WATER YOU DRINK?

Overview

In this activity students study adaptations made by Sonoran Desert plants and animals to scarce water. They then draw, display, and attempt to categorize these adaptations. Methods humans use to cope with scarce water are also examined.

Subjects: Science, Art, Social Studies
Group Size: pairs or teams of four, class discussion
Estimated Teaching Time: one hour
Curriculum Framework: IB1
Environmental Education Framework: Goals IA, IIA, IIB, IIC, VA
Vocabulary: Crassulacean acid metabolism (CAM), crepuscular, diapause, estivation, evaporation, evapotranspiration, gular fluttering, Henle's loop, irrigation, nocturnal, photosynthesis, stomata, torpid/torpor, transpiration, xeriscape

Objectives

Students will:

- observe that many desert plants and animals have adaptations that help them live in an arid environment.
- draw their own representations of desert organisms' adaptation to dryness.
- categorize adaptations of desert plants and animals.
- identify ways humans adjust to heat and dryness.

Background

Sources: ***THE AUDUBON SOCIETY NATURE GUIDES: DESERTS, NATURESCOPE: DISCOVERING DESERTS***, *Desert Botanical Garden:* ***PLANTS AND PEOPLE OF THE SONORAN DESERT****, and personal conversations with staff of Tucson Botanical Gardens.*

Many desert plants and animals have adapted behavorial strategies or physical characteristics that allow them to survive and prosper in an arid environment. These adaptations did not happen overnight. Fossil evidence indicates that structural adaptations slowly change as the conditions of the environment change, a process that can take hundreds of generations. Because genetic changes take many generations, organisms surviving successfully in the Sonoran Desert might not survive if moved to other ecosystems.

Plants, through a process called photosynthesis, use energy from the sun to change water and carbon dioxide into the sugars needed for growth and reproduction. During photosynthesis, plants capture carbon dioxide and release oxygen by opening tiny pores (stomata) in their leaves. When the stomata are open, water is also lost through a

process called transpiration. Cacti, yuccas, agaves, and many other succulents have developed a specialized chemical system, abbreviated CAM (crassulacean acid metabolism). These plants open stomata **only at night** when temperatures drop and there is less chance of evaporation. CAM enables the plants to take in carbon dioxide to produce and store malic acid, which is used during daylight to manufacture food through photosynthesis.

Other desert plant adaptations include: 1) having **smaller and fewer stomata**, and protecting the stomata from the sun's direct rays and the wind's evaporative power by having **ridges and a pattern of spines, hairs or thorns that provide shade** (cacti); 2) using a **waxy cover** to protect leaves and stems from the escape of water through cell walls (cacti, jojoba, creosote); 3) growing **tiny leaves, no leaves, or different size leaves** for different times of the year (small leaves in summer, large in winter as in brittle bush); thus cutting down on the amount of surface area exposed to sun and wind; 4) **orienting leaves away from the sun** so that leaves are never exposed to direct rays (jojoba); 5) **dropping leaves or branches during drought,** photosynthesizing through stems and twigs (palo verde, ocotillo, creosote); 6) giving off **chemicals** that keep other plants from growing in the vicinity (creosote); 7) growing light green to nearly **white leaves** which reflect the sun better than "forest" green leaves would (brittle bush); 8) having a **very long tap root** (mesquite) or 9) **shallow, broadly spreading roots covering large areas** (cacti); 10) **storing water** in pleats and folds (saguaro and other cacti) or in huge root balls (night-blooming cereus); and 11) **dying** after producing seeds which are covered with chemicals so they will not be eaten (ephemeral wildflowers, like Mexican gold poppies, lupine, owl's clover and many others).

Animals, unlike plants, have the advantage of movement. Animals **move to water** when they get thirsty (desert bighorn sheep, mule deer, bobcats) and **seek shade** during the hottest parts of the day (rabbits). Hawks and vultures fly high into the sky and soar where it is much cooler. Many animals are **nocturnal** (active only at night; most amphibians and snakes) or **crepuscular** (active during dawn and dusk; coyotes, mountain lions, birds, tortoise in the summer).

Other adaptations of **animals** in the Sonoran Desert include: 1) getting **moisture from what they eat** (Gila monsters, pocket mice, desert bighorn sheep and many other desert animals) as well as **manufacturing water during digestion** (kangaroo rat); 2) **regurgitate liquids** for young (mourning doves); 3) **estivate** or "sleep" through the dry times (spadefoot toad) or; 4) **becoming torpid or diapause**, slowing down metabolism or activity during hot times (torpor - pocket mouse; diapause - spiders); 5) produce **small amounts of urine** containing almost no liquid (kangaroo rat); 6) enter **burrows** in the ground (rodents, many insects and spiders); 7) **store fat in body parts** providing insulation as well as an energy reserve (Gila monsters) or

have thick **waxy coatings** around their bodies (insects); 8) have **elongated appendages**, like big ears (jackrabbits) and long legs (ants, beetles, lizards) which cool the animal by radiating heat (long legs also keep internal organs away from the heat of the ground); 9) use forms of **evaporative cooling**, like panting (most birds and mammals), and licking their fur (mammals). Two birds, the roadrunner and lesser nighthawk, lose even less water than panting by using their throat muscles to pump air in a process called gular fluttering.

Many think of deserts as nothing but sand dunes and camels. In reality, deserts are second only to rain forests in the diversity of plants and animals living there. For this activity students will be given information about the adaptations of specific plants and animals of the Sonoran Desert. In pairs or teams their tasks are to draw a picture representing types of desert plant or animal adaptations, and then to classify all these adaptations.

This knowledge will then be transferred to an examination of the ways humans have changed their behaviors to "adapt" to life with little water in deserts. A few examples include escaping the heat; dressing the body, home and land for desert survival; and developing canal systems to import additional water .

Many desert peoples live a nomadic life; by travelling from place to place they are able to survive. (The population of homeless people is higher in the Sonoran Desert winter than in the summer; and of course, Arizona's "snow birds" are legendary for their great escapes when it gets hot.) During hot summers humans seek shade or take a siesta, becoming nearly nocturnal!

People also wear loose-fitting clothing often covering as much skin as possible to trap sweat and reduce evaporation. Others, including the Hohokam as well as present-day Maricopa county residents, irrigate lands for agriculture. Many are now turning to xeriscape, using less water in landscaping their yards. Plants provide shade and add cooling moisture to the desert air. The technologies associated with swamp coolers and air conditioners were developed in the desert and are used by nearly all Sonoran Desert residents.

Materials

- flip chart paper or other large format paper suitable for drawing, one per team
- marking pens
- **SONORAN DESERT PLANTS** and **SONORAN DESERT ANIMALS**, one organism description per team
- large empty wall space to serve as gallery
- masking tape or other approved adhesive to hang drawings in "gallery"
- numbers to attach to finished art, for discussion and auction purposes
- **ADAPTATIONS CHECKLIST**, one per team

Procedures

1. Introduce the activity by telling students that over a great many generations individual species of Sonoran Desert plants and animals have made adjustments to survive conditions of limited water and intense heat. These adjustments are called adaptations. This activity is designed to teach students about how plants and animals have adapted to not having a lot of water available.

2. Provide each pair or team with information about one organism from one of the **SONORAN DESERT PLANTS** and **SONORAN DESERT ANIMALS** sheets. The students' task is to pick one adaptation from the information provided, and draw a picture representing that one way their organism has adjusted to the dryness of the Sonoran Desert. They are to use no words or conventional symbols.

3. When students have finished (usually within 15 minutes), have them attach their art work to the appropriate wall, adding an identification number to the front of the piece.

4. When all the works of art have been hung, open the gallery to the class. Remind students of proper art gallery etiquette. They should view the art silently or speak in hushed tones, confining their comments to the topic of adaptations, by determining what the adaptations depicted might represent as well as the plant or animal species (i.e., they are not art critics)!

5. Allow at least five minutes for the students to examine the adaptations, and let no team explain their adaptation. Distribute and have students complete the **ADAPTATIONS CHECKLIST**. Encourage discussions at this point among the artists and the viewing public! Determine students' success in understanding and completing the **ADAPTATIONS CHECKLIST**.

6. Summarize this study of adaptations to dryness by asking students to name the "adaptations" people have made to life in deserts. Lists might include air conditioning, siesta, and xeriscape or appropriate landscape for shade and additional moisture plants add to the air.

Extensions

1. Give students the opportunity to conduct a silent vote for art in several categories, including: best of show, best adaptation in animal category, best adaptation in plant category, best use of medium, etc. Or stage an auction with students assigned to committees in charge of: making a catalog of each numbered work of desert adaptation art, hanging art works, refreshments, pricing, sales, auctioning, etc.

2. Challenge students to invent their own desert-dwelling organism with adaptations borrowed from several real-life organisms. Invented organisms may be either drawn or written in short story style.

3. Riparian areas are the lifeblood of the desert for they are extremely important to native wildlife and plants in Arizona. Riparian vegetation is made up of associations of plants that occur along drainage ways and floodplains and differ from the species in the surrounding desert. Many species exist only in wet areas in Arizona. Some cannot adapt quickly enough as a species to survive the rapid destruction of this habitat.

   Have students investigate the types and status (endangered/ threatened) of plants and animals native to Arizona's riparian areas. Invite a speaker to talk about riparian communities and the actions students can take to protect this fragile habitat. View Arizona Game and Fish videos about riparian areas. Take field trips to study the plants and animals of different types of riparian areas, including a desert river (such as the Salt River), montane streams, cienegas, desert lakes or ponds, intermittent streams, and dry washes.

4. Have students research other adaptations of Sonoran Desert organisms to dryness and heat. Also have them study species that have adapted in similar (co-evolved species) and unique ways in other deserts of the world. Remind students there are three other North American deserts: the Chihuahuan, Great Basin and Mojave. Deserts in other parts of the world include: the Sahara, Namib, and Kalahari in Africa; the Arabian, Gobi, Iranian, Takla Makan, Thar, and Turkestan in Asia; the Gibson, Great Sandy, Simpson, Sturt and Victoria in Australia; and the Atacama, Monte, and Patagonian in South America. The National Wildlife Federation's **NATURESCOPE: DISCOVERING DESERTS** provides a poster for beginning this study.

   Whatever land straddles the equator, there are pairs of deserts, north and south. The Sahara is matched, south of the rain-soaked forests of central Africa, by the Kalahari and the Namib. The Mojave and Sonoran deserts in the southwest of the United States have their equivalent in the Atacama in South America. And in Asia, the vast deserts of Turkestan and central India are paralleled .. by the great deserts of central Australia. - David Attenborough, ***The Living Planet****, p. 144.*

5. Examine the regional differences within the

Sonoran Desert. The following illustration, provided by Organ Pipe Cactus National Monument, shows the importance of water to one species, the saguaro. In the Tucson area (at Saguaro National Monument East, which averages about 11 inches of rain per year), a twenty-five year old saguaro might be nearly three feet tall. At Organ Pipe Cactus N.M. (which is also in the Sonoran Desert but averages only 9 inches annually), it would take nearly fifty years for a saguaro to reach three feet. Interpolate the growth of saguaros in the part of the Phoenix area that averages only 7 inches of rain per year.

Evaluation

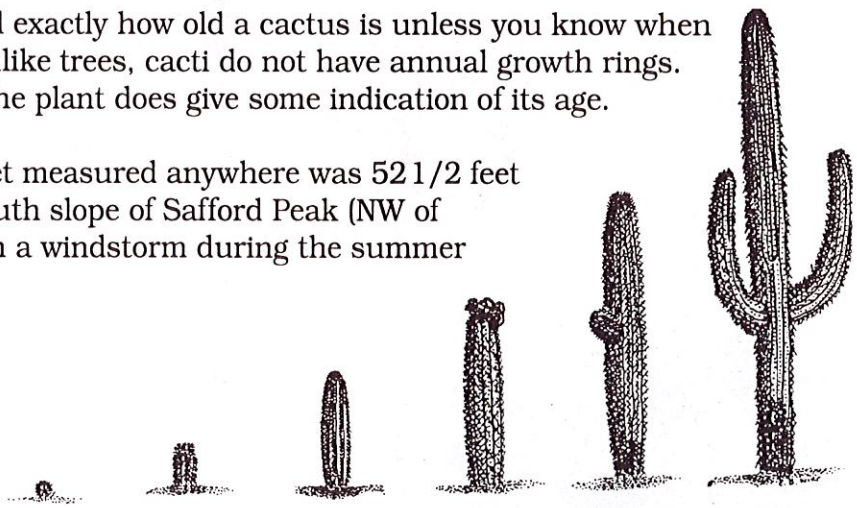
1. Describe **at least two** adaptations plant species have made to life with little water in the Sonoran Desert.

2. Describe **at least two** adaptations animal species have made to life with little water in the Sonoran Desert.

Age-Height Relationships for the Saguaro Cactus

There is no way to tell exactly how old a cactus is unless you know when it started growing. Unlike trees, cacti do not have annual growth rings. However, the size of the plant does give some indication of its age.

The tallest saguaro yet measured anywhere was 52 1/2 feet tall. It grew on the south slope of Safford Peak (NW of Tucson), until it fell in a windstorm during the summer of 1975.



Growth stage:	1 inch tall	1 foot tall	3 feet tall	First flowers 6 1/2 feet tall	First branch 15-16 feet tall	Full height
Approximate age, if found in dry area such as Organ Pipe Cactus National Monument:	10 years	31 years	50 years	69 years	95-100 years	200 years 43 feet tall
Approximate age, if found in wet area such as East side of Saguaro National Monument:	6-7 years	17 years	26 years	36 years	55-60 years	173 years 46 feet tall

Source: Organ Pipe Cactus National Monument

Resources

Arizona Municipal Water Users Association. 1994. **Plants for the Desert Southwest**.

Arizona Game & Fish Department. Videos: **Aquatic Education** and **Riparian Areas**.

Arizona Native Plant Society. 1992. **Desert Accent Plants**. Tucson: ANPS

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Braus, J., Editor. 1988. **NatureScope: Discovering Deserts**. Washington, D.C.: National Wildlife Federation.

Desert Botanical Garden. 1992. **Plants and People of the Sonoran Desert: Classroom and Trail Adventures**. Phoenix: DBG.

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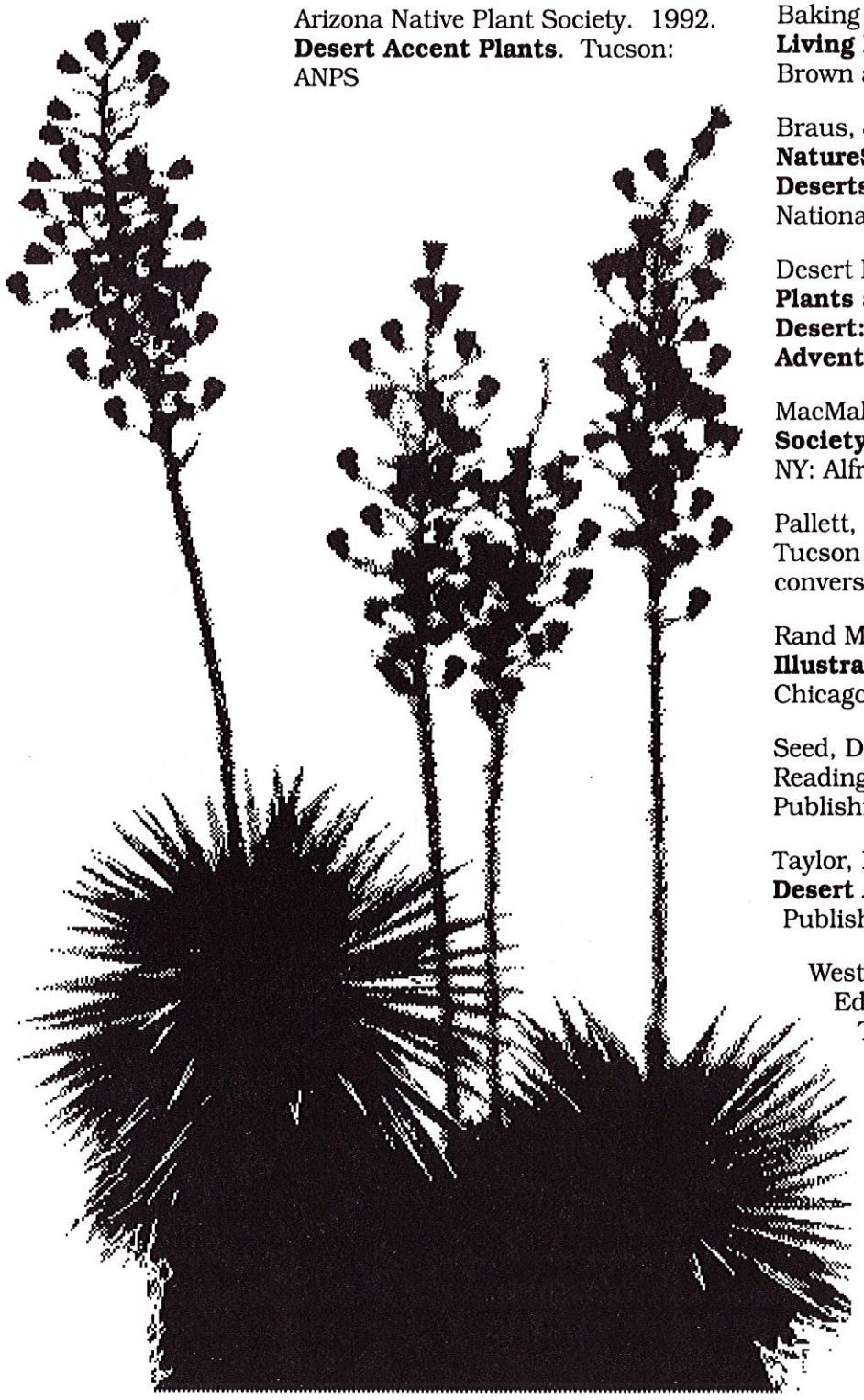

SONORAN DESERT PLANTS

Directions: Draw a picture to show one adaptation of this desert species to dryness.

brittle bush (Encelia farinosa) has a very light green leaf color that reflects the sun's rays and helps reduce evaporation. It also produces different leaf types: it drops large leaves when it gets dry and adds tiny leaves that are also hairier. Tiny leaves reduce the amount of water lost in transpiration because less surface area is exposed to sun and wind than in a plant with larger leaves. Hairy leaves provide shade and reduce drying effects of wind.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

ephemeral wildflowers include many species such as Mexican gold and California poppies (Eschscholtzia mexicana and E. californica), owl's clover (Orthocarpus purpurascens) and lupine (Lupinus arizonicus and others). These flowers bloom in spring following good fall and winter rains, and die after producing seeds. Seeds are covered by a chemical that inhibits sprouting until every trace of the chemical is washed away by water. This can take two or more years.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

saguaros (Carnegiea gigantea) have spines that provide shade and reduce wind, providing for less water loss due to evaporation. It also has: 1) a huge network of shallow roots to gather water, and 2) ridges which store water, swelling when water is abundant and shrinking as it gets dry. More than four-fifths of a saguaro's weight may be water stored in its stem to be used in times of drought. This cactus only opens its stomata (pores) at night when temperatures drop and there is less chance of evapotranspiration (evaporation during transpiration). A specialized chemical system, abbreviated CAM, enables the plants to take in carbon dioxide at night and store it for photosynthesis during daylight.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

night-blooming cereus (Perniocereus greggii) has a huge root tuber for water storage, and spines that provide shade and reduce evaporation through cell walls. Like most succulents, this cactus only opens its stomata (pores) at night when temperatures drop and there is less chance of evapotranspiration (evaporation during transpiration). A specialized chemical system, abbreviated CAM, enables the plants to take in carbon dioxide at night and store it for photosynthesis during daylight without losing water by opening its stomata. Plants are nocturnal in that they bloom only at night. Usually all plants in the same area bloom on the same night to promote cross-pollination by moths.

SONORAN DESERT PLANTS

Directions: Draw a picture to show one adaptation of this desert species to dryness.

creosote (Larrea divaricata) exudes a chemical to keep other plants from growing too near, taking water it needs. This bush has very tiny leaves covered with a waxy resin to protect from evaporation through cell walls. Tiny leaves reduce the amount of water the plant loses during transpiration, because less surface area is exposed to sun and wind than in a plant with larger leaves.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

palo verde (genus Cercidium) have tiny leaves that reduce transpiration (water loss when stomata are open during photosynthesis), because less surface area is exposed to sun and wind than in a plant with larger leaves. This tree drops its tiny leaves during low water periods, but still can make food through photosynthesis because it has green branches.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

mesquite (genus Prosopis) has tiny leaves that reduce the amount of water the plant loses during transpiration, because less surface area is exposed to sun and wind than in a plant with larger leaves. This tree also has a huge tap root, often as long as groundwater is deep.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

jojoba (Simmondsia chinensis) has a waxy coating on its stiff leaves that protect cells from losing water through evaporation. This bush adjusts leaves so the hot summer sun hits leaf edges instead of the leaf surface directly. This reduces the volume of water lost while the plants have their stomata open during transpiration.

SONORAN DESERT ANIMALS

Directions: Draw a picture to show one adaptation of this desert species to dryness.

desert bighorn sheep (Ovis canadensis) - Ewes (females) & lambs come to water almost daily when it is dry. Rams (males) often wait up to a week, traveling sixty miles or more between drinks. Rams drink nearly four gallons of water with each drink, storing the water in their stomachs! They have hairy coats to reduce water loss through evaporation, and thin bodies with slender legs. These mammals also get moisture from the plants they eat.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

desert tortoise (Xerobates agassizii, formerly classified as genus Gopherus) These reptiles store water in their bladders, and move underground in burrows up to thirty feet long to escape the heat. With extreme dryness and heat, they become active at dusk and dawn (or become crepuscular). Sonoran Desert subspecies is protected in Arizona; Mojave Desert subspecies is threatened with extinction.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

Gila monsters (Heloderma suspectum) - store water and fat in their tails. This venomous lizard gets moisture from what it eats: centipedes, bird and snake eggs and sometimes other lizards, small birds and mammals. This reptile seeks shade in underground holes where they can live off the fat in their tails (losing up to half their body weight in extreme dryness). Can also swim in the case of flash floods!

Directions: Draw a picture to show one adaptation of this desert species to dryness.

black-tailed jack rabbit (Lepus californicus) has long, thin ears (large surface area) with prominent veins that act as radiators, losing heat without sweating or losing any water. This mammal seeks shade in rocks or vegetation to keep cool. Also pant through their noses as a form of evaporative cooling. Long legs also help release body heat into the air. Get water from the plants they eat.

SONORAN DESERT ANIMALS

Directions: Draw a picture to show one adaptation of this desert species to dryness.

giant desert hairy scorpions (Hadrurus arizonensis) adjust their body temperature by moving deeper into burrows during the day, but active at night (nocturnal). They can reabsorb water from feces in their gut tracts, depositing very dry fecal matter. Undergo long periods of inactivity (diapause) when their metabolism actually slows (can withstand the loss of 30% of their body weight without damage). Also have extremely low oxygen requirements and thus very low respiration and very little water loss. Gets moisture from insects, and occasionally small lizards it eats.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

spadefoot toads (Scaphiopus couchi) use feet to dig burrow twenty-five inches below soil surface. This amphibian can be dormant (estivates) up to two years when dry, losing half or more of their body weight. To prevent water loss it covers itself completely with a dry hard covering. With heavy rain, it comes to the surface and sits in a puddle to reconstitute itself as water is soaked in through a spot on its stomach. Reproduces in temporary bodies of water, where eggs become tadpoles in 13 hours and toads in 7 - 10 days (this life cycle requires several months and can take more than a year in non-desert toad species).

Directions: Draw a picture to show one adaptation of this desert species to dryness.

kangaroo rat (genus Dipodomys) is a nocturnal mammal, active at night. It reabsorbs nearly all the water in its kidneys before it urinates. A tubule within the kidney of the kangaroo rat, called Henle's loop, is proportionately the longest of any mammal.

Directions: Draw a picture to show one adaptation of this desert species to dryness.

greater roadrunner (Geococcyx californianus) gets moisture from what it eats: insects, lizards, scorpions and snakes. Many birds pant as a form of evaporative cooling. By using throat muscles (gular) to pump air almost like a radiator, the roadrunner loses even less water than birds that pant to cool themselves. This process is called gular fluttering.

SONORAN DESERT SPECIES ADAPTATIONS CHECKLIST

Directions: Fill as many blanks as possible, listing at least one organism in each major category.

CHEMICALS:	CAM (stomata open at night)	
	keep other plants away	
HIDE:	move to burrow/hole	
	move leaves out of direct sun	
	seek shade	
LOSE IT:	drop leaves or branches	
	lose body weight	
	die, but produce lots of seeds first	
REPRODUCE:	seeds with protective coatings	
	fast life cycle	
AVOIDANCE:	nocturnal (out at night)	
	crepuscular (dawn & dusk)	
	estivate ("sleep") or enter diapause (inactive)	
SUCK WATER:	long tap root	
	huge root ball	
	shallow, wide roots	
	store water in cells	
SUPER PARTS:	waxy coating, spines or hair	
	fat layers	
	tiny, light-colored, or two sizes of leaves	
	long, thin ears or legs	
	green branches	
	kidneys gather or store water	
	flutter gular (and pant)	