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HUMAN HEALTH
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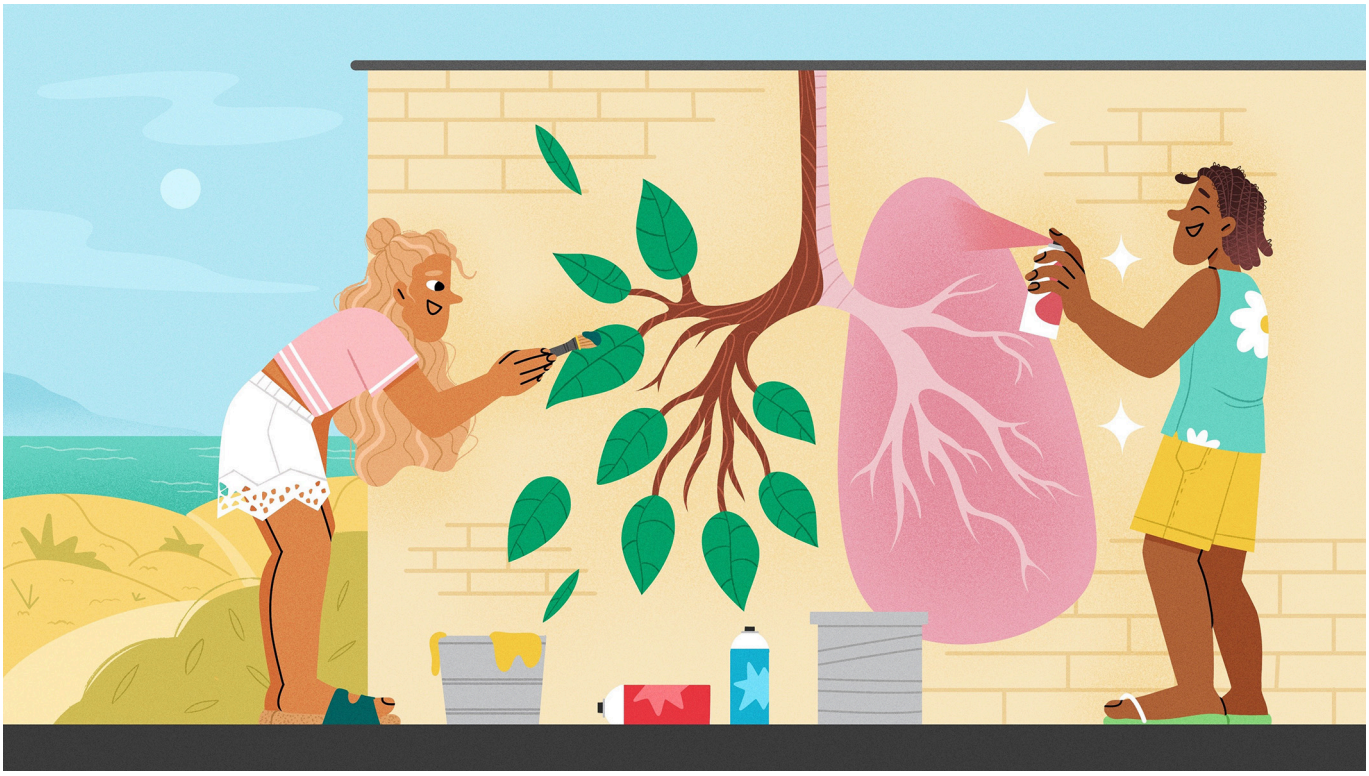

HEALTH EFFECTS OF CLIMATE CHANGE

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AGE: 14

Climate change affects Earth's ecosystems and human societies. Climate change results in hotter temperatures and more heatwaves, droughts and water shortages, floods and water-borne infections, sea level rise and population displacement, reduced agricultural and seafood harvests, spreading of organisms that carry disease, and increased numbers of wildfires creating additional air pollution. More people will probably be affected by hunger, lack of clean water, heatstroke, heat-related kidney disease, asthma, and infections like dengue, zika, cholera, salmonella, and listeria. Because each year is hotter than the ones before, younger people will experience changes in weather and climate throughout their lives. Paying attention to and learning about climate science can help you prepare for a different world. Because human activities cause global heating, humans can halt it. People can restore Earth's forests, oceans, plants, and animals while making their own lives better by substituting clean energy for fossil fuels.

GLOBAL HEATING AND HEALTH

A person born in 2020 is likely to experience two–seven times more heatwaves in their life than a person born in 1960 [1]. On average, a person born in 2020 will experience more wildfires, crop failures, **droughts**, river floods, heat waves, and tropical cyclones than the average person born in 1960. People born in 1960 experienced a stable climate for much of their lives, but those born in 2020 may never encounter a stable climate. Younger people will live through more years of global heating (global warming) and higher temperatures. These regrettable developments illustrate the importance of climate change on human health (for more details about the impact of global heating on young people, see this Frontiers for Young Minds article).

DROUGHT

A time of unusually dry conditions that may last for months or years. Drought may be caused by a decline in rainfall or snowfall or by heatwaves that increase water evaporation from soil. If rainfall or snowfall remain the same, but temperatures rise, a drought may follow.

The amount of energy at Earth's surface determines its climate. When the energy is increased, the climate becomes hotter, and storms become more powerful. Because **greenhouse gases** in the atmosphere absorb heat, like a blanket or insulation, they slow movement of heat to outer space and instead trap it in the atmosphere. This greenhouse effect has regulated Earth's climate for billions of years. However, human activities alter Earth's climate by adding enormous amounts of additional greenhouse gases (carbon dioxide, methane, and nitrous oxide) to the atmosphere, boosting Earth's insulation. Mainly because of emissions from burning fossil fuels, the global average temperature rose by 1.2°C since 1900 (Figure 1) and is rising by roughly 0.2°C per decade [2]. The concentration of carbon dioxide in the atmosphere is the highest in more than 2 million years.

GREENHOUSE GASES

Gases that absorb and emit heat, trapping it in the atmosphere and warming the planet. Common greenhouse gases are water vapor, carbon dioxide, methane, and nitrous oxide.

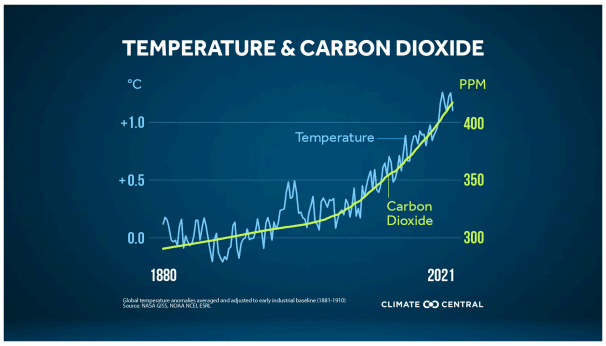

Figure 1

Change in Earth's average atmospheric temperature and carbon dioxide concentrations from 1880 to 2021. Atmospheric carbon dioxide has increased from about 220 parts per million (PPM) to 420 PPM. In recent years, people have added about 30–35 billion metric tons of carbon dioxide to the atmosphere each year, raising the atmospheric carbon dioxide concentration by about 2 PPM per year (Figure credit: Climate Central website; used with permission).

Higher greenhouse gas concentrations caused by burning fossil fuels cause more energy to remain in the atmosphere rather than leave for outer space. This extra energy can heat up the atmosphere and the oceans. Excess energy can also manifest as wind. For example, warmer ocean water causes hurricanes to have higher wind speeds. A hurricane takes heat from the ocean and changes it into kinetic (movement) energy, as wind. As a result, hurricanes now tend to

have higher wind speeds than they did when ocean waters were cooler [3].

Exposure to high temperatures (35°C or more) for several hours without relief may cause a dangerous health issue called hyperthermia. Symptoms and signs of hyperthermia may include body temperature of 40°C, fainting, confusion, rapid pulse, dizziness, hot skin, nausea, or vomiting. Without treatment, hyperthermia may damage the brain and nerves, which is called heat stroke. In summer 2023, 645 persons died from heat stroke in Maricopa County (Phoenix, Arizona) which was about 8–10 times more heat stroke deaths than 10 years earlier (Figure 2). Exposure to extreme heat is also associated with kidney injury and babies being born too early [3]. By 2050, higher temperatures could make some areas of Earth too hot for humans to live in.

EFFECTS ON FOOD

Global harvests of wheat, rice, and corn may decline as temperatures and weather disasters increase [2]. For example, the global land area affected by drought increased from about 20% in 1951–1960 to 50% in 2013–2022, limiting the amount of water available for drinking, farming, and washing [2]. Extreme heat reduces crop growth and pollination of crops. Droughts and wildfires happen in some areas when temperatures become hotter but rain does not increase. In other areas, there can be more downpours and flooding because the atmosphere holds more water vapor at higher temperatures. As the weather becomes more extreme, global food systems can become more and more unstable. High temperatures in 2021 shortened crop growth seasons globally by 9 days for corn, 2 days for rice, and 6 days for winter and spring wheat compared with 1980–2010 [2]. World hunger seems likely to increase from global heating.

Seafood harvests may also decline. Carbon dioxide from the atmosphere dissolves into and reacts with water to form carbonic acid, causing water to become more acidic [2, 3]. **Acidification** makes shell formation more difficult for some marine organisms like corals and some plankton. Greenhouse gas emissions are also boosting ocean and lake water temperatures. Average ocean temperature has increased by about 0.7°C from 1981–2020. As water warms, it holds less oxygen, which makes it more difficult for sea organisms to breathe. Fewer organisms may be able to live in oceans and lakes due to warming, acidification, and **deoxygenation**. Tiny, plant-like ocean organisms called phytoplankton produce about half the oxygen in Earth's atmosphere; we depend on the sea for our breath as much as we depend on forests. Many people also depend on the sea for food.

ACIDIFICATION

Adding hydrogen ions (H^+) to a solution and, as a result, reducing its pH. When water reacts with carbon dioxide to form carbonic acid, the water becomes more acidic: $H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$.

DEOXYGENATION

Reducing the concentration of oxygen (O_2). For example, as water becomes warmer, O_2 becomes less soluble and its concentration in water declines as O_2 moves from water to air.

Figure 2

Deaths from heat stroke in Maricopa County (Phoenix), Arizona from 2013 to 2023. The graph shows a large rise in heat stroke deaths. People who died from heat stroke in Maricopa County were often homeless and had drugs and/or alcohol in their blood at autopsy. In 2023, amphetamine-like and fentanyl-like drugs were most commonly associated with heat deaths. Babies, the elderly, and the intoxicated are more likely to suffer heat stroke. However, increasing temperatures put everyone at higher risk—as world temperatures rise, heat deaths are likely to increase (Figure credit: Maricopa County Public Health Department, used with permission).

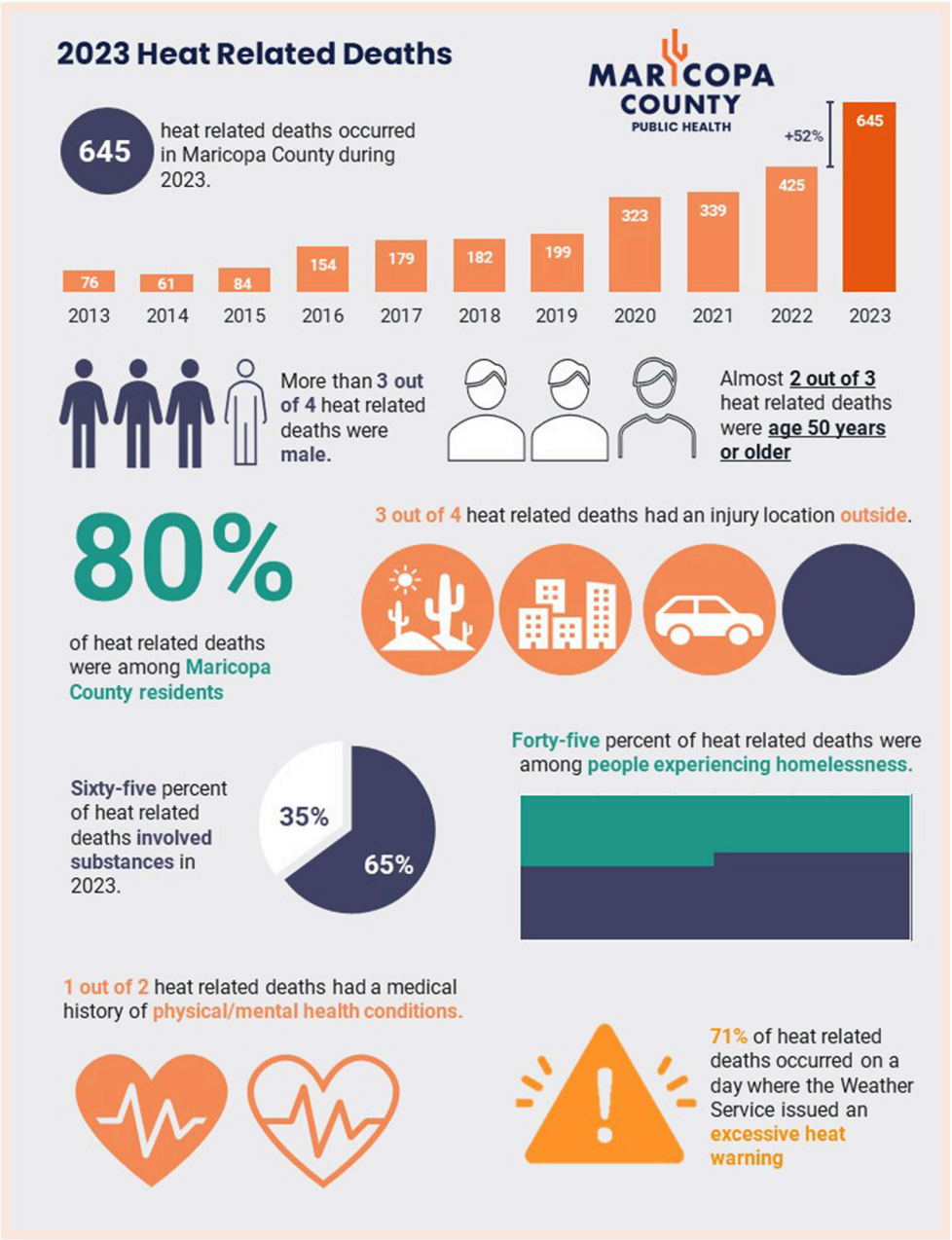

Figure 2

EFFECTS ON SEA LEVEL

As water warms, the average distance between water molecules becomes greater, boosting ocean volume. Melting of glaciers on land returns water to the sea, which is another cause of sea-level rise. At the present time, sea level rises at the rate of 3–4 mm per year, and this rate is increasing. As sea levels rise, coastal cities are threatened by flooding and contamination of their fresh water supply by salt water. One study reports that tens of millions to hundreds of millions of people may have to relocate due to sea-level rise and extreme heat [3].

A sea-level rise of 0.9 m might displace 100 million people worldwide from coastal lands.

EFFECTS ON INFECTIOUS DISEASES

Some human infectious diseases are carried by animal **vectors** such as mosquitoes or ticks [2]. As world temperatures warm, these organisms migrate toward Earth's poles. Food and water are also more likely to harbor dangerous bacteria when temperatures rise. The new climate is putting more people at risk of vector-borne and **water-borne infectious diseases**. Certain ticks transmit Lyme disease (an infection caused by bacteria), and certain mosquitoes transmit a virus that causes West Nile encephalitis. Both Lyme disease and West Nile encephalitis have migrated from the United States to Canada since 2000 as temperatures have warmed. Table 1 lists some human infections expected to increase as temperatures rise.

VECTOR

An organism that transmits a disease-causing agent from one organism to another. For example, a mosquito carries malaria from one person to another by biting or a tick carries Lyme Disease from a mouse to a human by biting.

Table 1

Examples of human infections expected to increase with global heating.

WATER-BORNE INFECTIOUS DISEASE

An infection from drinking or swimming in water contaminated by a disease-causing microorganism, or from eating contaminated food. Examples include cholera and wound infection (genus *Vibrio*), bloody diarrhea (genus *Salmonella* and *Escherichia*), and inflammation in and near the brain (called meningitis) (genus *Listeria*).

Infection name	Disease cause	Relationship to climate
Malaria (a blood infection)	Plasmodium is a protozoan that infects red blood cells	Tropical Anopheles mosquitoes transmit malaria and are now moving to higher altitudes in Africa
Dengue, zika, chikungunya (tropical fevers)	Related viruses causing tropical fevers. Zika virus also causes severe birth defects	Tropical Aedes mosquitoes transmit these viruses. Aedes mosquitoes are migrating toward the poles
Lyme disease (an infection passed to people from tick bites)	Borrelia is a bacterium that infects skin and lymph nodes and causes Lyme disease	Longer summers increase the risk of tick bites. Milder winters increase tick winter survival
Listeria, salmonella (food poisoning)	Listeria and salmonella bacteria cause intestinal and blood infections. Listeria may also cause brain infection	Warmer temperatures increase bacterial growth in food and water
Vibrio (infection of skin and connective tissues)	Vibrio is a bacterium causing wound and skin infections and called "flesh-eating bacteria" in news reports	Warmer coastal ocean waters expand the range of vibrio, leading to more infections
West Nile encephalitis	A flavivirus that causes brain inflammation, carried by Culex mosquitoes	Culex mosquitoes migrate toward the poles as temperatures warm
Coccidioidomycosis (valley fever)	Inhaled fungus that may cause pneumonia and brain infection	Heat and dryness promote transport of spores by wind

Table 1

EFFECTS ON AIR POLLUTION

Buring fossil fuels is the main cause of both global heating and air pollution. Each year, about four million people worldwide die prematurely from outdoor air pollution. When we inhale microscopic

soot particles, some particles move through the lungs to enter the blood. Once in the blood, they can be carried almost anywhere in the body. These particles accumulate not only in human lungs, but also in the brain, heart, and placenta [3]. This may partially explain how fossil fuel pollution causes lung cancer, increased susceptibility to lung infections, heart attack, stroke, early birth, dementia, and asthma.

Higher global average temperatures cause wildfires by lengthening the summer fire season and causing droughts. Smoke spreads for thousands of miles, adding to air pollution from fossil fuel burning. Reducing air pollution and wildfires would save millions of lives each year by cleaning our air and reducing heart, lung, and brain diseases.

WHEN WE SEE CLEARLY, WE CAN RESPOND EFFECTIVELY

By learning about climate change as a young person, you can prepare yourself for a career returning our planet to its former health, whether as a farmer, electrician, scientist, political leader, artist, or construction or health worker. Almost any career path can address some aspect of climate change. Because climate change is our biggest problem, knowledge of climate change creates career opportunities.

You may wish to consider trying some local and personal lifestyle ideas for reducing your energy use and **carbon footprint**. For example, talk with others about climate change, reduce flying or ocean cruising, choose carbon-free energy sources, learn to grow your own food, recycle, compost, avoid throwaway items, and vote for candidates who will reduce fossil fuel use. Some may not be possible for you, but others may work well. Taking action may reduce your personal fears or your anger. By cooperating with others, you can influence events. Emissions produced by most individuals are small in comparison to government, military, and corporate emissions. Examples of national and international goals include phasing out fossil fuel emissions by 2050 through the use of emission-free energy; reducing food waste; lowering emissions from transportation, manufacturing, and electricity; and increased climate change research and monitoring climate changes.

CARBON FOOTPRINT

A carbon footprint (or greenhouse gas footprint) is a calculated value that makes it possible to compare the total amount of greenhouse gases that an activity, product, company or country adds to the atmosphere (Wikipedia definition).

Imagine a world with clean, quiet transportation and breezes of fresh air without smoke from wildfires or pollution from fossil fuels. Imagine that there are fewer conflicts between countries because there is no need for oil, and imagine that atmospheric and oceanic temperatures have stabilized. There is a new Mother Nature that sustains people, plants, and animals. What benefits society and Earth also helps the life of each individual, because everyone is a part of the natural world.

Medical scientists expect climate change to be the greatest health problem of this century. Some climate scientists have estimated (guessed) that average earth temperature will reach 1.5°C by 2030 and 2°C by 2045. This situation will create career opportunities in science, social sciences, business, and the arts for persons with understanding of climate problems and solutions. I think social scientists and artists may have a singularly important role of communicating about global heating to all people. Helping to address climate change not only benefits yourself, but benefits everyone.

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ADDITIONAL RESOURCES

If you would like to learn more about climate related careers, check out The Gigaton newsletter or the Speed and Scale newsletter. You can also have a look at Climate Central for climate and weather data, the Lancet Climate Commission for climate-health data, or the World Health Organization for information about air pollution.

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CONFLICT OF INTEREST: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

JESSIE; AGE: 14

I enjoy science, sports, reading, baking, gaming, and spending time with my two dogs. I watched the Olympics (only the sports I understood) over the summer and had a great time. I also love watching nature documentaries, but never have the time to. I hope to become better at writing, which is why I am excited to have the opportunity to work on this project. I hope my input helps the success of this paper :)

AUTHORS

BRUCE R. KRAWISZ

Bruce is an anatomic and molecular pathologist who grew up in the 1960's when many people became concerned about air and water pollution. In a physical chemistry class in 1973 he first heard about global warming which was predicted by mathematical models, but was then too small to detect with measurements. He retired from medical practice in 2016 and now studies the health effects of climate change. He gives seminars about health and climate at schools, churches, clubs, and medical meetings to explain why climate change is the greatest public health problem of this century. *krawisz.bruce@marshfieldresearch.org