How Tornadoes Form

Name _____

A **tornado** is a violently rotating column of air, extending from a thunderstorm to the ground. The most violent tornadoes have rotating winds of 250 miles (402 kilometers) per hour or more.

Tornadoes form in the following sequence:

Fronts
In the atmosphere, cool air pushes against warm air. The place where the two masses of air meet is called a **front**. A front can stretch over 100 miles (161 kilometers).

As the cool air presses forward, it slides underneath the warm air. The warm air is pushed upward and water droplets form. Fast-growing clouds take shape. These clouds are called **thunderheads**. A line of thunderheads 100 miles (161 kilometers) or more in length may grow along a front.

Thunderheads
Thunderheads, or **cumulonimbus** (kyu-mya-lo-NIM-buhs) **clouds**, are the giant clouds that produce storms with lightning and thunder. When you see a thunderhead, you are looking at a place in the sky where warm, moist air is rising quickly through cool air. This can happen along and ahead of fronts as well as on hot, sunny days.

When the sun heats the ground, the air near it grows warm, too. The warm air rises, but it sometimes becomes trapped by a layer of cooler air above it. As the day continues, the sun keeps shining and more heated air pushes its way skyward. Finally, it breaks through. The warm air blasts high into the sky, like water shooting up from a fountain, and a thunderhead grows.

The thunderheads most likely to cause tornadoes are those that form along and ahead of fronts. This is because strong winds often blow high above fronts. The power of these winds, along with slower winds closer to the ground, can make the rising air in a thunderhead start rotating. This difference in wind direction and speed is called **wind shear.** At first the rotating winds spin around a horizontal axis parallel to the ground. However, as the warm air continues to rise, the updraft becomes strong enough to lift the rotating air into a vertical spin, roughly perpendicular to the ground.

A **supercell** is a thunderstorm with a persistent rotating updraft. Supercells are rare, but they are responsible for a remarkably high percentage of severe weather events, especially tornadoes, extremely large hail and damaging straight-line winds. Supercells

How Tornadoes Form

frequently travel to the right of the main environmental winds; that is, they are "right movers."

Mesocyclones

If the rising air in a thunderhead begins to rotate, the column of spinning winds is called a **mesocyclone** (mez-uh-SY-klon). As a mesocyclone rotates, it stretches toward warm air near the ground. The lower part of the mesocyclone narrows. The narrower it becomes, the faster it spins.

The mesocyclone acts like a giant vacuum-cleaner hose. Warm air is drawn in through the lower end of the mesocyclone and pulled upward through the thunderhead. The air swirls higher and higher. The spinning air may soar all the way to the top of a thunderhead, 10 miles (16 kilometers) above the ground.

Some mesocyclones spin like this for a few minutes and then just disappear. In others, however, a smaller column of faster-spinning air forms inside the bottom of the mesocyclone. This column is usually less than a half-mile (800 meters) wide. As it spins, it reaches toward the ground.

Funnel Clouds

When the column of tightly spinning winds dips down from the mesocyclone, it draws in warm, moist air. The air cools as it is pulled up into the column. Tiny droplets of water form and a whirling cloud appears. This cloud is called a **funnel cloud**.

Funnel clouds are named for their shape. They are often shaped like funnels—tubes that are wide at the top and narrow at the bottom. Some funnel clouds hang straight down from the storm cloud. Others stretch sideways through the sky. A funnel cloud may dip down and then retract into the mesocyclone. Or, it may touch the ground. If it does, the funnel cloud is called a **tornado**.

Sometimes when a tornado is forming, no funnel cloud can be seen. The air near the ground is so dry that, when it is sucked into the whirling column, no water droplets form. Then the fast-spinning air stays invisible until it becomes a tornado, stirring up dust and soil into a spinning **debris cloud**.

Tornadoes

If you see a funnel cloud dip down from a thunderhead, it is usually a sign that a tornado is on its way. But not all tornadoes look like funnels. They can be shaped more like jars—

How Tornadoes Form

with the same width from top to bottom. Or, they may have more than one funnel. Large tornadoes may have several narrow, twisting funnels circling around.

Some of the largest, most dangerous tornadoes do not look like funnels at all. These tornadoes appear to be big clouds moving along the ground. Tornadoes also change shape with time. Many funnels become thin, like pieces of rope, as they lose power. They look like giant elephant trunks snaking through the sky. The winds of a tornado can be so strong that they can blow large objects, such as parts of buildings, trees and cars, for miles.

Tornado Types
There are three types of tornadoes: weak, strong and violent. On the Enhanced Fukita Scale (EF Scale), these range in intensity from EF0 to EF5.

Weak Tornadoes (EF0, EF1)
If the winds of a tornado spin at 110 miles (177 kilometers) per hour or less, scientists consider the tornado weak. Weak tornadoes usually leave behind a path of damage less than 3 miles (5 kilometers) long and 50 yards (46 meters) wide. Weak tornadoes are the most common of the three tornado types.

Strong Tornadoes (EF2, EF3)
Strong tornadoes have winds ranging from 111 to 165 miles (178 to 266 kilometers) per hour. These tornadoes average a path about 9 miles (14 kilometers) long and 200 yards (183 meters) wide.

Violent Tornadoes (EF4, EF5)
Violent tornadoes are the least common type of tornado. Only 1 in 50 tornadoes in the United States is classified as violent. These tornadoes have winds ranging from 166 to more than 200 miles (267 to 322 kilometers) per hour and may last several hours. A typical violent tornado leaves a path of destruction about 26 miles (42 kilometers) long and 425 yards (389 meters) wide. A few violent tornadoes have left paths that were more than 100 miles (161 kilometers) long and 1 mile (1.6 kilometers) wide.

A Cartographer's Guide to Tornadoes

Name _____

Directions: Research to find the answers to the following questions. You will need to investigate both books and Internet resources to find the answers.

1. Weather in the United States is influenced by four air masses. What are they? On the map on the third page, show where these air masses can be found.

2. What forces move these air masses around?
   Hint: Find out about the jet stream and prevailing **westerlies**.
   Hint: Learn the definitions of a **cyclone**, **warm front** and **cold front**. How does the cyclone affect the movement of the warm and cold air masses?

   On the map on the third page, show the directions these air masses are likely to take as they move toward and into the United States.

3. How might landforms of the United States affect the air masses moving through the area?
   Hint: The Rocky Mountains and Appalachian Mountains are major players in this weather drama. Find out about **upslope** and **downslope** winds and how they affect the movement of air.
   Hint: Where are there no barriers to the movement of air?

4. What is a cold front and what is a warm front? What happens when the two air masses collide?

5. Think back to what you know about how tornadoes form. Based on information about the formation of cumulonimbus clouds, why does an **occluded front** create excellent conditions for the formation of severe thunderstorms and, eventually, tornadoes?

6. Collisions between cold, dry air masses and warm, moist air masses take place in the Great Plains. This part of the United States is sometimes called Tornado Alley. Compare an alley in your town to Tornado Alley. How are they similar?

7. Tornado season tends to move north with the sun. That is, tornado season starts earlier in the southern part of Tornado Alley than in its northern regions. Why is spring the most active time for tornadoes? Use the same reasoning to explain why the southeastern states sometimes have a "mini-tornado season" in the fall.

A Cartographer's Guide to Tornadoes

Resources:

- Think Quest: Thunderstorms and Tornadoes (*http://library.thinkquest.org/C0112425/stu_thundertornado.htm*)
- USA Today: Weather and Climate Science: Thunderstorms (*http://www.usatoday.com/weather/resources/basics/thunderstorms.htm*)
- The National Weather Servie: Tornado Climatology (*http://lwf.ncdc.noaa.gov/oa/climate/severeweather/tornadoes.html*)
- The National Weather Service: F5 Tornadoes of the United States (*http://www.spc.noaa.gov/faq/tornado/f5torns.html*)
- Physical Geography (*http://www.physicalgeography.net/fundamentals/7t.html*)
- The National Weather Service: Jetstream: An Online School for Weather (*http://www.srh.weather.gov/jetstream/matrix.htm*)
- Weather Patterns: Chapter 17 (a slide presentation by Cobb County Schools in Georgia) (*http://www.cobb.k12.ga.us/~dickerson/Weather%20Patterns%20Chapter%2017.ppt*)
- The Weather Channel: Special Reports—Tornado! (*http://www.weather.com/newscenter/specialreports/tornado/index.html*)
- National Severe Storms Laboratory, Tornadoes: Nature's Most Violent Storms (*http://www.nssl.noaa.gov/edu/safety/tornadoguide.html/*)
- The Why Files—Tornadoes (pages 1–5) (*http://whyfiles.org/013tornado/index.html*)

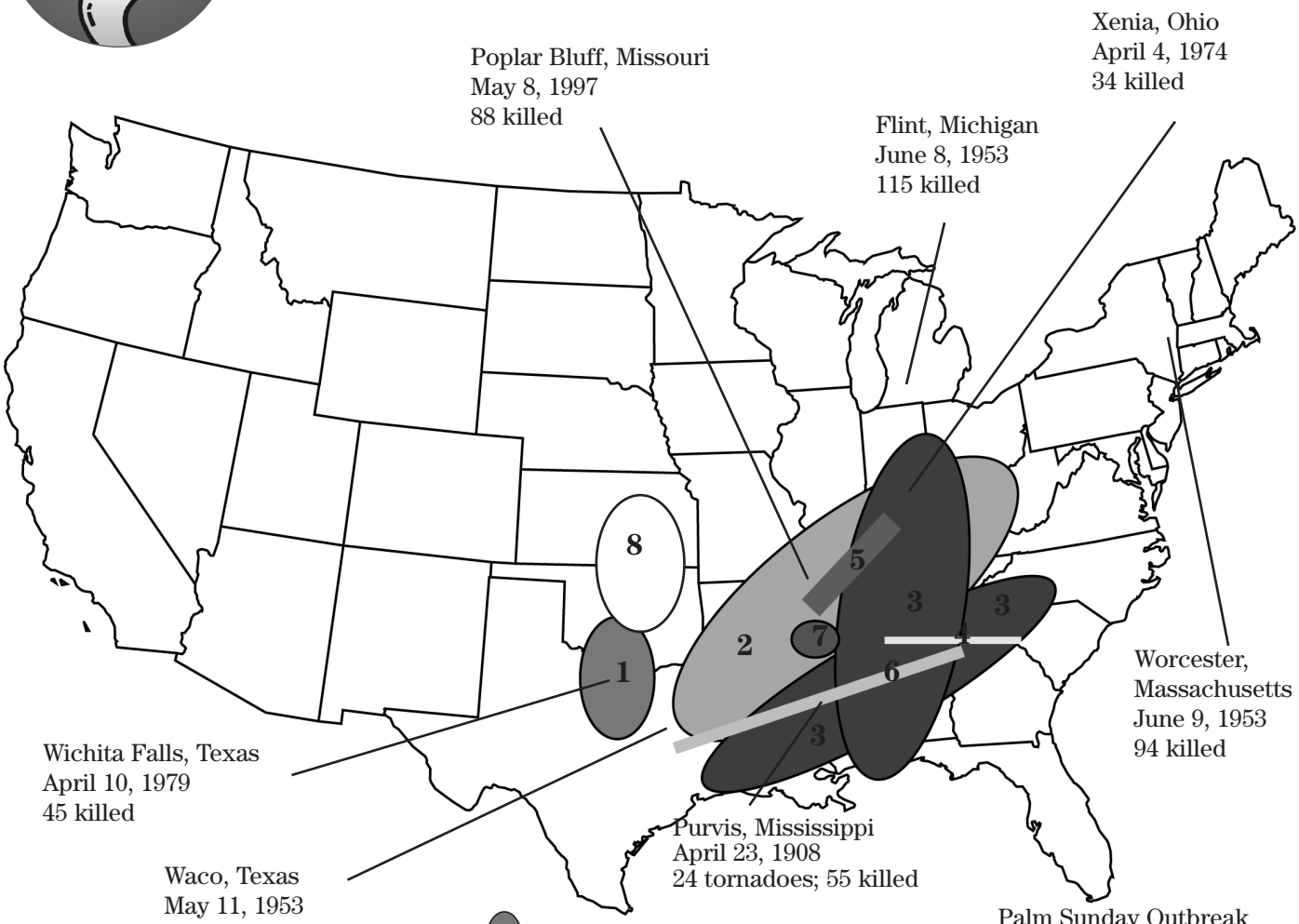
A Cartographer's Guide to Tornadoes

American Red Cross

Visit the American Red Cross Web site
at *www.redcross.org/disaster/masters*

Tornado Mapping

Name _____



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16 tornadoes
320 deaths

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May 3, 1999
48 killed

Adapted from The Weather Channel's "The Weather Classroom."

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The Enhanced Fujita Scale of Tornado Intensity

Name _____

The size of a tornado is not necessarily a sign of its strength. Large tornadoes can be weak, and small tornadoes can be violent. Another consideration is the stage in the life cycle of the tornado. A "small" tornado may have been larger and is at the "shrinking" stage of its life cycle.

On the next page is the Enhanced Fujita Scale (EF Scale), which is used to rate tornadoes. The EF Scale, launched in 2007, is an update of the Fujita-Pearson scale developed by Dr. Theodore Fujita (University of Chicago) and Allen Pearson (then director of the National Severe Storms Forecast Center). The EF Scale measures tornado intensity based on damage, not the appearance of the funnel or the measured wind speeds. The scale converts the degree and type of damage caused by a tornado into estimates of wind speeds. Categories are designated after the event.

The Enhanced Fujita Scale of Tornado Intensity

	EF Scale Number	Wind Speed (3-second gusts)	Description of Damage
	**EF0 Light damage**	**65 to 85 mph (105–137 km/h)**	Causes some damage to siding, shingles and gutters; breaks branches from trees and overturns trees with shallow roots
	**EF1 Moderate damage**	**86 to 110 mph (138–177 km/h)**	Causes considerable roof damage; can uproot trees, bend flagpoles and large signs; may overturn single-wide mobile homes, tear off exterior doors and break windows and other glass
	**EF2 Considerable damage**	**111 to 135 mph (178–217 km/h)**	Destroys most single-wide mobile homes; tears roofs off well-constructed homes and shifts these homes from their foundations; uproots or breaks large trees in half; debarks softwood trees; tosses and overturns cars; collapses flag poles and large signs
	**EF3 Severe damage**	**136 to 165 mph (218–266 km/h)**	Tears the bark from hardwood trees; destroys all but small portions of houses; causes severe damage to office buildings or shopping malls; overturns trains and throws cars; blows away structures with weak foundations
	**EF4 Devastating damage**	**166 to 200 mph (267–322 km/h)**	Completely destroys well-built residences, large sections of school buildings and large office buildings; throws about cars and other large objects; tosses small objects like missiles
	**EF5 Incredible damage**	**More than 200 mph (more than 322 km/h)**	Causes significant structural deformation of mid- and high-rise buildings; throws automobile-size missiles through the air 100 yards (91 meters) or more. To date, no EF5 tornadoes have been recorded.

American Red Cross

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Real-life Tornadoes

Name _____

Directions: Read the following stories that describe several actual tornadoes. Classify each tornado from EF0 to EF5, using *The Enhanced Fujita Scale of Tornado Intensity*, and state your reasons.

1. On March 18, 1925, at 3:35 p.m., Howard Rawlinson was in his classroom on the third floor of the Crossville, Illinois, Community High School, when the school janitor burst in and told Howard's class that if they had never seen a tornado, they were going to see one now. Howard watched as one of the dark clouds put two fingers down to earth. The tornado then came to a barn and the two funnels merged and ripped the roof and some of the walls right up into the air. Some pieces of the barn fell to the ground, and the others started swirling around the outside the tornado. The tornado was ripping the trees right out of the ground. After the tornado had left, damage was assessed. Most of the homes had some walls and roofs torn off. There was also the usual interesting stuff such as straws driven into trees.

   Category: _____

   Reason 1:

   Reason 2:

   Reason 3:

Real-life Tornadoes

2. A swarm of huge tornadoes ripped through Oklahoma and Kansas on May 3 and 4, 1999, killing 48 and destroying thousands of homes. As the search went on in dozens of dazed communities, Oklahoma Governor Frank Keating told CNN, "I've never heard of anything like this... The extent of devastation is unprecedented." The governor called out the National Guard. The National Weather Service said that 45 twisters had hit Oklahoma and 14 had hit Kansas. At least one twister was a mile wide at times. Some of the worst damage occurred in Oklahoma City, where whole residential neighborhoods were lifted off their foundations and were wiped out. In Moore, a suburb of Oklahoma City, John Ireland told CNN, "It looks like a bomb hit here. Houses are just leveled. It looks like a battlefield."

   Category: _____

   Reason 1:

   Reason 2:

   Reason 3:

3. The tornado had touched down for about 10 minutes in Nebraska on June 10. The Warrens had noticed the tornado coming and headed for shelter in their basement. The winds were very strong. After the tornado had passed, they came up from their basement to assess the damage. Only minimal damage was done to their home. Some of the shingles were ripped off their roof. Their neighbor was not so lucky. His mobile home had been pushed over. Luckily, he was out of town. Later that day, the news reported wind speeds of 86 mph (138 kph). In the city, cars had been moved by the tremendous winds. The windows in office buildings had been broken by flying debris.

   Category: _____

   Reason 1:

   Reason 2:

   Reason 3:

The Truth About Tornadoes

Name _____

Directions: Read these statements about tornadoes carefully. Which do you think are true? Which are false? Why do you think so?

1. **Large hail or a greenish sky:** When the sky turns greenish in color, take cover. Hail and tornadoes frequently emerge from such a sky.
2. **Location:** Tornadoes can occur only in Tornado Alley.
3. **Water safety:** Tornadoes never form over water, only over land.
4. **Pressure:** Always open the windows of a building if a tornado is coming so the building will not explode.
5. **Cloud of debris:** An approaching cloud of debris can mark the location of a tornado, even if a funnel is not visible.
6. **Driving in tornadoes:** If you are in a car during a tornado, get out of the vehicle and find a safe place.
7. **Funnel cloud:** A visible, rotating extension of the cloud base is a sign that a tornado may develop.
8. **Timing:** Tornadoes can occur in any month of the year if the geographic and climatic conditions are present.
9. **Safe place:** Highway overpasses are a safe place to hide during a tornado.
10. **Roaring noise:** People will often say they heard a roaring noise, much like the sound of a freight train.
11. **Calm behind the storm:** After the tornado has passed, you will probably see clear, sunlit skies.
12. **Safe in a city:** Tornadoes never strike big cities.

Tornado WATCH Versus WARNING

Name _____

What to Do During a Tornado WATCH

If a tornado WATCH is issued for your area, it means that a tornado is possible.

- Listen to National Oceanic and Atmospheric Administration (NOAA) Weather Radio or a local radio or television station for updated information. Tornadoes can change direction, intensity, and speed very quickly.

- Be alert to changing weather conditions. Tornadoes accompany severe thunderstorms, and weather conditions can change rapidly. Large hail, blowing debris, or the sound of an approaching tornado may alert you. Many people say an approaching tornado sounds like a freight train.

- Make sure your family disaster supplies kit is ready.

What to Do During a Tornado WARNING

If a tornado WARNING is issued, it means that a tornado has actually been spotted, or is strongly indicated on radar, and it is time to go to a safe place immediately. Remember, there is often no time to issue a tornado WARNING. If the signs are there and a WATCH is in effect, move to safety.

- Listen to NOAA Weather Radio or a local radio or television station for updated information. (NOAA Weather Radio, which is broadcast on seven VHF frequencies ranging from 162.400 MHz to 162.550 MHz, can be heard on handheld radio receivers that just pick up Weather Radio or desktop or console models that receive Weather Radio in addition to other broadcasts. These can be purchased at many retail outlets, including electronics, department, sporting goods and boat and marine accessory stores and their catalogs. They can alslo be purchased via the Internet from online retailers or directly from manufacturers.)

- If you are inside, go to your safe place to protect yourself from glass and other flying objects. The safest place to take shelter during a tornado is in a basement. If your home does not have a basement, go to the lowest floor and take shelter in a hallway, closet, or small room toward the inside of the building, away from windows.

Tornado WATCH Versus WARNING

- Get under a piece of sturdy furniture, such as a workbench or heavy table, and hold on to it. Sturdy furniture will help protect you from falling debris. If tornado wind enters the room and the object moves, holding on with one hand will help you move with it, keeping you protected. Use your other arm and hand to protect your head and neck from falling or flying objects.

- Stay away from windows. Opening windows allows damaging winds to enter the structure. Leave the windows alone.

- If you are outside in a car or in a mobile home or transportable classroom, go immediately to the basement of a nearby sturdy building. Tornado winds can blow large objects, including cars and mobile homes, hundreds of feet.

- If there is no nearby building, lie flat in a low spot. Use your arms and hands to protect your head. Do not go under highway bridges and overpasses because dangerous flying debris can be blown under them, or weakened overpasses and bridges can be destroyed. Tornadoes come from severe thunderstorms, which can produce a lot of rain. If you see quickly rising water or floodwater coming toward you, move to another spot.

- Avoid places with wide-span roofs, such as auditoriums, cafeterias, gymnasiums, large hallways or shopping malls. Wide-span roofs are frequently damaged or destroyed in tornado winds. Wide-span roofs provide less protection than roofs over smaller rooms and increase the risk of injury.

Knowing and taking the right safety actions during a tornado WATCH and a tornado WARNING can save your life and help you save the lives of others. In the event of a tornado, people must first go immediately to a safe place and then protect themselves by dropping to the floor or ground and protecting their heads and necks with their arms.

American Red Cross

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Myths and Facts About Tornadoes

Name _____

Myth

Tornadoes can happen only in "Tornado Alley."

Fact

Tornadoes can happen in every state.

Myth

You should open the windows if a tornado is coming so the building will not explode.

Fact

Research has shown that buildings do not explode from the low air pressure of a tornado. Opening windows can increase the chance of high winds entering and causing more damage to your home and exposing you to injury. Leave the windows alone.

Myth

You should try to "outdrive" a tornado.

Fact

A tornado can pick up a car and toss it about like a toy. If you are in a car during a tornado, you should get out and find a safe place.

Myth

Highway overpasses are a safe place to hide during a tornado.

Fact

People who take shelter under a highway overpass can be killed because the overpass acts like a wind tunnel and brings stronger winds and a lot of debris.

Myth

Tornadoes happen only in the springtime.

Fact

Most tornadoes do happen from March through August; however, they can occur in any month.

Myth

Tornadoes never strike big cities.

Fact

Tornadoes do happen in big cities. For example, St. Louis has had 22 tornadoes in the past 40 years; Oklahoma City and Salt Lake City have been struck by tornadoes.

Eyewitness to Time

Name _____

Directions: Use the data below to create a sequential time line and add at least five more documented tornadoes to the list. Beneath each entry on your time line, describe its importance in the development of greater tornado safety.

- 1880—First group of weather "reporters" documents tornadoes and the weather associated with them.
- 1950—Tornado and severe weather data and plotting are written out by hand.
- 1938—The word **tornado** is now included when weather conditions indicate.
- 1997—The National Severe Storms Laboratory is established as the foremost center for reporting severe weather.
- 1948—Scientists accurately predict an outbreak of tornadoes.
- 1974—More than 300 people are killed in a "super outbreak" of 148 tornadoes in 11 Midwestern states.
- 1952—The Weather Bureau–Severe Weather Unit is established and issues the first public tornado bulletin. Thirty-six tornadoes cause deaths in Arkansas, Mississippi, Louisiana, Alabama, Tennessee, Kentucky and Missouri.
- 1947—A centralized severe weather forecasting program is established in the United States.
- 1842—The principle of sound waves is identified by Christian Doppler.
- 1888—The mention of the word **tornado** is felt to provoke undue fear and panic and is banned from announcements to the public.
- 1999—Devastating outbreak of tornadoes strikes Oklahoma and Kansas.
- 1988—Doppler radar is used to more accurately predict severe weather.
- 1953—Deadly tornadoes strike Flint, Michigan; Worcester, Massachusetts; and Waco, Texas.
- 1980—An interactive computer arrives at the Centralized Storm Information Center.
- 1884—More than 800 people are killed by tornadoes in Mississippi, Alabama, North and South Carolina, Tennessee, Kentucky and Indiana.
- 1928—The first documented eyewitness account of a tornado is given by Will Keller, a Kansas farmer.
- 1950—The use of Severe Weather Bulletins saves lives.
- 1965—Computers begin to be used in weather forecasting.

Source: National Weather Service

American Red Cross

Storm Trackers

Name _____

At one time, meteorologists had to depend solely on the eyewitness accounts of tornado survivors to gather information about the nature of tornadoes. Today, the development of Doppler radar has made it possible, under certain circumstances, to detect the possibility of tornado development. However, people remain an important part of the tornado detection system. Not all tornadoes occur in situations in which radar can "see" a developing storm.

Volunteers make up a network of storm spotters, who work with their local communities to watch out for approaching tornadoes. Forewarning helps communities take appropriate action in the event of a tornado. Information from storm spotters is relayed to the National Weather Service (NWS), the official provider of weather forecasts for the nation. When appropriate, the NWS issues a WARNING that is then broadcast over a special weather link to NOAA Weather Radio and television and radio stations.

Communities monitor all resources to obtain the latest information on a tornado or a possible tornado: satellite and radar maps from the NWS, reports from storm spotters, utility company information, etc.

Professional and amateur storm chasers have perfected the art of being in the right place at the right time for a tornado. They race after nature's most destructive whirlwinds, armed with cameras, camcorders and measurement devices. Storm-chaser documentation of the path and passage of storms has added to meteorologists' knowledge about the nature of these deadly storms. The technology available today makes storm chasing more accurate.

Assignment:

1. As a member of a storm-chasing team, you must follow the path of a tornado.

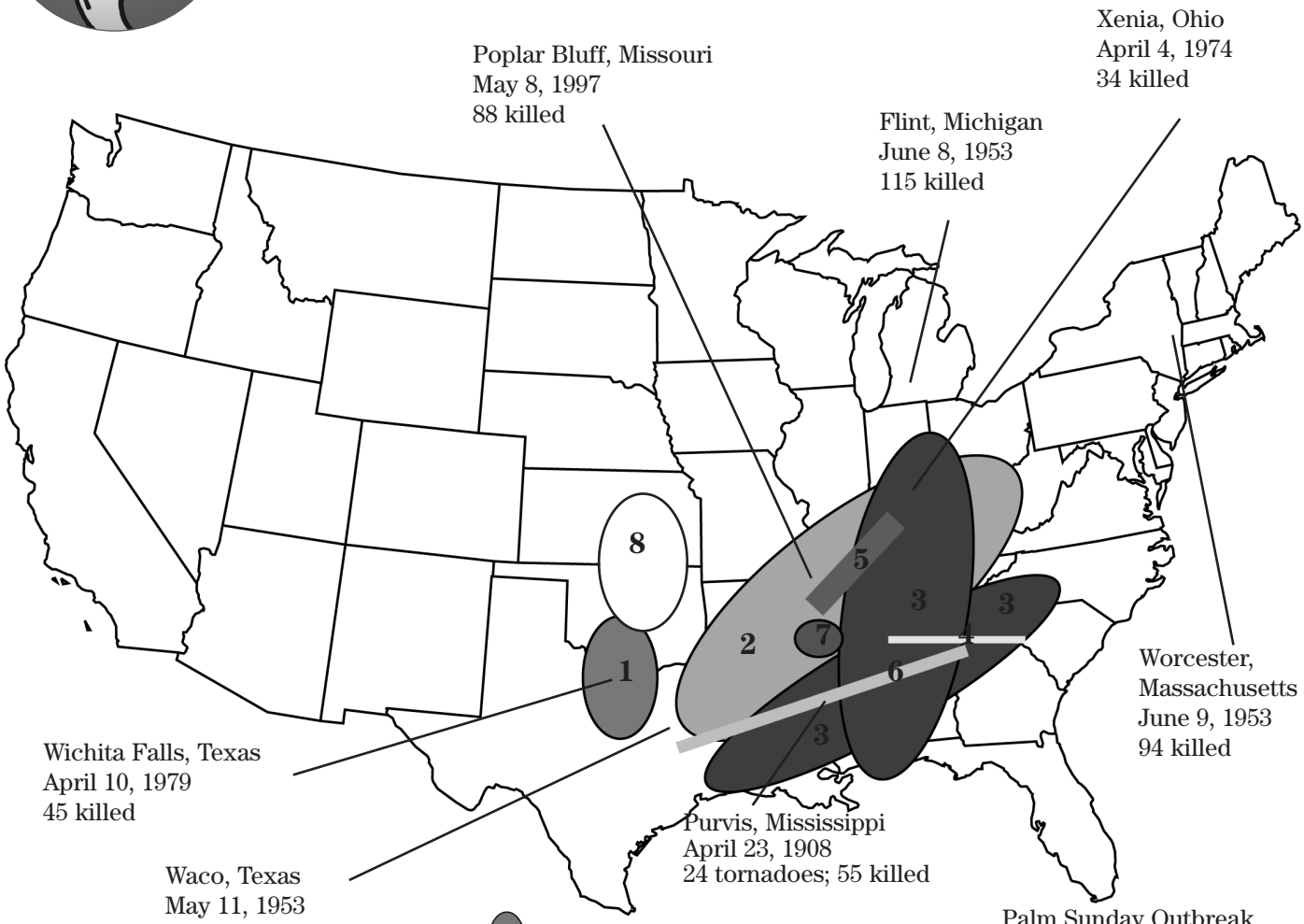
2. Select a historical tornado outbreak from the activity sheet *Tornado Mapping*.

3. Conduct research to follow the tornado: its path (length and width); the time of sightings; the number of touchdowns; eyewitness interviews; statistical information (wind speeds, Enhanced Fujita Scale number, damage reports, etc.).

4. Write your report in diary form, from the time you first set off to chase the possible storm, to your first sighting, through the final damage reports. Describe your tools and the type of information—measurements, videos and photographs, and eyewitness accounts—that you have gathered. Include a map of the track of the tornado.

Tornado Mapping

Name _____



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