Chain ReAcTion 7

Stories of Science and Learning from Arizona State University

People and Environment: **Our Heat Habitat**

How to keep your cool

What does heat look like?

Catch a wave... in the desert

Is it getting HOT in here?

Many of the largest and fastest-growing cities on Earth are located in hot places. Big cities make temperatures even higher through the urban heat island effect. The "island" is made up of buildings and roads, houses and parking lots. These human-made materials absorb the sun's warmth during the day. They keep temperatures high, even in the dark of night when surrounding areas cool off.

Scientists at Arizona State University are studying the heat island in Phoenix, Arizona. The city is located in the Sonoran Desert, one of the hottest places in the United States. They hope to find ways to keep cities cooler and help people who are most harmed by the heat. By understanding the heat island in Phoenix, they can help us understand the problems that other cities face, too.

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Bangkok, Thailand was named the hottest big city in the world by the World Meteorological Organization. The city has a population of more than 9 million and an average daytime high temperature of 95 degrees Fahrenheit. Rising pollution levels trap even more hot air in the city.

Action! 7

Chain Reaction: A series of chemical reactions in which the products of each reaction activate additional molecules of the reactants, thus causing new reactions...

chainreactionkids.org

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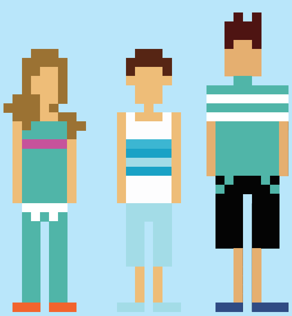
catalyst

CATALYSTS make things happen. They speed up reactions and make some ingredients combine that could not without them.

Human | Nature

By Sharon Harlan and Diane Boudreau

There are more than seven billion people on Earth today! Every one of us wants to eat food, drink water, wear clothes, travel around and get rid of trash. All of these things have an effect on the environment around us. But we don't fully understand what all of those effects are or how they will change the future.



Anthropocene comes from the Greek word "anthropos," which means "human." The suffix "cene" means it's part of the Cenozoic Era, the most recent geologic time period.

Can you think of any other words that start with "anthropo?" What do they mean?

Some scientists call this the **Anthropocene Epoch**. It's their way of saying that people are driving many big changes in the planet's natural systems. For example, there are more greenhouse gases in the atmosphere. There are fewer forests and wilderness lands. And coral reefs are disappearing from the oceans.

Scientists have known about many of these changes for decades. But they are only beginning to discover how closely connected people are to nature. They have created a new kind of science called coupled natural and human systems. They use it to study complex environmental challenges that affect our planet and all the living things on it.

The new science traces the human causes of environmental changes. It also studies how the environment affects us, in turn. The two-way link is called **feedback**.

Climate is a good example of a feedback loop. Human activities change the climate both globally and locally. And the changing climate affects how much water we have, what kinds of crops we can grow, how much energy we use and how healthy we are.

Global climate change affects the whole planet. But on a smaller scale, cities are getting hotter than the areas around them. Some are becoming "islands" of heat.

Phoenix, Arizona is one of these **urban heat islands**. In the desert wilderness, hot summer days turn into cooler nights after the sun sets. But in the city, human-made structures such as buildings, roads and parking lots hold onto daytime heat, releasing it slowly. As a result, temperatures stay high even in the dark of night.

In addition, cars, factories and even air conditioners release extra heat into the environment, adding to the heat island effect.

Many of the largest and fastest-growing cities on Earth are located in hot places. As scientists learn about the heat island in Phoenix, they can help us understand the problems that other cities face, too.

A team of researchers led by scientists at Arizona State University (ASU) is studying the heat island in the Phoenix metropolitan area. They are asking:

- How do different kinds of land cover affect temperatures?
- How are temperature differences among neighborhoods related to **socioeconomic status**?
- How does extreme heat affect people's health?
- How have these relationships changed over time? How might they change in the future?
- How can people adjust to climate in ways that are healthier for them and their environment?

Answering these questions requires information and tools from many different fields, such as ecology, sociology, geography, mathematics, computer modeling, geophysics and medicine. There are more than 20 scientists and educators working on the "Urban Vulnerability to Climate Change" project, or **UVCC** for short.

Their research will help people in Phoenix as well as other cities that are becoming heat islands.

This magazine is all about the UVCC study. You will learn how all of the scientists work together and share their skills to come up with answers that can help us understand heat and improve human health—in Phoenix and beyond.

"This study is a really nice example of the kind of work that scientists who come from a different range of disciplines can do when they sit down and talk to each other."

– Will Stefanov, NASA Johnson Space Center

What is socioeconomic status?

Social scientists study many aspects of people, such as culture and behavior. One measurement they use is socioeconomic status (SES). SES describes the social and economic position of a family or a neighborhood compared to others. SES is often measured as a combination of:

- Family income
- Education level (adult head of family)
- Occupation (adult head of family)

Heat island or climate change?

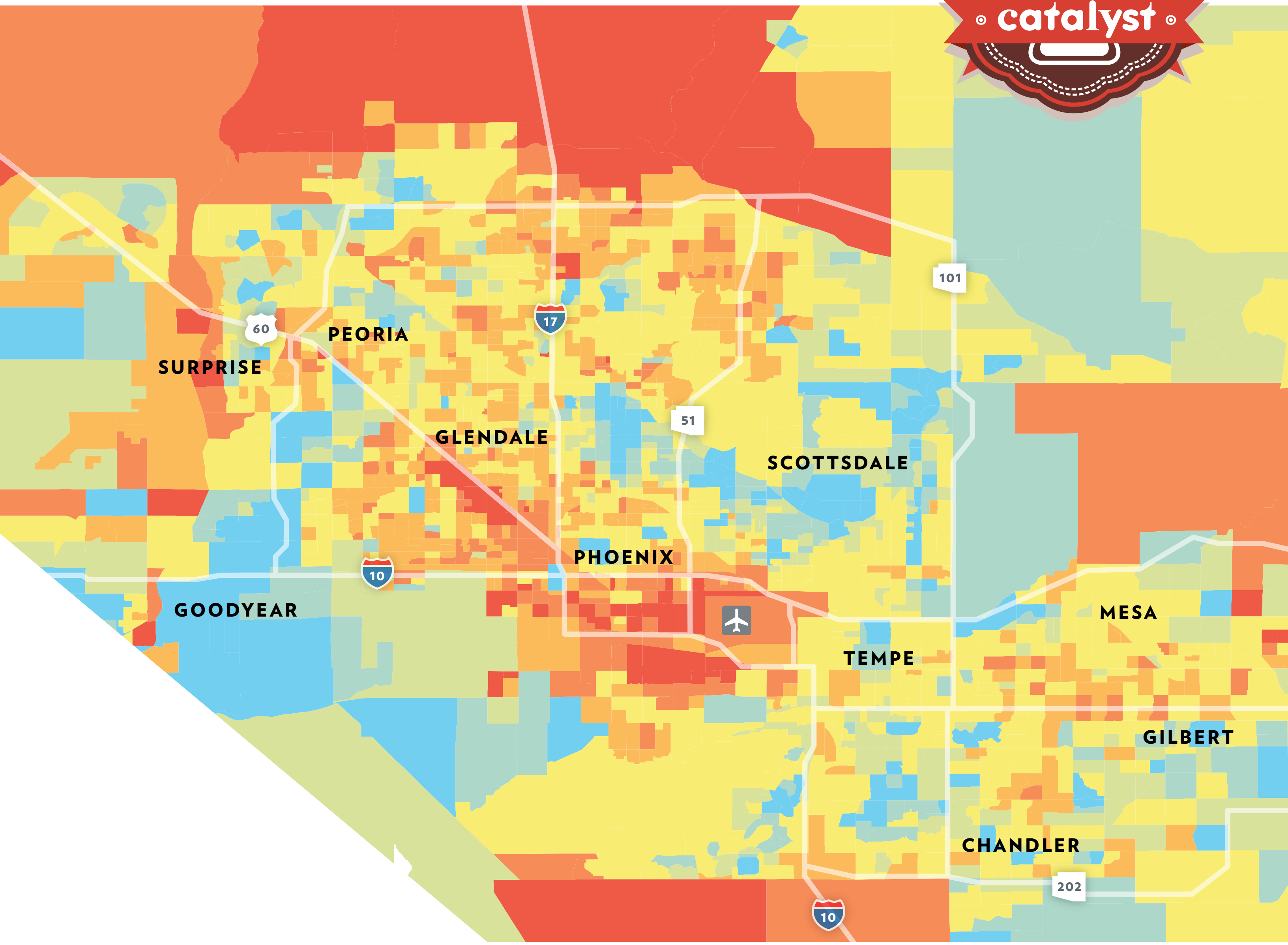
Global climate change and urban heat islands are both examples of how human beings can influence the climate. But they are not the same thing. Global climate change affects the whole world. Urban heat islands are limited to individual cities.

Human beings have an effect on both global climate change and heat islands, but in different ways. Global climate change is largely caused by greenhouse gases in the atmosphere. The most abundant greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide and ozone. People add greenhouse gases to the air by burning fossil fuels, cutting down forests and raising livestock.

The urban heat island is not caused by greenhouse gases. People affect heat islands mostly through the materials they use in building and paving. In addition, waste heat from cars, factories and air conditioners contributes to the heat island.

Hot in the City

By Diane Boudreau



	44.1 - 51.3°C	111.4 – 124.3°F
	51.4 - 52.2°C	124.5 – 126.0°F
	52.3 - 53.2°C	126.1 – 127.8°F
	53.3 - 55.2°C	127.9 – 131.4°F
	55.3 - 56.1°C	131.5 – 133.0°F
	56.2 - 57.1°C	133.2 – 134.8°F
	57.2 - 58.9°C	135.0 – 138.0°F

This map shows land surface temperatures in the Phoenix area taken by satellite on July 24, 2000 at 11 a.m. The surface temperature is the temperature you would feel if you touched the ground. Do you think the air temperature a few feet off the ground was cooler or hotter than the surface temperature?

Summertime rolls into Central Arizona with as much welcome as a pimple on prom night. While people in other parts of the country head outdoors for picnics and baseball games, Phoenicians hole up in air-conditioned buildings. Temperatures soar above 100 degrees Fahrenheit for months at a time.

Phoenix is located in the Sonoran Desert, which is known for its hot, dry climate. But the Phoenix metro area gets an extra helping of heat because it is an urban heat island.

But the heat island isn't exactly the same everywhere. Some neighborhoods within the city are hotter than others. The map above shows surface temperatures taken by satellite on a July day. You can see that temperatures vary across the metro area.

The reason for these differences has to do with land cover—the things people build or plant on the ground. Darren Ruddell, a spatial scientist at the University of Southern California, studied air temperature and land cover in 40 different Phoenix-area neighborhoods in July 2005. He worked with Arizona State University (ASU) sociologist Sharon Harlan and computer modeler Susanne Grossman-Clarke. They divided land cover into four categories:

- desert (undisturbed natural land)
- xeric (homes with "desert landscaping")
- urban (business and industry)
- mesic (homes with mostly grass landscaping)

They found that urban and xeric landscapes were hotter than mesic and desert areas. This might come as disappointing news for people trying to conserve water by xeriscaping their yards. Ruddell says that xeriscaping might not always be the best environmental decision.

"You change the landscape and then these neighborhoods become hotter. So people use the air conditioner more and for longer periods," he says. "And water is used in generating the electricity that runs the air conditioner."

In some inner-city neighborhoods, neither grass nor desert landscapes are common. Instead, these areas sport layers of concrete or simply bare soil. These are the hottest neighborhoods of all.

The UVCC scientists used airplane and satellite images to find out what kinds of land cover are used in different parts of metro Phoenix. They also looked at information from the U.S. Census to learn about the socioeconomic status (SES) of people living in those neighborhoods. They compared all of this information to temperature data.

They found a correlation between socioeconomic status and temperature. A **correlation** measures how strongly two things are related to each other. As SES gets lower, temperatures get higher. As SES gets higher, temperatures go down.

Unfortunately, people in low-SES neighborhoods may not have many resources for coping with the heat. For instance, they may not be able to afford air conditioning. They are also more likely to work outdoors in jobs like construction or landscaping. These things expose them to more heat.

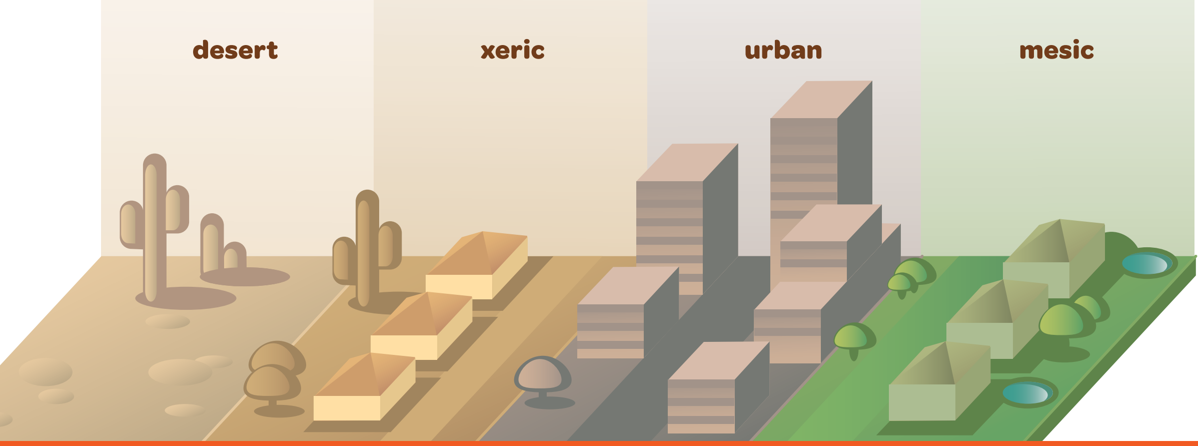
"It's an environmental justice issue," says Harlan. "The people who are most vulnerable are also living in the hottest conditions."

The scientists are also looking at how the heat affects human health. They want to find out who is at the most risk from the heat, so they can help community members create solutions. For example, cities might add more grass and trees to cool low-SES neighborhoods.

Redesigning neighborhoods is not as simple as it sounds, however. Growing trees requires time and money, but time and money don't grow on trees. A lush landscape requires water, which costs money, and time to care for it.

Another possibility is improving heat wave warning systems. "Right now, the heat wave warning systems aren't that effective," says Ruddell. "They're applied at really broad scales. With the information that we have we could be a lot more effective. We could identify areas that are vulnerable and set up aid stations there."

Harlan adds: "Designing better social and environmental policies for cities should help reduce the intensity of urban heat islands as well as reduce human vulnerability to heat."



How Heat Hurts

By Allie Nicodemo

Your palms are sweaty, your mouth is dry and you feel dizzy. Could heat be the ***culprit?***

There is a silent killer radiating through cities all over the world. It leaves no path of destruction. It is invisible to the human eye. It doesn't flood homes, rip trees from the ground or topple buildings over. But it kills more people than any other weather-related disaster.

The culprit is heat, and it's responsible for hundreds of deaths each year. While a sunny day might feel nice after a long winter, too much heat can be harmful to your health.

"Human beings are like all animals – they have a range of temperatures at which they can function best," says Diana Petitti, a medical doctor and professor at Arizona State University (ASU). "If it's so hot that you can no longer adapt, all sorts of bad things can happen."

You may have heard of the term **heat stroke**. This happens when the human body gets too hot. What's actually happening to the body during a heat stroke?

On a hot day, your body goes through changes to help it adapt. First, you sweat. Your body produces sweat because it's trying to stay at a comfortable 98.6 degrees Fahrenheit. As liquid sweat molecules appear on the skin, they change to gas molecules. This process is called **evaporation**. As the gas molecules leave your body, they take a little bit of heat with them, cooling you down.

When your brain registers the loss of fluid from sweat, you become thirsty. You might reach for a bottle of water to quench your thirst. But water isn't enough to replace the lost fluids, because sweat also contains important salts and sugars. If you drink too much water without taking in those other nutrients, you can dilute the calcium and sodium in the fluid outside your cells. This can cause the cells to swell up—including cells in your brain!

But it's a dry heat!

Not all heat is created equal. The amount of moisture in the air—humidity—can change how hot a temperature feels. A dry 90 degrees Fahrenheit in Arizona doesn't feel as bad as the same temperature in muggy Mississippi.

Weather forecasters use the term "heat index" or "apparent temperature" to describe how hot it actually feels outside. Learn more at: http://www.nws.noaa.gov/os/heat/

This kind of "water poisoning" is rare. But it's best to have juice or a sports drink when you've been sweating a lot more than usual.

If you ignore the feeling of thirst and fail to replace the fluid lost from sweat, your body will send out more serious warnings. You might start to feel tired, dizzy and lightheaded. These are signs that you're becoming dehydrated.

"Your body is trying to tell you to get out of the heat, drink more, get some salt and rest," Petitti says.

Dehydration means your body doesn't have enough fluid to work properly. This can lead to hyperthermia, when your body temperature rises so much that sweating alone cannot bring it back down. Hyperthermia causes fever, and if that fever gets too high, it can cause a type of seizure called a convulsion. "That can lead to shock, coma and sudden death," Petitti says.

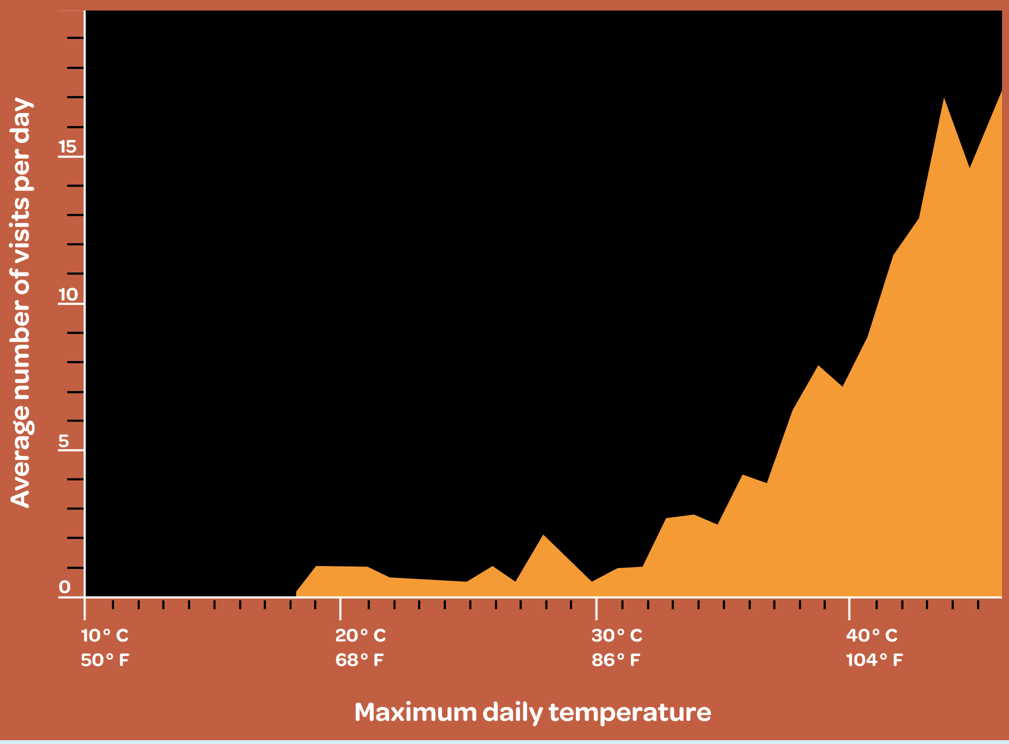
Severe heat strokes are rare, however. Doctors can usually treat patients before their symptoms become too serious. But certain groups of people are more at-risk from the heat than others.

For example, elderly people and infants are both more likely to suffer bad effects from heat. As the body ages, it has a harder time regulating temperature. Elderly folks also don't always realize they're thirsty. This makes them prone to dehydration. Infants are another high-risk group because they can't tell anyone when they need something to drink.

Certain medications can also make a person more likely to get dehydrated. Some drugs prevent sweating. Others make people less aware of the heat so they're less likely to drink fluids they lose from sweat.

People living alone without air conditioning are also more at risk of getting heat stroke, especially if they have no one to check on them. When a heat wave strikes, these people are especially vulnerable.

Heat-related emergency room visits in Maricopa County, Arizona during the summers of 2008 and 2009 (May-Oct.)



The maximum daily temperature was higher than 40° C (104° F) on 135 days. That's 36.7 percent of the whole time period.

There were 2,499 total visits to the emergency room for heat-related symptoms during this period.

In 1995, more than 700 people died during a heat wave in Chicago. In 2003, a massive heat wave that spread across Europe killed more than 30,000 people. These disasters sparked a movement to protect people against the dangers of heat.

"Public health officials realized that these deaths are preventable," says Sharon Harlan, a sociologist at ASU.

In the future, we will probably see more frequent heat waves with even higher temperatures. In order to plan for these events, public health officials must be able to predict how large the effect of the heat wave will be. This is hard to do, because the number of people who die from heat-related causes is hard to count. That's where scientists like Gerardo Chowell-Puente come in.

Chowell-Puente is a mathematical epidemiologist at ASU. He develops mathematical models to study different ways of dealing with events like epidemics or natural disasters. The models tell him which ways are most likely to be effective.

He is working with Harlan and Petitti to understand the connection between temperature and rate of heat illness or death. He studies death certificates and hospital records to find out what caused people's deaths and illnesses.

Chowell-Puente also uses climate data over a number of years. He creates graphs and maps to compare the data to see if there is a connection between health, temperature and location. And in Phoenix, there is.

All over the United States, families of similar socioeconomic status are likely to live in the same neighborhoods. This is partly based on the types of houses people can afford. Neighborhoods are often separated by race and ethnic group, as well.

Some families cannot afford a home with air conditioning, making it hard to cool off inside during the summer. Their neighborhoods have fewer trees, plants and open spaces like public parks that help to cool the outdoor environment.

Some people work in jobs that expose them to the heat, like landscaping and construction. "Many deaths from heat exposure in Maricopa County, Arizona, happen outdoors. People who work outdoors and homeless people who live outdoors are especially at risk," Harlan says.

The models Chowell-Puente creates will help find the people and the neighborhoods that are most affected by extreme heat. With this information, public health officials can do a better job of predicting which people are in danger when a heat wave strikes. Then they can create plans to help save lives.

"We are pointing out the connections between social and economic inequalities and exposure to extremely hot weather. I am hoping that our research will raise awareness of the impact the local environment has on people's health and guide our efforts to create solutions to the problems." Harlan says.

Keep Your COOL

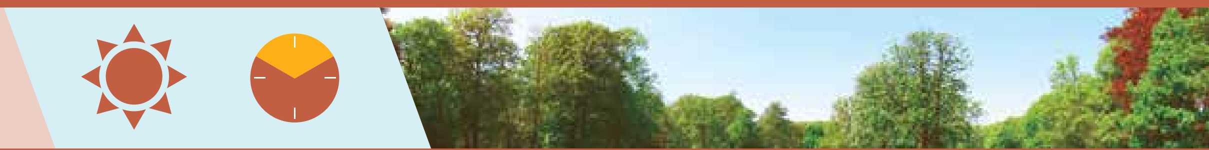
Planning to be out in the heat?
Follow these tips to stay healthy and safe:

1 Drink plenty of fluids —2 to 4 glasses per hour.

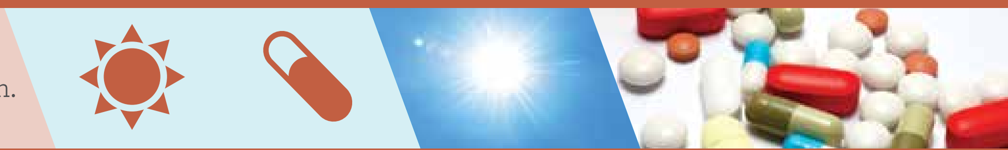
2 Replace salts and minerals with a sports drink.

Protect yourself from the sun with a wide-brimmed hat, sunglasses and a broad-spectrum sunscreen.

Avoid going out in the sun between 10 a.m. and 2 p.m.



If you take medicines, ask your doctor if they make you vulnerable to heat or sensitive to sun.



6 If you babysit, keep a close eye on infants and young children. They can't always tell you when they need a drink or a rest.

7 Never leave pets unattended in the car. Make sure outdoor pets have water and shade available.

8 Check in with elderly or sick friends and neighbors.

9 Learn the signs of heat stroke—high body temperature; red, hot and dry skin; rapid pulse; headache; dizziness; nausea; confusion; unconsciousness.

10 If someone shows signs of heat stroke, call for help. Move the victim into a shady area and lower their body temperature with cool water or wet cloths. Do not give them anything to drink.

Paving the Way to a Cooler Future

By Pete Zrioka

Do you ever walk across a parking lot on a summer night and feel heat radiating upward? This happens because the pavement soaks in the sun's heat during the day. It holds onto that heat and releases it well into the night.

Cities contain lots of pavement and other man-made materials that hold onto heat. As a result, they can be as much as 20 degrees Fahrenheit hotter than the surrounding countryside. This temperature difference is called the urban heat island effect.

High temperatures cause a spike in energy use as people try to keep cool. This costs money and contributes to air pollution. The heat island effect also causes more heat-related health problems. And of course, extreme heat is just plain miserable.

Heat islands develop as cities and towns grow, replacing plants and natural landscapes with roads, buildings and pavement. Built-up areas do not hold water as well as the natural landscape, causing them to collect more heat and hold onto it longer. These man-made materials—particularly roads— are major contributors to the heat island.

"If you look at the surfaces in an urban city like Phoenix, sidewalks, parking lots, roadways and highways are about 40 to 45 percent of the overall landscape cover," says Kamil Kaloush, a professor of engineering at Arizona State University (ASU). "That's why we should think about roadways when we talk about the urban heat island effect."

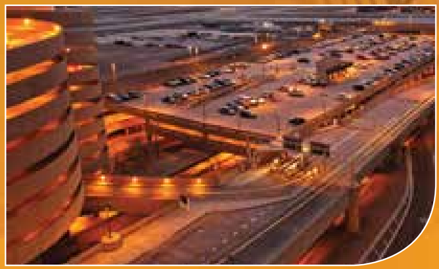
Kaloush is the director of ASU's National Center of Excellence for SMART Innovations, which looks for engineering solutions to environmental problems. Researchers at the center study alternative pavement materials and designs. They want to keep paved surfaces cooler during the day and reduce the amount of heat they release in the evening.

"When I think about the urban heat island, I think about a nighttime phenomenon," says Kaloush. "During the day most materials are hot. But what we're concerned with here in the Southwest region is the nighttime. When people go to their homes and get active with outdoor activities, you really want to have a cool environment as much as possible."

Kaloush has found that some types of pavement absorb more heat and hold onto it longer than others. Two basic properties cause these differences: a material's density and its reflectivity.

Density is how tightly a material is packed into a space. It is measured as mass per unit of volume. For instance, a rock is denser than a crumpled piece of paper of the same size. When it comes to pavement, density is determined by the amount of space between each piece of rock that makes up the pavement.

The above images show the infrared (heat) radiation coming from a highway interchange in Phoenix. The hottest areas appear in yellow, while the coolest areas are purple. The image on the left was taken during the day, while the image in the center was taken at night. The roadways are not the hottest surfaces during the day, but at night they continue to radiate heat while the surfaces around them cool down. On the right, you can see a photo of the highway.



“Usually, dense materials conduct heat at a faster rate,” says Kaloush. “Depending on how thick and how large a material is, it can retain heat much longer than a porous material.”

A porous material is the opposite of a dense one. It has more space between its components, which allows heat to escape faster. Imagine that you’re trying to make your way through a forest. If the trees are tightly packed, it will take you much longer to get out than if the trees were spread out. The same principle applies to materials. If there isn’t a lot of space to move, the heat will stay put.

“With dirt or gravel, it might be hot during the day but at night it cools down because it is loose material with air pockets,” says Kaloush. “So anytime you have a large, dense mass, it will have the tendency to keep that heat in the material, slowly re-emitting it into the atmosphere.”

Reflectivity is how much light bounces off a surface instead of being absorbed. It also plays an important role in a material’s temperature. Materials that reflect more stay cooler. White or light-colored surfaces reflect more light than dark ones.

So if we know what contributes to the heat island effect, why aren’t all of our roads made of light-colored, porous materials?

“You have to be careful,” cautions Kaloush. “You really have to think about the project and the issues at hand. There’s not really one solution that fits all.”

Roads must stand up to the wear and tear of traffic. Denser materials hold up better under lots of use. Simply making materials lighter in color presents challenges as well. The light would be reflected, lowering the temperature of the pavement. But in some cases it could be reflected up toward people walking on it. Kaloush compares it to getting sunburned at a ski resort when the light reflects off of the snow.

How and where materials are used also makes a difference in how much heat they release in the evening. Kaloush discovered this when he saw a nighttime satellite image of Phoenix, which revealed the hottest surfaces of the city.

“I was surprised to see that you have a good footprint of the road network standing out as a hot surface at night,” said Kaloush. “So I was very interested to look into this further. More importantly, I was looking at different highways and I was seeing some are cooler than others. So I was really curious to know what makes one section of a highway cooler than another section?”

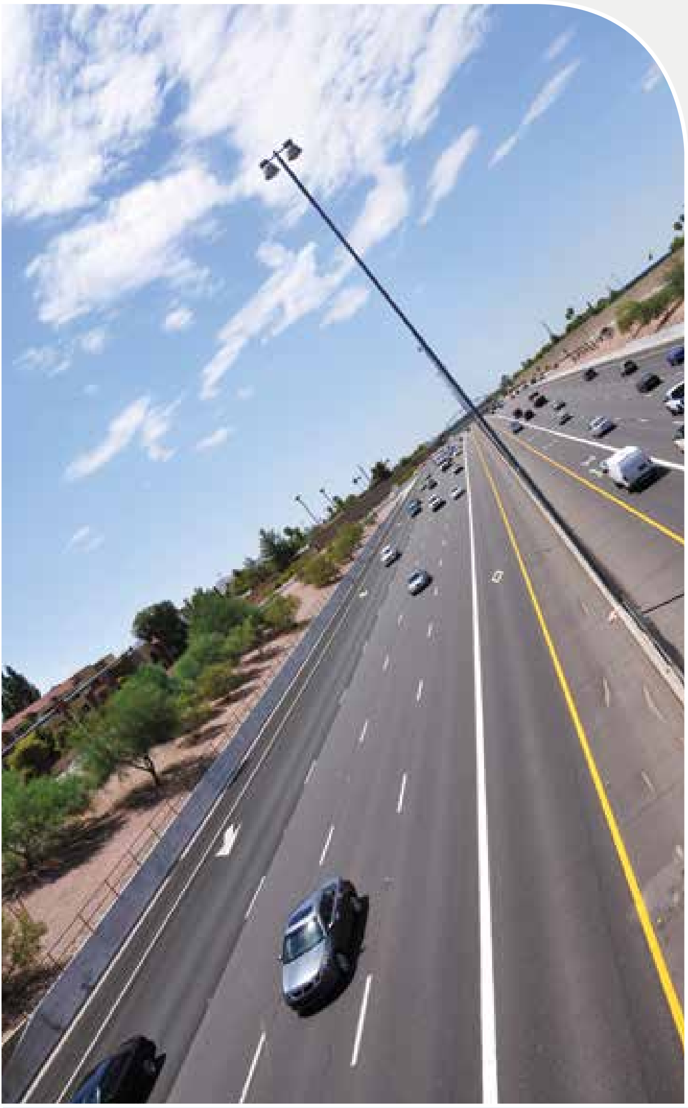
He found that highways that run lower in the ground than others tend to be hotter. The sound walls that surround them to trap traffic noise also trap the sun’s heat. They release it into the atmosphere later than highways at ground level or without sound walls.

The amount of traffic on a highway also plays a role in its temperature. Cars and trucks on the road can increase air temperature from engine heat and emissions. However, they actually make the pavement surface cooler.

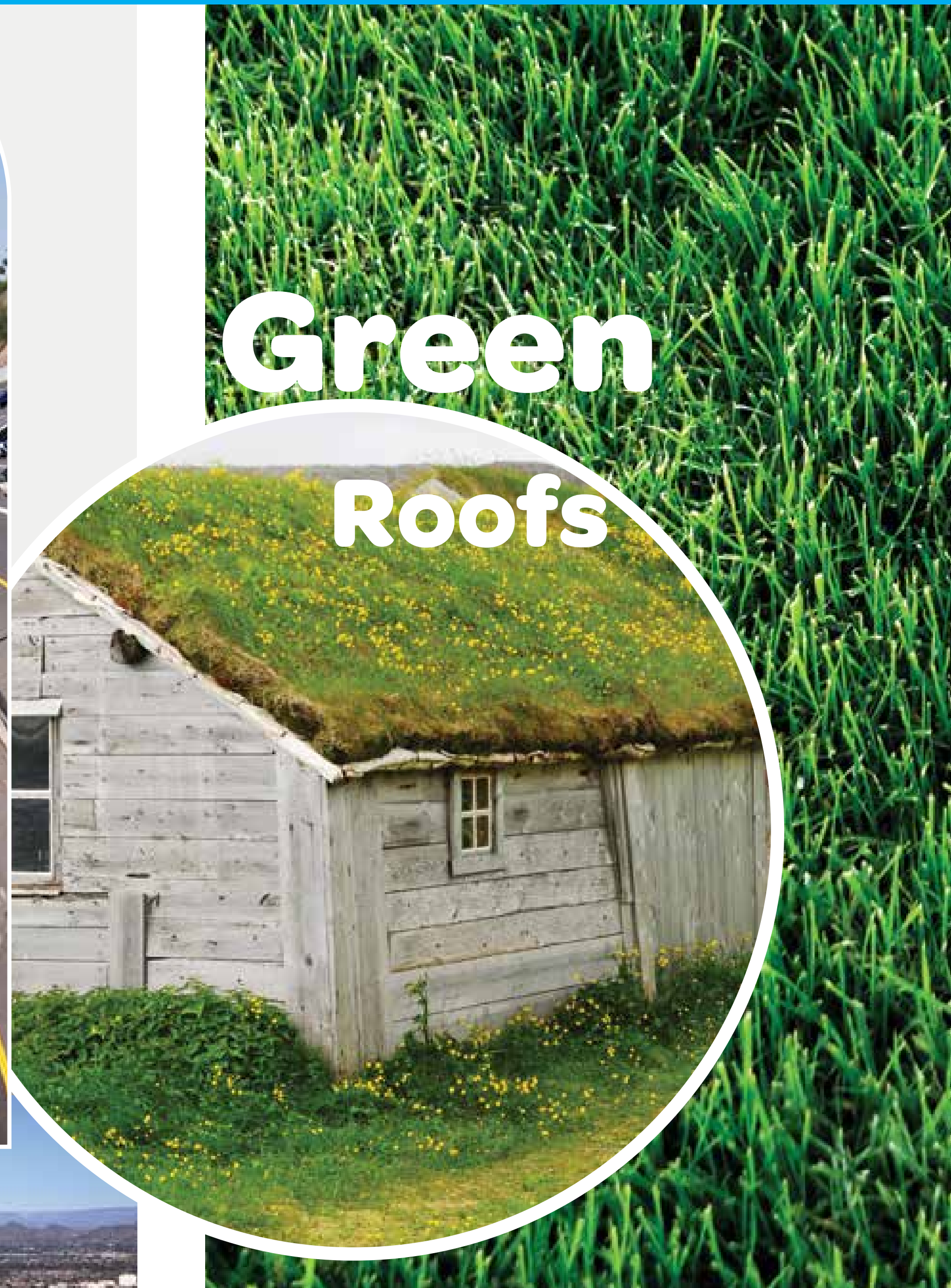
“In the beginning, I thought the traffic would only contribute to the heat, with the heat of engines and such—but I was wrong,” says Kaloush. “The movement of the cars actually helps cool the surface of the roadways. So if you have more traffic it cools down much faster, compared to a parking lot with no traffic.”

The materials used to make the pavement, where they are located, and how we use them all influence the urban heat island effect.

“Roadways are a big part of the urban landscape, and we can design them in different ways that actually work for our benefit,” says Kaloush. “Having all roadways white or black is not going to be the solution for all. We need to think through and evaluate different designs that are best suited and effective for what you are trying to achieve overall.”



Green Roofs



A green roof is a roof that is covered with plants. Green roofs were first used in Scandinavia. They became popular in Germany in the 1960s. Today, 10 percent of German houses sprout plants from their peaks.

In the U.S., NASA scientists have been studying green roofs as a way to reduce the heat island in New York City. They found that high temperatures for typical rooftops are 34 degrees F (20 degrees C) hotter than green roofs during the day. Buildings with green roofs were also 4 degrees F cooler inside during the summer.

What would be some pros and cons to using green roofs in a desert city like Phoenix?

The Coolest Hangouts

Chris Martin measures out the location for a temperature sensor in Hermoso Park in Phoenix.

Temperature sensors in trees.

Lindo Park in Phoenix.

By Diane Boudreau

Would you be able to find this?

A lush green lawn, a shady tree—when the temperature soars, we gravitate to green. Why are plants so much cooler than, say, a parking lot?

Some plants, like trees, provide shade. But a lawn won't shade anything bigger than a beetle. So how does it make the air above it cooler? The answer has to do with water.

Everyone knows plants need water to survive. They pull water from the soil through their roots. From there it moves up the stem and into the leaves.

Leaves use water to help make food from sunlight in a process called **photosynthesis**. Most of the water, however, escapes through tiny pores called **stomata**. Stomata open in response to sunlight, letting water evaporate into the air.

Evaporation means that a liquid, like water, is changing to a gas. When a substance changes from one state of matter (solid, liquid or gas) into another, it's called a phase change.

All phase changes require energy. When you boil water and make steam, you add the energy from outside using a stove, microwave, or even a fire. When water evaporates naturally, it takes heat energy from the liquid itself to make the change. The liquid that gets left behind is cooler than it was before, because it has lost some of its heat energy.

Chris Martin, a professor of horticulture at Arizona State University, says we've all felt this process firsthand.

"It's like the experience one has in the swimming pool on a hot day. You step out of the pool and the first sensation that you experience is, 'I'm freezing! It's 103 degrees out and I'm freezing!'" he says.

As the water evaporates from your skin, it carries heat away, leaving you feeling chilly. Your body takes advantage of this cooling process naturally through perspiration, or sweat. Evaporation from plant leaves is called **transpiration**. Transpiration helps pull more water up through the plant against gravity.

At night, the stomata on leaves close up, shutting down transpiration. Yet a golf course at night still feels cooler than a parking lot. Martin says this is because moisture in the soil continues to evaporate.

“The soil is very moist and the air is very dry, so the air is drawing that water out of the soil,” he says.

Taken together, transpiration from leaves and evaporation from the soil are called **evapotranspiration**.

“It’s a longer term to combine both evaporation and transpiration, both of which are technically evaporation. It’s just a question of whether it’s occurring from the soil or the leaves,” Martin explains.

Martin is working with Darrel Jenerette, a botanist at the University of California-Riverside. They are studying how plants influence temperature as part of the UVCC study.

Jenerette says there is a link between how green a neighborhood is and the socioeconomic status (SES) of the people living there.

“Up until about 1970 or so you didn’t see this in the Phoenix area," he says. But since about 1970, people with higher SES also tend to have more vegetation in their neighborhoods.

Some people may not be able to afford air conditioning in their homes, either. This makes living in a hot neighborhood even more difficult. Martin says one place people often go to escape the heat is a neighborhood park.

“Even in the heat, there are a lot of people using parks. And parks are one of the few places where homeless people can go to escape the heat,” he notes.

The researchers wanted to see if parks could serve as a "cool island" in the midst of the heat island. They also wanted to know if there’s a difference in temperatures between parks in different neighborhoods.

In the summer of 2011, they placed 100 temperature sensors in 10 Phoenix parks. They selected parks in low-, middle- and high-SES neighborhoods, putting sensors in trees and in the ground. The sensors took readings every 30 minutes for 42 days. The data are helping the researchers figure out if trees and grass have a cooling effect, and which neighborhoods have the coolest parks.

There are lots of things to consider when you try to put thermometers in public parks. You have to put them in places that will get you the information you want. At the same time, you can't put them in spots where people might break or take them.

"Ideally, we wanted to measure temperatures at the surface and at about 2 meters (6 feet) high," says Martin. "We ended up going with 3 meters (10 feet) so we could put them in the canopies of trees. There they were shaded from the sun. And then we buried sensors about one inch below the surface, to give us an idea of the soil surface temperature."

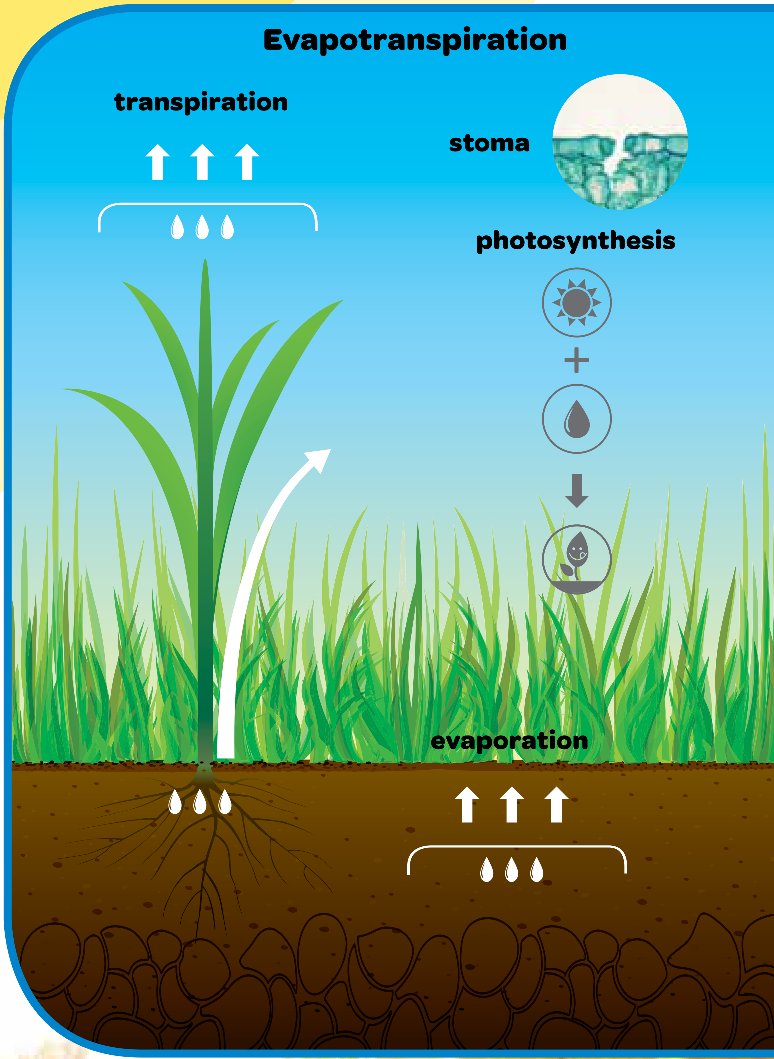
Some of the ground sensors were placed in the shade of trees. Others were in areas completely exposed to the sun. The scientists used zip ties to mark where the underground sensors were placed.

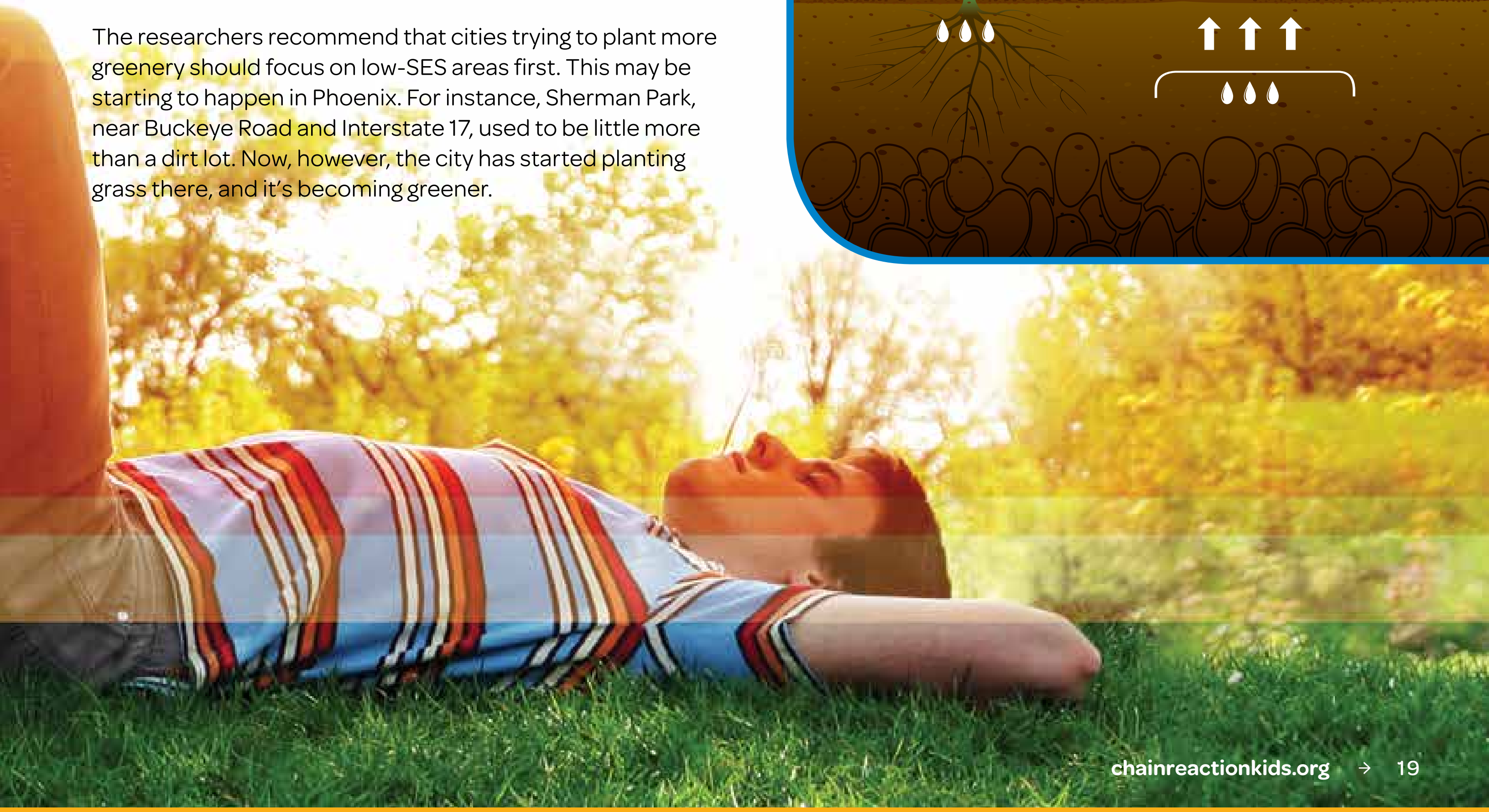
Even with the zip ties, the researchers had trouble finding the ground sensors when they returned in August. They were only able to retrieve about 40 percent of the underground sensors, mostly the ones near the trees in the shade. They did find all of the canopy sensors, however.

Their results show that parks in high-SES neighborhoods are cooler than parks in low-SES neighborhoods by about 2-3 degrees Celsius. In the future, the researchers would like to find out if the parks in low-SES areas are cooler than the neighborhoods around them, even if they aren't as cool as parks in high-SES areas. Computer models suggest that they could be.

The researchers recommend that cities trying to plant more greenery should focus on low-SES areas first. This may be starting to happen in Phoenix. For instance, Sherman Park, near Buckeye Road and Interstate 17, used to be little more than a dirt lot. Now, however, the city has started planting grass there, and it's becoming greener.

"It's interesting how parks have changed in Phoenix over the last five years or so," says Martin. "Phoenix has done an amazing job of upgrading the quality of turf and planting trees, particularly in low-SES neighborhoods. It's the best thing for places to escape heat."





How to

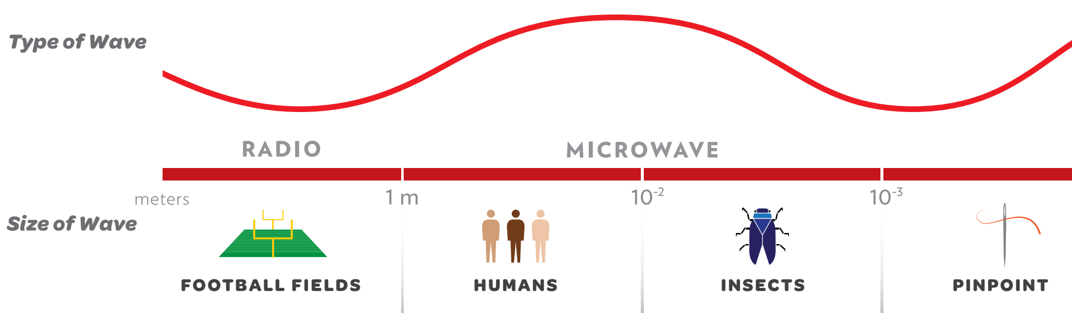
Catch a Wa

A plane flying over Phoenix uses invisible waves to find out what's on the ground—and how hot it gets.

By Diane Boudreau

THE EM SPECTRUM

EM waves can be as long as a football field (radio waves) or tinier than an atom (gamma rays). Visible light waves—the colors of the rainbow—are the only ones you can see.



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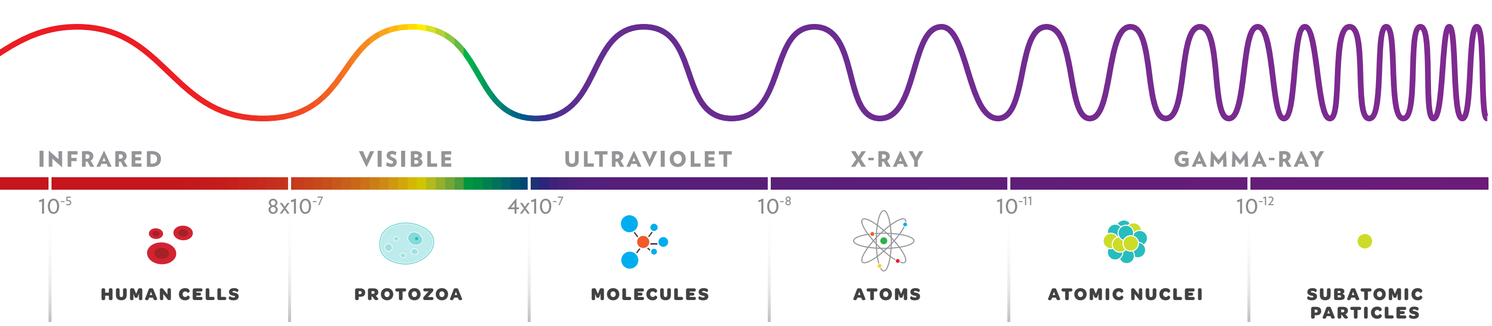
The air around you right now is full of waves. The sun emits light waves and other objects reflect them. Radio waves cruise by on their way to the nearest stereo. If you're outside, ultraviolet waves might be giving you a sun tan. In kitchens around town, microwaves are heating up leftovers from last night's dinner.

All of these waves are part of the **electromagnetic (EM) spectrum**. The waves along this spectrum range from the size of an atomic nucleus (gamma rays) to the length of a football field (radio waves) and beyond. The only waves you can see are light waves, which fall in the middle of the spectrum. If you look at a rainbow, the colors appear in order from the longest wavelengths (red) to the shortest (violet).

Scientists can use EM waves that are emitted or reflected by objects to get information. For example, cameras capture visible light to make pictures. Radar bounces sound waves off objects to find out where they are and how fast they are moving. Infrared thermometers can detect temperatures from a distance using infrared (heat) radiation.

All of these techniques are forms of **remote sensing**, a way of getting information about an object without touching it. Scientists working on the UVCC study at Arizona State University (ASU) are using remote sensing to find out how land is being used throughout the Phoenix area and how that affects temperature.



"When you talk about a city the size of Phoenix, going out on the ground and mapping objects is extremely time intensive. Remote sensing allows us to do this in a more efficient manner. Using a satellite or a plane, we can get a snapshot of data," explains William Stefanov, a contractor scientist with the NASA Johnson Space Center in Houston, Texas.

Stefanov is a geologist who specializes in remote sensing. He works with the UVCC team at ASU. He helped them set up an airplane flight over Phoenix using a NASA instrument called the MODIS/ASTER (MASTER) simulator.

MASTER's sensor measures 50 different wavelengths, ranging from blue light to infrared. The infrared data is particularly useful for determining surface temperatures.

The MASTER sensor was mounted on an airplane. The plane flew over Phoenix four times in July 2011—twice during the day and twice at night. It flew back and forth across the sky the way you might push a lawn mower back and forth across a lawn in rows, so you don't miss any spots.

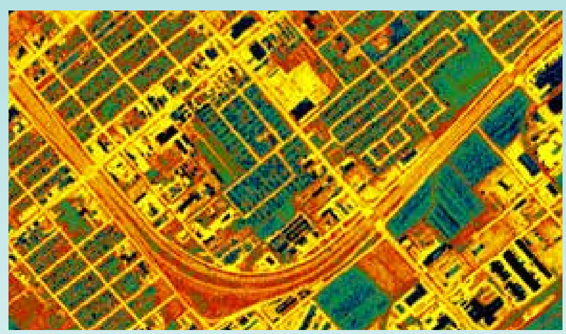
"The data give a good indication of what parts of the city are really hot and what parts are cool," Stefanov says. This information is especially useful when you compare it with census data about people living in the neighborhoods.

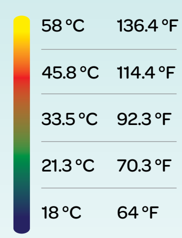
"When you start putting the social information on top, it's clear that people with the lowest socioeconomic status also tend to live in the most uncomfortable environmental conditions," says Stefanov.

Why would low-SES neighborhoods be hotter? Most likely because they have different land cover than other neighborhoods. Juan Declet-Barreto is using remote sensing data to find out exactly what kinds of land cover exist in different neighborhoods in Phoenix. Declet-Barreto is a Ph.D. student in environmental social science at ASU and a member of the UVCC team.

He has been using aerial images from the U.S. Department of Agriculture. The images were taken by airplane in 2007. They provide data on red, green, blue and infrared wavelengths. Declet-Barreto says the infrared information is especially useful for locating plants.

Declet-Barreto takes the data and pulls it into remote sensing software. The software turns all the measurements into pictures. The pictures don't have the full range of colors you'd see in a normal photograph. But it's still pretty easy to make out the shapes of roads, trees, houses and swimming pools.

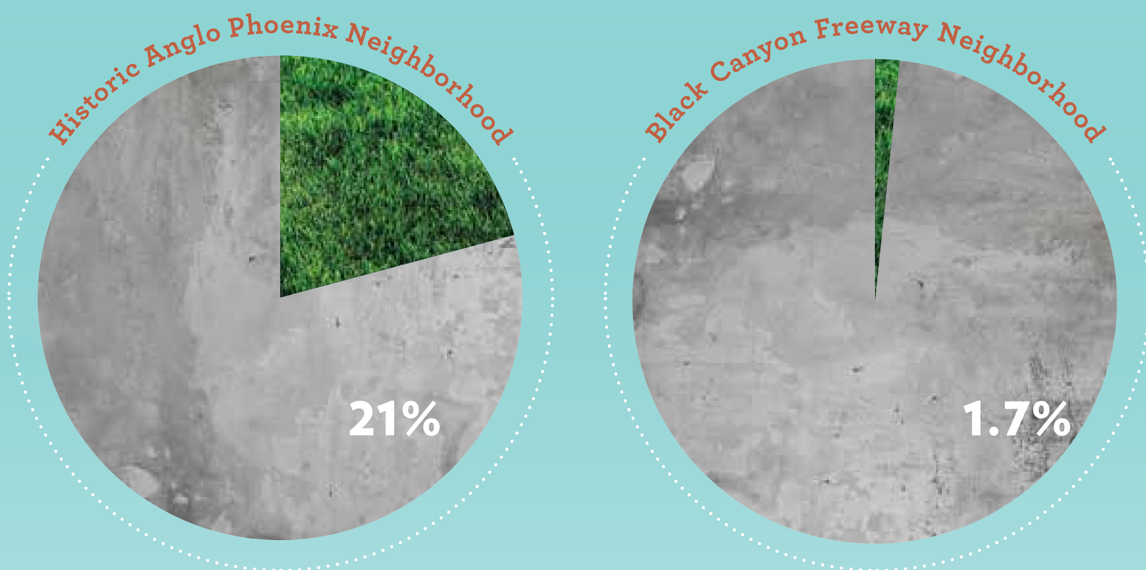




These two images show part of Phoenix from the air. The top image is a photograph. The bottom shows infrared (heat) data for the same area at night. You can see how the roads and rooftops are hotter than other areas.

Why do you think the highway is not quite as hot as the smaller roads?

HOW GREEN IS MY NEIGHBORHOOD?



Percentage of land surface covered by grass in two Phoenix-area neighborhoods.

Declet-Barreto has been programming software to tease out the different kinds of land cover in different neighborhoods. He is "teaching" the computer to recognize features like roads, grass or trees. When Stefanov has finished processing the MASTER data, Declet-Barreto will use it to help the computer do an even better job at recognizing what's on the ground.

But if Declet-Barreto can see these features with his own eyes, why does he need the computer to do it for him? For one thing, picking out every object by sight in 45 different neighborhoods would be terribly tedious.

"Land use/land cover classifications are done over large areas, usually on a regional scale," he says. "These are really time-consuming, menial tasks. If you can have them automated, then you can get to the really interesting questions."

The computer can also make calculations about what's in the pictures. For example, it can figure out what percentage of land in a neighborhood is covered by grass. It can also compare that neighborhood to others.

Declet-Barreto pulls up images of two neighborhoods. "Look at the percentage of grass in this Historic Anglo Phoenix neighborhood—it's 21 percent of the study area. Then you look at this Black Canyon Freeway neighborhood—it's only 1.7 percent. The difference is really staggering." He notes that the two neighborhoods are only about four or five miles apart.

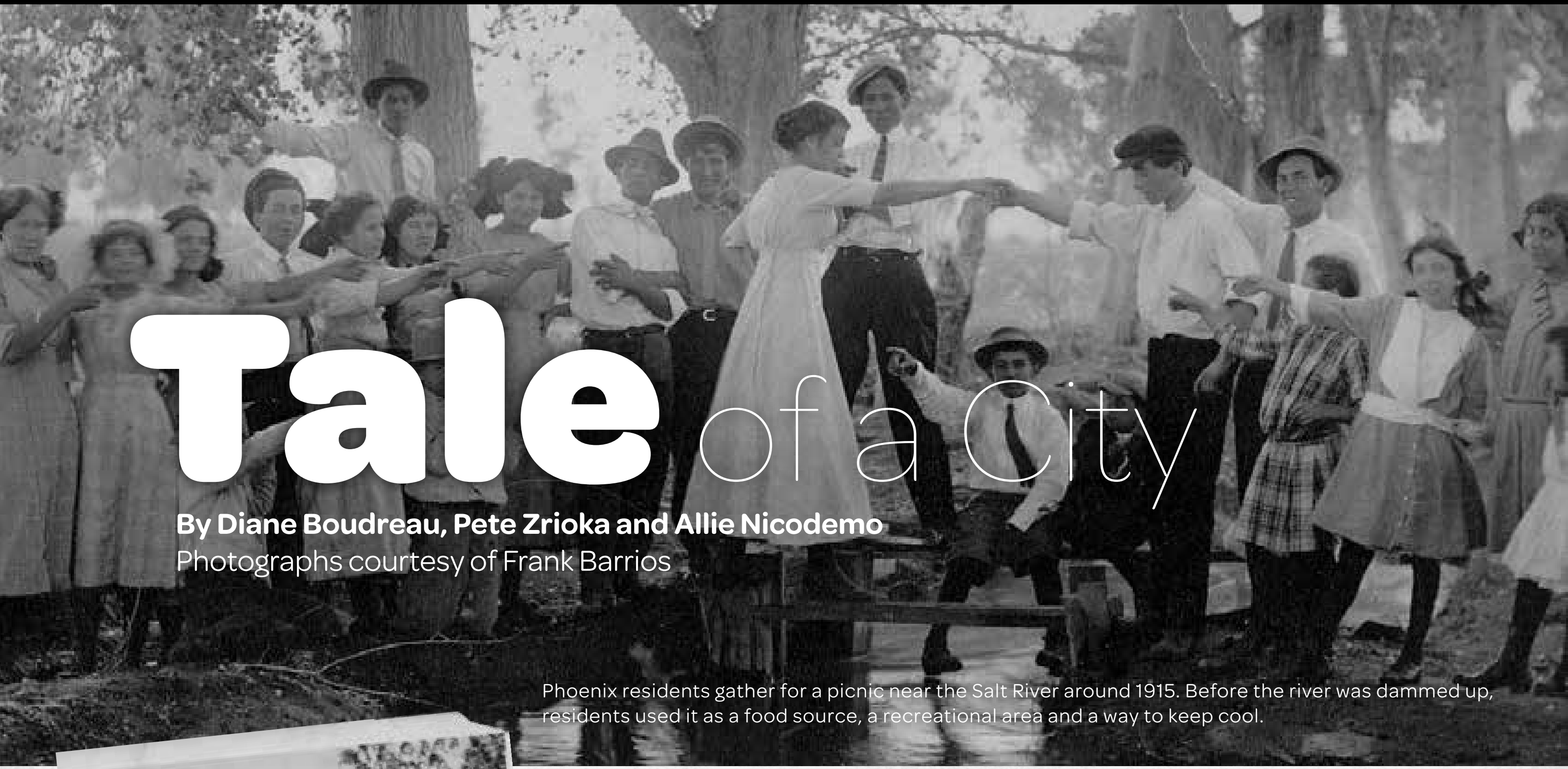
He adds: "For me the interesting question isn't knowing the percentage of trees in a particular neighborhood. For me the interesting question is figuring out why. Environmental benefits like those provided by trees and surface water are just an indicator of socioeconomic differences in the city."

Stefanov, who received his Ph.D. in geology from ASU before moving to Houston, says the UVCC study lets the scientists take their work a step beyond the usual research about urban heat islands.

"We know there's an urban heat island in Phoenix. That's well established. Can we find where people are most vulnerable in the city to the heat island and to extreme heat events?" he asks. "This study is a really nice example of the kind of work that scientists who come from a different range of disciplines can do when they sit down and talk to each other. We can all get together and compare our world-views and see how they interact with each other."

Tale of a City

By Diane Boudreau, Pete Zrioka and Allie Nicodemo
Photographs courtesy of Frank Barrios



Phoenix residents gather for a picnic near the Salt River around 1915. Before the river was dammed up, residents used it as a food source, a recreational area and a way to keep cool.

Once upon a time, the Salt River flowed freely through southern Phoenix. The canals that carried water to farms were flanked by shady cottonwood trees. Families picnicked on their banks and swam in the water. These were days before air conditioners existed, so families had to find creative ways to stay cool in the hot summer months.

"People have a lot of memories of stretching wet burlap over windows to try and keep cool," says Katelyn Parady, a Ph.D. student in environmental social science at Arizona State University (ASU). "Or they would have washtubs full of baby clothes and a little bit of water and put the baby in that to try and keep them cool."

Parady interviewed longtime south Phoenix residents to find out their memories of the city and changes that have happened in the environment. These kinds of stories are called **oral histories**.

These early 1900s south Phoenix residents find themselves in a greener environment than you'd see today. Due to the cutback of trees and other vegetation over time, area residents have lost an important resource for combating the heat.

"One of the most memorable things was people's description of the river. There was a man who was born in 1928 who talks about the river as a food source. He talks about walking into the river and the fish hitting his knees, and seeing turtles and geese and ducks and the trees—sort of this oasis," she says.

The way cities are laid out and the resources available to people living there are affected by a lot of factors. Some of these are natural features of the landscape, like rivers and mountains. Others are human-made, such as roads and railroads, factories and farms, dams and canals. Social values also play a role. And all of these things can change over time.

Some of the hottest neighborhoods in the Phoenix area today are located in south Phoenix. This wasn't intentional, but it didn't happen randomly, either. Most of the people living in this area are also low-income and people of color. To understand why, we need to look at the history of Phoenix.

Phoenix became a town in 1865. It was a small farming community founded by white Americans, mostly from the eastern U.S. However, the town was also home to many Latinos (mostly from Mexico), and smaller numbers of African-Americans, Chinese, and Native Americans. Many Latinos worked on the farms, and lived near them as well.

"Originally people sort of mixed and settled along the Salt River. The river was desirable because it was shady, there were trees. It was cooler than living out in the middle of the desert," says Bob Bolin, a professor at ASU.

The river became a less attractive neighbor after a series of large floods in the 1890s. The flat areas in the heart of Phoenix were especially hard hit. Those who could afford it moved north to higher elevation. Those who could not—mostly Latinos—stayed behind.

In 1887, railroad tracks sliced through Phoenix from east to west. Factories, warehouses and stockyards sprang up near the rail line, as they do in most cities. The railroad came to serve as an unofficial barrier between the low-income neighborhoods south of the tracks and the wealthier neighborhoods to the north.

The city installed water pipes, sewage lines and other services for residents north of the tracks. But the southern neighborhoods did without for the first half of the 20th century, because they didn't officially become part of the city until 1959. Ironically, the first sewage treatment plant in Phoenix was located in south Phoenix, but people living there couldn't use its services. The lack of city services coupled with the growth of industry left the area highly polluted and unsafe.

"Basically, very early on, a set of land uses took place that have cemented these sorts of environmental justice issues," says Bolin. "Areas where land values are low attract certain kinds of land uses. Businesses and factories aren't going to build where land is extremely expensive. It cuts into profits."

He explains that people in the past didn't think about environmental justice or racism. "In those times there wasn't a second thought to the fact that you put a sewage plant next to somebody's house, or a livestock processing facility right in the middle of people's neighborhoods."

Over time, Phoenix shifted from a farm community to a bustling city. Swaths of crops turned into housing developments and strip malls.

"What you see is a lot of open fields and agriculture in the 30s," Parady says. "That was slowly replaced by industry, businesses and denser housing development."

1930

1949

1979

These aerial photos show how Phoenix has changed from a farming town to a big city. Photos courtesy of the Flood Control District of Maricopa County.

Coping

Imagine two people in Phoenix on a hot summer day. Ana works in an air-conditioned office building and drives home in an air-conditioned car to an air-conditioned house. Zoe works outdoors and has to walk to and from the bus stop. Her air conditioner at home is broken, and she can't afford to fix it until the next payday.

Zoe is more **vulnerable** to the heat. In other words, she is more likely to be harmed by the weather than Ana.

Air conditioning (AC) is one **coping method** for dealing with heat. People with lots of coping methods available to them are less vulnerable to the heat than people who have very few.

People in the Phoenix metro area rely heavily on air conditioning to cope with the heat. That's not surprising—setting a thermostat to any temperature you want feels pretty great! However, AC has a lot of unseen drawbacks:

- The electricity it uses is very expensive.
- Power plants that produce electricity use a lot of water, which is a scarce resource in the desert.
- AC adds heat to the outside environment, increasing the heat island effect.
- Heat waves and monsoon storms can cause power outages. People who rely too much on AC may find themselves at risk.

In the 1950s, the city began constructing the I-17 freeway, which was later crossed by the I-10 freeway in south Phoenix. The canals, which had served as a cooling oasis for decades, were lined with concrete. Their water no longer supported trees on the banks. Many of the canals were even piped underground.

"Vacant land, impervious surfaces of cement and asphalt, and residential areas with very little vegetation are typical in much of south Phoenix today," says Tony Brazel, a geographer and climatologist who retired from ASU in 2011. "These areas are short on shade and cooling vegetation. They are exposed to intense sun and absorb a lot of daytime heat. This leads to higher temperatures later in the early evening and night."

Land cover changes made temperatures in south Phoenix higher. They also took away some of the coping methods—like swimming in the canals—that people once used to stay cool. However, people today have new options that they didn't have in the past. For example, public pools are inexpensive and open to everyone in the community. And public buildings, such as libraries and schools, are air conditioned.

In addition, residents are speaking up and working together to make their neighborhoods safer and healthier places to live.

Eva Olivas is the executive director and CEO of the Phoenix Revitalization Corporation (PRC). The PRC is a non-profit group that aims to improve living conditions in south Phoenix neighborhoods. Members of the UVCC team have attended some of the PRC's community meetings. They want to find out what community members want and how ASU's research can help their efforts.

"We have really been advocating for there to be a massive reinvestment in these neighborhoods, while at the same time, not moving out the people who live here. However, the residents here are very open to change, as long as they're included," Olivas says.

In 2005, the PRC launched a leadership academy to teach people skills for expressing their needs to policy makers. They provided education and resources to help the residents make informed decisions.

"We also had to encourage them to think big—really big," Olivas says. She uses a metaphor to help people expand their goals. "Don't just want the ice cream—want the ice cream store. And don't just want to have the ice cream store here—want to own it."

The work has been paying off.

"The crime in the community has been reduced 25 percent in the last six years, because the people are taking more responsibility for their

Thought question:

How many ways can you think of to cope with the heat without using air conditioning? Which of them can people do by themselves? Which require help from the community, city or state?

environment," Olivas says. With regard to the heat, the PRC runs a "Sizzling Safe Summer" educational campaign and encourages people to check in on their neighbors when the temperatures soar.

By working together, community members are making a difference in their lives and their neighborhoods.

"In 2010, the city wanted to close one of the senior centers here," Olivas says. "One hundred and ten of our residents went to the public hearings to keep the center. They're learning how to work with the system and hold the system accountable. They also learn that they are as much accountable as the city."

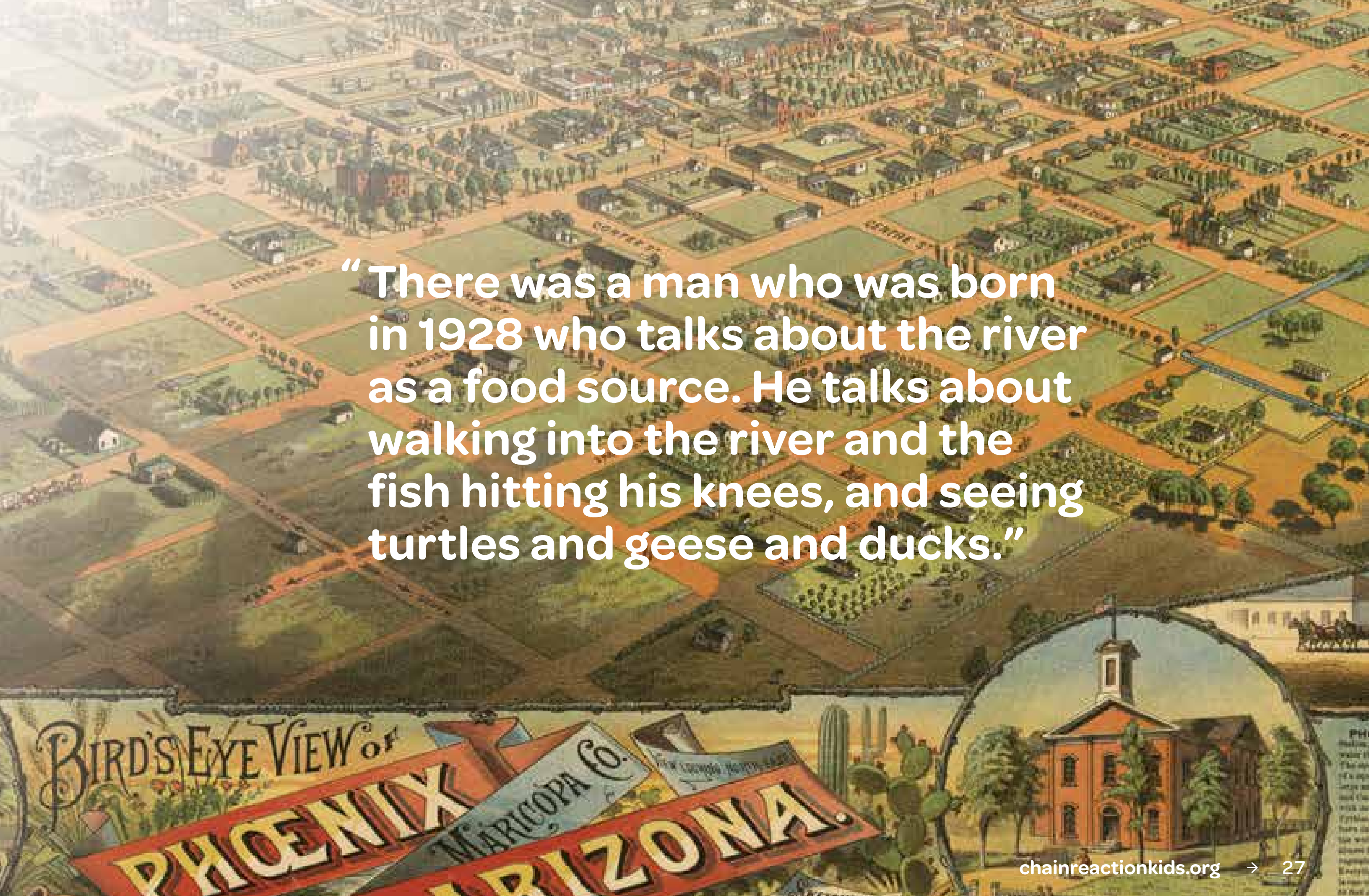
When Parady interviews residents of south Phoenix, she hears a lot of community pride in their stories.

"While these neighborhoods are at the center of the urban heat island and people are vulnerable to heat stress, this is still home for a lot of families that have been there for multiple generations. People have a lot of pride in these neighborhoods. There are flourishing parks and community gardens and a lot of really good things happening, too," she notes.

Parady adds that improving the environment in one community benefits the entire city.

"It's not good for air quality in the Valley for there to be polluting industry here, for example. Pollution crosses neighborhood boundaries. Just because a lot of environmental problems are clustered in one area doesn't mean that they don't matter to the rest of the metro area."

"There was a man who was born in 1928 who talks about the river as a food source. He talks about walking into the river and the fish hitting his knees, and seeing turtles and geese and ducks."



Justice for All

By Allie Nicodemo

Justice is all about treating people fairly.

Social justice is the idea that people are all equal and entitled to basic human rights. Some important social justice movements in the United States include:

- The women's suffrage movement, which fought for women's right to vote. This was achieved in 1920 through the 19th Amendment to the Constitution.

- The civil rights movement, which began in the 1950s to support the rights and freedoms of black Americans. Thanks to this movement, black and white children can attend the same schools, people of all races can use the same public facilities, and we have laws to promote equal access to housing and jobs.

- The labor movement, which has won better treatment for many American workers. In the 1960s, Cesar Chavez led the National Farm Workers Association (now the United Farm Workers) in seeking higher wages and safer conditions for people working on farms.

Martin Luther King, Jr., a prominent civil rights leader, in Washington, D.C., 1963.

Environmental justice is a type of social justice. It involves fair treatment with regard to environmental resources and risks. It promotes the idea that everyone has the right to a clean and safe environment.

In 1982, a protest broke out in Warren County, North Carolina. People were outraged because the state government was dumping truckloads of toxic soil close to neighborhoods where people lived. The soil was tainted when a waste disposal worker dripped thousands of gallons of toxic fluids along 210 miles of road. The state government built landfills to contain this poisonous soil. But the landfills were located mainly in African-American communities.

Five hundred people were arrested in the North Carolina protest. But their voices were heard. The protest sparked the environmental justice movement.

Climate justice is a type of environmental justice. It deals specifically with the effects of climate change. Climate is the set of long-term weather conditions for a region. The global movement for climate justice works to protect the most vulnerable people against the effects of climate change.

Climate justice issues can happen on a local level, as well. For example, certain neighborhoods can be more vulnerable to an urban heat island than others.

In 2010, floods in Pakistan left six million people homeless.
Photo courtesy of the IPCC.

Thought question:

Besides heat, what kinds of environmental problems are likely to harm low-SES communities more than others?

Solutions for the Future

One of the questions the UVCC scientists are asking is: How can people adjust to climate in ways that are healthier for them and their environment?

Research shows that climate issues affect people differently depending on where they live and work. This is connected to their jobs and their incomes. These factors are also often related to people's education, ethnicity and age.

A lot of factors, or **variables**, contribute to the climate-health problem. To find solutions, decision makers need to consider each of them. Decision makers can be people who work in business, government or educational institutions. They can also be members of the communities involved. In fact, we are all involved in this climate-health problem in some way.

The variables that contribute to the problem also shape the way people view it. That is why partnerships between groups are very important to finding sustainable solutions. A sustainable solution is one that will work for a long time without harming any particular group.

In looking for sustainable solutions, researchers think about three broad areas: **environment**, **economy**, and **society**. Each of these areas must be healthy and viable over time.

As we try to protect the environment, we also must ensure that people can earn a good living. Also, our sustainable solutions should not threaten cultural traditions or social institutions. Each solution involves trade-offs among environmental, economic, and social needs and interests.

For example, adding trees to a neighborhood provides an environmental benefit. But buying and watering those trees also involves an economic cost. Can you think of other examples of tradeoffs in climate-health solutions?

Deciding on sustainable solutions can be challenging. And no decision is ever a final endpoint. Variables and trade-offs change over time. As a result, our sustainable solutions will change, too.

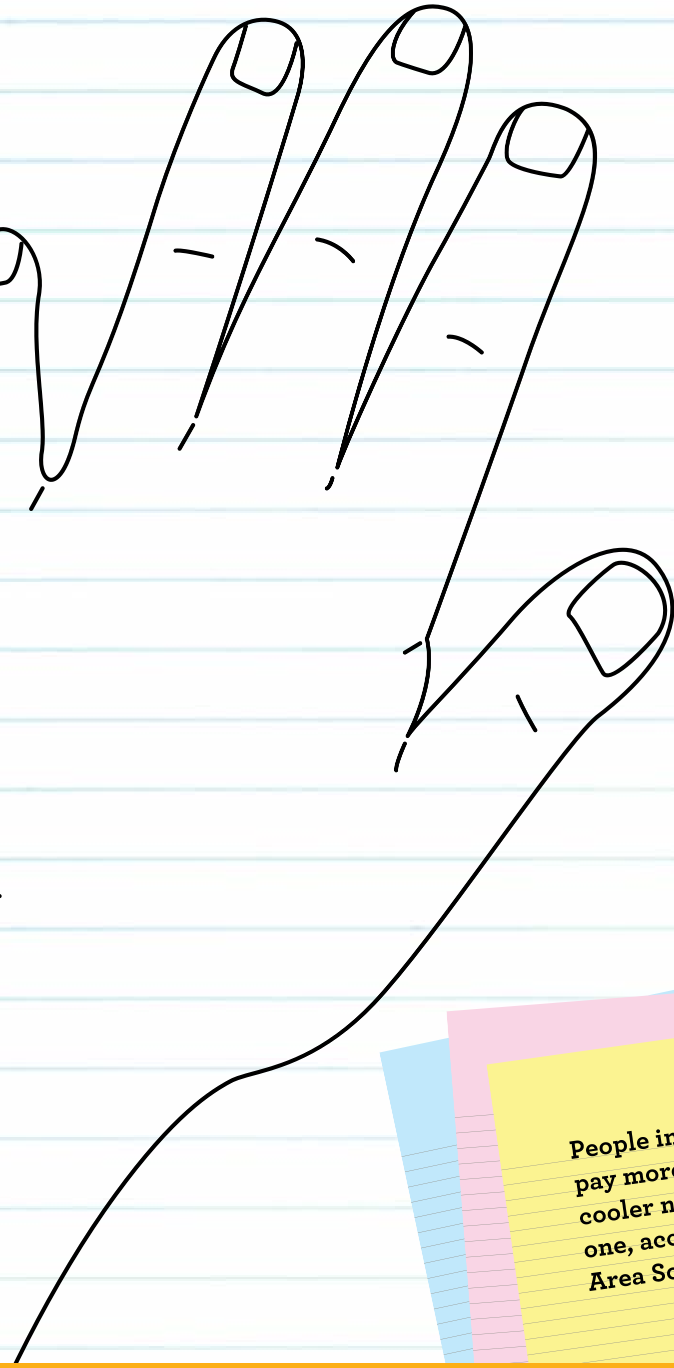
Thought question:

What kinds of sustainable solutions to the climate-health problem do you see in this magazine?

Yes!

Your Opinion Co

By Diane Boudreau



Scientists are always measuring things. Sometimes they measure temperatures. Or they count how many animals live in a certain area. Perhaps they count how many sick people get well using a new drug.

Social scientists study human behavior. They have to measure things like feelings, plans, behaviors and beliefs. You can't see these things like birds in a tree or degrees on a thermometer. So how can we learn about them?

The nice thing about studying people is that when you want to know what they believe or do, you can just ask them. That's why social scientists often use surveys to get information about how people think and behave.

A social **survey** is a set of questions that people can answer online, by mail, on the phone or in person. When they are done correctly, surveys provide data that scientists can quantify, or turn into numbers. This makes them useful tools for comparing people in different places or over time.

People in Phoenix are willing to pay more for a home located in a cooler neighborhood than a hotter one, according to the Phoenix Area Social Survey.

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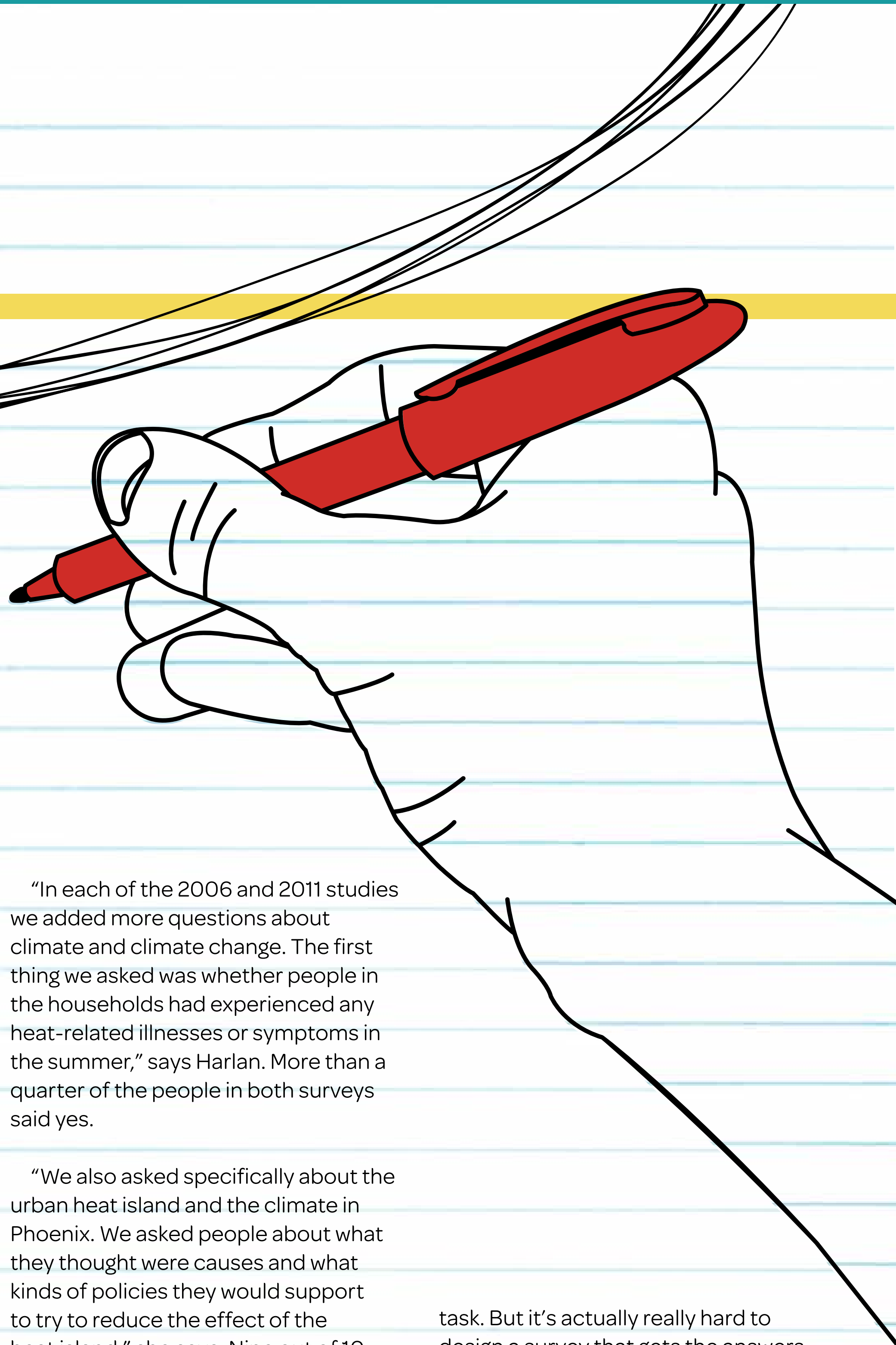


"Surveys turn people's opinions into numbers that can be compared. The individual people who answered disappear and you are left with numerical data that you can analyze with statistics," says Sharon Harlan, a sociologist at Arizona State University.

A survey could help you figure out if people in Nashville, Tennessee, enjoy country music more than people in Seattle, Washington. Or you could learn how many people plan to vote in the next presidential election. The possibilities are endless.

Harlan leads a project called the Phoenix Area Social Survey (PASS). The survey tracks Phoenix residents' attitudes, values and behavior with respect to the environment. The PASS team conducted the survey in 2001, 2006 and 2011.

Scientists working on the UVCC study are using tools like thermometers, infrared sensors, hospital records and computer models to get information. But there are some questions in the study that can't be answered with these kinds of tools. How do the people who live in the heat island feel about it, and how has it affected their lives? Harlan is using PASS to find out.

"In each of the 2006 and 2011 studies we added more questions about climate and climate change. The first thing we asked was whether people in the households had experienced any heat-related illnesses or symptoms in the summer," says Harlan. More than a quarter of the people in both surveys said yes.

"We also asked specifically about the urban heat island and the climate in Phoenix. We asked people about what they thought were causes and what kinds of policies they would support to try to reduce the effect of the heat island," she says. Nine out of 10 respondents supported planting more trees along streets and using new paving materials that absorb less heat.

Take a sample ☑

Asking people for their opinions and experiences seems like a pretty simple task. But it's actually really hard to design a survey that gets the answers you want. The first step is asking the right people.

"The very first rule is that your sample has to represent the population that you want to study," explains Harlan.

IS THE CENSUS A SURVEY?

A census is a special kind of survey. It gets information about the whole population, not just a sample. A census is much more accurate than a sample survey, but it takes a lot more time and effort. The U.S. Constitution empowers Congress to carry out a census every 10 years. The law requires people to fill out census forms. It also requires the Census Bureau to keep everyone's personal information private. Census data is used to plan for needs like hospitals and transportation. It is used to figure out how to distribute government funds. It is also used in research. Scientists on the UVCC study use census data to learn about the people living in the neighborhoods they study.

Learn more at census.gov

Suppose you want to learn how adults in Arizona use cell phones, if they use them at all. Your survey target **population** would be all the people in the state over age 18. That's more than four million people! It would take you more than a lifetime to interview them all.

To solve this problem, scientists select a **sample** of people from the target population to survey. A well-chosen sample will represent the whole population. So if 15 percent of your sample plays games on their phone every day, you can be pretty sure that 15 percent of adults in the state do, too.

There are several ways to get a representative sample. Scientists could use a simple random sample. This would be like throwing everyone's names into a bowl, mixing them up, and picking from them. Everyone in the population has an equal chance of being chosen.

However, if you want to study certain populations, such as dog owners or college graduates, you could pull a random sample out of people in those groups only. Or you could sample groups randomly—such as one class out of every grade level in a school.

Ask the right questions ☑

Once you have a sample, you need to decide what to ask. The questions have to make sense to the respondents, provide accurate answers, and be quantifiable. This means scientists must be able to turn them into numbers.

There are several ways to make questions quantifiable. You could ask yes-or-no questions. You could use multiple-choice questions. Or you could use a scale. For example, you might ask people to rate statements on a scale of 1 to 5, where:

- 1 means "strongly agree"
- 2 means "agree"
- 3 means "neither agree nor disagree"
- 4 means "disagree"
- 5 means "strongly disagree"

Each question should include all possible answers a person might have. You also need to make sure they don't overlap. Look at the example below:

My favorite dessert is:

1. fruit
2. strawberries
3. cake
4. pie
5. cookies

A person who loves strawberries would be confused because they could select answer 1 or 2. On the other hand, someone who finishes every meal with candy cannot answer the question at all.

Finally, survey writers need to make sure they don't ask biased questions. Biased questions push the reader toward one particular point of view. Compare the following three questions:

- Do you think students should have the freedom to choose to bring cell phones to class?
- Do you think the school should prohibit annoying, disruptive cell phones in class?
- Do you think students should or should not be allowed to bring cell phones to class?

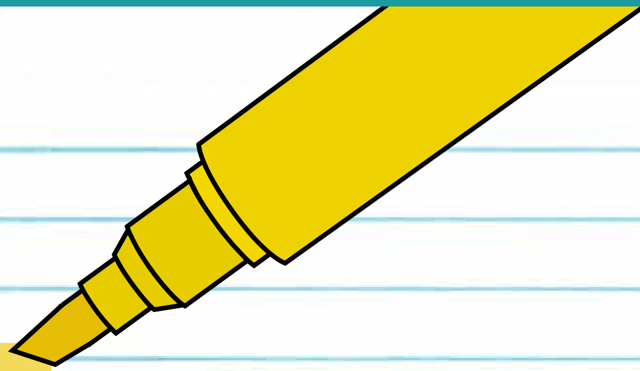
In the first question, the words "freedom to choose" create a bias in favor of cell phones. The second question uses words like "annoying" and "disruptive" to bias the reader against cell phones. Only the third question avoids using biased language.

Answer me! ☑

Once you have a survey and a sample, how do you get people to respond? Americans today are flooded with junk mail and phone calls. Convincing people to spend time taking a survey is a tough job. Also, people are often suspicious of surveys.

"There are people out there who are using surveys to make profits or to influence politics and people get suspicious. This makes it harder for academics to do their research," says Harlan.

Almost 30 percent of people who answered the Phoenix Area Social Survey said that someone in their household experienced symptoms of heat exhaustion in the summer of 2010.



The PASS interviewers used a combination of mail, phone calls and visits to invite people to take the survey. Respondents could answer the questions online, by phone or in person.

The researchers also paid the respondents for their time. Even so, only about half the people they contacted completed the survey. Harlan says this is actually a very good response rate.

"Most people are nice about it, it's just hard to get them to sit down and do it. In 2011 the survey took between 30 and 40 minutes, which was shorter than the 2006 version, but it's still a long survey," she says.

Harlan says she understands why people are reluctant to fill out surveys. But she hopes that people will take a moment to listen to what a survey is about.

Some good questions to ask about a survey are:

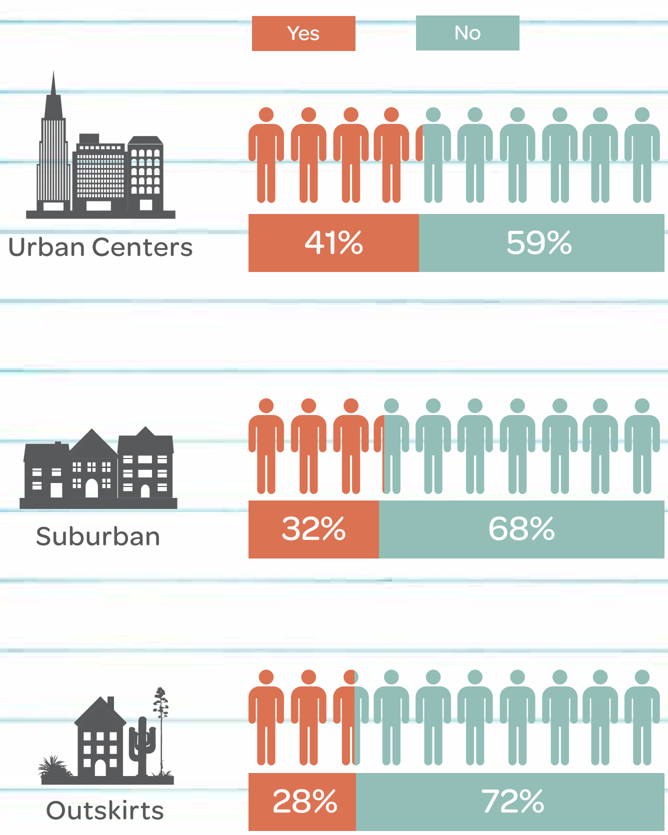
- What organization do you represent?
- Why are you doing this survey?
- How will you protect my personal information?

Researchers should keep your information secure and not include any information that could identify you personally when they share their results.

"There are legitimate purposes for universities doing surveys," Harlan says. "Often this information is put into reports, newspapers, and other things that people read—people who are responsible for making laws. It's a way of making your voice heard, or the voice of the community."

ARE YOU EVER TOO HOT INSIDE YOUR HOME DURING THE HOT SEASON?

This question was part of the PASS survey. The graph below shows how people in different neighborhoods answered. What neighborhoods had the hottest houses? Can you think of some possible reasons why?



Picturing Heat

We all know what heat feels like, but what does it *look* like?

By Diane Boudreau

Bryan Garcia 2010

Lizbeth Sillas 2011

If you were asked to take a photo of what summer heat means to you, what would you show? Equipped with disposable cameras and temperatures over 100 degrees Fahrenheit, seventh graders in Phoenix, Arizona took on this challenge.

Aaron Dammar 2010

They shared photos of dogs shaved down to stay cool, burned-out lawns and wilted flowers, melting ice-cream cones and a solitary runner on a track, water bottle in hand.

The students were part of an environmental biology class offered through the Junior ACE (Achieving a College Education) program at Phoenix College. The classes took place during the summers of 2010 and 2011.

The photos are helping researchers at Arizona State University (ASU) study the relationships among heat, landscapes and health in Phoenix.

“The theme of the course was observing interactions in our environment,” says Elena Ortiz, a biology professor at Phoenix College who taught the class. “We learned basic observation skills and practiced observing birds. We also studied the urban heat island effect, heat illness in humans and thermoregulation in other animals.”

The photography project uses a technique called Photovoice. “Photovoice is a method of participatory action research. Photovoice participants take photographs and then work together to show what is meaningful to them. This gives them a voice and empowers them in the process. Many times children’s voices are not heard,” says Dulce Medina, a Ph.D. student in justice and social inquiry at ASU. She explained the Photovoice method to the class and led the students' discussion groups with Ortiz.

Medina provided the students with disposable cameras. Scot Grey, a professional photographer, was invited to teach the students some basic

COUNT OR RECOUNT?

There are two basic types of research: **quantitative** and **qualitative**. Quantitative research involves numbers—things that can be measured and counted. Qualitative research is more like storytelling. It gives a rich description of the subject through words or images.

The students in the Junior ACE class used both kinds of research methods. When they counted birds and measured temperatures, they were doing quantitative research. They could use their measurements to make graphs and compare data using statistics.

The Photovoice project was a type of qualitative research. The students observed how heat affects people, animals, and the landscape and used photos to tell that story.

Gissel Marquez 2010

Cristian Sida 2011

techniques before they went out into the field. The students took half the photos with their cameras, then returned for a discussion session about what they photographed.

"For the first group discussion, the students had taken very literal pictures of what extreme temperatures 'looked like,' such as melting ice and boiling water. Thinking more abstractly, we discussed how temperature relates to people and the environment. Students worked through the exercise and fed off each others' ideas on what to take pictures of," says Medina.

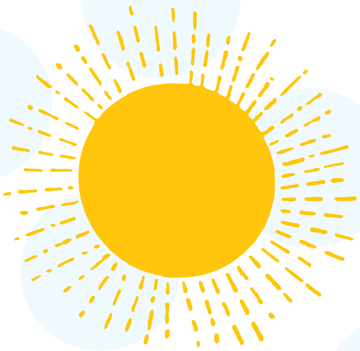
The students went back out into the field to take the rest of their photos. After developing them, they selected the best of their shots to present at the end of the course.

"The discussions were intriguing," says Medina. "One student showed a photo of a traffic intersection and spoke about cars contributing to global warming. His concern about the increasing temperatures at such as young age impressed me."

In addition to photographing images of heat, the students conducted their own research on the desert ecosystem. They counted birds and measured temperatures in different neighborhoods. Then they created graphs of the information they collected. Their data will contribute to research happening at ASU.

Cristian Sida 2011

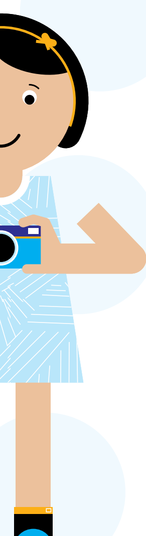
Misael Gamboa 2010



Raul Hernandez 2010

Where would you take a photo, and why?

Bryan Garcia 2010



LOOK AT THE FOLLOWING TYPES OF STUDIES

are they QUALITATIVE or QUANTITATIVE?

Placing thermometers in parks to compare temperatures

A B C D E

A multiple-choice survey asking people to rate their feelings about the environment

An oral history project collecting stories about how people cope with heat

A computer simulation to predict temperatures in the future

A case study on a patient describing his symptoms and treatment for heat stroke

Arizona's Next **Top**

A super modeling computer calculates weather in the past and future.

By Diane Boudreau

Before you read the next paragraph, try to think of all the different factors that affect outdoor temperature in a desert city like Phoenix, Arizona.

You probably thought of at least a few of these: building materials, pavement, plants and trees, bodies of water, humidity, cloud cover, wind and even global warming. Maybe you thought of other things, as well.

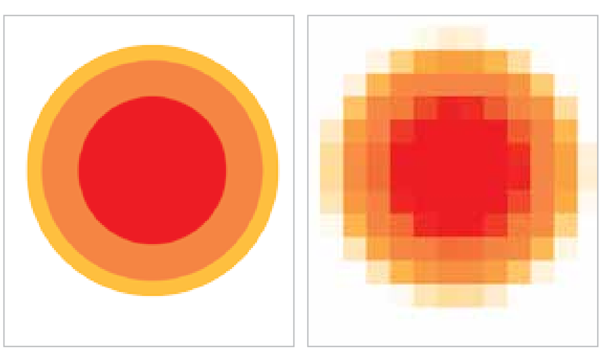
Now imagine that you are trying to understand how all of these things work together and affect each other. Perhaps you want to predict what the temperature will be in a future with more buildings or less water.

How could you calculate all those different factors in order to make a prediction? Actually, you can't. Even the world's smartest scientists can't—not without help.

"It's so complex that a brain cannot hold it all together and do the calculations. You have to have a computer to solve these equations," says Susanne Grossman-Clarke.

Grossman-Clarke is a physicist at the Potsdam Institute for Climate Impact Research in Germany. She works with researchers at Arizona State University (ASU) who are studying the heat island in metro Phoenix. She is trying to understand what influences heat in urban areas. She also wants to know what is likely to happen in the future.

The computer models that she uses "speak" in the language of mathematics. Scientists enter numbers into the model to represent a set of conditions, like building heights or wind speed. The computer runs these numbers through a set of equations to **simulate**, or imitate, what would happen in the real world under these conditions.



High Resolution

Low Resolution

Model

The computer spits out even more numbers in return. The scientists use software to take those numbers and turn them into graphs, maps or other images that help them understand the results.

"We take everything we know about atmospheric processes and how the air interacts with the land surfaces. Then we formulate equations and put them in these models," she explains. "You have to use the best supercomputers in the world. Even 10 years ago the computing technology available couldn't do these simulations on a city level."

Grossman-Clarke doesn't just use the computer models. She helped develop them, as well. She spent seven months at the National Center for Atmospheric Research in Boulder, Colorado. There, she worked on improving the physics for city surfaces so that they are represented in the models.

To show the effects of cities on weather, Grossman-Clarke needs to work at a very high resolution. What does that mean?

Resolution describes how many units are contained in a certain amount of space. In photos, for example, we measure resolution in dots per inch (dpi). Each dot contains a single color. The more dots you have (high dpi), the more detail you can see in the photo.

There is a tradeoff, however. A high-dpi photo is sharper, but it takes up more computer memory and requires more ink to print.

For computer models, each "dot" is a piece of information. So in a climate model, a "dot" might represent the average temperature for that area.

Global climate models usually have a 100-kilometer resolution. This means each "dot" measures 100 square kilometers. There may be lots of different temperatures inside of that area, but the model will only "see" the average of all of them.

This level of resolution cannot show the heat island effect for an individual city. But it lets scientists study global phenomena like the jet stream.

Grossman-Clarke runs models at a 1-kilometer resolution. This allows her to see differences between much smaller areas, like neighborhoods. She can figure out how city structures—like buildings and roads—affect temperature.

Just like with photos, the resolution of a computer model has its tradeoffs. Modeling at a high resolution, like 1 km, takes much more time and computing power than modeling at a lower resolution, like 100 km.

"To model a whole summer at 1 kilometer resolution takes the computer about a week," says Grossman-Clarke. And these are not average desktop computers. The supercomputer that she uses has 256 processors. Computers on this scale are housed at universities and research centers where lots of scientists can use them.

Grossman-Clarke has been simulating past and future heat waves for Phoenix. But why simulate the past if we already know what happened? She says that our observations can tell us *what* happened in the past, but they can't explain *why*. Models help her to understand the processes that caused the heat waves we all sweated through.

Another reason to simulate the past is to find out if our models of the future will be reliable. For instance, a scientist might enter information about the weather, buildings, pavement, plant life and wind flow for a particular day in the past. Then he or she will run the model to simulate the rest of the summer. If the simulation matches what really happened, the scientist can be confident that the model is accurate.

"You never know if the model predicts the future right, but you can trust it more if it simulated the past well," says Grossman-Clarke.

Grossman-Clarke knew that heat waves happened in Phoenix in 2003, 2005, 2006 and 2007. She simulated each of those summers in her model.

She found that the model simulated the heat waves quite well. She also found that changes in land use played a big part in causing temperatures to rise. These changes mostly involve converting farmland to city spaces.

"The development hugely increased the nighttime temperatures," she says. "If you develop agricultural land into urban, it's 10 degrees Celsius warmer at night."

These results help Grossman-Clarke answer her main research question: how much is temperature change affected by land use, and how much by global climate change?

"For the future, we can separate land use and global warming effects, because we understand now what land use effects do," she says.

WHAT IS A HEAT WAVE?

The term "heat wave" refers to extended periods of unusually high heat. But how you define "high" depends on where you are. In some places, a week of temperatures in the 90s would count as a heat wave. In Phoenix, normal temperatures climb over 100 degrees Fahrenheit almost every day from June through August. So how do we define what counts as a heat wave?

Physicist Susanne Grossman-Clarke identified heat waves in Phoenix by looking at summer temperatures over the past few decades. She found that temperatures rose above 45.5 degrees Celsius (113.9 F) only 2.5 percent of the time. These are the highest temperatures that occur in this area, and they don't happen very often.

Then she looked for periods of three or more days in a row with temperatures above that level. She defined these periods as heat waves.

Some scientists use slightly different definitions. They might look for extreme heat five days in a row instead of three, for instance. But all definitions involve an extended period of time in which the temperature is higher than the average for that region.

The definition can change even within the same area. Have you ever heard a weather forecaster say something like, "Today's high temperature was five degrees above normal?" The definition of "normal" actually changes over time. In fact, the National Weather Service just updated these numbers for the whole country in 2011.

Before 2011, the average temperature was based on weather records from 1971 to 2000. Now, the 1970s are off the list and the years 2001-2010 have been added.

So what will happen in the future? Grossman-Clarke says it's hard to make predictions, because we don't know how much the population will grow, how land use will change or how much carbon dioxide people will emit. However, she simulated the summer of 2058 using land use information from today.

She found that the future is likely to bring more frequent, and longer, heat waves (by today's definition) than we experience today. In fact, they could last as long as 50 days!

"In the future the risk that it will get hotter, and for longer periods of time, is very high," she says, adding, "But I would be very happy to be proven wrong!"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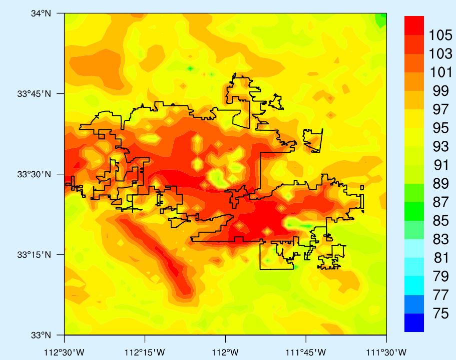


A computer model "speaks" in numbers, like the ones shown on the left. Mapping software "translates" those numbers into something we can understand—in this case, a picture showing temperatures across the Phoenix area.

What does that mean for Phoenix? The average temperature is now a little hotter—by less than one degree. The average rainfall has decreased by about one-quarter of an inch.

We need to know average temperatures for more purposes than just weather reports. For example, electric companies use them to predict how much power people will need for heat and air conditioning. Farmers also look at average temperatures to decide what crops to grow and when to plant them.

FOOD FOR THOUGHT

In the Chicago heat wave of 1995, more than 700 people died during five days when temperatures reached up to 106°F. In Phoenix, 106 is not considered extremely hot for summer weather. Why would the same temperature be more dangerous to people in Chicago than to people in Phoenix?

Cultivating the Food Desert

By Allie Nicodemo

Candy bars for breakfast and potato chips for lunch? It might sound delicious, but that kind of diet won't fuel a healthy body. But for some urban families, these foods may be easier to find than fresh vegetables and whole grains.

Certain communities are considered "food deserts." This means that most residents do not have access to a grocery store or supermarket.

Living in a food desert makes it tough to prepare healthy meals. The local corner store might stock some fresh produce, but it often costs more than it would at the supermarket. And instead of lean meats like chicken breast, convenience stores sell processed meats like beef jerky. For people who do not own cars, shopping in neighborhoods with a better food selection may not be possible.

"The supermarkets around these neighborhoods have either moved or gone out of business. If you don't have an easy way to get to a supermarket, then you don't have equal access to the quality of food that somebody living in another neighborhood might," says Tommy Bleasdale.

Bleasdale is a Ph.D. student at Arizona State University (ASU) studying environmental social science. He wanted to understand the challenges that some inner-city residents face in finding healthy food. He worked with Carolyn Crouch, a master's student in sustainability. The pair studied one community in the heart of Phoenix.

Crouch looked at each of the community's 14 food outlets to learn about the nutrition environment in the area. There is no grocery store within one mile of the neighborhood. So these food outlets included convenience stores, ethnic food marts and dollar stores.

She found that the community, like many others across the U.S., is a food desert. A week after Crouch published her findings, the U.S. Department of Agriculture released its own survey confirming that the area is a food desert.

Homegrown health

People in urban areas have found that community gardens offer one solution to the food desert problem. A community garden is a plot of land used by many people to grow plants. They can be particularly useful for people who don't have their own backyards.

"That's something that people can do—they can afford the produce because they're growing it themselves. It's kind of a ground-up strategy," Bleasdale says.

Photo by Kendal Drake, Phoenix Revitalization Corp.

The Phoenix Revitalization Corporation (PRC) works with people in a part of Phoenix known as Central City South. The PRC runs a community gardening program and wants to expand into more neighborhoods. To help them understand the needs of the community, Bleasdale surveyed 149 residents on the benefits and burdens of gardening.

Most of the respondents said they were interested in community gardening. But 82 percent didn't know that gardens already exist in Central City South.

The respondents saw many benefits in community gardening. The main one was that it would provide them with more nutritious food. Other benefits included exercise, helping the environment and relaxation.

But people also mentioned obstacles to gardening, such as lack of space and excessive heat. Lack of time was also a concern.

"A lot of the residents have multiple jobs and the only way they can pull through is working 60 or 70 hours a week, so time was a huge issue," Bleasdale says.

Now the PRC has a better understanding of the community's thoughts on gardening. They can tailor the program and make it possible for more residents to participate. Bleasdale suggests using colorful signs to advertise gardens and a community bulletin board to increase communication. Providing education on gardening methods would allow residents with no experience to participate.

Recently, the PRC received funding to build a new half-acre garden. Bleasdale says that's one reason why it's important to do this kind of research.

"It gives the organization leverage in getting grants. Also, by showing what this particular community wanted, we can start to discuss other food desert communities around it."

Visit the USDA Food Desert Locator to find out where food deserts exist in the United States: http://www.ers.usda.gov/data-products/food-desert-locator.aspx

CROSSLINK
Food in the City

CROSSLINK
Food in the City

Fresh
from the Farm

Farmers markets make fresh, healthy local food available to the whole community.

By Allie Nicodemo

Wander around a local farmers market and you'll see a rainbow of brightly colored fruits and vegetables, bundles of herbs and salad greens, grass-fed beef and even honey from local bees.

Farmers markets are growing more and more popular across the U.S. There are about 75 markets just in Arizona, with more than 20 in the Phoenix metro area.

Farmers markets are an excellent place to find healthful foods. But some people have had trouble accessing them.

For example, more than one million Arizonans use the government's Supplemental Nutrition Assistance Program (SNAP). SNAP helps people afford the food they need for good health.

But for a long time, people had trouble using SNAP benefits at farmers markets. That's because SNAP provides benefits on an EBT card, which is like a debit card. But many farmers markets do not have the technology to accept EBT cards.

Christopher Wharton is a nutrition professor at ASU. He has worked with the U.S. Department of Agriculture (USDA) to make farmers markets more accessible.

Wharton found eight farmers markets in Arizona that did not have EBT technology. He installed wireless terminals that could accept both EBT and regular credit and debit cards. He then tracked sales at five of those markets over time.

"What we found was EBT sales went up. We expected that because it was zero before. But we also see that overall sales jumped at four of five markets and increased beyond the EBT sales alone," Wharton says. This may be due to the convenience of being able to use a debit or credit card.

Planning healthy and affordable meals can be difficult for many reasons. For instance, some neighborhoods have low access to fresh fruits and vegetables because they are located in "food deserts" (see p. 43).

"In some urban areas, fruits and vegetables are more expensive because they're being sold out of corner markets rather than larger grocery stores. Grocery stores sell to a lot of people, so they can sell things at lower prices. Corner markets can't do that," Wharton says.

Studies show that prices at farmers markets are similar to prices at supermarkets. Another benefit of farmers markets is what they don't offer – heavily processed "junk food" and sugary drinks.

"You don't have vendors selling sugary beverages like sodas and things at farmers markets," Wharton says. "Instead, you have the farmer there selling squash and tomatoes and things like that. You're getting the healthiest foods available – whole, local fruits and vegetables – into people's diets if they're shopping at farmers markets."

The USDA keeps track of farmers markets all over the country. You can search for a market near you by typing in your zip code at: http://1.usa.gov/Sx2fad

The number of farmers markets in the U.S. increased by 9.6 percent from 2011 to 2012. The USDA says there are 7,864 in operation today. The top three states for farmers markets are California with 827, New York with 647 and Massachusetts with 313.

WANT TO GROW YOUR OWN FRUITS AND VEGGIES? TRY THESE TIPS TO BEAT THE HEAT AND CONSERVE WATER:

- Spread a layer of mulch over the soil around plants. This will hold in moisture and deter weeds. Some eco-friendly mulches include pine needles, eucalyptus bark chips, straw and newspaper (topped with yard clippings to hold it down).
- Water efficiently. A simple soaker hose doesn't cost much and can reduce water use up to 50 percent over other methods.
- Group plants in the same families close together because they have similar water needs. For instance, cucumbers, melons, squashes and gourds are in one family. Another family includes tomatoes, peppers and eggplant.
- If you live in a dry climate, look for drought-tolerant varieties of plants.
- Even if you don't have a yard, many food plants do well in containers. Lettuce, strawberries, tomatoes and herbs are great choices for smaller planters. You can also move the pots around to get the right amount of sun and shade.

Water **Power**

How important is water to cool down a desert city?

By Diane Boudreau

Water is the ultimate coolant. From your body, to plants, to the engine of a car—water helps hot things chill out.

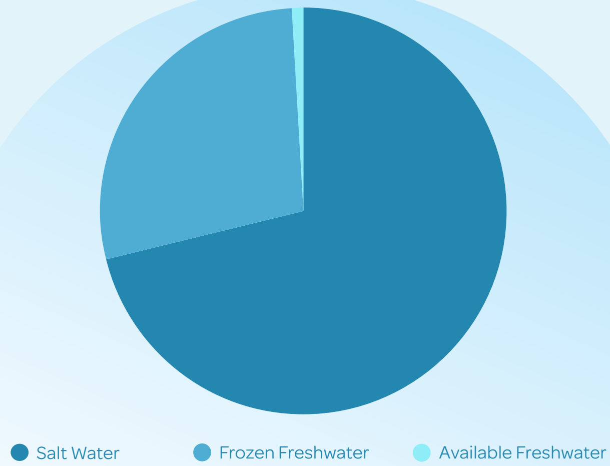
But water is a limited resource, especially in dry climates. Plants cool the environment, but they require watering. On the other hand, if your landscape heats up, you may use more electricity for air conditioning. Guess what? Producing electricity uses water!

Water is used to pump oil out of the ground, make the steam that turns turbines, remove pollutants and residue from power plants, and cool the power plant. In the U.S., burning fossil fuels for electricity uses more than 500 billion liters of water per day! Just keeping a 60-watt light bulb on for 12 hours uses up to 60 liters of water.

How can we stay cool without wasting water? Scientists at Arizona State University recommend a balanced approach. For instance, cities should focus on adding plants to neighborhoods that have the least green space. This is where they will have the biggest effect on temperatures.

There are also ways to lower temperatures without increasing water use. For example, we can use roof and pavement materials that absorb less heat. We can also increase the density of our desert cities. People grouped closer together use less water than people who are spread out.

Water Facts

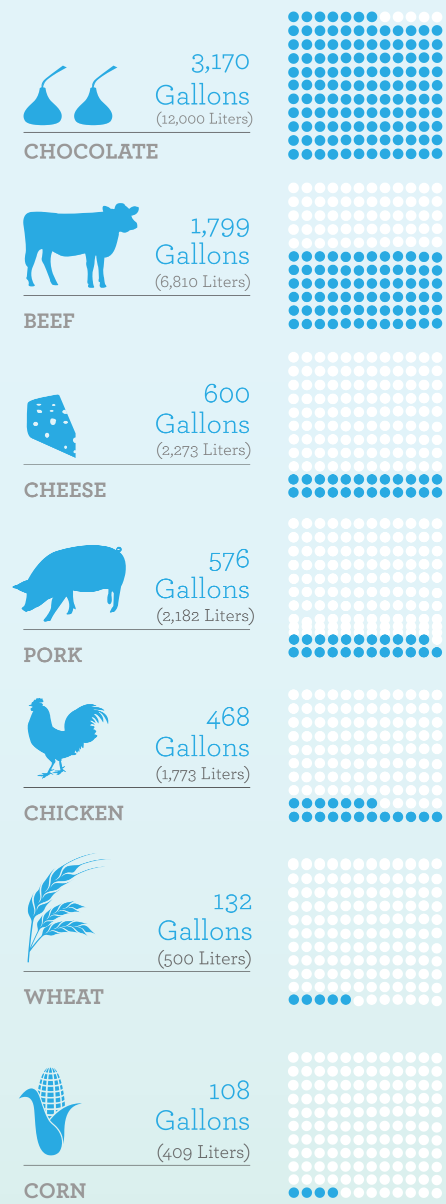


Although 70 percent of the Earth's surface is covered with water, less than one percent of that water is available for human use. The rest is full of salt or permanently frozen.

The average American uses 80-100 gallons (300-380 liters) of water per day for drinking, washing and watering. This doesn't include hidden water use for things like growing food or generating electricity.

In Arizona, 77 percent of all the water used by humans goes to farming. In Phoenix, about 67 percent of water goes to outdoor uses like parks, golf courses, lawns and keeping pools full.

WATER NEEDED TO PRODUCE ONE POUND OF:



● = 25 gallons of water

Source: National Geographic

Food for Thought

Look at the chart on the right. Why do you think it takes more water to produce meats than to produce grains? How many ways can you think of that water might be used to make the foods listed?

How Can You Conserve?

1. Adjust your sprinklers so you aren't watering the sidewalk and street.
2. Only run the dishwasher and washing machine when they are full.
3. Avoid flushing the toilet too often.
4. Refrain from running the garbage disposal. Compost when possible.
5. Insulate your hot water pipes for quick hot water at the faucet.
6. Fix leaky faucets and toilets promptly.

Ecology Explorers

What types of plants and animals share your backyard and schoolyard environments? How can you study them? How do human activities and structures, like buildings and streets, influence these organisms? How do they influence us? Teachers and students can participate in the Ecology Explorers program, which links them with ASU scientists who are studying the ecology of cities. **ecologyexplorers.asu.edu**

Teachers: We offer a complete urban heat island unit at ecologyexplorers.asu.edu/overview/urban-heat-island

Ask a Biologist

Science is about curiosity. Science is about asking questions. One answer often leads to a brand new set of questions. That's how science works. Just think how great it would be if you could ask a real scientist for help with a tough question. You can at Ask a Biologist. Don't have a question? No problem! The site also features podcasts with scientists, games, virtual experiments, coloring pages for young students, quizzes, and a new comic book science mystery with Dr. Biology. **askabiologist.asu.edu**

Teachers: Our "Teacher Toolbox" makes it easy to locate activities by type and grade level.

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