the botany of desire

Based on the book by Michael Pollan

in the arms of Morpheus (intoxication)

In this lesson, students will explore the history and use of mind-altering plants as well as the science behind them. They will learn about the molecular structures and physiological effects of several of the drugs derived from plants. The lesson provides an opportunity and a forum for students to consider the consequences of intoxication.

in the arms of Morpheus (intoxication)

overview

Note to Educators:

The Botany of Desire *examines the human desire to alter consciousness by telling the story of cannabis, which is one of several psychoactive plants that affect our brains. This lesson focuses on another of those plants, the opium poppy, and explores the molecular structures of some of the drugs that are derived from it, such as morphine and codeine, or synthesized in labs. These drugs, which are regulated as controlled narcotics by the federal government, provide people who are sick or injured with effective pain relief, but can also lead to addiction. The purpose of this lesson is to provide tools that can help students better understand what happens when psychoactive plants alter the brain, and how the chemical compounds in those plants produce their effects. It also provides an opportunity and a forum for students to consider the consequences of intoxication. This subject of drugs and their mind-altering affects is clearly a sensitive and controversial one, not only for students but also for parents and other stakeholders in education. Therefore, we urge you to consider carefully the appropriateness of using this lesson plan in your school and community, and to have whatever discussions may be necessary before doing so.*

"In every culture and in every age of history, an enormous amount of human energy has gone into the production, distribution and consumption of psychoactive plants."

– Dr. Andrew Weil in

The Botany of Desire

In every society except the Inuit, whose climate is too harsh for vegetation, people have sought to change the way they experience the world by using a variety of mind-altering plants. Some of them, such as coca, poppy, and cannabis, are considered intoxicating because they can cause profound changes to our consciousness. Other plants that yield psychoactive products (products that affect the mind or behavior), like coffee, tobacco and tea, affect our thoughts and perceptions in subtler ways. The relationships between these various plants and the people who use them have evolved over time, both influencing and reflecting the values of the societies in which they are used. And all of these plants contain molecules that cause changes to the biochemical processes that go on deep inside our brains.

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overview

The opium poppy and the family of drugs that can be made from it present humanity with a paradox. Because of their remarkable effectiveness at relieving pain, opiates are a shining example of the good that plant drugs can do for us. But, unfortunately, opiate use can turn people into drug addicts. Opiates actually mimic chemicals produced by the brain. While the human body can tolerate these substances in low doses, our system cannot handle higher doses without extreme changes in biochemistry that ultimately lead to craving for them.

Opium itself is a resin that's naturally produced by the seedpods of a species of poppy flower called *Papaver somniferum.* In the early 19th century, a German scientist discovered the chemical that is opium's primary active ingredient. He named it morphine, after Morpheus, the Roman God of dreams, because it is so effective at inducing sleep. Morphine is also one of the most effective painkillers ever discovered. But doctors and patients soon realized that some people become addicted to morphine. In the late 19th century, scientists developed a chemical variant of morphine that they thought would be less addictive. It is called diacetylmorphine — but it is better known as heroin. Unfortunately, the scientists were wrong, and heroin turned out to be even more addictive than morphine. These two chemical cousins show how powerfully the molecules found in the opium poppy plant can alter what goes on in the human mind.

This lesson consists of two distinct and complementary parts. First, using movie clips from *The Botany of Desire* and then the online interactive feature Altering Consciousness, students will study the background science about these mind-altering plants. Next, students will explore the molecular structures of several of the drugs derived from plants, learn about their physiological effects on humans, and explore their portrayals in popular culture. Finally, using gumdrops and toothpicks, students will build several models of alkaloid compounds. These models will show how the number and position of carbon, hydrogen, and oxygen atoms on a benzene ring are all that separates one opiate compound from a close chemical relative that is more or less psychoactive.

This lesson is an opportunity to explore the connections between chemistry, culture, and anthropology. Both the film and the interactive web feature provide useful background information to help frame the students' exploration.

objectives

Students will:

- Explore the concept of humans' desire for mind-altering experiences (e.g., kids dizzying themselves, adventurers risking their safety, adults taking drugs).
- Discuss the impact of Tetrahydrocannabinol (THC) on the human brain.
- Discuss the importance of forgetting to the normal functioning of the human brain.
- Study information about a mind-altering drug and its active molecule to gather insights about:
    - The source plant for the molecule.
    - The history of the use of the drug.
    - Current uses for the drug (both positive and negative).
    - The representation of the drug in popular culture.
    - The physiological effects of the molecule on human beings.
    - The skeletal structures and ball and stick structures of the molecule.
    - Other interesting facts about the molecule.
- Construct molecular models of morphine, heroin, codeine, and THC to compare and contrast them.

grade level: Grades 9-12

subject areas:

Physical Science, Life Science, Biology, and Chemistry

National Science Education Standards

Science National Content Standard 1:
Science as Inquiry

As a result of activities in grades 9-12, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Science National Content Standard 2:
Physical Science

As a result of their activities in grades 9-12, all students should develop an understanding of:

- Structure and properties of matter

Science National Content Standard 5:
Science and Technology

As a result of activities in grades 9-12, all students should develop:

- Abilities of technological design
- Understandings about science and technology

Science National Content Standard 7:
History and Nature of Science

As a result of activities in grades 5-8, all students should develop understanding of:

- Science as a human endeavor
- Nature of science
- History of science

materials needed

- Overhead copy (or individual copies) of the reproducible *Chemical Structures: A Quick Tutorial*
- 6 bags of various-color gumdrops
- 6 boxes of toothpicks
- Clips from the film *The Botany of Desire* (available online)
- Access to the online interactive Altering Consciousness
- Digital camera (optional)

estimated time needed

120 – 150 minutes

background

The following background information on the opium poppy provides some context for this lesson. One of the oldest known pain remedies, opium, a resin that can be harvested from a particular species of the poppy plant, originated in the Fertile Crescent region, bordered on the east by the Tigris/Euphrates River basin and on the west by the Mediterranean Sea. A 6,000 year-old Sumerian text refers to the powerful little poppy.

In Homer's classic Greek epic *The Odyssey*, Helen spikes the wine of a grieving son with opium, suggesting that opium was also used as a remedy for depression.

In the early 19th century, a German scientist discovered morphine – the chemical that is the principal active ingredient in opium. Morphine has a much stronger effect on the brain than does raw opium and soon became one of medicine's most relied-upon painkillers. It also became a widely used treatment on battlefields, to soothe the excruciating pain of wounded soldiers.

But morphine also has a dark side: it makes many of its users into addicts. Those who took it over a sustained period found it very difficult to stop. If they tried to wean their bodies off the drug, they would become sick with chills, shakes and nausea – symptoms that would dramatically ease if they started using morphine again. The social and political battles over opium, and the drugs that can be made from it, stem from its dual nature as a pain reliever and cause of addiction. Between 1839 and 1842, Great Britain and China fought a war over opium. China had tried to halt the trade of the drug, which had made addicts of many of its citizens.

Scientists developed other pain-killing drugs from opium, such as codeine, which, like morphine, can be isolated directly from opium resin. Around the turn of the 20th century, the German pharmaceutical company Bayer brought to market a new opium derivative: heroin. First synthesized from morphine in 1874, heroin was thought to be (and was marketed as) less addictive than morphine. But by 1910, studies showed that heroin was not only no less addictive, but also faster acting and more powerful.

As scientists learned more about the ability of poppy-derived opiate drugs to treat pain, governments around the world began controlling these drugs more strictly. Nonetheless, during the 20th century, heroin became a popular recreational drug in many countries. Its use led to the deaths of celebrities such as Janis Joplin in 1970 and John Belushi in 1982.

Today, opium poppies are grown mainly in the "Golden Triangle" region of Southeast Asia (Myanmar/Burma, Thailand, and Laos) and in Afghanistan.

(Sources: *Napoleon's Buttons: 17 Molecules That Changed History* by Penny Le Couteur and Jay Burreson; http://www.pbs.org/wgbh/pages/frontline/shows/heroin/etc/history.html; http://opiates.net/)

The Molecule

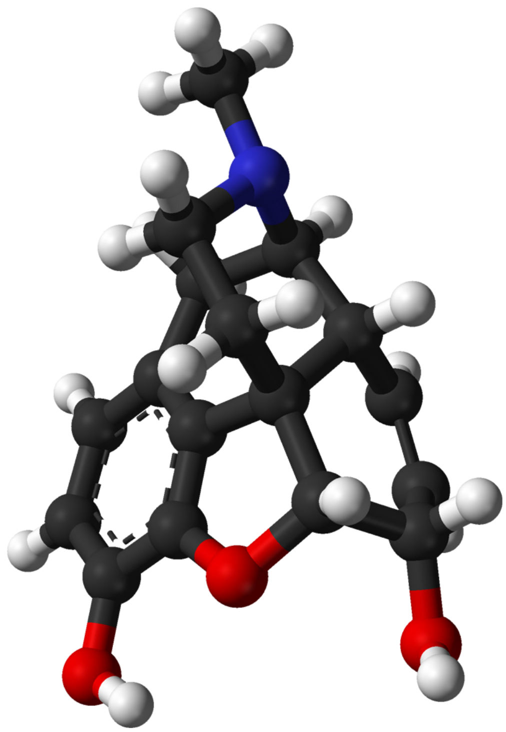


Image source: http://upload.wikimedia.org/wikipedia/commons/6/62/Morphine-from-xtal-3D-balls.png (Creative Commons)

The structures of morphine, codeine, and diacetylmorphine (heroin) are very similar, but the physiological effects of each of these molecules are different. Compare morphine to heroin and codeine. Heroin has a CH3COO group that replaces the HO of morphine and codeine has a CH3O that replaces the HO of the morphine at the upper left of the molecule.

Interactive Molecular Model online

Morphine (requires Java and/or CHIME plug in) http://www.worldofmolecules.com/3D/morphine_3d.htm

The Physiological Effects

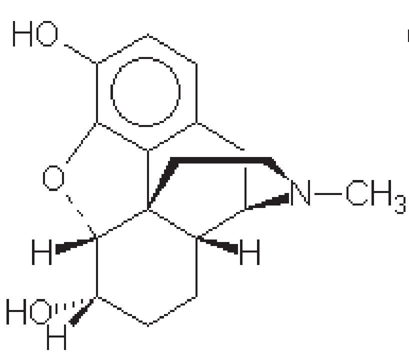
Morphine:

$\mathbf{C}_{17}\mathbf{H}_{19}\mathbf{NO}_{3}$ is a highly potent opiate used for pain relief. It is the principal active agent in opium. Like other opiates, such as diacetylmorphine (heroin) and the milder pain reliever codeine, morphine acts directly on the central nervous system.

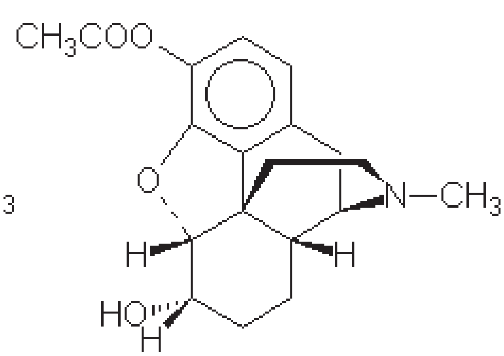
Morphine blocks pain receptors inside the brain, changing how it responds to pain messages traveling to it along nerve pathways from other parts of the body. In addition to euphoria and pain relief, morphine can also cause serious side effects such as nausea, constipation, and confusion. It can also cause addiction, inhibit respiration, and lead to unconsciousness, coma, and even death. Morphine is a powerful and dangerous substance.

Heroin:

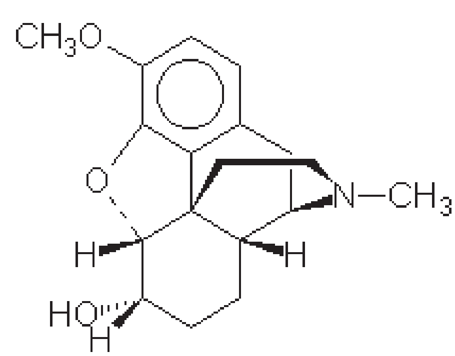
After an intravenous injection of heroin, users report feeling a surge of euphoria (“rush”) accompanied by dry mouth, a warm flushing of the skin, heaviness of the extremities, and clouded mental functioning. Following this initial euphoria, the user goes “on the nod,” an



Morphine



Heroin



Codeine

Image source: http://www.chm.bris.ac.uk/motm/atropine/alkaloids.htm#The%20Alkaloids alternately wakeful and drowsy state. Users who do not inject the drug may not experience the initial rush, but other effects are the same.

With regular heroin use, tolerance develops, in which the user's physiological (and psychological) responses to the drug decrease and more heroin is needed to achieve the same intensity of effect. Heroin overdoses frequently involve a suppression of respiration. Heroin users are at high risk for addiction. The NIH's National Institute on Drug Abuse estimates that about 23 percent of individuals who use heroin become dependent on it. Heroin can also cause serious side effects such as nausea, constipation and confusion. It can also lead to unconsciousness, coma, and even death.

Codeine:
Codeine is used medically to relieve moderate pain and suppress coughs. Codeine increases tolerance to pain, decreasing discomfort, but the pain remains apparent to the patient. In addition to reducing pain, codeine causes drowsiness and depresses breathing. Compared to morphine, codeine produces less analgesia (pain relief), sedation, and respiratory depression, and is usually taken orally.

In addition to euphoria and pain relief, codeine can also cause side effects such as nausea, constipation, confusion, unconsciousness, coma, and even death. Although not as addictive as heroin, sustained use of codeine can lead to addiction.

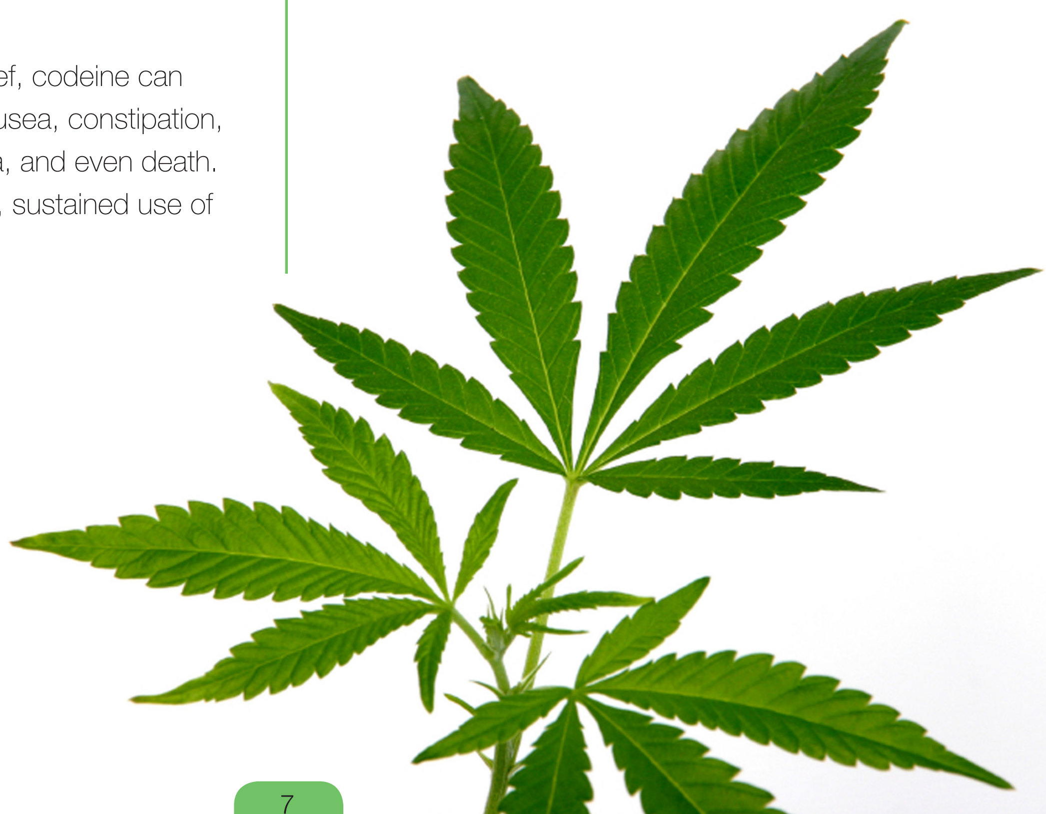
For more information on the effects of these drugs, visit the following sites:

http://www.drugabuse.gov/pubs/teaching/Teaching2/Teaching4.html

http://www.nida.nih.gov/infofacts/heroin.html

http://www.drugabuse.gov/ResearchReports/Prescription/prescription2.html#Opioids

http://www.unodc.org/documents/data-and-analysis/Afghanistan/Afghan_Opium_Trade_2009_web.pdf



Note to Teachers: To view the movie clips referenced in these steps, please go to this lesson plan's page on The Botany of Desire website at **http://www.pbs.org/thebotanyofdesire/lesson-plan-intoxication.php** *and choose the clip from the video player.*

Part 1: Intoxication Discussion (25 – 30 minutes)

1. *The Botany of Desire* film will help establish the scientific and anthropological focus of this exploration of psychoactive plants. As a class, view the following clips from the film and discuss the following questions:
    - *Clip 1 – Background on mind-altering compounds*
        - In the film, scientists assert that human beings have an innate drive to experience other states of consciousness. Do you agree? If so, why do you think that is? How do we most commonly explore altered mental states? What evolutionary benefits do you think there might be to this drive?
    - *Clip 2 – Drugs and culture*
        - Which drugs are tolerated in particular cultures? How have drugs been used in various cultures? How was cannabis used in the United States in the 19th century?
    - *Clip 3 – The impact of THC on the brain*
        - What is the psychoactive molecule found in marijuana and what does it do to the brain?
    - *Clip 4 – The importance of forgetting*
        - Why is forgetting important to the normal functioning of the brain? Part of the value of sleep is that it gives the brain an opportunity to process and organize the day's experiences – retaining some and discarding others. How does this understanding of sleep expand on the notion that forgetting can be good?

Part 2: Inquiry Path (10 – 15 minutes)

2. As a result of the discussion, students are likely to have questions related to the science of the mind-altering molecules. Questions on the physiological effects, on the specific molecules that are derived from the plants, on the reasons for the effects on the brain can form the basis of further investigation. Divide students into groups of 3 – 4 and assign groups to research one of the following molecules: morphine, heroin, codeine, and THC. Each group should identify the questions that they would like to explore to learn more about their assigned molecules, ultimately picking five questions to drive their inquiry.

Part 3: Molecular Research & Presentation (50 – 75 minutes)

<u>Note to Teachers:</u> *This section makes use of the Altering Consciousness web interactive available at* **http://www.pbs.org/thebotanyofdesire/altering-consciousness.php.** *Take some time to go through the interactive and familiarize yourself with its content, as it contains much of the information referenced in the lesson steps below.*

3. Provide each group with a copy of the document entitled: *Chemical Structures: A Quick Tutorial.* Additionally, review the octet rule and the concept of valence electrons.

4. In addition to having students answer the questions from Step 2, make sure they find out the following information:
   - The source plant for the molecule
   - The history of the use of the drug
   - The current uses for the drug (both positive and negative)
   - The representation of the drug in popular culture
   - The physiological effects of the molecule on human beings
   - Pictures of the skeletal and ball and stick structures of the molecules
   - Other interesting facts about the molecule

5. Provide each group with 2 – 3 minutes to present its findings to the rest of the class. Students should present their inquiry questions as well as the key findings of their research. In addition, encourage students to ask questions of each group and discuss similarities and differences in the different groups' research.

Part 4: Model Building (15 – 20 minutes)

Note: The Altering Consciousness web interactive will, once again, be a useful resource for this modeling activity.

6. Ask students to determine the total number of each type of atom they would need to build their molecule.
7. Ask students to choose four different colors of gumdrops to represent carbon, hydrogen, oxygen, and nitrogen.
8. Remind students of the following: Every molecule can be represented as a ball and stick and as a skeletal structure. Just remember when viewing these organic molecules that carbon and hydrogen atoms are found at the points where two lines meet. Carbon always "wants" to have four bonds — this desire can be satisfied by connecting to hydrogen or by increasing the number of bonds (double or triple bonds). Oxygen "wants" to have 2 bonds and hydrogen "wants" to have 1 bond. In this activity, toothpicks are the bonds and gumdrops are the atoms of carbon, oxygen, hydrogen, and nitrogen.
9. Ask each group to work together to build its assigned molecule using toothpicks and gumdrops.
10. When the molecules are complete, allow students to visit one another to see the finished products. As an option, digital photographs of the molecules may be taken and distributed to the class.
11. Ask the students to compare and contrast each of the molecules, looking for structural similarities and differences.

Assessment

Option 1: Evaluate the group presentations and the models of molecules on the basis of achieving the objectives of the lesson.

Option 2: Discussion or essay questions

Ask your students the following questions. Then, discuss their answers or have them submit them in writing.

1. Why do people desire intoxication? How have natural substances been used to fulfill this desire?
2. Sometimes the term "adrenaline junkie" is used to describe someone who enjoys dangerous activities that give him/her an adrenaline rush — a hormone-induced reaction that includes elevated levels of oxygen and glucose in the brain. You don't need to skydive to get a rush of adrenaline (also called epinephrine). Performing in front of others or participating in an athletic competition can also give you that rush. How would you describe an adrenaline rush to someone who has never experienced it? How does this differ from what you have learned about the effects of the plant molecules you researched?

References:

- Penny Le Couteur and Jay Burreson, *Napoleon's Buttons: How 17 Molecules Changed History*. New York: Jeremy P. Tarcher/Putnam, 2003.
- Pollan, Michael. *The Botany of Desire: A Plant's-Eye View of the World.* New York: Random House, 2001.
- National Institute on Drug Abuse
  http://www.drugabuse.gov/infofacts/heroin.html
  http://www.drugabuse.gov/pubs/teaching/Teaching2/Teaching4.html
  http://www.drugabuse.gov/ResearchReports/Prescription/prescription2.html#Opioids
- U.S. Drug Enforcement Administration
  http://www.usdoj.gov/dea/concern/codeine.html
- MedicineNet.com
  http://www.medicinenet.com/codeine/article.htm

Reproducible: Chemical Structures: A Quick Tutorial

Some plants can affect the way we think and feel because of the organic compounds they contain. Organic compounds are those that contain the element carbon and are associated with living organisms. Organic compounds are made of only a few different types of atoms: carbon, hydrogen, oxygen, and nitrogen.

Carbon – Symbol C
Hydrogen – Symbol H
Oxygen – Symbol O
Nitrogen – Symbol N

One of the simpler organic molecules is methane or CH4. This gas is released as a result of decomposition in swamps or in our stomachs. When we pass gas, we are giving off methane.

Organic molecules can be represented in skeletal structures — the letter symbols for the atoms can be connected with lines that represent bonds. (Or, they can be represented in 3-D with ball and stick models or gumdrops and toothpicks.)

Immediately below is the skeletal structure of methane. We can tell by looking at it that it is made up of 1 carbon atom bonded to 4 hydrogen atoms.

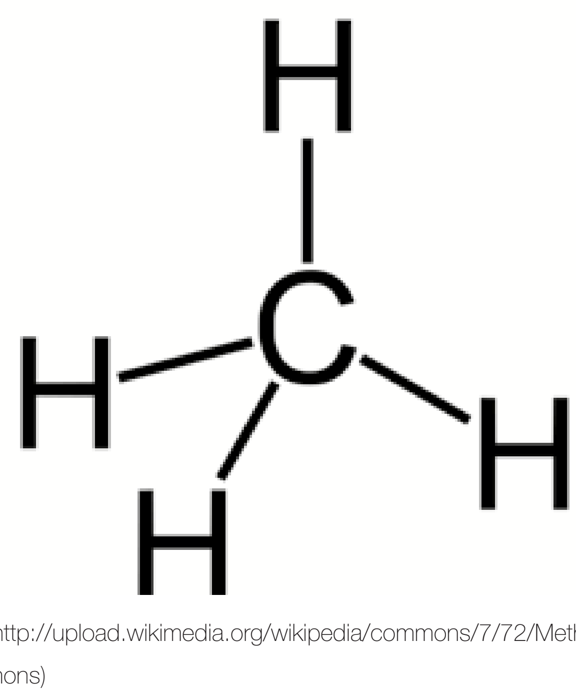


Image source: http://upload.wikimedia.org/wikipedia/commons/7/72/Methane-2D.svg (Creative Commons)

In ball and stick models, white represents hydrogen; black represents carbon; red represents oxygen; and blue represents nitrogen. Below is the ball and stick model of methane.

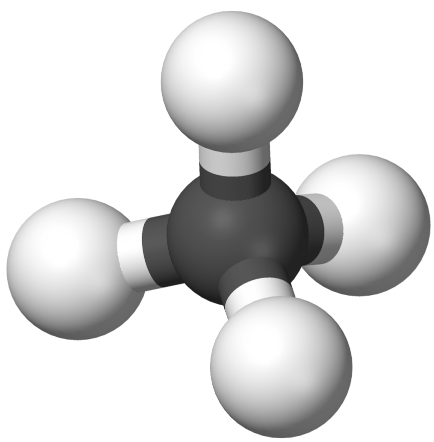


Image source: http://upload.wikimedia.org/wikipedia/commons/5/58/Methane-3D-balls.png (Creative Commons)

Organic molecules are made of many atoms. Chemists had to find ways to represent these molecules without writing out all of the symbols. For example, you will find a benzene ring in many of the skeletal structures of the molecules found in plants. The benzene skeletal structure looks like this:

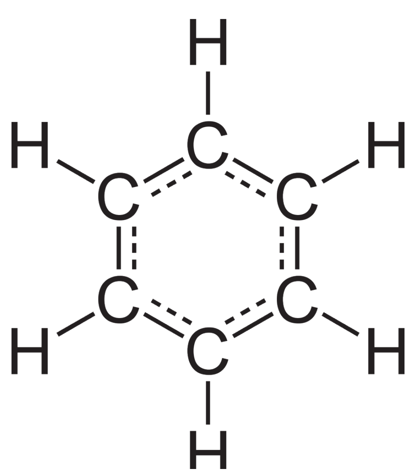


Image source: http://upload.wikimedia.org/wikipedia/commons/2/23/Benzene-2D-flat.png (Creative Commons)

However, scientists also like to write it in a shorthand version that looks like this:

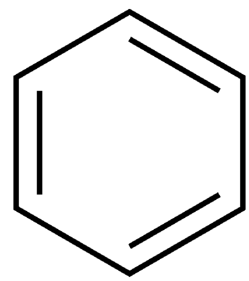


Image source: http://upload.wikimedia.org/wikipedia/commons/f/f1/Benzene_ring.png (Creative Commons)

Even though the carbons are not shown with letter "Cs" in this structure, there are six of them: one at each "point of the hexagon." In addition, the double lines on three of the sides of the hexagon represent double bonds. And there are hydrogen atoms at each of the points of the hexagon, too.

The ball and stick version of benzene looks one of two ways:

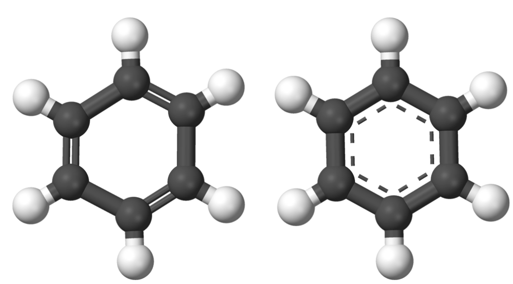


Image source: http://upload.wikimedia.org/wikipedia/commons/a/a3/Benzene-aromaticity-3D-balls.png (Creative Commons)