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OCTOBER 2022

DON'T SWEAT IT

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COVER IMAGE: SHUTTERSTOCK

CHEMISTRY IN PICTURES by c&en

Pichayut Tananchayakul

SPOOKY POTION. This swirling green liquid may call to mind a witch's brew from a children's movie. In fact, it's being used to inspire children to take an interest in chemistry. Pichayut Tananchayakul, a Ph.D. candidate in organic chemistry at Mahidol University, a research institution in Thailand, and his adviser, Tienthong Thongpanchang, performed this demonstration for secondary school teachers, who will use it in their classrooms. The group dissolved turmeric powder in ethanol and filtered it to produce a yellow solution. They then dropped the solution into a glass of ethanol under black light to achieve the effect you see here. — *Pichayut Tananchayakul/Chemical & Engineering News*

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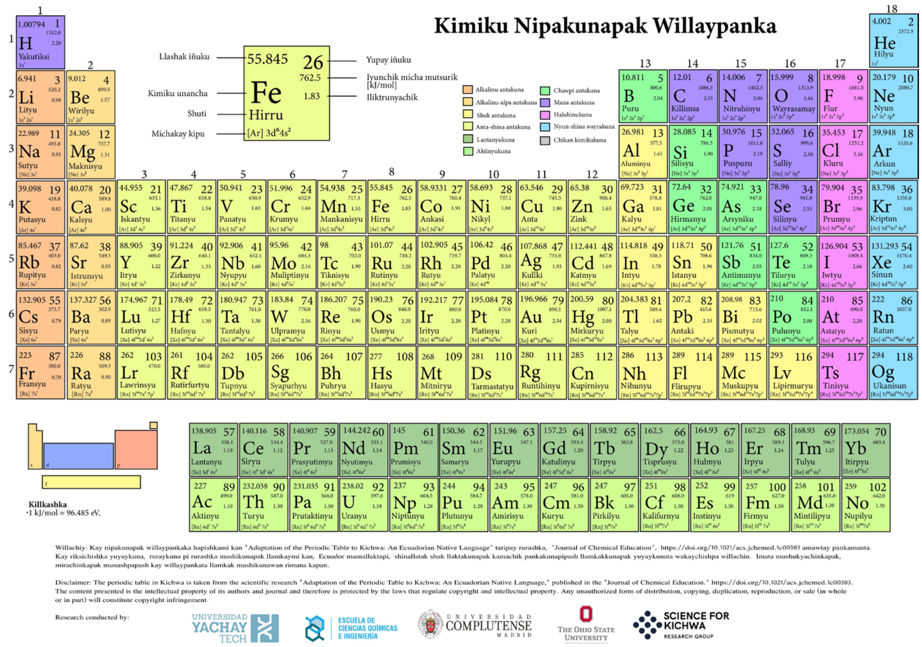
OPEN FOR DISCUSSION

A Periodic Table of Its Own?

By Sam Lemonick



The periodic table is considered the bedrock of chemistry education. Students use it to look up values such as an element's atomic mass, and it serves as a visual reference for the trends in physical properties. But what use is it if a student can't read it?

In many ways, the periodic table is a universal language. The symbols, the arrangement of the elements into rows and columns, the data for each element are bits of information that have meaning regardless of what language a student may speak. But the names of the elements are a different story.

The International Union of Pure and Applied Chemistry created official names for chemical elements, relying heavily on the English language. So, the official name for the element with atomic number 8 is oxygen and the name for 29 is copper.

The official names are used in international publications, but it's still common to see researchers using names accepted in their home countries.

Of course, everyone grows up knowing the names of at least a few chemical elements. Some elements have been known in their pure, uncombined, or elemental form for thousands of years. Gold, silver, and sulfur are very stable and can exist in recognizable forms all over the world.

Over the past 200 years many more elements were identified and most of them entered the common vocabulary of each language. For example, copper is known as cuivre in French, Kupfer in German, rame in Italian, tóng in Chinese, and cobre in Spanish.

The element known as iron in English is fer in French, Eisen in German, ferro in Italian, cheol in Korean, and hierro in Spanish. For elements discovered more recently, the names in various languages are much more similar. For example, technetium is known as technetium in French, Technetium in German, tecnecio in Spanish, and tekunechiumu in Japanese.

Periodic tables that include the names of the elements and titles for the data in native languages are very common. It's easy to find examples of tables that were translated into various foreign languages. A quick search turned up nearly 100 versions in various language, including Spanish, French, Portuguese, Swahili, Japanese, Chinese, Croatian, and even one in Klingon.

While that is a lot, it is important to keep in mind there are some 6,000 languages spoken in the world, and not having access to science information in indigenous languages can be a major problem for native speakers who want to advance in their education.

In one instance, researchers solved that problem for people who speak Kichwa, a language used by about half-a-million people in parts of Ecuador, Colombia, and Peru. The Kimiku Nipakunapak Willaypanka (periodic table of chemical elements) presents Kichwa words for all 118 elements and other terms, such as atomic weight.

The researchers say the adapted periodic table will help Kichwa speakers learn science. At the same time, having Kichwa words for elements could help Kichwa speakers communicate local knowledge of, say, medicinal plants to non-Kichwa speakers.

The researchers started their adaptation by translating element names into Kichwa in different ways. For some elements, such as helium, the team used the element's etymology to make a new Kichwa word.

Helium comes from the Greek word for the sun, so they proposed "intiku," from the Kichwa words inti (the sun) and ku (belongs to). For other elements, they transliterated the sound of the English word into Kichwa, so nickel became "nikil."

The group then used an online survey to ask approximately 150 Kichwa speakers whether they approved of the group's element names and periodic table terms. In some cases, the survey asked respondents to rank different possible adaptations of element names.

The researchers noted that many of the respondents preferred names that sounded similar to the words for the elements in Spanish, the language most widely spoken in Ecuador. This was especially true in the case of a particular sound that doesn't exist in Kichwa, such as for several elements with an "f" sound. For fluorine, they settled on flur for Kichwa, which is similar to flúor in Spanish.

Translations into indigenous languages are important for people to feel included in the process of science, it helps to be able to understand science in their own language, because a language carries with it the values and traditions of a culture.

But indigenous speakers will likely need to learn one of the major languages to be successful at higher levels of education. Where is the balance among various languages? That is open for discussion.

This article was adapted from "Adapting the Periodic Table into Kichwa. A Team Including Native Speakers Created a Periodic Table in an Indigenous South American Language," which was originally published in Chemical & Engineering News *on November 16, 2021.*

Sam Lemonick is a freelance contributor to *Chemical & Engineering News*, the independent news outlet of the American Chemical Society.

DON'T SWEAT IT

How Moisture-Wicking Fabrics Keep You Cool and Dry

By Brian Rohrig

SHUTTERSTOCK

Visit your local sporting goods shop and you will be met with a dizzying array of choices in athletic performance apparel and clothing for the outdoors. A shirt you think might cost $20 costs $60. What gives?

Welcome to the world of fabric technology. In 2020, people spent $160 billion worldwide on sportswear. The goal is not just to look good, but to feel comfortable, too. Compression garments are designed to massage and support muscles, improving blood flow. Running shoes offer abundant cushioning and traction.

Sweat-wicking fabrics are designed to keep you cool and dry. Do they really work? Are they worth the cost?

If you go for a run on a hot day in a cotton shirt, it will quickly become soaked with sweat. This is not only uncomfortable, but a sweat-saturated shirt can cause no small amount of skin irritation.

While cotton fabrics are soft and comfortable, they are not the best choice for most athletic endeavors. Cotton fabric absorbs and holds on to water like a sponge.

Textile engineers (engineers who work with fibers, yarn, and fabric) have coined a term for how much water a fabric retains when wet: the **moisture regain** value. This value is found by dividing the mass of water in a saturated fabric by the mass of the dry fabric.

For example, if a 100-gram (g) sample of fabric has a mass of 110 g when wet, its moisture regain is 10% (mass of water/mass of dry fabric).

The moisture regain values for some common fabrics are as follows:

Cotton » 8.5% | **Wool** » 16% | **Cotton-polyester (50/50)** » 4.45% | **Nylon** » 4% | **Polyester** » 0.4%

To understand why some fabrics absorb water better than others, let's take a closer look at water, from a chemist's perspective.

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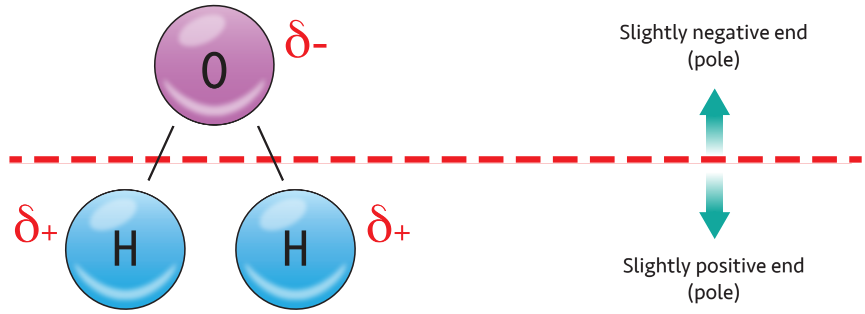

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A difference in pull on electrons leads to the polar nature of water molecules.

Water molecules are polar—their charges are divided. The word polar is derived from the word “pole;” the charges are distributed as if at the two ends of a stick. Overall, the molecule is neutral, but its negative charges congregate on one side while excess positives remain on the other.

Atoms form bonds by sharing their outer (valence) electrons, but this sharing isn’t always even. In water, oxygen has a greater pull for the shared electrons than hydrogen. Where the shared electrons spend more of their time is controlled by a property known as electronegativity. Electronegativity is a measure of an atom’s ability to attract shared electrons in a chemical bond.

Because the oxygen atom has a greater electronegativity, it draws electrons closer to itself and the oxygen side of the molecule becomes slightly more negative. The electrons are now closer to oxygen, which exposes the positive nuclei of the hydrogen atoms, making the hydrogen side of the molecule slightly positive.

Water doesn’t have full charges, as in ionic compounds, but rather partial negative (δ-) and partial positive (δ+) charges. We use partial charges because even though the electrons spend the majority of their time with the oxygen atom, they still spend some of their time with the hydrogens. Nonpolar molecules share their electrons evenly, or symmetrically, so there is no partial positive or negative side.

The polarity of water contributes to all sorts of interesting phenomena. Water droplets form because billions and billions of water molecules stick together through an intermolecular force of attraction known as hydrogen bonding. Hydrogen bonding is the attraction between the positive hydrogen side of one water molecule and the negative oxygen side of another water molecule. The attraction of like things is termed cohesion. Because of the strong attraction between molecules due to hydrogen bonding, water is said to be highly cohesive.

Adhesion, in which different things stick together, is more involved. Water droplets that stick to the end of your finger when you dip it in water are held by adhesion. This happens because there are enough polar charges on your skin to attract the water molecule.

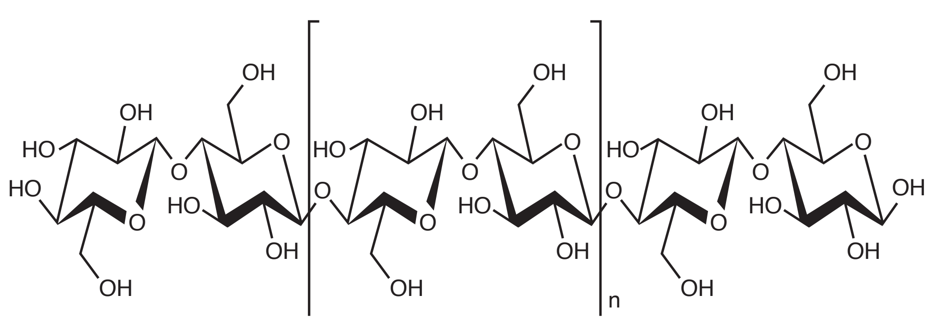
One of the most significant phenomenon that depends on the polarity of molecules is the solubility of one type of molecule in another. The polarity of molecules determines what they are attracted to, according to the “like dissolves like” principle. Salt and sugar both dissolve in water. Salt and sugar are both polar. Polar things are attracted to other polar things.

Oil, being nonpolar, will not dissolve in a polar substance. Nonpolar substances, however, will tend to dissolve in other nonpolar substances. Oil will dissolve in olive oil, but not in water.

Another phenomenon based on polarity is how a liquid may spread out on a surface. If a polar liquid is placed on a nonpolar surface, it tends to bead. You may have seen this when water lands on a newly waxed car. The water beads into droplets. When the car is dirty, the water spreads out much more, due to all the polar molecules in the dirt.

One final example of a phenomenon based on these forces is capillary action. Capillary action occurs when the forces of adhesion are stronger than the forces of cohesion. If water molecules have a stronger attraction to the sides of a narrow tube than to one another, they will creep upward.

Capillary action is responsible for a variety of phenomena, from the movement of water in plants to the filling of our tear ducts. Paper towels make use of capillary action, containing tiny channels for water to travel through, greatly increasing their absorbency. Put a strip of paper towel in water and the water wicks up the strip.



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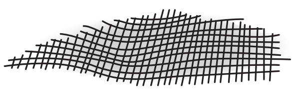
Projecting -OH (hydroxyl) groups give parts of cellulose its polar nature.

Fibers are the raw material used to make textile items. They are spun or twisted together to make yarns.

Yarns are made from fibers from either natural or synthetic sources. They are interlaced, interlooped, or bonded together to make fabrics.



Fabrics are made from yarns. Different fabric types are produced by different methods of joining the yarns together.

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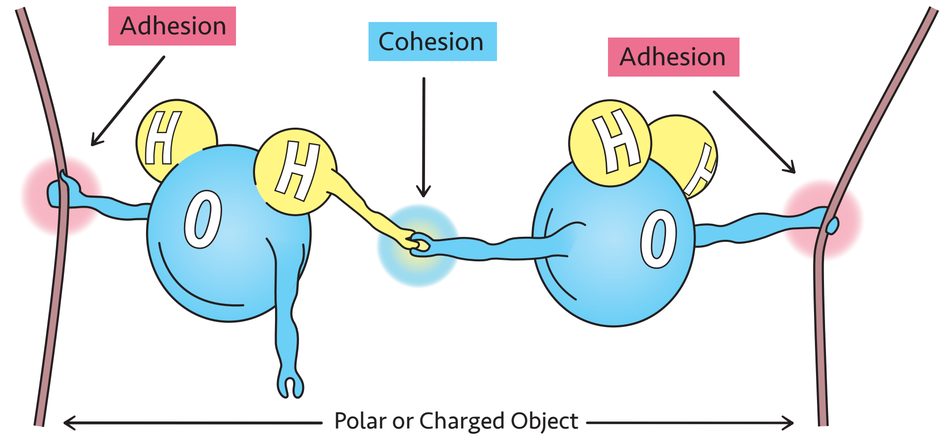

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Adhesion is when different things stick together, cohesion is when like things stick to each other.

Can you now explain why that cotton shirt becomes so drenched? If you guessed that cotton fibers are polar, you are correct, sort of. Cotton is primarily made of cellulose, a polymer (or macromolecule) made of many glucose molecules strongly linked together, with the basic formula $(C_6H_{10}O_5)_n$.

Cellulose is a fiber that is found in all plants. But cellulose is not water soluble, otherwise that cotton shirt would dissolve when it got wet.

There are parts of the cellulose that are polar. If you zoomed in to the molecular level, you would notice a bunch of little -OH's, known as hydroxyl groups, sticking out, like thorns on a rose stem.

Each hydroxyl group is composed of one oxygen atom and one hydrogen atom. Since oxygen is more electronegative than hydrogen, these groups are polar and have a strong attraction for water. As a result, cellulose is strongly attracted to water.

So, if we don't want to work out in a hydrophilic fabric, do we want to work out in a hydrophobic (lacking an affinity to water) one? If you've ever weathered a storm in a plastic raincoat, you soon realized you were just as wet on the inside as on the outside.

This leaves your perspiration with nowhere to go, so it just sits against your skin, which explains why you get that wet and clammy feeling. If you place a drop of water on plastic and it is repelled, demonstrating its hydrophobicity, it is most definitely *not* sweat wicking.

Wouldn't it be great if there was a fabric that allowed your perspiration to pass right through, that didn't keep it against your skin but didn't absorb it either? That's exactly what sweat-wicking fabrics are designed to do.

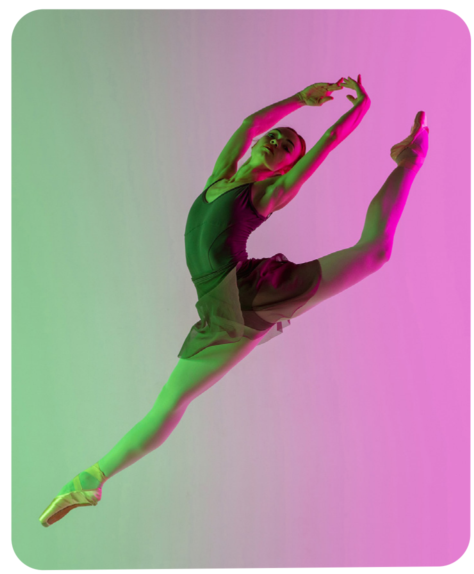
Sweat-wicking fabrics work due to capillary action—the tendency of a liquid to move upward in a narrow tube or space, in apparent defiance of gravity.

The first step in designing a sweat-wicking fabric is to find the right fiber. A fiber is the base material from which clothing is made, and can be natural like cotton or wool, or synthetic like nylon or polyester.

A fiber is a threadlike strand. If a bunch of fibers are twisted together, you have a strand of yarn. When strands of yarn are woven together, you have fabric or cloth. The fabric is then cut and sewn together to make the clothes we wear.

It is important that the fiber is not too hydrophilic, like cotton, which won't wick away moisture at all. But purely hydrophobic fibers that repel water won't work either. As the goal is for capillary action to occur, there must be some attraction to water—just not too much.

One popular fabric used in sweat-wicking



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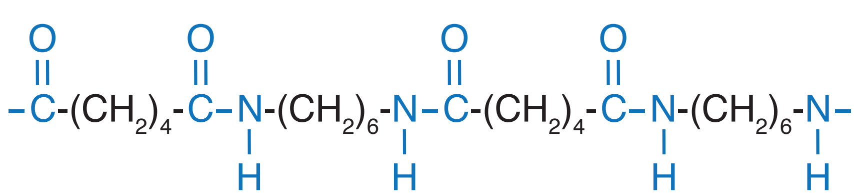

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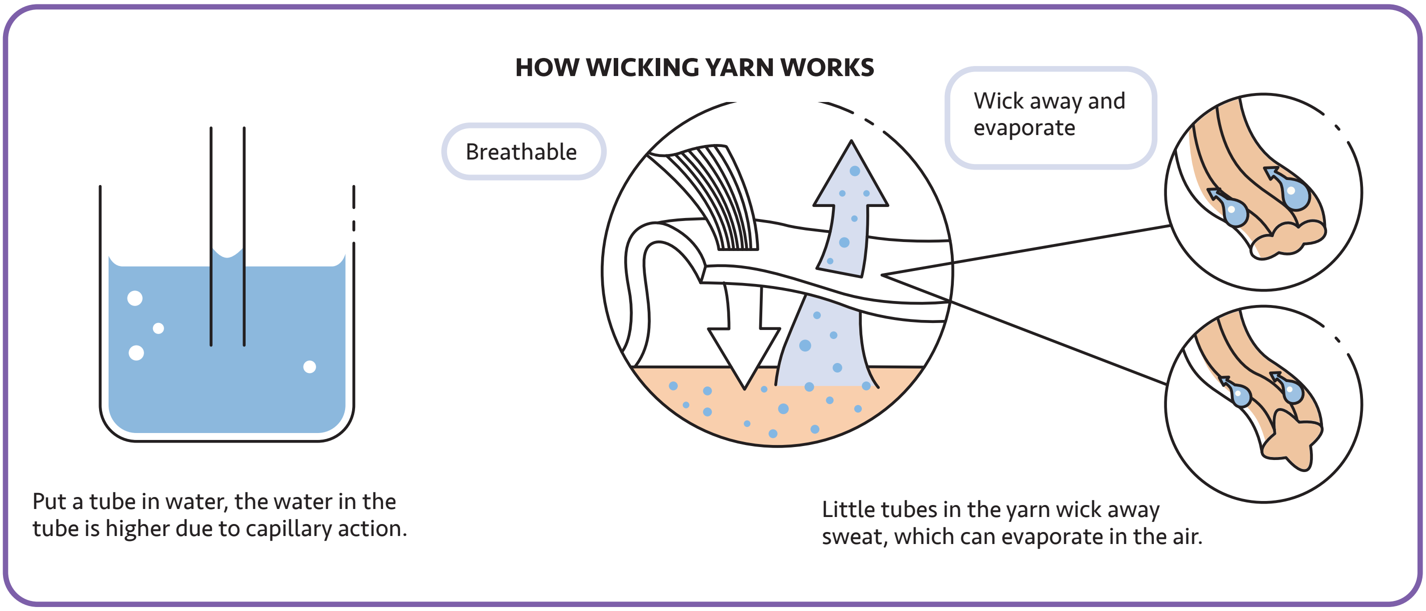
The N-H (amide) groups are polar and make nylon attract water.



clothing is polyester. Being petroleum based, polyester is quite hydrophobic, with a moisture regain of only 0.4%. To make it a little less so, it can be chemically treated with a hydrophilic coating. Or the polyester fibers may be interwoven with hydrophilic fibers, forming a blend, which can create an excellent moisture-wicking garment.

Nylon is a popular choice for sweat-wicking clothing. Nylon is also known as polyamide, because it is composed of repeating units of amides, each containing a carbonyl (C=O) group linked by a single bond to a nitrogen atom. Since amide groups are polar, nylon is hydrophilic—it attracts water.

But nylon is not nearly as hydrophilic as cotton, which contains the highly polar hydroxyl group. An amide group contains nitrogen, which is not nearly as electronegative as the oxygen in the hydroxyl group, so nylon is not as hydrophilic as cotton. But it is just hydrophilic enough.

Spandex, the stretchy fabric commonly found in leggings and bike shorts, has only moderate wicking ability. Spandex is mostly made of polyurethane, but you will never find a garment made of pure spandex—it is usually used in conjunction with nylon or polyester. So, yoga pants not only allow for freedom of movement, they also keep you dry, even during intense workouts.

Some types of sweat-wicking clothing have an inner layer next to the skin that is somewhat hydrophobic and an outer layer that is hydrophilic, creating a push-pull effect. As the hydrophobic layer repels water, moisture is pushed upward into the hydrophilic layer, where it can evaporate.

Wool, especially Merino wool, has excellent moisture-wicking properties. Wool fibers are hydrophilic on the inside but hydrophobic on the outside, due to the presence of lanolin, a waxy material secreted by the sheep's sebaceous glands, enabling their coats to repel water.

The next step in creating a sweat-wicking fabric requires the most ingenuity: The yarn must be constructed in such a way as to allow capillary action to occur. Most yarns have a circular cross section. When woven together, they fit snugly. There is little room for water to travel between the strands. Their ability to wick moisture is limited.

But if the yarn is designed with spaces between the strands, then moisture can travel through these spaces via capillary action. This amazing little feat of engineering is accomplished by constructing yarns with *noncircular* cross sections—they may be triangular, cross-shaped, or some other odd shape.

When these strands of yarn are placed together, they do *not* fit snugly. There is space between them. These little spaces create micropores that are just the right size to facilitate capillary action. Moisture can freely travel through these pores to the outer surface—almost like magic, sweat is wicked away.

The magic doesn't happen, though, without a lot of rigorous testing. Before ever hitting the market, a battery of tests will be performed to make sure a fabric will perform as predicted. These experiments are easy enough to perform yourself—all you need is water and some samples of fabric.

In a vertical wicking test, two strips of cloth are suspended with their ends in water. The fabric in which water travels the fastest will have the greatest wicking ability.

In a horizontal wicking test, a predetermined amount of water is dripped onto the fabric and the horizontal spread of the water is measured. Fabrics with greater wicking ability will show larger spreads in a given amount of time

A transverse wicking test most closely mimics what a moisture-wicking garment is designed to do. Water is absorbed from below the fabric, and its rate of spread through the fabric and along its surface is measured. The faster the spread, the better.

For clothing to keep you cool and dry, sweat must evaporate once it reaches the surface of the garment. Sweating itself does not cool you, it is the evaporation of sweat that cools you. And because evaporation is endothermic, it must absorb energy.

When liquid water vaporizes, the weak cohesive bonds between the water molecules are broken. It takes energy to break a bond. This energy comes from your body, thus cooling you down.

Making choices to make you feel cool and comfortable when you are working out are much easier with the advent of high-tech fabrics that allow moisture to be wicked away. Thanks to a good understanding of fabrics and the nature of water, there are plenty of choices. Looking cool is another matter. You're still on your own for that!

Brian Rohrig is a chemistry teacher based in Columbus, Ohio.

REFERENCES

Priyalatha, S.; Dhanakodi, D. R. A Multi-Directional Wicking Instrument to Measure Wicking Characteristics of Fabrics Under Dynamic Movements. *Journal of the Institution of Engineers* (India), September 2018: https://www.researchgate.net/publication/327712897_Wicking_Instrument [accessed August 2022].

Miao, M.; Xin, J. H., Eds. Engineering of High-Performance Textiles. United Kingdom: Elsevier Science, September 2017: https://www.elsevier.com/books/engineering-of-high-performance-textiles/miao/978-0-08-101273-4 [accessed August 2022].

Crow, R.; Dewar, M. Liquid Transport Across Fabric Layers. Defense Research Establishment Ottawa, Report No. 1002, March 1989: https://apps.dtic.mil/dtic/tr/fulltext/u2/a209567.pdf [accessed August 2022].

SHUTTERSTOCK

What are GLOW STICKS and What Is the Chemical Reaction that Makes Them Light Up?

This article was adapted from "What Are Glow Sticks, and What Is the Chemical Reaction that Makes Them Light Up?", which was originally published in Chemical & Engineering News *on October 19, 2021.*

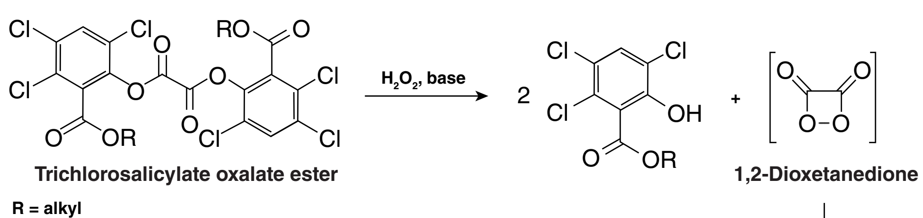
By Bethany Halford, *Chemical & Engineering News*

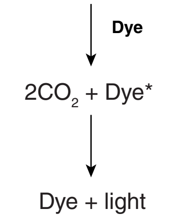
Breaking something rarely sparks joy—unless you're activating a glow stick. Just bend the plastic stick until you hear a snap, and behold, you have a radiant wand to illuminate your way. Whether you're trick-or-treating on Halloween or dancing the night away, glow sticks provide a cool source of light. That light is made by a chemical reaction—a phenomenon known as chemiluminescence.

In glow sticks, the chemicals that react together to create the light are kept separate until the right moment. The glow stick contains a solution of an oxalate ester and a fluorescent dye. There is a thin-walled glass vial filled with a hydrogen peroxide (H_2O_2) solution inside the stick, as well. The signature snap that starts the reaction signals that you've broken the glass tube, releasing the hydrogen peroxide. When the chemicals mix, the reaction goes through several steps before releasing light.

Chemical reactions involve the breaking of bonds in reactants and combining the parts in new arrangements. This process often includes unstable intermediates that form briefly before the atoms form new bonds to make the final product. It takes energy to break the initial bonds, and energy is released when the new bonds form.

In glow sticks, first the hydrogen peroxide and oxalate ester react to form a high-energy intermediate, but the precise nature of that intermediate is still something of a mystery. Many chemists believe it's the unstable molecule 1,2-dioxetanedione. But despite 50 years of looking for it, there is no direct evidence of that compound.





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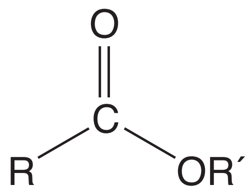
Glow sticks light up when oxalate esters react with hydrogen peroxide to form a high-energy intermediate (possibly 1,2-dioxetanedione). This intermediate reacts with dye, which moves to an excited state (indicated with *) and then releases light as it relaxes.

Even though chemists aren't certain of the precise structure of the high-energy intermediate, they know it's a good electron acceptor. It snags an electron from the fluorescent dye and then breaks down into carbon dioxide and a negatively charged carbon dioxide radical anion. A radical anion is a negatively charged species that has an atom with an unpaired electron. The dye, which has become a positively charged radical cation, then takes back an electron from the CO_2 radical anion.

In taking back the electron, the dye gains excess energy. The molecule uses that energy to move into an excited state before dropping back down and emitting the energy as a photon of light, causing your glow stick to glow.

The basic glow stick technology was discovered in a janitor's closet in New



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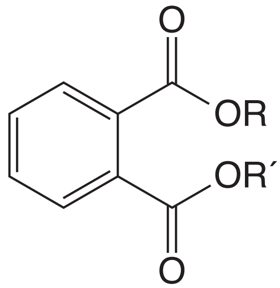

PHTHALATE

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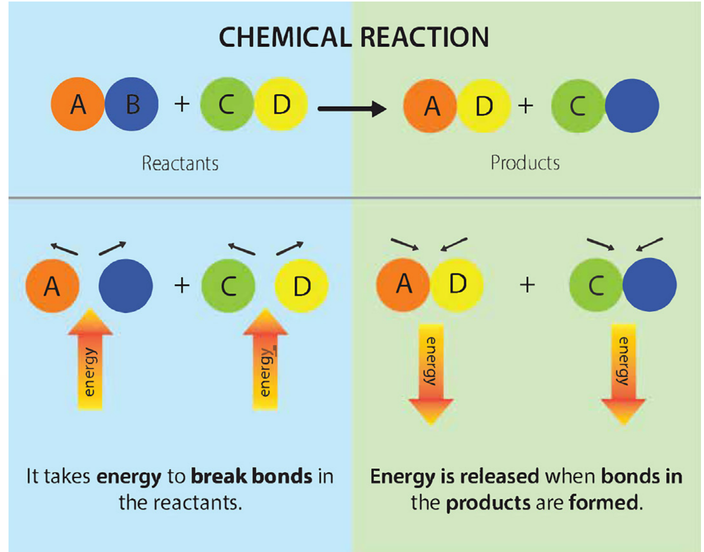


AMERICAN CHEMICAL SOCIETY

Jersey in 1962. Back then, Edwin A. Chandross, a newly minted chemistry Ph.D. working at Bell Laboratories, was tinkering with light-producing chemical reactions. "The company had very generously provided me with a dark room to do chemiluminescence experiments," Chandross says, alluding to the small, dark closet next to his lab.

One day Chandross exposed a xanthone derivative he had prepared with oxalyl chloride to hydrogen peroxide with a little added anthracene dye in the mix. The reaction produced weak light. But when Chandross tried to repeat the reaction with a cleaner sample of the xanthone derivative, the mixture stayed dark. That's when it occurred to Chandross that it had been leftover oxalyl chloride reacting with the hydrogen peroxide and dye in the first experiment. When he tried mixing those three components, the light returned.

Later on, other chemists tweaked the reaction by substituting oxalate esters instead of oxalyl chloride and adding some salicylate base as a catalyst. They also experimented with various colored dyes, which produced different colors.

While most people associate glow sticks with the novelty market, they also have more serious uses. That's why the U.S. military financed part of the work that the American Cyanamid chemists did to develop glow-stick chemistry. Chemists led by Herbert Richter at the U.S. Naval Air Weapons Station China Lake was developing chemiluminescent glow sticks around the same time that Chandross made his chemiluminescent discovery at Bell Labs.

Today, the government market for glow sticks is considerable, says Donald Schmidt, a senior vice president for Cyalume Technologies, a company that grew out of American Cyanamid. He says the government market is about $35 million per year compared with his estimate of about $40 million for the novelty market.

Cyalume provides glow sticks to the U.S. military and Department of Defense to use for training exercises and field operations, and glow sticks can also save lives. Flotation vests equipped with the devices, for example, can help rescuers find people lost at sea. When there is a danger of flammable fumes, glow sticks can provide illumination without the risk of ignition.

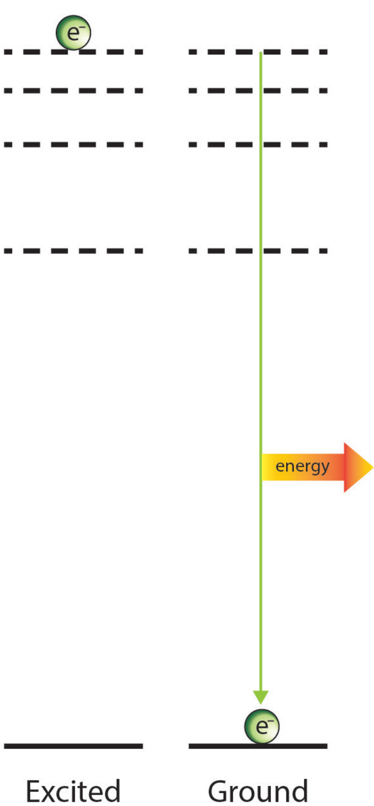
In the 60 years since glow-stick chemistry was first discovered, there have been several chemical innovations, says Linda Jacob, Cyalume's director of chemical services.

Several of those changes relate to safety. For example, the oxalate esters that were used in glow sticks decades ago produced trichlorophenols—chemicals that could go on to form toxic halogenated dioxins. To eliminate trichlorophenols, Jacob says, Cyalume turned to trichlorosalicylate oxalate esters, which are safer. The firm now also uses butyl benzoate and triethyl citrate as solvents instead of phthalates, some of which have been identified as endocrine disruptors. Most novelty glow sticks still use phthalates, however, she says.

Chemical innovations have also helped expand glow sticks' lifetimes and operating temperatures. Jacob says chemists have learned how to tune the chemiluminescent reaction's illumination time by tweaking the salicylate catalyst. "You can change the length of the chemiluminescence from 30 seconds to 24 hours," she says. Other chemical additives allow glow sticks made for the military to work whether the temperature is –50 °C or 50 °C (-58 °F to 122 °F). "Whether you're in the Arctic or in the desert in the hot summer sun, you'll get pretty close to the same performance," Jacob says.

So, the next time you snap a glow stick, take a moment to appreciate the cool chemistry that brightens your night.

DEPOSIT PHOTOS



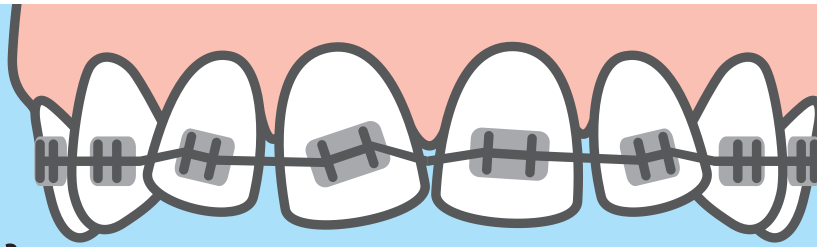
AMERICAN CHEMICAL SOCIETY

Bethany Halford is a senior correspondent for *Chemical & Engineering News*, the independent news outlet of the American Chemical Society.

QUICK READ

Braces!

How Do They Straighten Your Teeth?



SHUTTERSTOCK

At some point, many students in middle school or high school will get braces on their teeth. It may not be obvious, but there is a lot of science and technology that goes into straightening teeth with braces.

COMPONENTS OF BRACES

Braces are composed of different parts that work together to move and align teeth. The small metal part on the front of a tooth is called a **bracket**, and it is attached to the tooth with a special glue or type of cement. The brackets are fastened to 12 or 14 upper and lower teeth and act like anchors or little hooks. The purpose of the brackets is to securely hold a thin flexible wire that stretches across both sets of teeth.

DEPOSIT PHOTOS

MATERIALS USED

The material used for braces has to be chosen carefully. The mouth is a pretty watery place, so the metal used for braces cannot be the type that rusts.

In addition to rust, another possible problem is corrosion from **acid**. Many foods contain acid, and bacteria that live on the tongue, gums, and inside the crevices of your teeth also produce acid.

DEPOSIT PHOTOS

A common metal for brackets is stainless steel, which doesn't rust and resists corrosion from acid. Stainless steel is made from iron with a small amount of carbon, chromium, or nickel added.

When a metal is combined with another metal or other substance, the resulting substance is called an **alloy**. An alloy has properties different from those of the materials it is made from.

Brackets can also be made from titanium, and from an alloy of the metals, chromium and cobalt. None of these metals will rust when exposed to water. They are also resistant to corrosion from the acid in the mouth.

Luckily, your saliva contains a substance called a **base** which acts like the opposite of an acid. The base helps neutralize the acid, so your saliva is less acidic and less challenging to the metal alloys in the braces.

NITINOL: SHAPE-MEMORY METAL

The wire that is connected to the brackets and goes across the teeth is called the **arch wire**. Some arch wires are made from a high-tech metal called **nitinol**. This material is made from an alloy of the metals, nickel and titanium.

Nitinol is often called "shape-memory" wire because of its shape-changing ability. During the shaping process, a nitinol wire is heated and bent into any shape, such as a paper clip for example. When cooled, it can be stretched into a straight wire or bent into another random shape. But when warmed again, the wire returns to the same shape it was bent into originally.

WIKIPEDIA/ PETERMAERKI

To use the shape-memory wire for braces, the dentist makes very detailed measurements of the position of your teeth. The nitinol wire is then shaped, so the warmth from your mouth will cause the wire to bend back to that shape and straighten your teeth.

Nitinol will not rust and is also resistant to corrosion. Studies have also shown that Nitinol can be in contact with the tissues in the mouth without causing allergic reactions that might happen with some other metals.

After the Nitinol arch wire begins to straighten the teeth, a stronger, stiffer stainless-steel wire is often used to move teeth into their permanent position.

Wearing braces may not be the most fun you've ever had but keeping them clean and visiting your orthodontist for regular checkups should eventually give you a beautiful smile.

That's because chemists, engineers, and orthodontists have braces down to a science.

THE OPIOID EPIDEMIC

HOW DID IT GET THIS BAD?

By Steven Farmer

As waves of coronavirus variants keep communities on constant alert, another epidemic has continued its relentless growth. In 2021 alone, more than 100,000 people in the United States died from a drug overdose, a 15% increase over the previous year.

The data, reported by the U.S. Centers for Disease Control and Prevention, which is the agency that monitors and responds to public-health threats, showed that drugs called opioids are a huge part of the problem. Opioid-related deaths are also growing worldwide.

Another troubling aspect of the opioid epidemic concerns young people. Among teens in the United States, overdose deaths related to fentanyl, a potent synthetic opioid, jumped from 492 in 2019 to 954 in 2020 and 1,146 in 2021, according to a study published in April in the *Journal of the American Medical Association* (*JAMA*).

People working in the field of public health say that stress during the COVID pandemic may have fueled a surge in opioid use and related deaths. Illicit drug use among teens, however, decreased, while their overdose deaths rose.

What is going on? Why is the opioid epidemic getting worse, and why are more teens dying when drug use among this age group is going down?

Public-health specialists may not have all the answers, but the story of how opioids have changed over the years helps put some of the pieces together—and offers clues to help address the crisis.

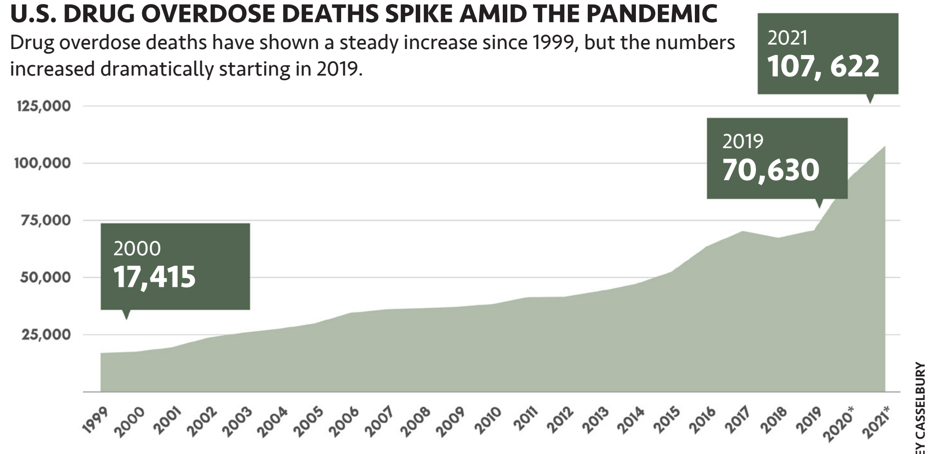
AN EPIDEMIC'S LONG ROOTS

Opioids are a class of drugs found naturally in the opium poppy plant that work in the brain to relieve pain by blocking pain signals between the brain and the body, while enhancing feelings of pleasure. Synthetic man-made opioid drugs are also included in this class.

Opioids have long been a part of human history. The earliest recorded references to the use of opioids date back to 3400 BCE by the Sumerians of lower Mesopotamia who cultivated natural sources of the compounds from the *Papaver somniferum* flower, which is commonly known as the opium poppy. When its seed pods are cut, they

U.S. DRUG OVERDOSE DEATHS SPIKE AMID THE PANDEMIC

Drug overdose deaths have shown a steady increase since 1999, but the numbers increased dramatically starting in 2019.



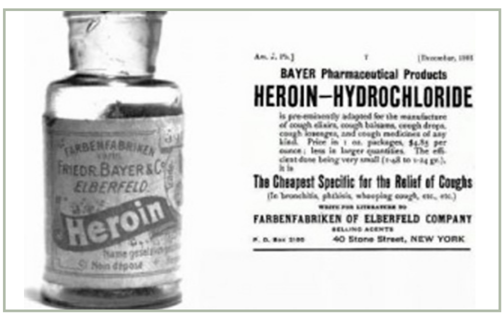
*Estimates for 2020 and 2021 are based on provisional data | Source: Centers for Disease Control and Prevention

SHUTTERSTOCK

Fields of opium poppies have been cultivated for centuries.

ooze a milky fluid that when dried is called opium.

Because of its medicinal potential, scientists wanted to zero in on the active compounds in opium. In 1804, German pharmacist, Friedrich Wilhelm Sertürner, succeeded in isolating morphine, the primary compound in opium responsible for its effects. Starting in 1827, morphine wasfreely sold to the public by the Merck pharmaceutical company.



Doctors quickly realized that morphine was highly addictive, so drug companies set out to develop a nonaddictive substitute. In 1874, one of the world's oldest pharmaceutical companies, Bayer, used morphine to create an opioid painkiller, called diacetylmorphine, which was given the trade name Heroin.

Heroin was up to two times as effective at pain reduction as morphine. Bayer started selling it as a painkiller in 1898—until it became clear heroin was even more addicting than morphine.

Then, in 1916, Bayer, used thebaine, a compound also isolated from the opium poppy, to create a semi-synthetic opioid painkiller called oxycodone. It is only half as potent as morphine, but oxycodone is significantly less addictive.

For the past 100 years, oxycodone, has remained a commonly prescribed opioid painkiller. But for severe acute pain, oxycodone is not strong enough.

So, in an attempt to develop a more potent painkiller, Paul Janssen, a Belgian physician, developed the fully synthetic compound, fentanyl, in 1960. Fentanyl is a highly potent painkiller, roughly 80 to 100 times stronger than morphine.

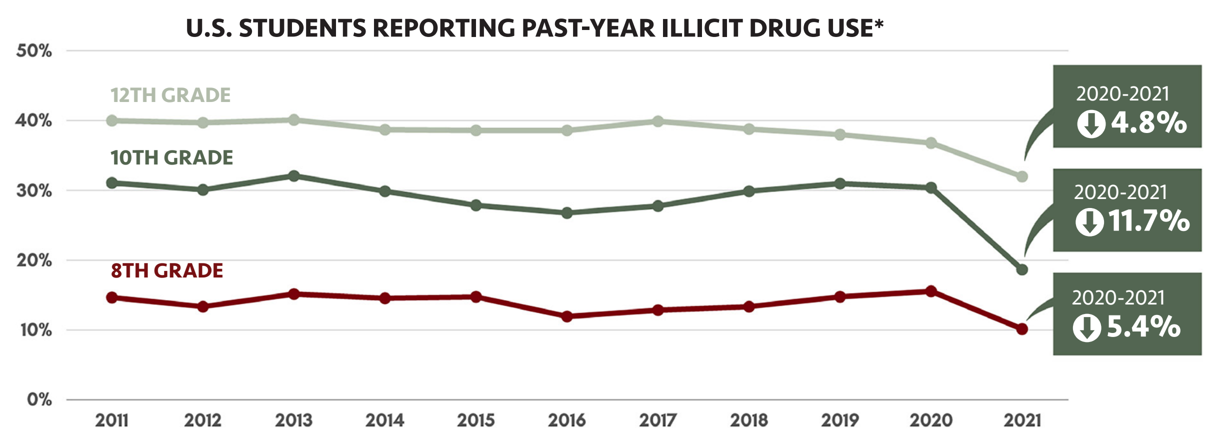
HOW OPIOIDS WORK

Opioid painkillers are addictive, but still prescribed because they are unmatched in their ability to relieve severe pain. To get an idea of how they work, let's look at what happens when we feel pain. In the human body, nerves branch out from the brain and spinal cord to other parts of the body as part of the peripheral nervous system (PNS). During an injury, a chain of nerve cells, or neurons, transmit an impulse from the PNS to the spinal cord and then to the brain, which tells us through pain that we've been hurt.

Pain messages are transmitted to the brain by specialized nerve cells known as pain receptors. When pain receptors are stimulated by temperature, pressure or chemicals, they release neurotransmitters. Neurotransmitters are chemical "messengers" in the nervous system that facilitate communication between nerve cells. Receptors on the surface of a neighboring nerve cell recognize and bind these neurotransmitters, creating an electrical impulse that continues down the length of the neuron.

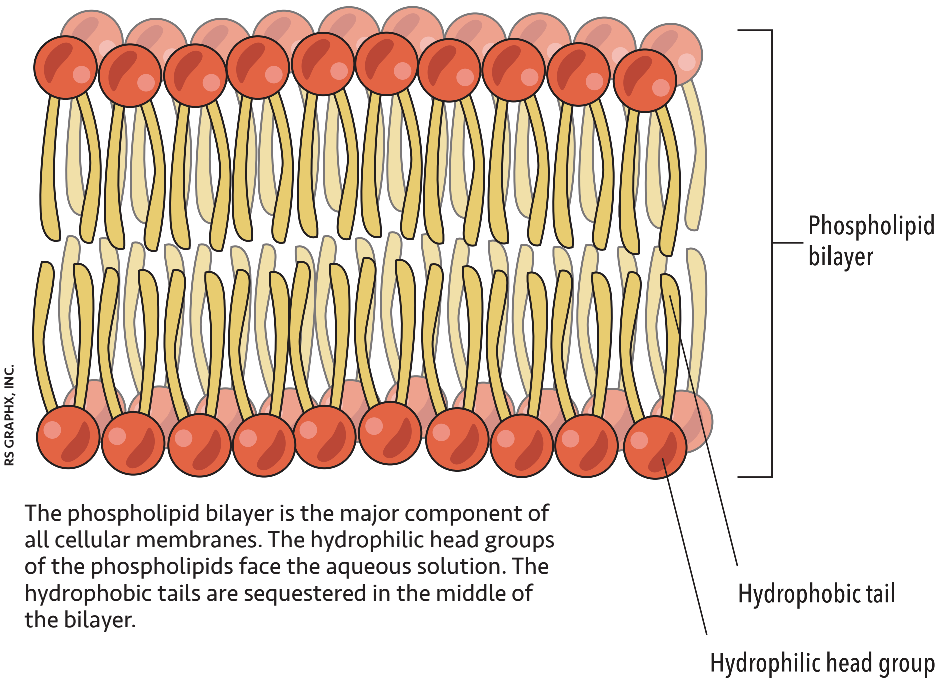
When this impulse reaches the end of the neuron, neurotransmitters are again released. They travel across the gap between the two neurons and bind to receptor molecules on the membrane of the second neuron. The binding of neurotransmitters to the receptors stimulates the second neuron to transmit an electrical impulse along its length. Much like students passing notes in class or dominoes falling, the message continues to be passed from one neuron to the next until it reaches the brain.

Certain types of molecules, however, can block signals rather than sending them. Opioids are such molecules—they attach to proteins called opioid receptors on nerve cells in the brain, spinal cord, gut, and other parts of the body and stop pain signals from getting to the brain.



*Defined as use of marijuana, LSD, other hallucinogens, crack, other cocaine, or heroin; or use of narcotics other than heroin, amphetamines, sedatives (barbiturates), or tranquilizers not under a doctor's orders. | Source: 2021 Monitoring the Future Survey

KELSEY CASSELBURY



The phospholipid bilayer is the major component of all cellular membranes. The hydrophilic head groups of the phospholipids face the aqueous solution. The hydrophobic tails are sequestered in the middle of the bilayer.

A representation of a fatal dose of fentanyl (2 milligrams).

The problem is that opioids affect more than just pain pathways in the PNS. They get in the brain and affect the nerves that control respiration. An overdose can cause a person to stop breathing.

Opioids also block specific brain cells that are responsible for switching off the release of dopamine, the neurotransmitter that leads to feelings of pleasure. Dopamine is normally released when people do something rewarding, such as eating a treat or getting a good grade.

With these neurons inhibited, dopamine surges in the brain and leads to feelings of euphoria. High levels of dopamine from chronic opioid use triggers changes in the brain, so increasing amounts of the drug become necessary to induce the same effects.

When a person stops using opioids, severe withdrawal symptoms take hold in just eight hours. A dip in dopamine levels in the brain causes depression and creates intense cravings. Additional opioid withdrawal symptoms can include body aches, diarrhea, vomiting, profuse sweating, fever, and shaking.

DEADLY CHEMISTRY

Normally, the brain is well protected from potentially toxic compounds in the bloodstream, although it lets through molecules necessary for normal function, such as glucose. A structure, called the blood-brain barrier (BBB) is the vigorously guarded gate that allows selective passage of molecules to cross.

The BBB is a tight-knit layer of cells that coat the capillaries and blood vessels in the brain. The BBB must be crossed for compounds to enter the brain, and it plays a central role in the function of opioids.

In general, the BBB blocks polar molecules from crossing, but allows small nonpolar molecules to pass through. Polar molecules are more soluble in water, while nonpolar molecules are more soluble in lipids, such as fats and oils.

The structure of a drug can be modified to enhance the ability to cross the BBB by decreasing its polarity. Changing a few sections of a molecule can have dramatic results. For example, two hydrogen bonding—OH groups of morphine can be replaced with nonpolar hydrocarbon side groups to produce heroin.

This simple change makes heroin more than 10,000 times more effective at penetrating the BBB and giving it a faster action than morphine. The fast action explains what is called the "heroin rush" and is directly related to its highly addictive nature.

Because fentanyl is nonpolar and low molecular weight, it is approximately 40 times more lipid soluble than morphine and readily crosses the BBB. Its high solubility allows for fentanyl's rapid onset with peak effect within five to six minutes of an intravenous dose compared to 15 to 30 minutes for morphine.

ROOTS OF THE EPIDEMIC

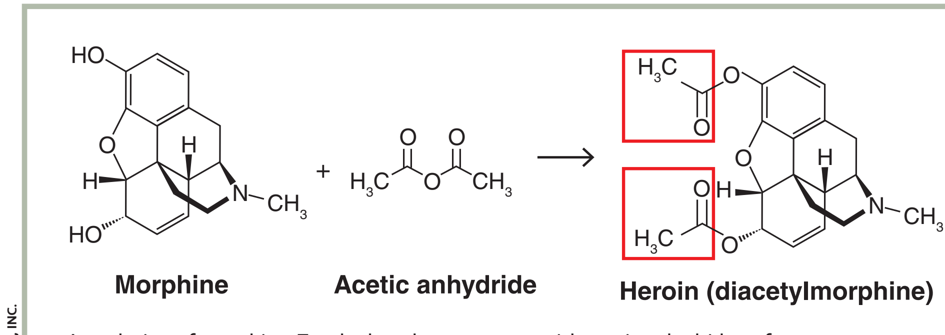
Starting in the 1990s, a number of factors combined to create the beginnings of the current opioid epidemic. Approximately 10 million people in the United States suffer from chronic pain that is enough to hinder their daily activities. Chronic pain increasingly became recognized as a problem that required adequate treatment to allow patients to live pain-free lives.

Patients with chronic pain conditions began to be offered prescriptions for opioid painkillers with the understanding that they would be overseen by a doctor and the amounts would be strictly controlled.

This trend was abused by some unscrupulous doctors who opened "pill mills," which were for-profit pain clinics that would prescribe opioid painkillers to virtually anyone for a fee.

As the scope of the prescription-opioid problem became clear, U.S. state and federal agencies began to clamp down on the availability of opioid painkillers. Also, physicians' organizations retooled their policy for the treatment of chronic pain, which caused a drastic reduction in the number of opioid painkiller prescriptions being written.

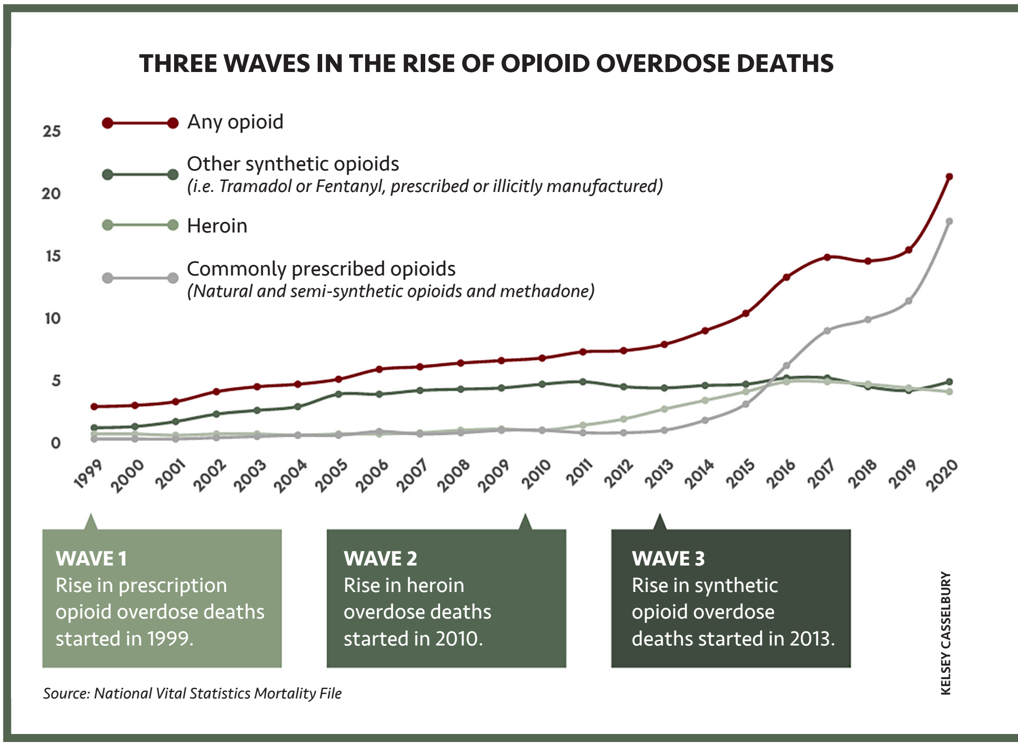
A new era of the opioid epidemic began in 2013, when victims of fatal opioid overdose began to show the presence of the synthetic opioid fentanyl. In 2021, a reported 66% of the 105,000 drug overdose deaths in the United States were



Acetylation of morphine: Two hydroxyl groups react with acetic anhydride to form two acetate esters (red boxes) (heroin).

SHUTTERSTOCK

Narcan (or Naloxone hydrochloride) can stop an opioid overdose.



KELSEY CASSELBURY

related to fentanyl and other synthetic opioids.

Due to their complex structure, morphine, heroin, and oxycodone are made using compounds isolated from the opium poppy. Mass production of these compounds is constrained because they require the growing and processing of large fields of opium poppies. As a synthetic, fentanyl does not require the opium poppy.

Now, countries that are not typically associated with the cultivation of opium poppies can easily produce fentanyl. China remains the primary source of illicit fentanyl being smuggled into the United States. The synthetic nature of fentanyl also allows for it to be made illegally in the United States, thus circumventing the need for smuggling.

The increased availability led drug dealers to begin making and selling counterfeit oxycodone and Xanax pills made with fentanyl. Because fentanyl is so powerful, roughly 2 mg—about the weight of a grain of sand—can be lethal.

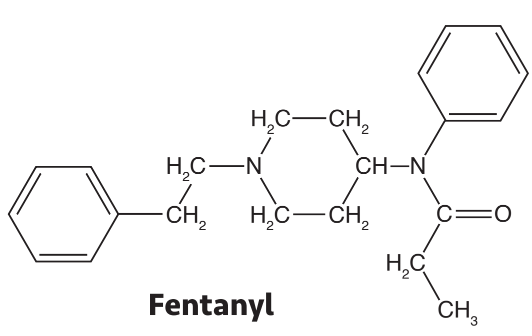
Dose amount is very difficult to control in counterfeit pills, and the U.S. Drug Enforcement Administration (DEA) says two out of every five of these counterfeit pills contain a potentially lethal dose of fentanyl. A number of people have died after ingesting a single counterfeit pill.

In addition, the strength of fentanyl has led drug dealers seeking to increase their profits to begin adulterating other drugs with fentanyl to increase their potency. Tests have shown that confiscated heroin samples often contain fentanyl.

This means that people using these drugs could be taking lethal amounts of fentanyl without knowing it. The results have been catastrophic. Between 2014 and 2018, the number of deaths in the United States that involved cocaine, methamphetamine, or an opioid almost tripled, with more than 70% involving illicitly made fentanyl, according to the DEA.

The most shocking aspect of the appearance of fentanyl is that it has caused the number of overdose deaths among high school students (ages 14-18) to more than double in the past decade.

In 2010, there were 518 overdose deaths in this age group, with fentanyl only being involved in 7.3% of the cases. In 2020, however, there were 1,097 overdose deaths with 954 (87%) involving fentanyl, researchers reported in the JAMA study.



Fentanyl

RS GRAPHX, INC.

Opioid overdose is commonly treated by the administration of naloxone through an injection, or with Narcan nasal spray. Naloxone, an opioid competitive antagonist, aggressively binds to and blocks the opioid receptors in nerves but without the inhibitory response typically caused by opioid painkillers.

During an opioid overdose, Naloxone has such a strong affinity for binding to opioid receptors it is capable of displacing opioid painkillers such as heroin and fentanyl, which can prevent an overdose from being fatal. Medical personnel and first responders often have naloxone on hand.

Several states have also passed laws which allow pharmacists to dispense naloxone to anyone, without a prescription. Although aspects of the opioid epidemic appear to be getting worse, federal, state, and local governments are working together to reduce the effects.

These efforts include the following: increasing the availability of overdose-reversing drugs, improving treatments for those with an opioid addiction, increasing oversight of the illicit opioid trade, and fostering the development of nonaddictive pain-relieving medicines.

Steven Farmer is a chemistry teacher and science writer based in Rohnert Park, California.

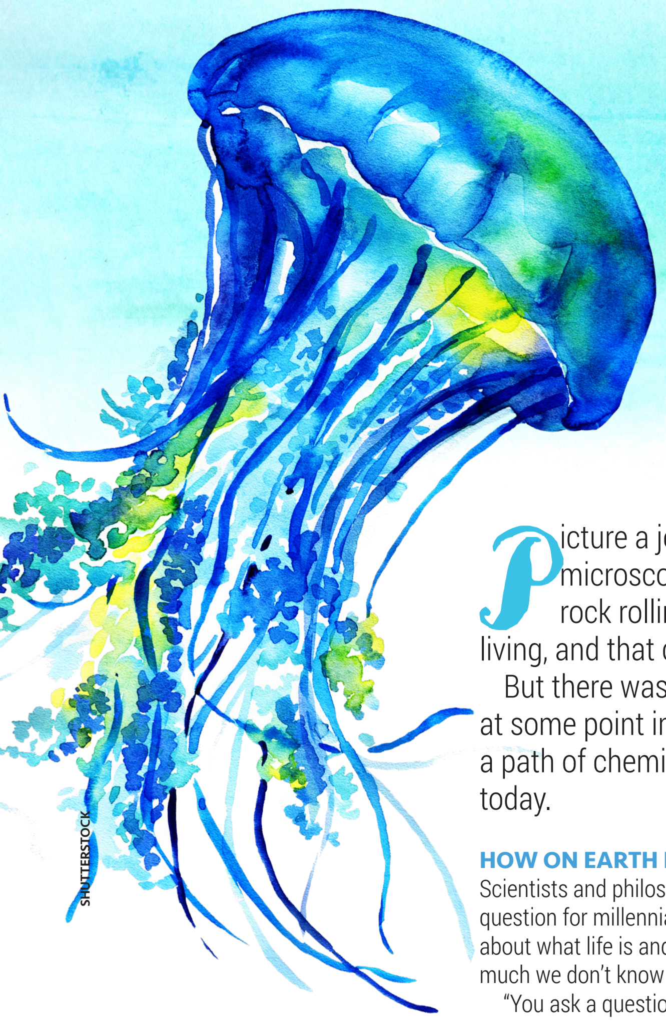
REFERENCES

Research on the Use and Misuse of Fentanyl and Other Synthetic Opioids. National Institutes of Health, National Institute on Drug Abuse, June 30, 2017: https://archives.drugabuse.gov/testimonies/2017/research-use-misuse-fentanyl-other-synthetic-opioids (accessed August 2022).

Akpan, N; Griffin, J. How a Brain Gets Hooked on Opioids. *PBS NewsHour*, Science, Oct 9, 2017: https://www.pbs.org/newshour/science/brain-gets-hooked-opioids (accessed August 2022).

Burns, S. M.; Cunningham, C. W.; Mercer, S. Dark Classics in Chemical Neuroscience: Fentanyl. *ACS Chemical Neuroscience*, June 12, 2018: https://pubs.acs.org/doi/10.1021/acschemneuro.8b00174 (accessed August 2022).

Hopper, L. Teens Who Abuse Opioids Are More Likely to Later Use Heroin, USC Study Shows. *USC News*, University of Southern California, July 8, 2019: https://news.usc.edu/158816/teen-opioid-abuse-heroin-use-high-school (accessed Aug 2022).



SHUTTERSTOCK

Origin of Life

By Danielle Sedbrook

Picture a jellyfish drifting serenely in the ocean or bacteria wiggling under a microscope—and think of yourself. Now picture a cloud floating in the sky or a rock rolling down a hill. Intuitively, you know that jellyfish, bacteria, and you are living, and that clouds and rocks are not.

But there was a time before life existed, when Earth was only land and ocean. Then, at some point in our planet's 4.5-billion-year history, nonliving matter started down a path of chemical transformation that led to the incredible diversity of life we see today.

HOW ON EARTH DID THIS HAPPEN?

Scientists and philosophers have been pondering this question for millennia. We know more today than ever about what life is and how it works, but there's still so much we don't know about how life began.

"You ask a question, and you don't get an answer. You get a lot more questions," says Matthew Powner, a chemistry professor at University College London who is one of many researchers trying to get to the bottom of this mystery. "That's how science works. That's when you know you're doing the right thing."

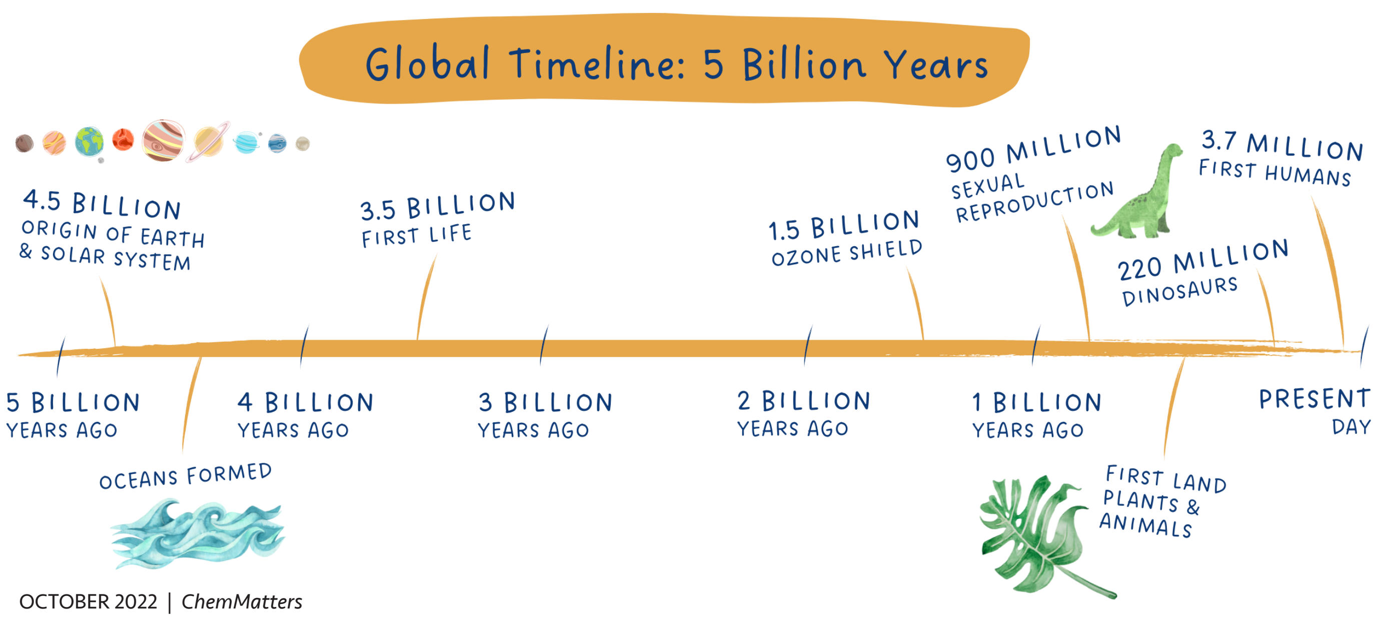
Scientists have made progress in their search, despite the ample questions that center on how life started. At its core, life is a complex system of chemical reactions that obey the same chemical and physical laws that cause clouds to float and rocks to roll.

Chemists, such as Powner, work alongside biologists, physicists, geologists, astronomers, and others to advance what we know about how those laws got life rolling, too.

WHAT IS THE CHEMISTRY OF LIFE?

Before we get to where origin-of-life science is now, consider the chemistry of life.

All life on Earth is remarkably similar at the chemical level. Life's diverse menagerie is made mostly from just six elements: carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur.



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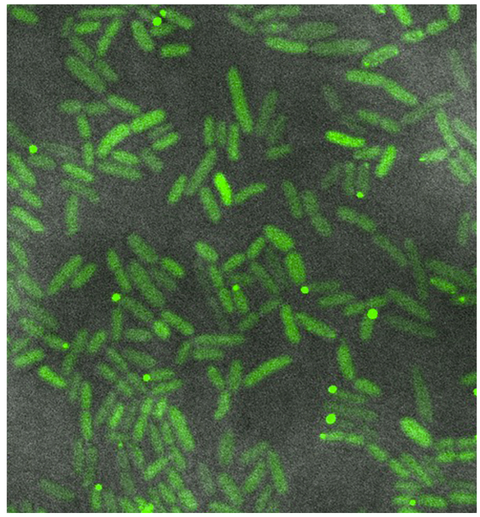


UNIVERSITY OF QUEENSLAND BRAIN INSTITUTE

Jellyfish and bacteria are totally different in appearance, but they share the same system of DNA and RNA.

All life uses water as its solvent of choice, and requires smaller amounts of metals, such as iron, nickel, sodium, and magnesium, along with a few other essential elements. These elements combine to form a set of molecules and processes that are consistent across all organisms.

Take the genetic code, the instruction manual for building a living organism. Organisms must replicate themselves for life to continue, and their genetic code is what allows them to do so.

Every single living creature on Earth, from single-celled bacteria to huge, multicellular mammals such as whales, uses the same DNA language to survive and reproduce.

From a chemistry perspective, DNA, or deoxyribonucleic acid, is a polymer. Polymers are large molecules made by bonding a series of building blocks called monomers. Think of a polymer as a chain, with each of its links a monomer. In the case of DNA, the links in the chain are nucleotides. A nucleotide consists of a sugar molecule attached to a phosphate group and a nitrogen-containing base.

Although there are many different possible nucleotides, DNA contains only four: adenine, cytosine, guanine, and thymine. Think of DNA as a language and the nucleotides as its four-letter alphabet.

Different combinations of the nucleotide alphabet make genes, the words in the DNA language. Each gene is part of a complex system that tells an organism how to make its component parts.

To do this, the gene is first copied into RNA, or ribonucleic acid. RNA is chemically similar to DNA, except it uses four slightly different nucleotide bases. Like DNA, RNA's chemistry is the same for all life.

"DNA and RNA are just 100% universal," says Powner. "I can take a jellyfish gene, from one end of the phylogenetic tree, and put it in bacteria at the other end of the phylogenetic tree. If the jellyfish glows green, the bacteria will glow green."

Similar to DNA and RNA, proteins in living things are made up of a defined set of smaller molecules—in this case amino acids—linked together by chemical bonds. Most living creatures use 20 amino acids to make almost all of their proteins.

Proteins do most of the work of keeping living things alive. Proteins are the primary structural materials, especially in animals. Almost every process that happens in a cell requires proteins known as enzymes, which act as catalysts that speed up a chemical reaction by providing an alternate reaction pathway that requires less activation energy. Some enzymes help information pass from DNA to RNA, while still others help build cell membranes and convert sugars into energy an organism can use.

In sum, all life uses the same set of nucleotides in its DNA and RNA alphabets, and the same 20 amino acids to make proteins. And that is just the beginning of organisms' chemical similarities.

MIXING AND MATCHING MOLECULES

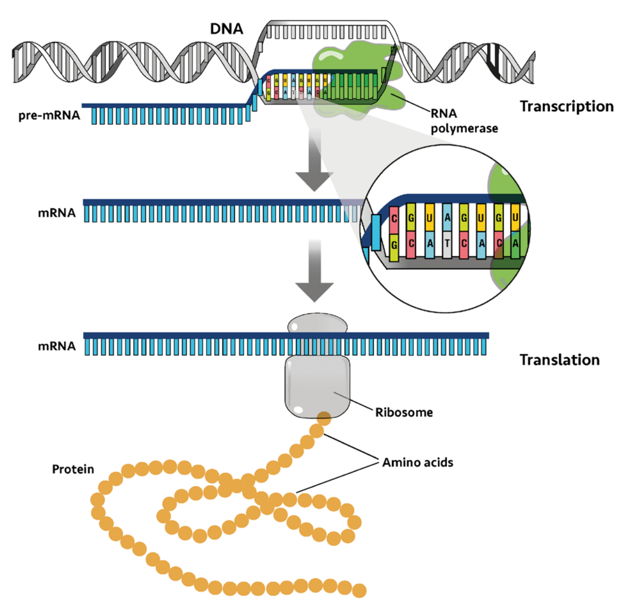
"The big problem for origin-of-life researchers," says Powner, "Is that you know where you want to get to—life and chemical systems that look like life and could operate like a cell—but you have very little idea of where you should start."

Earth formed 4.5 billion years ago. And for the next half-billion years—a period of time named the Hadean epoch after Hades, the Greek god of the underworld—the planet was an unfriendly place.

Volcanoes erupted continuously, asteroids and comets bombarded the surface, and the sun's radiation was relentless. But as the atmosphere formed and the planet began to cool, the chaos seeded the perfect chemical recipe for life.

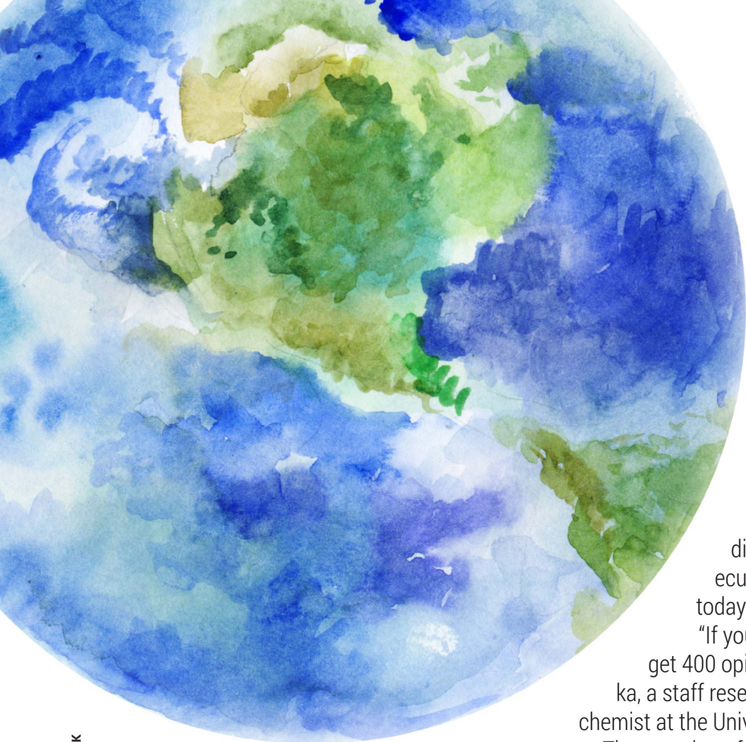
Scientists suspect that there was life on Earth by at least 3.5 billion years ago because of rocks called stromatolites. The oldest stromatolites might be remnants of the ancient ancestors of all life on Earth.

Stromatolites are funny-looking, bumpy, scaly, layered rocks that still form today when primitive, single-celled organisms secrete



CLODFELTER DESIGN

DNA is transcribed to RNA that is translated into a protein.



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You'll do lots of experiments over many years, and in 20 years' time, you'll look back and go, 'Oh, look, actually when you put all this together, that now all makes sense.' The continuum will then become obvious.

Matthew Powner

minerals, such as limestone (calcium carbonate, $CaCO_3$) and pyrite, or fool's gold (iron(II) disulfide, FeS_2).

"The history of how chemical evolution happened on early Earth has been destroyed by Earth itself and by life itself," says Ramanarayanan Krishnamurthy, a chemistry professor with Scripps Research Institute in California.

Krishnamurthy and Powner both study prebiotic chemistry—chemistry that plausibly could have taken place on the early Earth before life existed.

Various research and experiments have demonstrated that the types of molecules common to all life forms, such as amino acids and nucleic acids, can be made without biological intervention, as long as the essential ingredients come together in favorable conditions. Amino acids, nucleic acids, sugars, and lipid precursors have even been discovered trapped inside meteorites that formed billions of years ago!

Today prebiotic chemists like Powner and Krishnamurthy are curious about how these kinds of primitive chemical reactions can lead to the large and complex biopolymers in modern organisms that create chemical systems that involve RNA and proteins.

WHICH CAME FIRST?

At some point in Earth's history, basic molecules had to start assembling and replicating themselves in a way that would produce more self-replicating molecules. But what did those steps look like? You need proteins to make DNA and RNA, and you need DNA and RNA to make proteins.

You need metabolism to power life and the synthesis of DNA, RNA, and proteins, and you need proteins (and thus DNA and RNA) to drive metabolism.

You need cell membranes to keep DNA, RNA, and proteins in the right place, and you need DNA, RNA, and proteins to make cell membranes.

So, which came first? How did any of the biological molecules and processes that exist today get rolling?

"If you interview 400 people, you'll get 400 opinions," says Kamila Muchowska, a staff research scientist and prebiotic chemist at the University of Strasbourg in France.

The question of which molecules or processes came first is a major debate in origin-of-life science. Many scientists believe that gene replication was the key to getting life on Earth started.

Some even think that Earth was once an "RNA world," where primitive living organisms were made of and powered by RNA instead of proteins. Those organisms then "invented" proteins and metabolism to replicate themselves more efficiently.

Others, like Muchowska, are testing the hypothesis that primitive versions of metabolic reaction cycles influenced the initial creation of DNA and RNA.

Metabolism is the set of interconnected chemical reactions that harness and dissipate energy, and that create the molecules an organism needs to sustain itself, including the building blocks for DNA, RNA, proteins, cell membranes, and carbohydrates.

"Chemistry provides us with so many tools that we know how to build [these] molecules in a number of different ways," Muchowska says. "But if we mix them all together, and there is no energy flow that puts these molecules in motion, then we will not sustain in life."

Powner is more convinced by the "genetics first" hypothesis that assumes that the creation of DNA and RNA and their replication process is what led to the first life form.

"Life is everywhere, and lives off different molecules," he says. "It changes its metabolism in accordance to this. Some bits are near universal, but no bits are totally universal, and the biology changes in accordance with what it has available to it."

For Powner, the importance of DNA and RNA all comes back to the bacteria and the jellyfish.

"These are biologically as far apart as physically possible," he says, "but at the level of genetics, they are identical systems. I struggle to not take that into account."

Still, Powner says that every approach to research into the chemistry of life contributes to a big-picture understanding of where life came from.

WHERE IS THIS FIELD GOING?

There are so many ways that carbon-based molecules can react that Krishnamurthy says the point is not to identify the specific reactions that took place on the early Earth. In fact, he thinks that task is impossible.

Powner is more optimistic about scientists' ability to discover the chemistry that led to the origin of life. "I think you will learn how life started, but you won't know it when you do," he says.

"You'll do lots of experiments over many years, and in 20 years' time, you'll look back and go, 'Oh, look, actually when you put all this together, that now all makes sense.' The continuum will then become obvious," says Powner.

Krishnamurthy's and Powner's disagreement about whether we will ever know the chemistry of life's exact origins is just one of many disagreements among prebiotic chemists. Argumentation and debate are hallmarks of all of science, and there are still so many unanswered questions. Given that we will never be able to go back in time to get direct evidence, we have to do our best with the data available to explain how the story of life began.

Danielle Sedbrook is a freelance science writer based in rural southern Germany. She previously taught organic chemistry lab and lectured at Columbia University in New York City, where she also received her PhD in chemistry. Her last article for ChemMatters explored the philosophy of science.

REFERENCES

Nelson, D.L.; Cox, M.M. *Lehninger Principles of Biochemistry*, 8th Ed. MacMillan Learning, 2021; Chaps. 3, 8, and 13.

Cleaves, H.J. Prebiotic Chemistry: What We Know, What We Don't. BMC Series Journal, *Evolution: Education and Outreach*, September 27, 2012: https://evolution-outreach.biomedcentral.com/articles/10.1007/s12052-012-0443-9 (accessed August 2022).

Lane, N. *The Vital Question*. W.W. Norton & Company, New York, 2015.

Mesler, B.; Cleaves, H.J. *A Brief History of Creation.* W.W. Norton & Company, New York, 2016.

Prebiotic Chemistry and Early Earth Environments (PCE3): A NASA Collaboration. YouTube Channel: https://www.youtube.com/channel/UCltrERrfpO1LQ_LhewoFlsw (accessed August 2022).

CHEMISTRY IN PERSON

Keeping Us Safe

In 2020, as consumers snapped up every bottle in the early days of the COVID-19 pandemic, Kayla Ivey set to work. A product development scientist at GOJO Industries, a company that makes skin health and hygiene products, Ivey is the lead formulator for the Purell brand of hand sanitizer.

The company activated its demand-surge preparedness team in December 2019, in response to news of the virus that we now know as SARS-CoV-2. Over subsequent months, the company responded to staggering demand by adding multiple new facilities and hiring more than 500 extra employees.

Meanwhile, Ivey took on more projects than ever, including launching multiple new hand sanitizer products. In August 2021, she introduced herself on Twitter using #BlackinChemRollCall—a hashtag for Black scientists to talk about their expertise and their journeys in chemistry—and shared photos of two products she had developed. The tweet generated thousands of likes and scores of appreciative comments. *—Carmen Drahl*

AMANDA HEMSTREET PHOTOGRAPHY

KAYLA IVEY

B.S.: Chemistry, Kent State University
WHAT SHE DOES NOW: Product Development Scientist, GOJO Industries

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What general components make up hand sanitizer, and what's the purpose of each?
The main component is the active ingredient, the thing that's actually doing the germ-killing. In our sanitizer, it's mostly ethanol. The U.S. Food and Drug Administration sets the minimum concentration of ethanol in hand sanitizers at 60%.

For our gel sanitizers, we have gelling agents, usually water-soluble polymers. For the foam sanitizers, we have foaming agents, usually a water-soluble surfactant. The rest of the formula is mostly skin moisturizers.

Tell me how the early days of the pandemic unfolded for you.
The company ramped up manufacturing starting in January 2020. I remember having a meeting about the ramp-up at the end of that January, but at the time I didn't think it was that big a deal. The pandemic definitely elevated the use of hand sanitizer, and these new products met consumers' preferences for formulation and usage.

In a normal year, I would only have two or three projects, and usually we give ourselves one to two years for each one. Getting six new projects and being told that almost all of them needed to be launched within the next six to nine months was a little wild.

#BlackInChemRollCall Hi! I'm Kayla and I have a BS in Chemistry from @ksuchemistry I work in R&D at GOJO and am the lead formulator for Purell hand sanitizers. Here's me and my most recent launches #blackinchem

What was it like for your #BlackInChemRollCall tweet to, if you'll pardon the expression, go viral?
In 2020, I tweeted something very similar, and it got some likes. But, in 2021, almost the exact same tweet went a lot further. It was kind of shocking. I tweeted it and just went about my day. When I checked back, I saw a text from my uncle, who said, "Did you know your tweet's going crazy?" I think something that helped with the second tweet is that by that point, two new hand sanitizers I'd launched were on shelves. Some people were responding to the tweet to say, "I just bought this yesterday. That's so cool that you made this!"

How have you been using Twitter to encourage Black excellence in chemistry?
Because of that tweet, teachers and professors have invited me to speak to their high school and college chemistry classes. One of the main things I try to get across is how far you can go with a bachelor's degree, like me.

I was hired a week after I graduated. After starting at GOJO, I met scientists in advanced roles who only had a bachelor's degree, and I realized that I could work my way up.

Also, it wasn't until I got to college that I found out that a lot of science Ph.D. programs are funded and that you can actually get a stipend. I think some people are discouraged about even going into grad school for science because they think they have to fork over the money for it.

What has working during the pandemic taught you about yourself?
It taught me that I easily adapt to change, more than I thought I could. It pushed me out of my comfort zone.

The structure of working from home and social distancing helped me become a better bench chemist. We had to reserve lab time to make sure that there wouldn't be too many people in the lab at once.

When I was home, I did a lot of ideation before going into the lab, to make my lab time run as smoothly as possible. I'm a lot more confident in my abilities. I was able to make a final product with fewer iterations along the way, which as a chemist is very exciting.

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