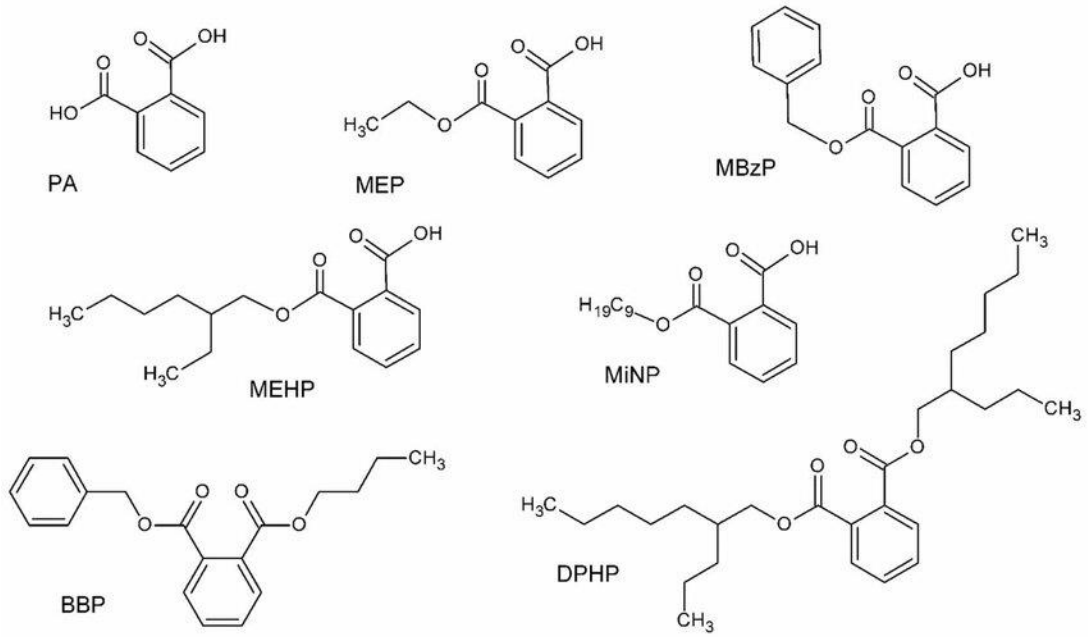
The simple implication of this statement is that the extraction, refinement, transportation, and storage of petroleum is connected to a raft of health concerns.

Plastics and Human Health

The Toxicity of Plasticizers.

Mixed with oils are an array of compounds known as plasticizers. The most common chemical family of plasticizers is the phthalate group.

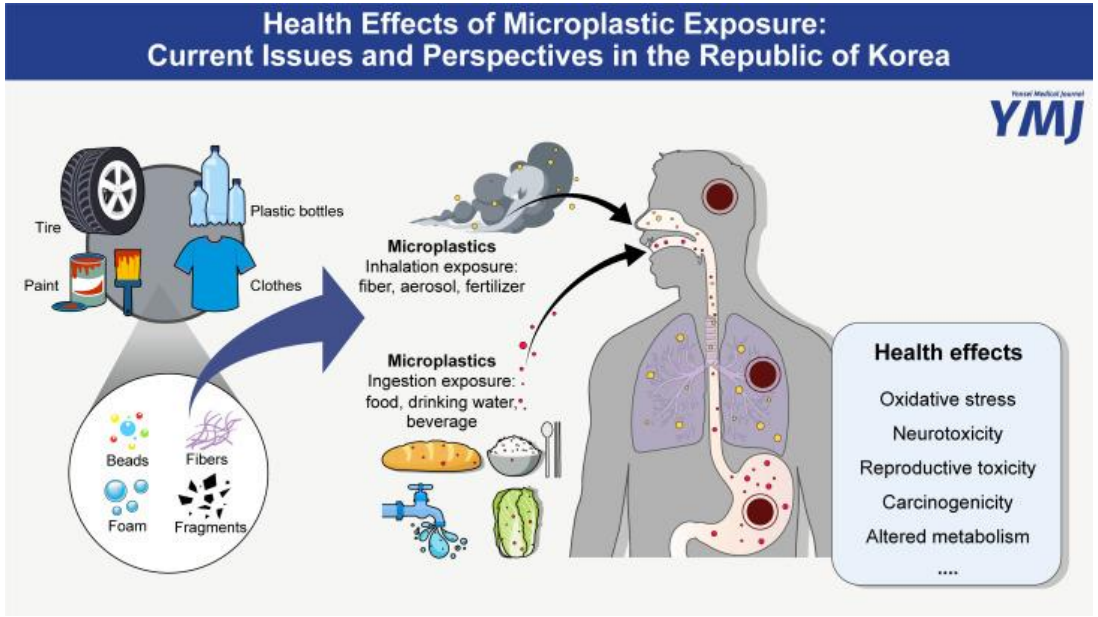
Phthalates are known to disrupt endocrine functions and have a known detrimental effect on fecundity, gene development, and pregnancy loss. Further phthalates are linked to a variety of adverse obstetrical outcomes.



Plastics and Human Health

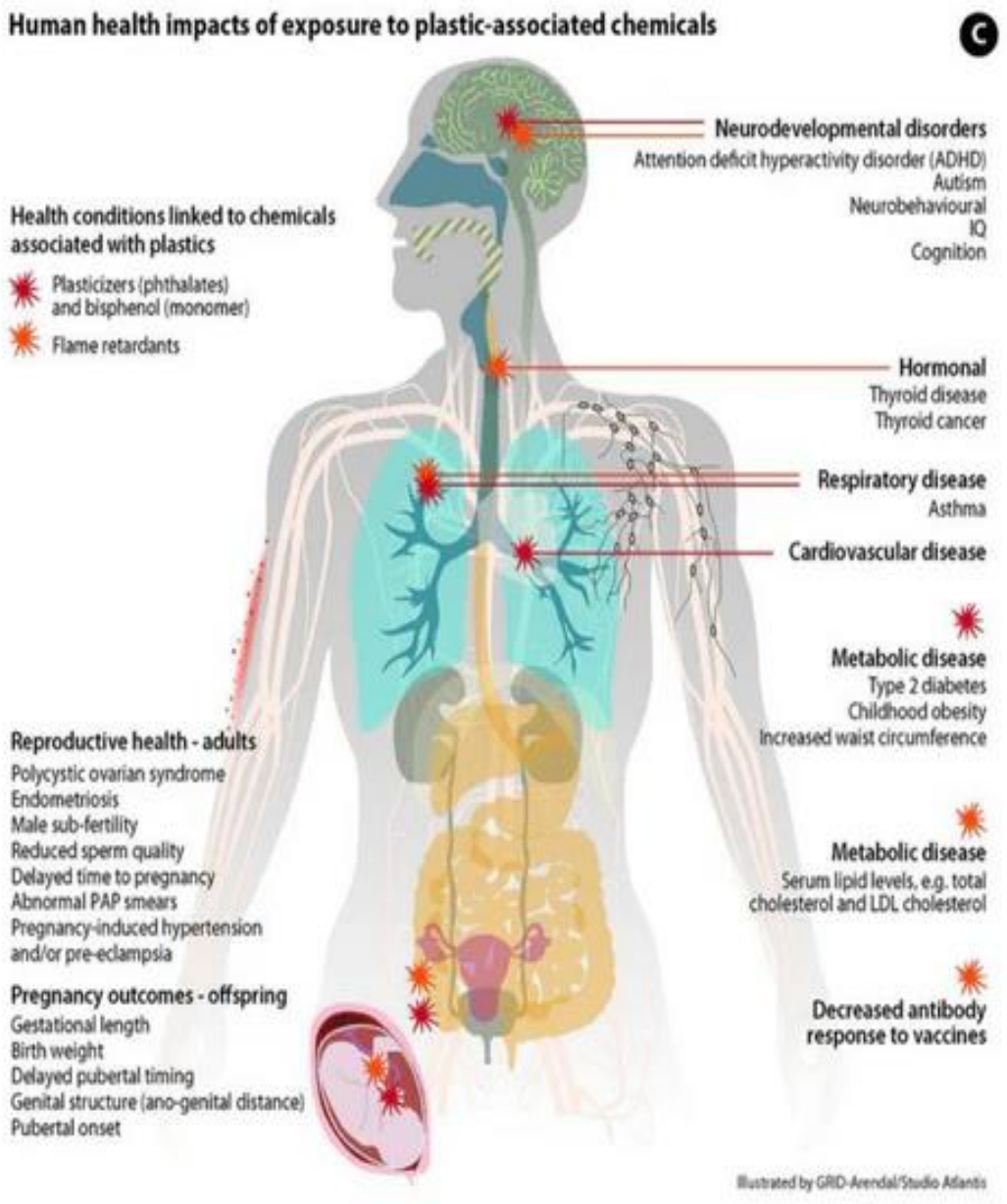
Plastics enter the human body through various routes depending on the plastic. Ingestion and inhalation remain the dominant routes of exposure.

It is currently estimated that humans in the developed world consume as much as 0.05 grams of plastic per week. A recent article in *Smithsonian* magazine estimated that Americans ingest about 50,000 particles of microplastics per year and inhale an additional 25,000 to 50,000 particles.



Plastics and Human Health

In recent years, micro-plastics and nano-plastics have been found in the brains, hearts and lungs of humans. They have been discovered in the arteries of people with arterial disease, suggesting they may be a potential risk factor for cardiovascular disease. And they have been detected in breast milk, the placenta and, most recently, penises.



Human Health Impacts

Plastics have been found in:

- Lung tissue
- Placental tissue
- Breast milk
- Brain tissue
- Testicular tissue

Plastics and Human Health

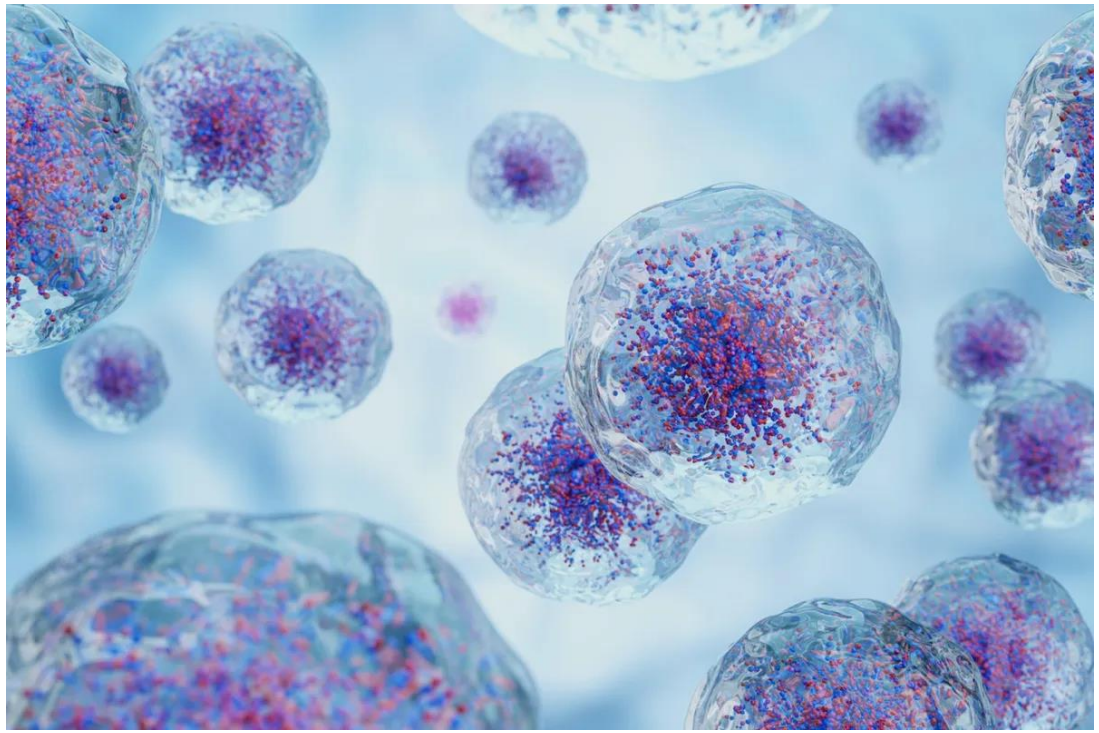
Human brain samples collected in early 2024 contained more tiny shards of plastic than samples collected eight years prior. By weight, 0.5% (roughly 6-8 grams) of the human brain is now plastic, according to data from autopsies performed by the U. of Mexico.

Plastics and Human Health

Researchers from the Univ. of New Mexico looked at testes tissues from 4 dogs and 23 men.

Researchers identified 12 different micro-plastic types in the dog and human testes samples. They found that the amount of micro-plastics in men was about three times higher than in dog reproductive tissue. Among humans and dogs, the most common type of polymer was polyethylene (PE), and the second most common was polyvinyl chloride (PVC).

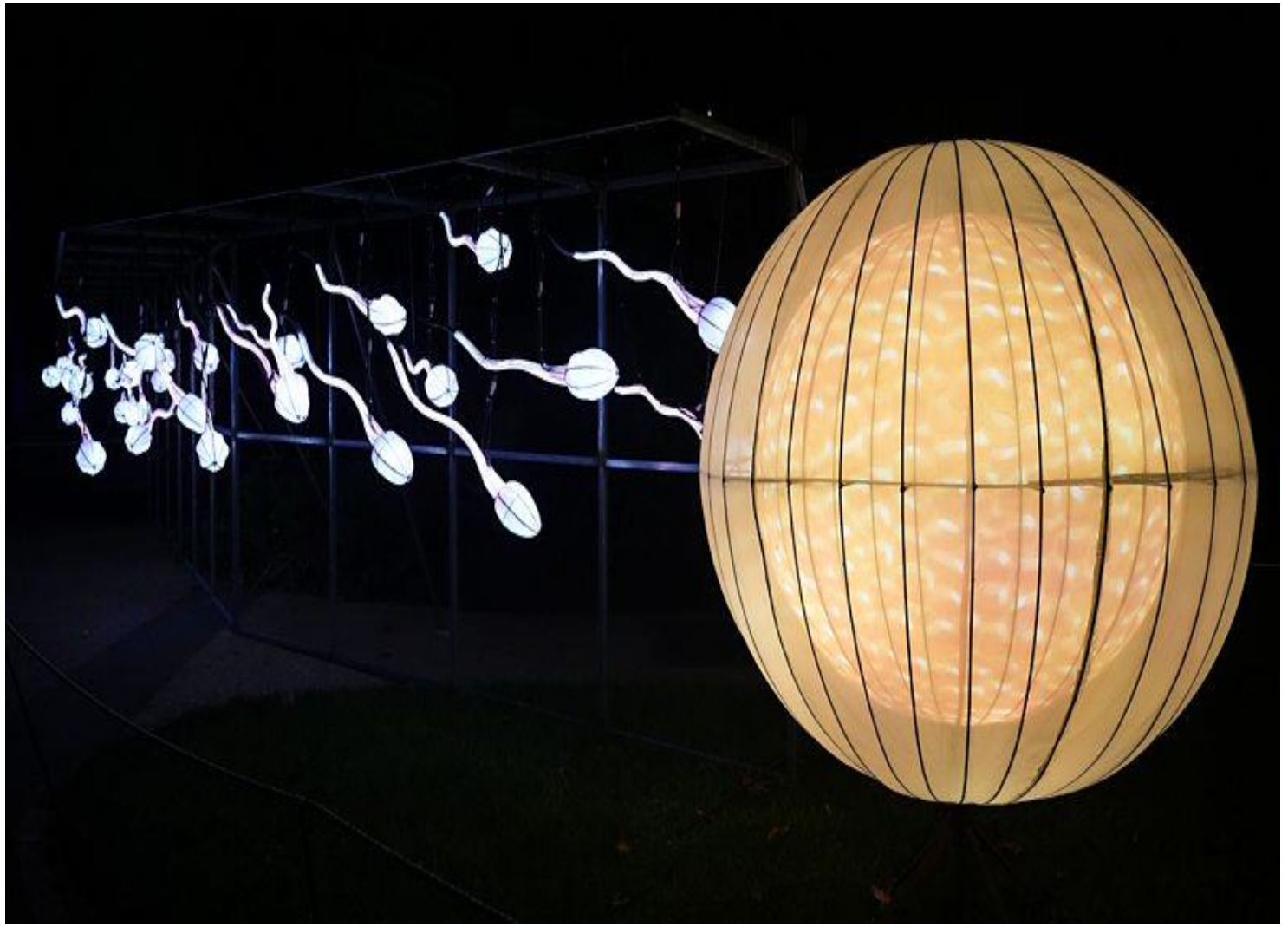
In a separate study out of the U. of Miami, micro-plastics were discovered in tissue in penises of men undergoing erectile dysfunction procedures. 80% of patients were found to have PET and PP micro-plastics embedded in soft tissue “in measurable concentrations”.



Plastics and Human Health

The impact of plastics on fertility is being studied. Recent data from England suggest that sperm counts are steadily declining, sperm motility is decreasing, and testosterone levels are dropping. A 2022 study documented sperm counts fell on average by 1.2% per year between 1973 to 2018, from 104 to 49 million/ml.

But is there causality here?



Plastics and Animal Health

Plastics affect animals in all ecosystems, although the predominant focus has been on sea creatures.

According to the United Nations, at least 800 species worldwide are affected by marine debris, and as much as 80 percent of that litter is plastic. It is estimated that up to 13 million metric tons of plastic ends up in the ocean each year—the equivalent of a rubbish or garbage truck load's worth every minute.

Plastics and Animal Health

Plastic waste kills up to a million seabirds a year. As with sea turtles, when seabirds ingest plastic, it takes up room in their stomachs, sometimes causing starvation. Many seabirds are found dead with their stomachs full of this waste. Scientists estimate that 60 percent of all seabird species have eaten pieces of plastic, a figure they predict will rise to 99 percent by 2050.

Plastics and Animal Health

The plastic degrades as it is exposed to sunlight (photodegradation), making the plastic available for uptake by marine life. Albatrosses are particularly susceptible to plastics because they skim the ocean surface for food, ingesting plastics directly or feeding the plastic to their young. Bird carcasses were the focus of a recent (2021) photo exhibition at the Smithsonian.

Plastics and Animal Health

According to a 2021 study out of New Zealand, almost 75% of all albatross species are threatened or endangered with plastic waste being the principal stressor of these populations. In areas of known garbage patches and albatross populations (e.g., off the coast of Brazil), it is estimated that almost 20% of all deaths are the result of plastics ingestion.

Plastics and Animal Health

Hermit crabs use the discarded shells of other animals to protect themselves. But when they go on their hunt for a new home or for food on polluted beaches, they can become trapped in trash—like bottles or cans—and die. This sets off a deadly chain reaction, because when they die, they emit a scent that tells other hermit crabs in the area that their shell is available to use. These crabs will follow that scent just to become entrapped and perish with the first hermit crab.

Plastics and Animal Health

A research **expedition to two remote islands** found half a million hermit crabs had been killed by being trapped in trash.

Around 61,000 (2.447 crabs/m^2) and 508,000 crabs (1.117 crabs/m^2) are estimated to become entrapped in debris and die each year on Henderson Island and the Cocos (Keeling) Islands, respectively.

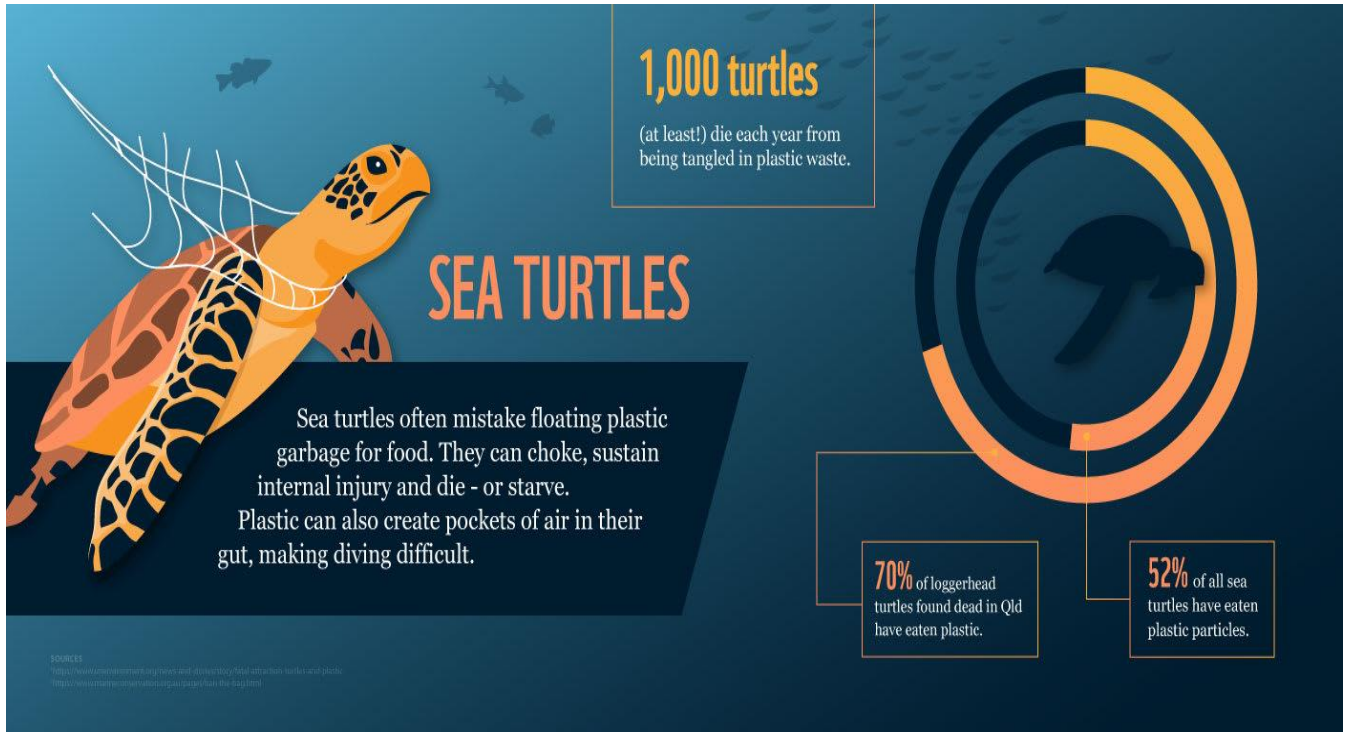
Plastics and Animal Health

Sea turtle diets are highly varied; some sea turtles are carnivorous (e.g. loggerheads) while others are herbivorous (e.g. green sea turtles).

Turtles provide a “service” of consuming species toxic to other life forms including humans. Turtles will consume jellyfish, sea cucumbers and other organisms that contain compounds toxic to humans.

Plastics and Animal Health

Plastic bags look very similar to jellyfish, fishing nets often look like tasty seaweed. Sea turtles think they're consuming some of their staple foods when really they're welcoming harmful substances into their digestive tract.



Plastics and Animal Health

Ingesting plastics isn’t a harmless mistake, the consumption of this man-made material can cost sea turtles their lives. That’s because plastic can cause blockages in their intestines and even pierce the intestinal wall causing internal bleeding.

Perhaps the most distressing fate of all is when the plastic in the turtle’s stomach imitates the sensation of being full. Turtles then neglect to seek out other food sources and ultimately die from starvation.

Plastics and Animal Health

According to research coming out of Australia, the ingestion of even a single piece of plastic increases turtle mortality rates.

Impacts of Plastics on Ecosystems

The impact of plastic on ecosystems includes:

- **Alteration of habitats and natural processes**, reducing ecosystems' ability to adapt to climate change.
- **Harm to wildlife**, particularly marine life, due to plastic pollution in the ocean.
- **Contributions to climate change** and economic effects.

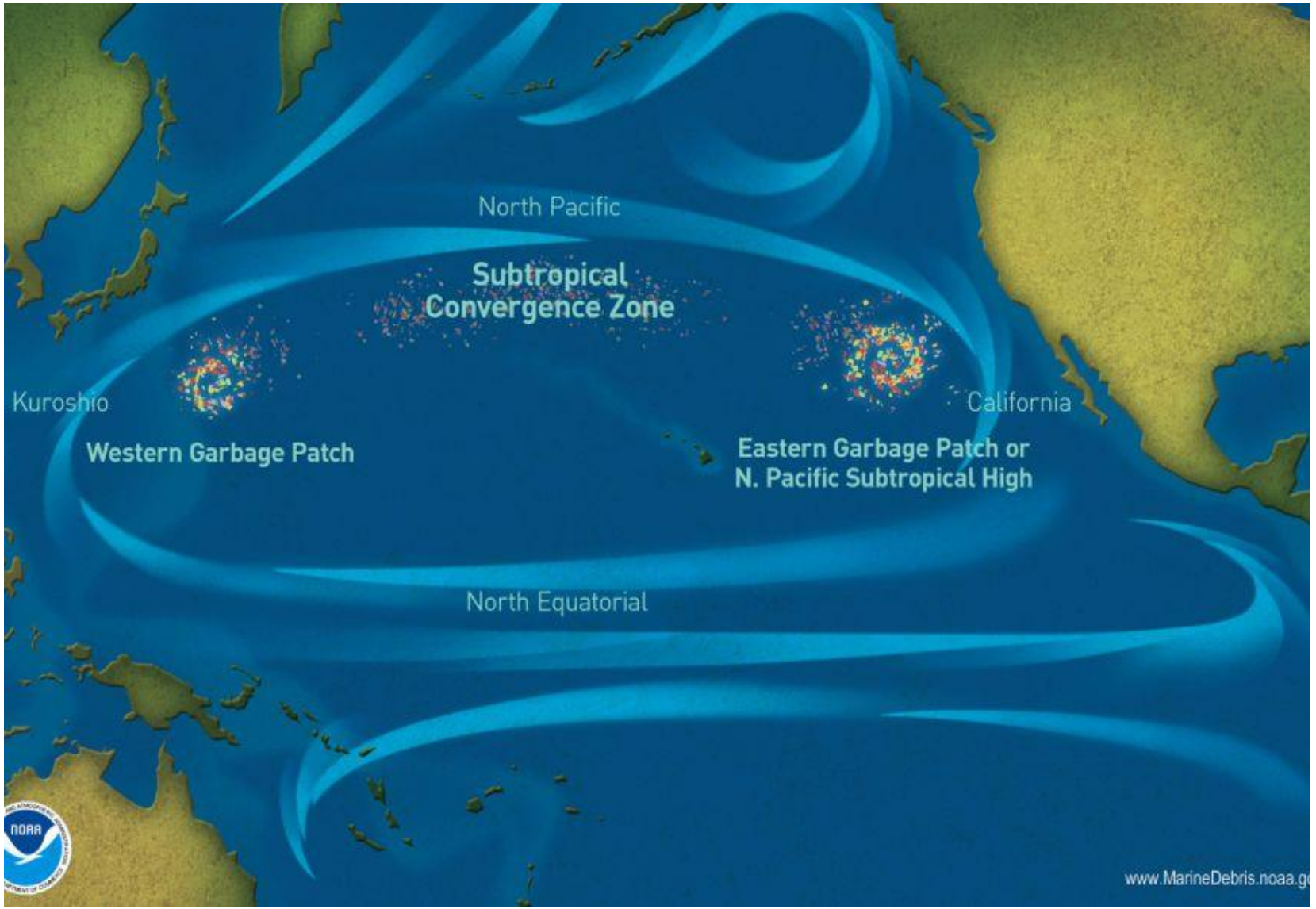
Plastics in Aquatic Ecosystems

Much of the illegally dumped waste and the litter ends up in streams to rivers to the ocean.

According to Conservation.org:

- 12 million tonnes of plastic enter the oceans every year. This volume is expected to increase to 29 MMTs by 2040.
- An estimated **5.25 trillion pieces of plastic** are currently in the oceans.
- The slow agglomeration of plastic waste has resulted in the formation of 5 “garbage patches”.

Plastics in Aquatic Ecosystems



The largest of these “Patches” is located in the northern Pacific Ocean. A 2015 study estimates the size of this Patch to be 617,763 square miles (1.6 million square km), over two times the size of Texas.

The study suggests that some 1.8 trillion pieces of plastic are present in this “Patch” weighing nearly 90,000 tons. 80% of plastic waste in the Patch originated from land.

The “Patch”, also known as the Pacific Trash Vortex, is formed (and maintained) by the clockwise circulation of currents in the northern Pacific Ocean.

Plastics in Aquatic Ecosystems

According to *National Geographic*:

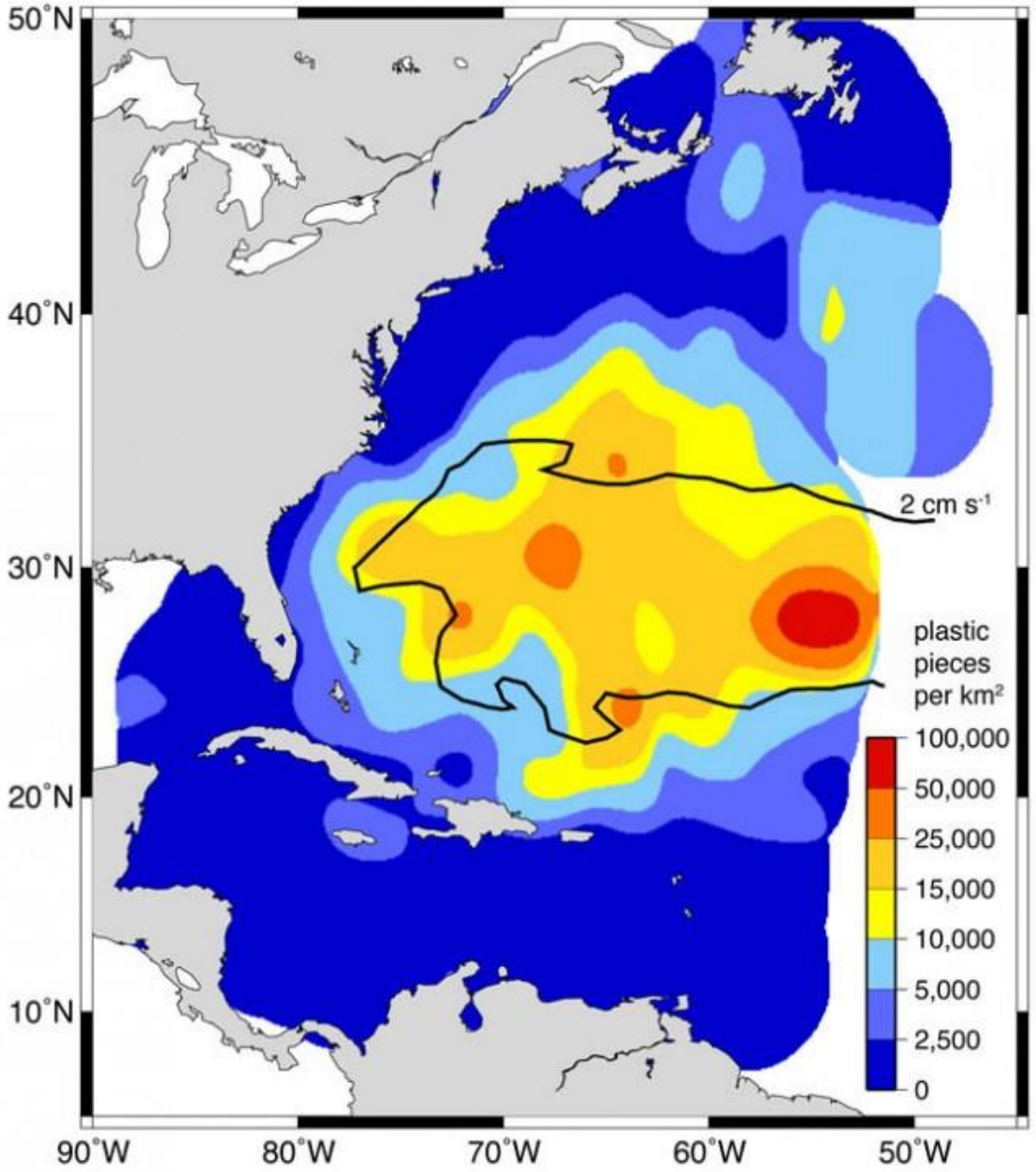
"[T]hese patches are almost entirely made up of micro-plastics. Micro-plastics can't always be seen by the naked eye. Even satellite imagery doesn't show a giant patch of garbage. The micro-plastics of the Great Pacific Garbage Patch can simply make the water look like a cloudy soup. This soup is intermixed with larger items, such as fishing gear and shoes."

Source: National Geographic (3/2023)

Plastics in Aquatic Ecosystems

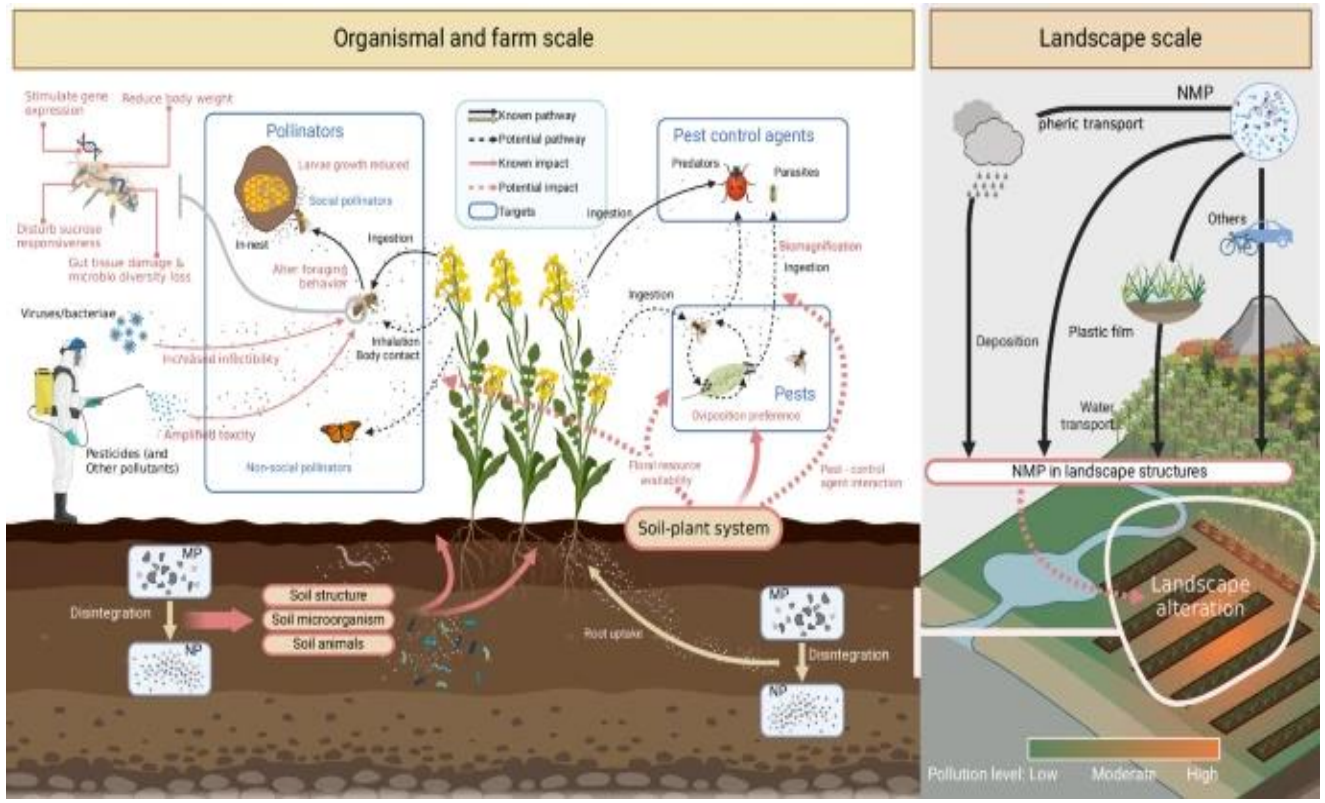
A similar area of floating waste exists in the Atlantic Ocean:

- The patch is estimated to be hundreds of kilometers across in size, with a density of over 200,000 pieces of debris per square kilometer.
- Despite its enormous size and density, the patch is, more often than not, invisible to the naked eye and even satellite imaging. The photodegradable plastic that makes up the vast majority of the mass shrinks to smaller than .01 of an inch and is pushed under the surface of the water by deep waves.
- Principal impacts include the consumption of micro-plastics by aquatic organisms and the loss of phytoplankton production.



Plastics in Terrestrial Ecosystems

Unlike in other well-studied ecosystems, for example, marine and freshwater environments, micro-plastics in terrestrial systems are relatively understudied. The impact to food supplies and biodiversity could be enormous.

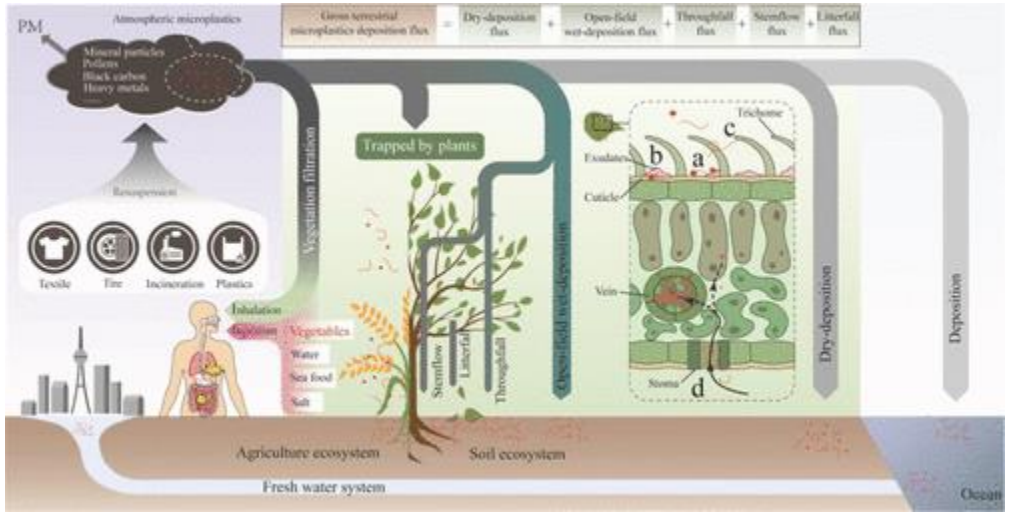


Plastics in Terrestrial Ecosystems

Terrestrial micro-plastic pollution is much higher than marine micro-plastic pollution – estimated at four to 23 times higher, depending on the environment, according to a recent (2018) UN report. An estimated 33% of all discarded plastic ends up in terrestrial ecosystems, not including plastic products that are in use and slowly degrading (e.g., artificial turfs or plastic decking).

Plastics in Terrestrial Ecosystems

Terrestrial plants, viewed as the lung of earth, play an important role in filtering atmospheric pollutants. Plant leaves, due to large and uneven surfaces, demonstrate high rates of capture of atmospheric particulate matter (PM) and act as an important sink for various atmospheric pollutants in urban areas including micro-plastics.



Plastics in Terrestrial Ecosystems

As plastics degrade in a terrestrial ecosystem, breakdown chemicals are especially problematic. Additives such as phthalates and Bisphenol A (widely known as BPA) leach out of plastic particles. These additives are known for their hormonal effects and can disrupt the hormone system of vertebrates and invertebrates alike.

Plastics in Terrestrial Ecosystems

In addition, nano-sized particles may cause inflammation, traverse cellular barriers, and even cross highly selective membranes such as the blood-brain barrier or the placenta in all animals, particularly other mammals. Within the cell, they can trigger changes in gene expression and biochemical reactions, among other things.

Photo is of elephants foraging in garbage dumps in Sri Lanka.

Closing Thoughts

What we know to date is that plastics in bulk form and as deteriorated sub-particles known as micro- and nano-plastics, **are decimating aquatic ecosystems.**

There is evidence to suggest that plastics have **impacted our food supplies and plant systems.** In doing so the very biodiversity that we rely upon for our existence is being threatened.

And plastics are directly **affecting our human health**.

Can we balance our desire to reap the benefits of plastics with responsible management of this product to eliminate the damage that this product is inflicting on the planet?