# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>PAGE</th>
<th>TOPIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>SPECIES LIST</td>
</tr>
<tr>
<td>8</td>
<td>VENOMOUS ANIMALS OF THE SOUTHWEST</td>
</tr>
<tr>
<td>10</td>
<td>SCIENCE</td>
</tr>
<tr>
<td>12</td>
<td>STATISTICS</td>
</tr>
<tr>
<td>15</td>
<td>CLASSIFICATION AND CONCEPTS</td>
</tr>
<tr>
<td>18</td>
<td>PLANTS 1: TERMINOLOGY</td>
</tr>
<tr>
<td>22</td>
<td>PLANTS 2: TYPES OF PHOTOSYNTHESIS</td>
</tr>
<tr>
<td>23</td>
<td>CLIMATE 1</td>
</tr>
<tr>
<td>25</td>
<td>CLIMATE 2</td>
</tr>
<tr>
<td>26</td>
<td>ADAPTATION</td>
</tr>
<tr>
<td>28</td>
<td>DESERT ADAPTATION CONCEPTS</td>
</tr>
<tr>
<td>30</td>
<td>DESERT ADAPTATION STRATEGIES</td>
</tr>
<tr>
<td>32</td>
<td>BIRDS</td>
</tr>
<tr>
<td>33</td>
<td>MATING SYSTEMS</td>
</tr>
<tr>
<td>35</td>
<td>ARTHROPODS</td>
</tr>
<tr>
<td>37</td>
<td>FISH, AMPHIBIANS, AND REPTILES</td>
</tr>
<tr>
<td>39</td>
<td>MAMMALS</td>
</tr>
<tr>
<td>44</td>
<td>PLATE TECTONICS</td>
</tr>
<tr>
<td>45</td>
<td>GEOLOGY CONCEPTS</td>
</tr>
<tr>
<td>46</td>
<td>GEOLOGY AND GEOGRAPHY OF THE SOUTHWEST</td>
</tr>
<tr>
<td>48</td>
<td>PLANT COMMUNITY STUDY</td>
</tr>
<tr>
<td>54</td>
<td>WILDFLOWER/POLLINATOR SYSTEMS</td>
</tr>
<tr>
<td>57</td>
<td>BIRD IDENTIFICATION</td>
</tr>
<tr>
<td>61</td>
<td>OWL PELLET LAB</td>
</tr>
<tr>
<td>65</td>
<td>GEOLOGICAL DETECTIVE STORY</td>
</tr>
</tbody>
</table>
127 COMMON SPECIES OF PERENNIAL PLANTS AND ANIMALS IN TUCSON AREA

Words in parentheses are optional on identification tests.

**PLANTS (28)**

**Trees**
- Catclaw Acacia
- Whitethorn Acacia
- Desert Ironwood
- Velvet Mesquite
- Foothills Palo Verde
- Blue Palo Verde

**Shrubs**
- Fairy Duster
- Desert Mistletoe
- Jojoba
- Brittlebush
- Limberbush
- Ocotillo
- Triangle-leaf Bursage
- Ratany
- Creosote Bush
- Desert Broom
- Burroweed
- Canyon Ragweed
- Sotol [or Desert Spoon]
Cacti

Saguaro
Fishhook Barrel Cactus
Hedgehog Cactus
Prickly Pear Cactus
Fishhook Pincushion cactus
Chain-fruit Cholla
Teddybear Cholla
Staghorn Cholla
Christmas Cholla

ARTHROPODS (20)

Bark Scorpion
Giant Desert Hairy Scorpion
Tarantula
Black Widow Spider
Brown Spider [or Brown Recluse]
Desert Millipede
Giant Desert Centipede
Desert Stink Beetle
White-lined Sphinx Moth
Pipevine Swallowtail
Tarantula Hawk
Red Velvet Ant
Carpenter Bee
Leaf-Cutter Ant
Pallid-winged Grasshopper
Desert Clicker
Flame Skimmer
Termite
Cochineal Bug
Convergent Ladybird Beetle
**FISH (2)**
- Desert Pupfish
- Gila Topminnow

**AMPHIBIANS (6)**
- Tiger Salamander
- Sonoran Desert Toad
- Red-spotted Toad
- Canyon Treefrog
- Desert Spadefoot
- Southern Spadefoot

**REPTILES (18)**
- Desert Tortoise
- Western Banded Gecko
- Zebratail Lizard
- Collared Lizard
- Short-horned Lizard
- Regal Horned Lizard
- Side-blotched Lizard
- Tree Lizard
- Spiny Lizard
- Sonoran Spotted Whiptail
- Western Whiptail
- Gila Monster
- Gopher Snake
- Common King Snake
- Blackneck Garter Snake
- Coral Snake
- Western Diamondback Rattlesnake
- Sidewinder
BIRDS (29)

Turkey Vulture
Harris's Hawk
Red-tailed Hawk
American Kestrel
Gambel's Quail
White-winged Dove
Mourning Dove
Inca Dove
Roadrunner
Black-chinned Hummingbird
Costa's Hummingbird
Gila Woodpecker
Gilded Flicker
Verdin
Cactus Wren
Northern Mockingbird
Curve-billed Thrasher
Black-tailed Gnatcatcher
Phainopepla
Northern Cardinal
Pyrrhuloxia
Canyon Towhee
White-crowned Sparrow
Black-throated Sparrow
House Finch
House Sparrow
European Starling
Great-tailed Grackle
Killdeer
MAMMALS (24)

Lesser Long-nosed Bat
Western Pipistrelle
Desert Cottontail
Black-tailed Jackrabbit
Harris’ Antelope Squirrel
Rock Squirrel
Round-tailed Ground Squirrel
Kangaroo Rat
Grasshopper Mouse
White-throated Woodrat [or Packrat]
Coyote
Kit Fox
Gray Fox
Ringtail
Raccoon
Coati
Striped Skunk
Bobcat
Mountain Lion
Collared Peccary [or Javelina]
Mule Deer
White-tailed Deer
Pronghorn
Bighorn Sheep
VENOMOUS ANIMALS OF THE SOUTHWEST

I. Introduction
A. Statistics
1. AZ has more venomous reptiles than any other state. Also more rattlesnakes.
2. None of these venomous reptile species are Endemic to AZ (occur only in AZ).
   Native (naturally occur here)/Introduced (brought here by humans)
3. Chance of being bitten is very slim if you don’t touch venomous animals and are aware of
   where you put your hands and feet.
B. Venomous (inject toxins into victim) vs. Poisonous (toxic but don’t inject it into victim)
C. Severely Venomous Animals: need prompt, appropriate treatment by physician.
   1. Arachnids: bark scorpion, "black widow", "brown recluse"
   2. Two lizards: gila monster, Mexican beaded lizard
   3. Thirteen snakes: coral snake and 12 rattlesnakes
D. Types of Venom:
   1. Hemolytic: affect circulatory system. Symptoms may include severe pain, swelling, discoloration, and local tissue death. Shock can occur
   2. Neurotoxic: affect nervous system. Symptoms may include local pain, headache, lethargy, facial paralysis and occasionally death by circulatory arrest or respiratory paralysis
   3. Other: Pain (gila monster) and proteolytic (destroys proteins) (brown spider).
D. Why be venomous? Food Digestion, Subdue prey, Defense against threats
F. Venom Conservation Measures
   1. Offensive: match amount of venom to prey size and type
   2. Defensive: cryptic (camouflage) or aposematic (warning) coloration, retreat, dry bites
   3. Batesian Mimicry: pretend to be venomous/poisonous
G. Useful Terms: nocturnal (active at night), diurnal (active during daylight), and crepuscular
   (active at dawn and dusk).
II. Arachnids: two body segments, 8 legs, no antennae or wings
A. Scorpions
--- Bark Scorpion (Centruroides): most dangerous; long, thin pincers
--- Nocturnal, territorial, ambush prey.
B. “Black Widow” Spider

-- female has large, black abdomen with hourglass marking underneath

C. "Brown Recluse" Spider

-- 3 pairs of main eyes with one pair facing forward and the other two pairs facing diagonally to each side. Brown with "spindly" legs and violin-shaped marking behind eyes

III. Reptiles: have scales

A. Gila Monster and Mexican Beaded Lizard

-- Only venomous lizards in world; fatalities very rare

-- Tropical Origins: has "leaky" skin.

-- Activity: 98% underground, diurnal, peak period in Spring

-- Diet: search-and-dig strategy usually for small mammal nestlings; also eggs

-- Tail as storage organ (energy and metabolic water)

-- Venom apparatus; venom used for defense (pain)

B. Coral snake (cobra family)

-- Aposematic coloration: red-and-yellow kill a fellow; red-and-black friend of jack.

-- Neurotoxic

C. Rattlesnakes (only in Americas; about 30 species, 12 in sw US)

1. Rattle myths: what info. do segments give? When does rattle form?

2. Rattle functions: acoustical warning display

3. Sense organs: eyes (vision), nostrils (senses smell), pit organ (senses heat), Jacobson's organ (senses chemicals brought to it by tongue; augments smell) and body (ground vibrations).

4. Give birth to "live" young (vs. eggs)

GOOD SOURCES


The Venomous Reptiles of Arizona by Lowe, Schwalbe, and Johnson (1986). Arizona Game and Fish Department.
**SCIENCE**

**Science Definition:** Science is a way of learning about the natural world using a process designed to reduce the chance of being misled.

**Products of Science**

**Hypotheses:** possible answers to a question.

**Theories:** broad-application, well-tested, widely accepted, explanations. As close to certainty as science gets.

**Process of Science**

1. **Observations:** quantified as much as possible
2. **Question:** two major types: descriptive or causal
3. **Literature Review:** Find out what is already known on the subject, especially by using peer-reviewed, scientific journal articles
4. **Multiple Hypotheses:** Formulate as many alternative answers to the question as possible.
5. **Deductions** data that would support or refute each hypothesis.
   Often written in the form, "If hypothesis 1 is correct, then these specific observations could be expected if the hypothesis were true (or not true)."
6. **Tests** (collecting data)
   To answer descriptive questions, may be just carefully recorded observations.
   To answer causal questions, usually requires controlled studies.
7. **Tentative Conclusions:** Compare actual results from tests with deductions (expected results for each hypothesis) and state which hypotheses were supported (including evidence).
   Note: nothing in science is ever definite or proven.
8. **Peer Review:** Submit report for publication. The journal editors give your paper to other experts in the scientific community to scrutinize.

**Rules of Science** (established to minimize the chance of being misled)

**Representative Sample:** sample must reflect population as a whole.

**Adequate Sample Size:** sufficient data must be collected to accurately represent the variability in the population.

**Controlled Study:** to determine whether a particular factor causes a particular effect, a controlled study must be conducted. A controlled study is one that uses at least two study groups. Both groups are alike (and are treated alike) in all ways. The experimental group then has the one factor changed. Any differences between the two groups then can be presumed to have been caused by the factor that was different between the two groups. Cause and effect relationships cannot be inferred from correlation alone; a controlled study must be conducted.

---

1 If you want to know whether a particular factor (e.g., study time) has caused a particular effect (e.g., test grade), then a controlled study must be conducted. **CONTROLLED STUDIES** are based on comparing a control group (those that did not study for test) with an experimental group (those that did study). The control group and experimental group are treated identically (same amount of sleep, etc.) except for the one factor being tested for in the study (the independent variable; e.g., study time). The dependent variable (e.g., test grade) is the factor that changes as a result of what the scientist does to the independent variable and is what is measured by the scientist. Controlled studies usually change only one variable at a time so the scientist can pinpoint the factor causing the effect.

**Limitations of Science**

Cannot answer all questions. For example, questions about right and wrong are the realm of religion, ethics, philosophy, and politics.

Scientists can explain how to do something, technologists can make it so it is possible to do it, but politicians, etc. decide if we should do it.

Science, like all human endeavors is subject to human error, fraud, and conflict of interest.
PROCESS OF SCIENCE

OBSERVATION
↓
QUESTION
↓
LITERATURE REVIEW
↓
MULTIPLE HYPOTHESES
(as many as possible)
↓

DEDUCTIONS
→
TESTS
↓

EXPECTED RESULTS ← COMPARE → ACTUAL RESULTS
↓

TENTATIVE CONCLUSION
↓
PEER REVIEW
The discipline of statistics gives us the tools to help us design experiments, analyze our data, and know how much confidence we can place in our data. Unless we apply statistical tools, we cannot gauge how much confidence we should place in our conclusions.

We are going to examine two widely used statistical tools (chi-square and t-test) used to determine whether two sets of data are different (i.e. whether the data sets show statistically significant differences or not). To determine which of these two tests to use, you must first decide what kind of data you plan to collect.

We use the chi-square test when the data are discrete, meaning the data can take on only certain values along an interval with gaps between possible values (e.g., counts). Some examples of discrete data are:
- number of leaves per stem
- number of kangaroo rat burrows on a hillside
- number of gallons of milk purchased at a supermarket (0.25, 0.5, 0.75, 1.0, etc.)

We use the t-test when the data are continuous, meaning the data can take on a value at any point along an interval, without gaps between values (e.g., measurements). Note that the actual data values we collect will be limited by the accuracy of our instruments (e.g. to the nearest millimeter), but are still counted as continuous. Some examples of continuous data are:
- length of leaves
- diameter of burrow openings
- number of gallons of milk in a cow

**CASE STUDY 1: CHI-SQUARE TEST -- DISCRETE DATA**

Research Question: Do the number of Ponderosa Pine trees differ on north facing slopes and south facing slopes in Bear Canyon in the Santa Catalina Mountains?

Hypotheses:
- Null Hypothesis: There is no difference in the number of Ponderosa Pine trees on north facing slopes compared to south facing slopes in Bear Canyon in the Santa Catalina Mountains
- Alternate Hypothesis: There is a significant difference in the number of Ponderosa Pine trees on north facing slopes compared to south facing slopes in Bear Canyon in the Santa Catalina Mountains

Predictions:
- If hypothesis one is true, then there will be no statistically significant difference (using chi square test) between the number of Ponderosa Pine trees on north and south facing slopes. [This hypothesis is called the null hypothesis because it assumes no difference. We use the null hypothesis to predict the expected values in many chi-square tests.]
- If hypothesis two is true, then there will be a statistically significant difference (using chi square test) between the number of Ponderosa Pine trees on north and south facing slopes.

Data:
- North facing slope: 150
- South facing slope: 30
The chi-square test requires that we create a table comparing our observed values with the values we would expect if our null hypothesis is true (i.e., there is no difference). In this case, the expected values are calculated based on our prediction that we will observe equal numbers of Ponderosa Pines on each type of slope. We calculate these expected values by adding the observed values together \((150 + 30 = 180)\) and dividing this number \((180)\) by \(2\) (because there are only two categories in this chi-square table. In this chi-square table, the expected values will be 90 in both cases). These observed and expected values should be placed in chi-square table:

<table>
<thead>
<tr>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>90</td>
</tr>
<tr>
<td>30</td>
<td>90</td>
</tr>
</tbody>
</table>

Use the following table to calculate the chi-square value:

<table>
<thead>
<tr>
<th>Observed</th>
<th>Expected</th>
<th>Obs - Exp</th>
<th>((\text{Obs - Exp})^2)</th>
<th>((\text{Obs - Exp})^2/\text{Exp})</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>90</td>
<td>60</td>
<td>3600</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>90</td>
<td>-60</td>
<td>3600</td>
<td>40</td>
</tr>
</tbody>
</table>

The chi-square value in this case is 80. To determine if this value is significant, we have to consult a table of chi-square values. To use this table of values, you need to know the degrees of freedom and how sure you want to be (we will use \(p < 0.05\) which means we are 95% sure that we have accepted and rejected the right hypotheses. The \(p < 0.05\) level of confidence is commonly used by biologists.) The degrees of freedom are calculated by multiplying the number of rows minus 1 by the number of columns minus 1. In the chi-square table above, there are two rows and two columns (shaded gray). Therefore, the degrees of freedom equal 1.

Looking at the table of chi-square critical values (see below) for 1 degree of freedom and 95% confidence, we find that the critical chi-square value is 3.84. Because 80 is greater than 3.84, we can conclude that there is a statistically significant difference between these two samples. Therefore, we will reject the null hypothesis and accept the alternative hypothesis.

<table>
<thead>
<tr>
<th>degrees of freedom</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>critical value</td>
<td>3.84</td>
<td>5.99</td>
<td>7.81</td>
<td>9.49</td>
<td>11.1</td>
<td>12.6</td>
<td>14.1</td>
<td>15.5</td>
<td>16.9</td>
<td>18.3</td>
</tr>
</tbody>
</table>

**CASE STUDY 2: T-TEST – CONTINUOUS DATA**

Research Question: Does the average height of Ponderosa Pine trees differ on north facing slopes and south facing slopes in Bear Canyon in the Santa Catalina Mountains?

Hypotheses:
- Null Hypothesis: There is no statistically-significant difference in the average height of Ponderosa Pine Trees on north facing slopes and south facing slopes in Bear Canyon in the Santa Catalina Mountains.
- Alternate Hypothesis: There is a statistically-significant difference in the average height of Ponderosa Pine Trees on north facing slopes and south facing slopes in Bear Canyon in the Santa Catalina Mountains.
Predictions:
- If the null hypothesis is true, then there will be no statistically significant difference (using the t-test) between the average height of Ponderosa Pine Trees on north and south facing slopes in Bear Canyon.
- If the alternate hypothesis is true, then there will be a statistically significant difference (using the t-test) between the average height of Ponderosa Pine Trees on north and south facing slopes in Bear Canyon.

Data (height in meters)

<table>
<thead>
<tr>
<th>North facing slopes</th>
<th>South facing slopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>12</td>
</tr>
<tr>
<td>39</td>
<td>21</td>
</tr>
<tr>
<td>55</td>
<td>11</td>
</tr>
<tr>
<td>51</td>
<td>18</td>
</tr>
<tr>
<td>44</td>
<td>13</td>
</tr>
<tr>
<td>45</td>
<td>16</td>
</tr>
<tr>
<td>56</td>
<td>19</td>
</tr>
<tr>
<td>49</td>
<td>11</td>
</tr>
<tr>
<td>52</td>
<td>17</td>
</tr>
<tr>
<td>46</td>
<td>12</td>
</tr>
</tbody>
</table>

To determine if there is a statistically significant difference between these two sets of data, we must calculate a t-test value for this set of data and compare it to a critical t-test value. Using MS Excel’s Data Analysis feature (you may have to click on add-ons to add it), use “t-test: two sample assuming equal variances” to get this output.

**t-Test: Two-Sample Assuming Equal Variances**

<table>
<thead>
<tr>
<th></th>
<th>North facing slopes</th>
<th>South facing slopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>47.8</td>
<td>15</td>
</tr>
<tr>
<td>Variance</td>
<td>33.066666667</td>
<td>13.33333333</td>
</tr>
<tr>
<td>Observations</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Pooled Variance</td>
<td>23.2</td>
<td></td>
</tr>
<tr>
<td>Hypothesized Mean</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>df</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>t Stat</td>
<td>15.22701773</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) one-tail</td>
<td>5.01139E-12</td>
<td></td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>1.734063592</td>
<td></td>
</tr>
<tr>
<td>P(T&lt;=t) two-tail</td>
<td>1.00228E-11</td>
<td></td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>2.100922037</td>
<td></td>
</tr>
</tbody>
</table>

Because the P(T<=t) two tail is less than 0.05, the null hypothesis is rejected and the tentative conclusion is that the height of Ponderosa Pines on the north slope was significantly greater than the south slope.
CLASSIFICATION AND CONCEPTS

CLASSIFICATION

A. **Species**: A group of individuals capable of interbreeding and producing fertile offspring.

B. Naming species using the **Binomial System**: Every species is given a two word name. The first word is the genus and the second word is the specific epithet. The first letter of the genus is capitalized and none of the specific epithet is capitalized. Both words are put in italics. An example is *Canis lupus*.

C. Hierarchical System based on evolutionary lineage

- **Kingdom**, **Phylum**, **Class**, **Order**, **Family**, **Genus**, **specific epithet**

[one way to remember it: King Philip Came Over From Germany Smiling]

Example:

D. The Kingdoms: **Archea**, **Bacteria**, **Protista**, **Fungi**, **Plantae**, and **Animalia**

E. Phyla/Divisions

- About 34 Animal Phyla: we will study **Arthropoda** and **Chordata**
- About 10 Plant Divisions: we will study **Anthophyta** (flowering plants)

**KINGDOM Plantae** (Botany) (just the groups we will focus on identifying)

**DIVISION Anthophyta** (Flowering Plants)

- FAMILY Cactaceae: cacti
- FAMILY Agavaceae: agaves and yuccas
- FAMILY Fabaceae: pea (legume) family

**KINGDOM Animalia** (just the groups we will focus on identifying)

**PHYLUM Arthropoda**: joint-legged animals with exoskeleton

- **CLASS Arachnida**: spiders, scorpions, ticks, mites (Arachnology)
  - 1 or 2 body parts, 8 legs, no antennae
- **CLASS Insecta**: insects (Entomology)
  - 3 body parts, 6 legs, antennae present

**PHYLUM Chordata**: nerve cord down center of back

**SUBPHYLUM Vertebrata**: nerve cord surrounded by vertebrae

- **CLASS Osteichthyes**: bony fish (98% of all fish) (Ichthyology)
- **CLASS Amphibia**: amphibians such as frogs, toads, salamanders (Herpetology)
CLASS Reptilia: reptiles such as snakes, lizards, turtles, crocodiles (Herpetology)
CLASS Aves: birds (all have feathers) (Ornithology)
CLASS Mammalia: mammals (all have hair and produce milk) (Mammalogy)

Vertebrate Evolution: Fish > Amphibians > Reptiles > Mammals
> Reptiles > Birds

F. Diversity

~ 2 million described organisms on Earth; ____% animals, ____% plants

Of the Animals, ____% are beetles, ____% are insects, ____% are vertebrates

CONCEPTS

A. For a species to be somewhere it had to get there, survive there, and reproduce there.
   1. Native Species: occur naturally in the location
   2. Endemic Species: occurs naturally only in the location
   3. Introduced Species: was brought to the location by humans.

B. Habitat and Niche
   1. Habitat: an organism’s place or type of place in which it lives and thrives.
      a. Microhabitat: a part of the habitat that the organism really uses.
   2. Niche: what the organism does in its habitat
      a. Specialist vs. Generalists
   3. Range of Tolerance: The range of variability in a particular physical factor that an organism
can withstand. Limiting Factor: a factor outside the range of tolerance of an organism.

C. TROPHIC STRUCTURE
   A. Food Chain: the pathway along which food is transferred from individual to individual
   B. Trophic Levels: each link of the chain (producers, consumers, decomposers)
      Consumers include herbivores, carnivores, and omnivores
   C. Food Web: all feeding relationships in a community
D. INTERRELATIONSHIPS

**Mutualism:** Both benefit -- relationship between two species that benefits both (mutualists).

**Competition:** Both lose -- use or defense of a resource by one individual that reduces the availability of that resource to other individuals (competitors).

**Parasitism:** one gains the other loses.
Parasites feed on the tissues of their host usually without killing the host.

**Predation:** one gains the other loses.
Predators kill and eat their prey.

**Commensalism:** one gains (comensal) the other (host) is unaffected.
PLANTS 1

I. Diversity
A. Over 4200 species in AZ alone, ranking 4th in US  (90 endemic; 7 endangered)
B. Annuals versus Biennials versus Perennials
C. Growth Forms: Grass, Forb, Shrub, Succulent, Tree

II. Characteristics for identification
A. Flower: sex organ from modified leaves
   -- Consists of four rings of structures
     1. sepals: protective covering for flower bud
     2. petals: often showy and fragrant: attract pollinator
     3. stamens: filament + anther >> produce sperm (pollen)
     4. pistil: ovary + style + stigma >> produce eggs (then seeds after fertilized)
   -- Perfect flowers have stamens and pistil
   -- Imperfect flowers have either stamens or pistil
     -- Dioecious: male and female flowers on separate plants
     -- Monoecious: male and female flowers on same plant
B. Leaf: photosynthetic organ
   1. Three parts: blade, petiole (stalk), expanded leaf base
   2. Structure of blade
      a. Simple: blade is a single structure
      b. Compound: blade divided into multiple structures (called leaflets)
         -- Palmately Compound: leaflets radiate from single point (like fingers from the palm)
         -- Pinnately Compound: leaflets extend out both sides of an elongated axis like the barbs of a feather.
         Can be pinnately compound, bipinnately compound, tripinnately compound
3. Edge of blade
   a. Entire: smooth edge
   b. Toothed: tooth-like projections from edge of blade
   c. Lobed: blade has indentations
4. Shape of blade -- many
5. Position of leaves on stem
   a. alternate: single leaf at each point along stem
   b. opposite: two leaves at each point along stem
   c. whorled: three or more leaves at each point along stem

III. Life Cycle

A. Germination
   -- Timing depends on interplay of a number of factors, including photoperiod, temperature, fire, light, moisture, digestive enzymes, abrasion

B. Growth
   -- uptake of carbon dioxide, water, minerals

C. Reproduction
   1. Asexual versus Sexual
   2. Steps
      a. Produce Gametes
         -- male reproductive organ is stamen which consists of:
            -- anther: produces the sperm and packages into pollen grains (2 sperm/pollen grain)
            -- filament: holds the anthers up
         -- female reproductive organ is pistil which contains:
            -- ovary: where eggs are produced and fertilized
            -- stigma: where pollen lands and is accepted or rejected
            -- style: holds the stigma up; pollen tube goes through this
      b. Pollination: transfer of pollen from an anther to a stigma
c. Double Fertilization:
-- if pollen is accepted by stigma, then the pollen grows a tube down style to ovary
-- two sperm travel down tube to ovary; one fuses with egg to form zygote which
develops into embryo (becomes new plant) and the other fuses with the two
polar nuclei to form endosperm (food for developing embryo).

d. Seed Production: embryo and endosperm surrounded by seed coat
e. Seed Dispersal: movement of seeds from parent

D. Death: annual versus perennial life cycles

IV. Distinctive Southwestern Plant Families

A. Cactaceae: Cacti

1. Unique Characteristics
   a. Have Areoles: modified branch containing buds, hairs, and spines (leaves)
   b. Flower
      i. many petals and sepals that blend into one another
         -- note: agaves have 3 sepals and 3 petals that are distinct; ocotillos have 5
         sepalas and 5 petals that are distinct.
      ii. many stamens (usually hundreds)
      iii. several to many stigma lobes

B. Agavaceae: Agaves, Yuccas, etc.

   -- Most are evergreen leaf succulents with sharp-pointed leaves arranged in a rosette around
      a very short stem (but may be longer in some species).
   -- Provide food, fiber, and alcohol
   -- Agaves: ovary inferior (8 species in AZ, more than any other state)
      -- Most flower only once in lifetime, usu between 10 and 30 yrs of age.
      -- Mostly pollinated by bats (complete diet provided)
         -- bats migrate N with Cereus and S with Agave
      -- overharvesting of agaves affecting bat populations -- threatened.
-- **Yuccas**: ovary superior

-- Flower annually (most in May)

-- Mostly pollinated by Yucca Moth (**Pronuba**)

-- goes to mature flower, climbs up stamen, collecting pollen, rolling it up into a ball, which she tucks under her chin. After visiting several flowers, her ball may be larger than her head. It is now time to lay eggs (20-30 in all) by inserting her ovipositor into an ovule and laying one egg. After laying each egg, she climbs to the stigma and rubs some pollen on it, thus insuring fertilization takes place. The larvae eat only a few seeds, leaving the rest to perhaps grow into new yucca plants.

C. **Fabaceae**: Legumes (pea family), including Paloverdes, Acacias, Mesquites, etc.

-- Have pea-like flowers with 5 sepals, 5 petals, 10 (or 5) stamens, 1 pistil

-- Add nitrogen to soil by mutualistic relationship with bacteria in root nodules.

-- Act as nurse plants

-- Provide food and wood for people

GOOD SOURCES

Botany textbooks


*Southern Arizona Wild Flower Guide* by Tucson Citizen (1972). Tucson Citizen
PLANTS 2: TYPES OF PHOTOSYNTHESIS

Water Use Efficiency (WUE): ratio of photosynthesis to transpiration (thus how much carbon is gained per unit of water lost).

Photorespiration: Occurs when the photosynthetic enzyme, RUBISCO, reacts with O₂ to cause respiration rather than with CO₂ to cause photosynthesis (this slows the rate of photosynthesis). Occurs more under high light intensity and high leaf temperatures.

Types of photosynthesis:

C3: typical plants (CO₂ first incorporated into 3-carbon compound)

- **Adaptive Value**: more efficient under "normal" conditions.
- **How It's Done**: brings in CO₂ during the day using RUBISCO
- **Examples**: most plants

C4: C4 plants (CO₂ first incorporated into 4-carbon compound)

- **Adaptive Value**:
  1. photosynthesizes faster under high light/heat by eliminating photorespiration
  2. has greater Water Use Efficiency
- **How It's Done**:
  1. outer cells bring in CO₂ during the day using PEP carboxylase, then CO₂ is delivered directly to inner cells that use RUBISCO for photosynthesis. By "hand-delivering CO₂ directly to RUBISCO, it cannot grab O₂ and undergo photorespiration which reduces photosynthetic rates under high light intensity and high heat.
  2. because PEP carboxylase pulls in CO₂ faster, the stomata don't have to stay open as much, thus reducing loss of water by transpiration.
- **Examples**: several thousand species in at least 19 plant families; e.g., corn

CAM: CAM plants (CO₂ first incorporated into an acid. Crassulaceae was first family found in.)

- **Adaptive Value**: 1) better Water Use Efficiency and 2) can CAM idle.
- **How It's Done**: Brings in CO₂ (using PEP carboxylase) at night when evaporation rates are lower. CO₂ is converted into acid that is stored until daytime when CO₂ is released to RUBISCO for photosynthesis. CAM Idles by keeping stomata closed all the time, storing CO₂ produced by respiration and then using the CO₂ again for photosynthesis.
- **Examples**: Many succulents like cacti and agaves, also some orchids and bromeliads.
CLIMATE 1

I. What is a Desert?
   A. Definition: Potential Evapotranspiration (PET) much greater than Precipitation
   B. Ratio of potential evapotranspiration:precipitation = index of relative aridity
      Tucson: 100" PET:12" Precip./year; ratio = 8 ; Yuma: 120" PET:3.5" Precip./year; ratio = 30
      Peru Atacama Desert: ratio = 700
   C. What affects evapotranspiration rates? Relative humidity, high radiation, temperature, wind speed, and plant activity

II. Four North American Deserts: classified by precipitation
   A. Cold Deserts: > 1/2 precipitation as snow
      1. Great Basin: year-round but more than half is winter snow; Big Sagebrush
   B. Hot Deserts: most precipitation as rain
      2. Mojave: winter rain; Joshua Tree
      3. Chihuahuan: summer rain; Tarbush
      4. Sonoran: winter & summer rain; Columnar Cacti and Leguminous Trees

III. Biotic Communities and Sky Islands
   A. Biotic Community: change in species with elevation.
   B. Sky Islands: communities isolated from other such communities by distance and incompatible habitats between them.
   B. Riparian Habitat: occurs beside permanent and temporary streams (dry washes) and other sources of water
IV. Meteorological Concepts: Climate is determined by precipitation and temperature.

-- hot air rises, cool air sinks

-- as air rises it cools; as air descends it heats: rising air expands and cools (fewer molecular collisions); sinking air contracts and warms

-- cooler air holds less water than warmer air and vice versa. Cooler air has less water vapor capacity and warmer air has more water vapor capacity.

-- specific (absolute) humidity is moisture content of air (measured in g of water per kg of air).

This is the water vapor content of the air.

-- relative humidity (RH) is the amount of water in air as a percentage of amount that could be held at a given temperature. Water vapor content divided by water vapor capacity.

-- dew point is the temperature at which the air is completely saturated (RH=100%)

V. What causes it to rain?

There must be moisture in the air (from Pacific in winter; from Gulfs in summer)

The air must cool (usually by moving upward) Air is moved upward in three major ways:

1) convection – the sun heats the ground which heats the air above the ground, which makes the air rise

2) orographic -- air is blown up the side of a mountain

3) frontal -- a cold front pushes the warmer air in front of it upward.

After the air rises, it cools, the relative humidity increases, and the chance of rain increases.

VI. Temperature is determined by elevation, latitude, (and gas content of air)

A. Elevation: already talked about

B. Latitude: 0 degree latitude is the equator; 90 degrees N and S are the poles

1. Equator is warmer because sun’s rays are more perpendicular thus:
   a) are spread over less area (more concentrated)
   b) pass through less atmosphere (which means less is reflected and absorbed)

2. Poles are colder because sun’s rays are less perpendicular so rays are spread over more land surface and rays have to pass through more atmosphere so less reaches the ground as more is reflected and absorbed.

C. Seasons: depend on how perpendicular the sun’s rays are to the hemisphere in question as the tilted Earth revolves around the sun.
I. Causes of deserts

1. **Distance from source** of moisture: less water vapor in air so less chance of rain.

2. **Rainshadow Effect**: sinking air on downwind side of mountain range heats, relative humidity decreases, and chance of rain decreases.

3. **Hadley Cell**: sinking air in the Hadley Cells at 30 degrees N and S heats, relative humidity decreases, and chance of rain decreases.

4. **Cold ocean currents**: air heats as it moves over warmer land, relative humidity decreases, and chance of rain decreases. Oceans generally circulate clockwise in N hemisphere and counter-clockwise in S hemisphere so western coasts are cold and eastern are warm.
ADAPTATION

TERMINOLOGY

Adapted: successful at producing grandchildren in its environment (reproductive success).

An Adaptation: a trait that improves a population's reproductive success.

Adaptation: the process by which a population becomes more adapted to its environment (i.e. evolution through natural selection).

Genetic Information is contained in the sequence of nucleotides (A, T, C, and G) along the DNA molecule. Each sequence of 3 nucleotides codes for a specific amino acid. A chain of amino acids makes a protein. Proteins are the basis of all our traits.

Gene: a specific discrete portion of the DNA molecule in a chromosome that encodes for a product (usually a protein).

Allele: one of the alternative forms of a gene.

Mutation: change in a gene’s DNA sequence. Random by copying error, radiation, chemicals.

Gene Pool: the sum of all alleles carried by members of a population; the total genetic variability present in any population.

BIOLOGICAL EVOLUTION: genetic change in a population. Change in a gene pool

Mechanisms are natural selection, mutation, migration (gene flow), and chance (genetic drift)

NATURAL SELECTION: Genes in the most reproductively successful individuals get passed on and become more prevalent in future generations. Mutation creates new genes; natural selection gets rid of the ones that don't work.

Natural Selection is based on two major concepts:

1. Genetic Variability: Sum of all alleles and allelic combinations in a population.
   Arises by: mutation (random errors in DNA sequence; may form new genes)
   recombination (sexual reproduction produces mix of parental genes).

2. Differential Reproductive Success: Some parents leave more grandchildren than others.
   Aspects of the environment that affect relative reproductive success are referred to as Selection Pressures. Examples include weather, fire, predators, potential mates, etc.

Whether a species is going to be able to adapt to a changing environment depends on the species' genetic variability and the degree and rate of environmental change.
NATURAL SELECTION

↓ MUTATION
New Genes
Random
↓

↓ RECOMBINATION
New combinations of existing genes
Sexual Reproduction
↓

GENETIC VARIABILITY
Current mix of genes -- GENE POOL
↓

ENVIRONMENTAL SELECTION PRESSURES
Climate, weather, predation, mate selection, nutrient availability, etc.
↓

DIFFERENTIAL SURVIVAL ⇒
Some genes and gene combinations help the individual survive better than others.

DIFFERENTIAL REPRODUCTION ⇒
Some genes and gene combinations help the individual reproduce more successfully (ie. more grandchildren) than others.

TYPES OF EVOLUTION

1. DIVERGENT: two or more populations within a species, by experiencing different selection pressures, become genetically different.

   If the two populations become so genetically different that they no longer can reproduce successfully, then they are classified as separate species (speciation).

2. CONVERGENT: two very different species, by experiencing similar selection pressures, become similar (appearance/behavior).

3. COEVOLUTION: interacting species act as selection pressures on each other.

GOOD SOURCES
DESER T ADAPTATION

VAN’T HOFF’S RULE: for every temperature rise of 10 degrees C, rate of biochemical reactions double, up to a point. Too hot – proteins break down. Too cold – slow reactions.

ENERGY PIE: distribution of individual’s energy among growth, reproduction, activity, maintenance, and storage (GRAMS).

HOW PLANTS AND ANIMALS GAIN AND LOSE HEAT

Radiation, Convection, Conduction, Metabolism, and Evaporation

Rate of heat gain and loss depends on surface area to volume ratio, amount of insulation, and temperature difference between environment and body.

SURFACE AREA TO VOLUME RATIO

Small and thin bodies/parts = greater surface area to volume ratio = greater rate of temperature change.

TEMPERATURE DIFFERENCE

The greater the difference in temperature between the body and the air, the faster the rate of heat loss.

Animals are grouped based on the way their body temp. is maintained:

ENDOTHERMS: principal source of body heat is internal from metabolism (mammals/birds)

Advantage: always ready to go. Disadvantage: use 10x more energy.

ECTOTHERMS: principal source of body heat is from the environment (all else)

Advantage: use 10x less energy. Disadvantage: slow when cold (prisoner of envir.)

Types of Thermoregulation:

BEHAVIORAL THERMOREGULATION: using 1) posture, 2) orientation, and 3) microclimate selection to regulate body temperature.

PHYSIOLOGICAL THERMOREGULATION: altering metabolic generation of heat to regulate body temperature.
TORPOR

**Definition:** lowering of body temperature below activity temperature.

**Types:**

1) **Daily Torpor in Response to Cold:** daily (less than 24-hour period) torpor in response to cold and insufficient energy uptake

2) **Hibernation:** seasonal (multiple days) torpor in response to cold and insufficient energy uptake

3) **Daily Estivation:** daily torpor in response to heat and/or dryness

4) **Seasonal Estivation:** seasonal torpor in response to heat and/or dryness

**Adaptive Value:**

Reduces energy needs:

1) lower the difference in temperature between the body and the air (so rate of heat (energy) loss is slower)

2) less tissue demand (due to Van't Hoff's Rule).

Reduces water needs:

1) decreases cutaneous water loss (less evaporation)

2) decreases excretory water loss (less waste products produced)

3) decreases respiratory water loss (less breathing and less water lost per breath).
DESERT ADAPTATION STRATEGIES

**EXPIRE** have annual lifecycle (live less than one year)

Only heat and drought-resistant eggs and seeds live during harsh times

**EVADE**: avoid harsh conditions

**WATER STORAGE**: succulence; fat storage

**SPATIAL**
- Migration
- Microhabitat Selection: burrows, etc.

**TEMPORAL**
- Activity Time: nocturnal (night)/crepuscular (dawn & dusk) versus diurnal (daylight)
  - Plants through CAM photosynthesis (stomata open at night)
- Daily/Seasonal Torpor

**ENDURE**: can tolerate harsh conditions

**TEMPERATURE STRESS**

**REDUCE HEAT INPUT**
- Orientation/Posture of body, parts of body, leaves, etc.
- Shading/Insulation from spines, hairs, etc.

**REMOVE HEAT FROM BODY**
- Evaporative Cooling
  - transpiration, sweat/saliva/urine
- Body/Stem/Leaf Size
  - Larger heats up more slowly but goes above environmental temp.
  - Smaller (less than 1 sq. cm) matches environmental temp. by convection
  - Long extremities radiate heat

**TOLERATE HYPERTHERMIA (higher than normal body temperature)**
- Antelope squirrels and prickly pear cacti tolerate high body temperatures
- $C_4$ photosynthesis: photosynthesis still occurs at high temperatures
WATER STRESS

WATER CONSERVATION

DECREASE CUTANEOUS (BODY SURFACE) LOSS

- Decrease total surface area
- Waxes in outer coverings of some plants and animals
- Don’t sweat

DECREASE EXCRETORY (URINE AND FECES) LOSS

- Concentrate Urine with efficient kidneys (long loops of Henle)
- Produce Uric Acid: uses 10 times less water than urea
- Dry Feces

DECREASE RESPIRATORY/TRANSPIRATION (BREATHING) LOSS

- Nasal water condensation
- Torpor: decreases respiration rate and less water lost with each exhalation
- Stomata: density, size, position, sunkeness
- Drought Decidousness (leaves/twigs fall off in response to dry conditions)
- C4 Photosynthesis: decrease stomatal opening by increasing efficiency of acquiring/utilizing CO₂

TOLERATE DEHYDRATION

- A saguaro can tolerate water loss up to 81% vs. humans of only 12%

GOOD SOURCE
EVOLUTION OF FEATHERS AND FLIGHT

Thermoregulation >> Lift

As line of dinosaurs that became birds evolved endothermy, this created the selection pressure for insulation which led to the lengthening of their scales up to a point. At this length, the scales provided lift for gliding and now the additional selection pressure of lift selected for even longer scales that were modified into feathers for flight (and insulation).

BIRDS: SPECIALIZATIONS FOR FLIGHT (ie. Why we can't fly)

A. First, birds have feathers and wings:

B. Huge Flight Muscles: that require
   1. Rigid Skeleton so flight muscles don’t crush skeleton
      a) Fused bones of pelvis, feet, hands, and head
      b) Uncinate processes on ribs: these are bone projections off the ribs that overlap with previous rib, adding extra strength to the rib cage.
      c) Furcula or wishbone: prevents lateral compression of the chest during downstroke of wings and anchoring site for pectoral flight muscles.
   2. Efficient Respiration: one-way flow lungs
      This brings fresh air into lungs (vs stale air in mammals) and allows for countercurrent gas exchange (where air flow and blood flow in opposite directions to maintain concentration gradient to result in almost complete saturation of the blood with oxygen vs. only partial saturation in mammals).
   3. Hot body temperature adds to speed of neuronal and muscular systems
   4. Highly developed neural systems and senses aid in flight and navigation, etc.

C. Weight Reduction
   1. Bones are hollow, spongy, and strutted
   2. Lack teeth
   3. Only one ovary
   4. No urinary bladder (concentrate urea into uric acid)
   5. Hot air in air sacs
MATING SYSTEMS

Mating Systems

**Monogamy**: single mate per mating season

Pros: two-parent care; Cons: out-reproduced

**Polygamy**: multiple mates per mating system

Pros: choose best partners; Cons: single parent care

**Polyandry**: one female with multiple male mates

**Polygyny**: one male with multiple female mates

**Promiscuity**: males and females both have multiple mates.

**Sexual Dimorphism**: males and females differ in appearance (secondary sexual characteristics)

Primary sexual characteristics: reproductive organs

Secondary sexual characteristics: other external features of an organism that differ between males and females

**Two Components of Natural Selection**

Ecological Selection: selection for attributes (physical or behavioral) that contribute to survival.

Sexual Selection: selection for attributes (physical or behavioral) that contribute to reproductive advantage.

How does Sexual Dimorphism Arise?

Ecological Selection Hypotheses

Sexual Selection Hypotheses

**Two Components of Sexual Selection**

Intrasexual selection: within one sex. Usually male-male competition.

Intersexual selection: between sexes. Usually female choice.

**Intrasexual Selection Strategies**

Mate defense: whoever defends mates best against rivals

Resource defense: whoever defends best resources (e.g., food, shelter, etc.) against rivals

Scramble competition: Whoever gets to most mates first. May or may not lead to sexual dimorphism

**Intersexual Selection Main Types**
Good Gene Selection (aka Direct Fitness Benefits): the chooser gains better nest site, territory, provider (of food or protection), parental care, lack of contagious disease or parasites, etc.

Runaway Selection (aka Indirect Fitness Benefits): the chooser's offspring gain better sexual attractiveness and viability (not better genes for surviving, but better genes for being chosen as a mate).

**Intersexual Selection Strategies**

Lek: Female chooses male holding best spot at ritual gathering place (note: males often have to compete for best spot).

Prenuptial gifts: Whoever offers best “gifts” (e.g., food)

Good looks: Whoever looks/smells, sounds, etc. the best
I. Diversity

A. Percentages

1. 86% of animals are arthropods (over 1 million species).
2. 74% of animals are insects (33% of animals are beetles).
3. less than 4% of animals are vertebrates (fish, amphibs, reptiles, birds, mammals)

B. Classification

Phylum Arthropoda: jointed legs with exoskeleton; major classes below:

Class Crustacea: crabs, shrimp, barnacles. Sowbugs

-- 2 body regions, 5+ pairs of legs, 2 pairs of antennae

Class Arachnida: spiders, scorpions, ticks, mites

-- 2 body regions (a few with 1), 4 pairs of legs, no antennae

Class Diplopoda: millipedes

-- 2 pairs of legs per segment, 1 pair of antennae

Class Chilopoda: centipedes

-- 1 pair of legs per segment, 1 pair of antennae

Class Insecta: beetles, flies, butterflies, ants, crickets

-- 3 body regions (head, thorax, abdomen), 3 pairs of legs, 1 pair of antennae

II. Characteristics

A. **Exoskeleton**: hard outer covering providing support and protection

1. limits maximum size (but useful being small)
2. does not grow so must be shed
B. **Metamorphosis:** development from immature to mature stages

1. **Incomplete:** grasshoppers, bugs, roaches, mantids, etc.
   -- egg >> nymphs (look like small adult) >> adult

b. **Complete:** butterflies, beetles, flies, bees, etc.
   -- egg >> larvae (look different from adult) >> pupa >> adult
   -- Immature stages concentrate on eating, adults concentrate on reproducing (often not needing to eat at all) and dispersal. Larvae and adults usually don’t compete for food.

C. **Wings:** see only in insects, but not all insects
   -- benefit when small for finding mates, dispersing eggs, escaping, feeding, etc.

D. **Sense Organs:** may be very acute
   -- Often scattered over the body surface: bristles, hairs, eyes, “ears”, antennae

E. **Respiratory System:** brings air directly to tissues via spiracles and tracheae

III. **Africanized Bees:** More dangerous than European Bees because you end up getting more stings. Note: each bee can only sting once and the sting is not worse than a European bee, you just get stung by more bees due to:

   - Defending hive from farther away
   - Getting mad faster
   - Staying mad longer
   - More coming out at once to defend hive

Honeyguide bird in Africa leading predators to bee hives is selection pressure.

IV. **Bee Dance:** European/Africanized Bees dance to direct other bees to food sources

   Round Dance: Bee dances in circles and has nectar in mouth to communicate that food is close.

   Waggle Dance: Bee dances in figure 8 and communicates both distance (time taken to compete each circuit of dance) and direction (direction of the waggle part of the dance in comparison to up which equates to direction to food in comparison to sun).

**GOOD SOURCES:**
Sonoran Arthropod Studies, Inc.: P.O. Box 5624, Tucson, AZ 85703
FISH, AMPHIBIANS, AND REPTILES

**FISH**: (Ichthyology) have fins and complete lifecycle in water.

- Respiration: mostly by gills
- More species than other vertebrate groups; 21,000 world; 700 freshwater spp U.S.
- Three Classes: Aganatha (jawless fish), Chondrichthyes (cartilaginous fish) & Osteichthyes (bony fish)
- Desert Fish: many endangered by habitat loss (pumping groundwater, diverting water, dams, livestock, etc.) and introduced fish species

**AMPHIBIANS**: (Herpetology) most have 4 legs, water-permeable skin without scales, and a larval stage.

- Respiration through skin and augmented by either gills or lungs.
- Anamniotic egg: jelly-like and must be laid in water (or kept totally moist at all times)
- Fewest species of vertebrates -- 3900 spp World; 200 spp U.S.; 23 spp AZ
- Salamanders: tailed (unlike frogs, toads), no claws (unlike lizards), and smooth, moist, scaleless skin.
- Frogs are semi-aquatic as adults, generally have smooth skin; have teeth
- Toads are terrestrial as adults and have rough, "warty" skin; lack teeth.
- Spadefoots: pupil vertical; no parotoid glands; black, hardened spade on hind feet
REPTILES: (Herpetology) dry, scaly skin; no larval stage

Respiration by well-developed lungs.

Amniotic eggs: with shell; must be laid on dry land; embryo surrounded by amniotic fluid

First vertebrates to become completely terrestrial.

Turtles, lizards, snakes, crocodilians. 7000 spp World; 300 spp U.S.; 100 spp AZ

Lizards: moveable eyelids (unlike snakes). 43 spp AZ

Snakes: No eyelids. 50 spp AZ

Turtles/Tortoises: Carapace and Plastron. 4 native spp AZ

   Desert Tortoise, Desert Box Turtle, Sonoran Mud Turtle, Spiny Softshell

Tail autotomy: can drop tail and regenerate new one

Oviparous: lay eggs

Ovoviviparous: produce yolk-filled eggs but retain within mother and then give live birth.

Viviparous: young within mother, but feed off mother rather than yolk and then live birth.

Parthenogenesis: clone so the whole species is only females.

   Advantages: 1) No energy, time, and risk associated with mating

   2) Population potentially can increase twice as fast because all individuals are females.

   3) Keep successful gene combination of mother.

   Disadvantages: 1) less adaptable because less genetic diversity

   2) no chance for two-parent care.

Geographic Range: everywhere the species occurs.

Home Range: total area used by an individual animal

Territory: defended area used by an individual animal.

GOOD SOURCES

Peterson's Field Guide to Western Reptiles and Amphibians by Stebbins (1985)


Horned Lizards: Unique Reptiles of Western North America by Wade Sherbrooke (1981)
MAMMALS

KEY CHARACTERISTICS: (evolved from reptiles)

1. Hair (in all but mature whales)
2. Milk produced by specially modified glands (mammary glands)

CLASSIFICATION: Class Mammalia

MONOTREMES: egg-laying; platypus and 2 echidna species; none in SW

MARSUPIALS: bear tiny, embryonic young; 1 in SW (Virginia Opossum)
   -- yolk sac fed by "uterine milk"; after birth, feed from nipple; may have pouch where
   embryonic newborn completes development; 260 spp in world.

PLACENTALS: true placenta, completing embryonic development in uterus; 138 in AZ

EVOLUTIONARY HISTORY OF EACH GROUP -- in other words, why do we have one and only
   one marsupial in the U.S. and no monotremes?

DIVERSITY: 19 Orders in world; 10 in Arizona

<table>
<thead>
<tr>
<th>Order</th>
<th>World: 4060 spp</th>
<th>Arizona: 137 spp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rodents</td>
<td>1690 spp (42%)</td>
<td>67 spp (49%)</td>
</tr>
<tr>
<td>Bats</td>
<td>853 spp (21%)</td>
<td>28 spp (20%)</td>
</tr>
<tr>
<td>Insectivora</td>
<td>406 spp (9%)</td>
<td>6 spp (4%)</td>
</tr>
<tr>
<td>Carnivora</td>
<td>284 spp (7%)</td>
<td>17 spp (12%)</td>
</tr>
<tr>
<td>All Others</td>
<td>852 spp (21%)</td>
<td>19 spp (14%)</td>
</tr>
</tbody>
</table>

TYPES OF HEAD GEAR

1. Antlers: bone; shed annually; occur only in mature males (except in caribou)

3. Horns: bone core with outer sheath; not shed; both sexes in N. America.

3. Pronghorns: bone core with outer sheath, sheath shed; occur in both sexes

**WHAT EXPLAINS THE CURRENT DISTRIBUTION OF MAMMALS?**

**TABLE 1. CURRENT DISTRIBUTION OF MAMMALS**

<table>
<thead>
<tr>
<th>Continent</th>
<th>Monotremes (lay eggs)</th>
<th>Marsupials (embryonic young)</th>
<th>Placentals (have placenta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>None</td>
<td>Few</td>
<td>Many</td>
</tr>
<tr>
<td>South America</td>
<td>None</td>
<td>Some</td>
<td>Many</td>
</tr>
<tr>
<td>Eurasia</td>
<td>None</td>
<td>None</td>
<td>Many</td>
</tr>
<tr>
<td>Africa</td>
<td>None</td>
<td>None</td>
<td>Many</td>
</tr>
<tr>
<td>Australia Region</td>
<td>All 3 Species</td>
<td>Many</td>
<td>Some</td>
</tr>
<tr>
<td>Antarctica</td>
<td>None</td>
<td>None</td>
<td>Few</td>
</tr>
</tbody>
</table>

**FIGURE 1. MAP**

YOUR IDEAS:
I. Monotremes (Prototheria) and marsupials (Metatheria) evolve in N. America and spread throughout Pangea.

II. Antarctica, Australia, and India break off from Pangea
   - Primitive placental (Eutheria) mammals evolve on remaining megacontinent and spread throughout (note: they can’t get to Antarctica, Australia, or India).

III. South America breaks off from megacontinent; India collides with Eurasia.
   - Advanced placental mammals evolve on megacontinent and spread throughout (note: they can get to India but they can’t get to Antarctica, Australia, or S. America).
   - Everywhere advanced placentals occur, monotremes and marsupials go extinct for reasons we don’t know.
   - Antarctica loses all mammals when moves to south pole and climate becomes too cold; Monotremes go extinct on S. America for unknown reasons.

IV. South America forms a landbridge with North and Central America (3-5 million yrs ago).
   - Marsupials and other S. American mammals cross into Central and North America (note: only one species of marsupial -- the Virginia Opossum -- makes it to the U.S.).
   - Advanced placentals cross into S. America.

Thus, now we have monotremes only in the Australian region. Marsupials occur predominantly in the Australian region but also in South and Central America, with one species occurring in the U.S.
HOW INSECTS AVOID BECOMING BAT FOOD


HISTORY OF OUR UNDERSTANDING

1700s: Spallanzani (experimental biologist pioneer) showed that blinded bats can, while flying, avoid objects and catch insects in mid-flight. After hearing this, Jurine (surgeon and entomologist) demonstrated that flying bats cannot avoid obstacles or catch insects when their ears are plugged. Their observations were not widely accepted for over a century because no one could explain how a bat could hear the precise location of such small, essentially silent objects.

1920: Hartridge (English physiologist) suggested bats might use high frequency sounds to detect the objects. These sounds might be ultrasonic, beyond human hearing.

1938: An undergraduate (Donald Griffin), in collaboration with a Harvard physicist (Pierce) and physiologist (Galambos) determined that bats emit ultrasonic chirps from their mouths and use their ears to detect the echoes reflecting off objects in their environment (a form of sonar). Griffin called this process of navigation echolocation.

1960s: Roeder found that some insects can detect the ultrasonic chirps of bats and will perform aerobatic maneuvers to avoid capture.

BAT ULTRASOUND

Upper limit of human hearing is about 20 kilohertz.

Bats emit ultrasound (from mouth or nostrils) in the range of 30-140 kilohertz.

Shields and flaps on the face may direct the sound

Object distance determined by time interval between emitting and detecting.

Eight foot moth detection range (Alcock 1984)

Direction toward or away is determined by Doppler shift -- object moving toward bat reflect an echo of higher frequency than chirp and vice versa.

Size is determined by the fact that small objects reflect high frequency sound better.

Shape and texture also is determined by quality of echo.
INSECT DETECTION AND REACTIONS

"the encounter between a bat and an insect is one that might rival the tactics of modern air-to-air combat, involving an efficient early-warning system, some clever aerodynamic engineering and the simple economics of making do with what is available."

Moths

Detection

"Ears" located on either side of thorax

Each ear contains a tympanic membrane and two sensory fibers, A1 and A2.

**A1 fiber** is highly sensitive to low-intensity, pulsed, ultrasound and begins firing when bat is about 100 feet away. The insect then flies in the opposite direction to try to avoid detection and capture. Rate of firing of fiber is proportional to loudness so indicates distance to bat. Direction to bat is indicated by timing and loudness to each ear (the moth's body blocks some sound to opposite ear); up or down is indicated by whether wings block sound (bat up) or not.

**A2 fiber** responds only when ultrasound chirps are very loud (<10 feet) and the insect responds reflexively to cause an evasive maneuver.

Reaction

When only **A1 fibers** are firing, moth will fly away from bat (intensity to both ears equal).

When **A2 fibers** fire, the central steering mechanism is inhibited, causing the moth to make an evasive maneuver. This results in neither the moth nor the bat knowing where the moth is going and a 40% reduction in capture rate.

Other Insects: locusts, tiger beetles, katydids, praying mantids, crickets
PLATE TECTONICS

Major geological theory explaining the movement of Earth's plates and the processes that occur at their boundary, and critical to understanding mountain formation, volcanic eruptions, earthquakes, the whereabouts of mineral resources, biogeochemical cycling, evolutionary history, and much more.

A. **Convection Cells** in mantle split crust into a number of moving **Plates**.

B. These plates move in 3 different ways, resulting in 5 different plate boundaries:

1. **Divergent Plate Boundaries**: plates move apart; occurs where convection cells upwell; mantle magma extrudes onto surface as "blooping" volcanos.
   -- Geographical Features: Rifts, ridges, and new oceanic crust
   -- Example: Mid-Atlantic Rift and Ridge

2. **Ocean-Continent Convergent Plate Boundaries**: Oceanic crust collides and **subducts** beneath continental crust, causing explosive volcanic eruptions.
   Geographical Features: Volcanic Mountain Chains and Trenches
   Examples: Sierras, Cascade Mts., Andes, Philippine Trench

3. **Ocean-Ocean Convergent Plate Boundaries**: Denser oceanic crust collides and **subducts** beneath less dense oceanic crust, causing explosive volcanic eruptions.
   Geographical Features: Volcanic Island Arcs and Trenches
   Example: Japan

4. **Continent-Continent Convergent Plate Boundaries**: Continental crust collides with continental crust, causing both crusts to buckle and fold together.
   Geographical Feature: Uplifted Mountains
   Examples: Himalayas, Appalachians

5. **Transform (Transform Plate Boundaries)**: plates slide past each other, causing earthquakes.
   Geographical Feature: Strike-Slip Faults
   Example: San Andreas Fault

C. **Hot Spots**: a concentration of heat in the mantle produces a magma plume that rises up and extrudes blooping lava onto the Earth's surface, creating a hot spot. These blooping volcanos often occur far from a plate boundary and often form a chain of volcanos as the plate moves over top of the mantle plume.

D. Results of Plate Tectonics

   a. Coalescence and Breakup of Continents (e.g., Pangea: the former mega-continent)
   b. Plate Boundaries are most active (earthquakes and volcanoes) places on earth.
   c. Changing Climate on Piece of Land
   d. Evolutionary Isolation resulting in speciation
GEOLOGICAL CONCEPTS

1. Uniformitarianism: processes acting today, acted in past
   Application: helps us interpret features that were produced long ago

2. Original Horizontality: sediments are usually deposited in horizontal layers
   Application: finding folds and tilted rock

3. Superposition: older layers lie below younger
   Application: determining relative age of rock layers

4. Lateral Continuity: rock layers usually are deposited over wide area
   Application: finding faults and erosional features

5. Law of Cross-cutting Relationships: intruding rock is younger than the rocks intruded.
   Application: determining relative age of intrusions compared to surrounding rock layers

III. GEOLOGICAL STRUCTURES

A. Types of Forces that break and bend rocks
   1. tension: pulling apart
   2. compression: pushing together
   3. shear (lateral) forces: sliding past

B. Types of Faults
   1. normal fault: tension; detachment if low angle (eg. Tucson mts)
   2. reverse fault: compression; thrust if low angle
   3. strike-slip fault: shear forces (easiest to see when look down on ground surface vs. cliff)

C. Types of Folds (compression)
   1. Anticline: folds up like "A"
   2. Syncline: folds down like "U"
GEOLOGY OF THE SOUTHWEST

I. LANDFORMS
Alluvial fans, bajadas, and playas

II. ROCK CYCLE
1. Rock Types
   a. Igneous: from molten magma
      Intrusive Igneous: magma cools underground (e.g., granite)
      Extrusive Igneous: magma cools above ground (e.g., rhyolite)
   b. Sedimentary: formed from sediment that has solidified (e.g., sandstone)
   c. Metamorphic: formed from existing rock changed under heat and pressure (e.g. gneiss)
2. Rock Cycle: Rocks change to adapt to their environment
   Igneous <> Sedimentary <> Metamorphic <> Igneous, etc.

III. GEOLOGY OF THE SOUTHWEST
A. Sierras, Basin and Range, Colorado Plateau, S. Rockies
B. Geological Development of Above Provinces
   1. Sierras: Farallon Plate subducts under NA Plate producing volcanic mountain chain.
   2. Rockies: Farallon Plate subducts under NA Plate at low angle and “sticks”, causing compression on the NA Plate which creates the Rockies by thrusting and folding.
   3. Basin and Range: After the last of the Farallon Plate subducts beneath the NA Plate, crustal extension occurs, producing a series of normal faults throughout the southwest, causing down-dropped valleys (basins) and uptilted mts (ranges).
   4. Colorado Plateau: uplifted block; don't know why
C. Formation of Tucson Mountains
   a. Large volcano collapses and forms Caldera
   b. Crustal extension causes Detachment Fault that moves top of Catalinas (caldera) 20 miles to the sw (to approximately where Tucson Mts are today)
   c. Further crustal extension (the Basin and Range Disturbance) produce a series of normal faults, dropping down Tucson Valley and lifting up Tucson and Catalina Mountains.
   d. Erosion has resulted in current form of Tucson Mts., Tucson Basin, and Santa Catalinas.

GOOD SOURCES
PLANT COMMUNITY STUDY

OBJECTIVES:
1. To obtain experience in natural history field research and techniques.
2. To identify many of the plant species occurring here.
3. To better understand the composition of our local flora.
4. To examine possible plant associations.

PROCEDURE: Quadrat Sampling Technique
Form groups of four. Get measuring tape, compass, and meter stick.
Go to established starting point and lay out transect line using compass and tape.
To establish each of the ten 1X2 meter quadrats (plots)
Use 1 meter of the transect line and measure out 1 meter on each side of the transect line so that you end up with a 1X2 meter plot.
The following portions of the transect line should be used: 0-1, 5-6, 10-11, 15-16, 20-21, 25-26, 30-31, 35-36, 40-41, 45-46 meters.

Data Collection -- for each species, record:
1. plots in which the species occurred (any part of plant in plot) (need percentage of plots for frequency)
2. tally of individuals (more than half of main stem in) (need total for each species for density)
3. how much of the transect line (in cm) covered or was covered by the species (need total for each species to determine percent cover).

Example:

<table>
<thead>
<tr>
<th>Species</th>
<th>Plots</th>
<th># Individuals</th>
<th>Transect Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-L Bursage</td>
<td>y, y, y</td>
<td>3+2+5+1</td>
<td>15+24+39+18</td>
</tr>
<tr>
<td>Creosote Bush</td>
<td>y, y, y</td>
<td>1+2+1</td>
<td>75+4+82</td>
</tr>
<tr>
<td>W-T Acacia</td>
<td>y, y</td>
<td>1</td>
<td>21</td>
</tr>
</tbody>
</table>

SUMMARY DATA
For each species, calculate absolute and relative values of each of the following: density, frequency, and cover. Relative values are just the percentage the particular species comprises of the total of all species for that measure (all relative values for a particular measure always add up to 100%).

CALCULATIONS

FREQUENCY = # plots in which species occurs X 100
total # plots sampled

DENSITY = # individuals per unit area (in our case, just use # individuals)

RELATIVE DENSITY: density for a species X 100
total density of all species

COVER = total intercept length of species X 100
total transect length sampled

REL. COVER = cover of a species X 100
total cover all spp
PROCEDURE: Plant Association Technique

Establish definitions for your target species (e.g. height) and for what will be counted as an associate (e.g. stem of target species beneath branches of associate).

Determine area to be sampled:
- Size: large enough to contain no less than 20 target individuals.
- Location: best if established by some random procedure.

Determine percent cover of potential associates: randomly or systematically establish transect lines within the area. Determine percent of line covered by associates. Example: if 22 meters of a 100 meter transect are covered, then 22% of the ground is covered by the associate. Note: you may use the data obtained from the quadrat sampling study above if you use the same area.

For every target individual, record whether it is "associated" with another plant or not; if it is associated, record the name of the other plant.

Statistically compare results you observed with those expected if no association existed (use data from transect line for cover of associates).

Example: If 20% of the ground was covered by nurse plants (shrubs/trees) then you would expect 20% of the target species to be found under the nurse plants if the target species were randomly distributed (not associated with associates). If you sampled 100 target individuals, and 60% of them were found under associates then conduct the following chi square analysis:

<table>
<thead>
<tr>
<th></th>
<th>Under</th>
<th>Not Under</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Expected</td>
<td>20</td>
<td>80</td>
</tr>
</tbody>
</table>

\[ \chi^2 = \text{sum of } \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}} = \frac{(60-20)^2}{20} + \frac{(40-80)^2}{80} = 80+20 = 100 \]

If \( \chi^2 > 3.84 \) then there is significant difference (i.e. association).

Thus 100 is greater than 3.84 so there is an association.

Hypothesize about possible association: parasite-host, nurse plant, etc.
## Plant Community Study Raw Data Sheet

There are 10 boxes for each species for each column in which to enter your data for each of the 10 plots.

<table>
<thead>
<tr>
<th>Species</th>
<th>Present? Y/N = Frequency</th>
<th># Individuals = Density</th>
<th>Transect Intercept = Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-thorn Acacia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foothills Paloverde</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triangleleaf Bursage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creosote Bush</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Ratany</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fairy Duster</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocotillo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Christmas Cholla</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**SUMMARY PLANT COMMUNITY DATA FORM**

Names: ___________________  Meters along baseline: ___________  Date: ___________

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>FREQUENCY</th>
<th>DENSITY (d) per 20 m²</th>
<th>RELATIVE DENSITY</th>
<th>PERCENT COVER (c)</th>
<th>RELATIVE COVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whitethorn Acacia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foothills Palo Verde</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHRUBS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triangle-leaf Bursage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creosote Bush</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratany</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fairy Duster</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocotillo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CACTI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saguaro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SW Barrel Cactus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hedgehog Cacti</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prickly Pear Cactus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pincushion Cacti</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jumping Cholla</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staghorn Cholla</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Christmas Cholla</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS (T)</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Frequencty = % of plots containing the species  
Calculate as: # of plots containing the species times 10 (e.g. 7 out of 10 plots = 70%)

Density = number of individuals per area  
Calculate as: sum of # of individuals for that species

Relative Density = % of all individuals that are of that species  
Calculate as: Species Density divided by Total of all densities times 100 (round to nearest tenth)  
Total of all Relative Densities = close to 100

Percent Cover = % of transect line covered by that species  
Calculate as: sum of transect intercepts for that species divided by 10 (round to nearest tenth)

Relative Cover = % of all plant cover that is of that species  
Calculate as: Species Cover divided by Total of all covers times 100 (round to nearest tenth)  
Total of all Relative Covers = close to 100
WILDFLOWER/POLLINATOR SYSTEMS

Plants are rooted in place. This poses a problem when plants want to mate -- how is the sperm going to get transferred to the egg? Plants package their sperm in specially-designed capsules (called pollen grains) and then use pollen vectors -- wind, water, and animals -- to propel the pollen from the plant's anthers (where pollen is produced) to another plant's stigma (which receives the pollen). This process of transferring pollen from anther to stigma is called pollination. Plants have evolved specialized adaptations to help ensure their pollen vector's interest in and success at picking up, transporting, and leaving off the pollen at the appropriate place (e.g. providing food or housing materials for their animal vectors and making aerodynamic or sticky pollen). Animals, in turn, have evolved special adaptations to increase their effectiveness at acquiring the goodies provided by the plants (e.g. wings, long tongues, scrapers, and holding devices). A variety of pollination systems have resulted from the interactions between the plants and their corresponding pollen vectors.

- Wind (anemophily)
- Water (hydrophily)
- Beetles (cantharophily)
- Bees (melittophily)
- Butterflies (psychophily)
- Moths (phalaenophily & sphingophily)
- Flies -- bee-like (myophily)
- Flies -- carrion & dung flies (sapromyophily)
- Birds (ornithophily)
- Bats (chiropterophily)

In this lab you will learn how to identify wildflowers and their probable pollination system.

PROCEDURE

1. Find a wildflower in bloom.
2. Use the Southern Arizona Wildflower Guide (published by the Tucson Citizen) to identify the wildflower. Record its name in the space provided on your Worksheet.
3. Use the Polyclave Key to Pollination Systems (Tyrrell 1989) to determine the probable pollination system for that wildflower. Steps to using the key:
   a. Select any of the Flower Characters given in the key that is observable for your flower (such as flower symmetry).
   b. Choose the Description of the character that best matches your flower (such as bilateral). Record the Description in the space provided on your Worksheet.
   c. On your Worksheet cross out those pollination systems listed as not involved and put parentheses around those that are unlikely (those in parentheses in the key).
   d. Select another Flower Character and continue to record the Description and to cross out or put in parentheses the pollination systems not involved or not likely involved until you have examined all the Flower Characters available for you to use.
   e. The pollination system or systems not crossed off are the ones likely involved with your wildflower. Note: some plants may use more than one pollination system.
4. Throughout the lab, record any observations of wildflower/pollinator interactions. Realize, though, that some insects visit flowers, and may even take the goodies, without actually transferring pollen (technically referred to as cheats).

A POLYCLAVE KEY TO POLLINATION SYSTEMS
(from Tyrrell 1989)

<table>
<thead>
<tr>
<th>FLOWER CHARACTER</th>
<th>DESCRIPTION</th>
<th>POLLINATION SYSTEM NOT INVOLVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOWER SYMMETRY</td>
<td>radial</td>
<td>NOT: --</td>
</tr>
<tr>
<td></td>
<td>bilateral</td>
<td>NOT: BT, F-M, F-S, (BU)*, MO</td>
</tr>
<tr>
<td>FLOWER SHAPE</td>
<td>tubular</td>
<td>NOT: WI, BT, F-M</td>
</tr>
<tr>
<td></td>
<td>not tubular</td>
<td>NOT: MO, (BU), (BL), BA</td>
</tr>
<tr>
<td>FLOWER COLOR</td>
<td>white</td>
<td>NOT: WI, F-S, (BE), (BI)</td>
</tr>
<tr>
<td></td>
<td>yellow</td>
<td>NOT: WI, BT, F-M, F-S, MO, BA</td>
</tr>
<tr>
<td></td>
<td>blue</td>
<td>NOT: WI, F-M, F-S, (MO), (BI), BA</td>
</tr>
<tr>
<td></td>
<td>red</td>
<td>NOT: WI, BT, F-M, F-S, (BE), (MO), BA</td>
</tr>
<tr>
<td></td>
<td>dull or dark</td>
<td>NOT: BE, BU, (BI)</td>
</tr>
<tr>
<td>ODOR</td>
<td>no odor</td>
<td>NOT: F-S, MO, BA</td>
</tr>
<tr>
<td></td>
<td>putrid (rotting meat smell)</td>
<td>NOT: WI, MO, BI, BA</td>
</tr>
<tr>
<td></td>
<td>fragrant</td>
<td>NOT: WI, F-S, BI</td>
</tr>
</tbody>
</table>

Key:  
WI (wind)  F-M (bee-like flies)  BE (bees)  MO (moths)  
BT (beetles)  F-S (carrion & dung flies)  BU (butterflies)  BI (birds)  BA (bats)

* Parentheses around a pollination system means the system is unlikely, but possible.

Radial  Bilateral  Tubular  Not Tubular
Capable of being divided into two equal-appearing halves along more than one lengthwise plane  Capable of being divided into two equal-appearing halves only by a single lengthwise plane passing through the axis  Shaped in a tube or funnel shape.  Not shaped in a tube or funnel shape.

EXAMPLE demonstrating how to fill out the Pollination System Worksheet

1. **Sunflower**  
   wildflower species
   
   Flower Descriptions Used:  radial, not tubular, yellow, fragrant
   
   Proposed Pollination System:  bees and possibly butterflies
   
   Possible Pollen Vectors Observed:  1 bee visited flower

Note: You must give all 4 flower descriptions used (symmetry, shape, color, and odor).
Note for flower color, you only have a few choices and you must use one of those choices (for example, if your flower is orange, you have to choose either yellow or red).
# POLLINATION SYSTEM WORKSHEET

<table>
<thead>
<tr>
<th>Wildflower Species</th>
<th>Pollination System Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>WI BT F-M F-S BE BU MO BI BA</td>
</tr>
<tr>
<td>Flower Descriptions Used:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Proposed Pollination System:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Possible Pollen Vectors Observed:</td>
<td>__________________________</td>
</tr>
<tr>
<td>2.</td>
<td>WI BT F-M F-S BE BU MO BI BA</td>
</tr>
<tr>
<td>Flower Descriptions Used:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Proposed Pollination System:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Possible Pollen Vectors Observed:</td>
<td>__________________________</td>
</tr>
<tr>
<td>3.</td>
<td>WI BT F-M F-S BE BU MO BI BA</td>
</tr>
<tr>
<td>Flower Descriptions Used:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Proposed Pollination System:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Possible Pollen Vectors Observed:</td>
<td>__________________________</td>
</tr>
<tr>
<td>4.</td>
<td>WI BT F-M F-S BE BU MO BI BA</td>
</tr>
<tr>
<td>Flower Descriptions Used:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Proposed Pollination System:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Possible Pollen Vectors Observed:</td>
<td>__________________________</td>
</tr>
<tr>
<td>5.</td>
<td>WI BT F-M F-S BE BU MO BI BA</td>
</tr>
<tr>
<td>Flower Descriptions Used:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Proposed Pollination System:</td>
<td>__________________________</td>
</tr>
<tr>
<td>Possible Pollen Vectors Observed:</td>
<td>__________________________</td>
</tr>
</tbody>
</table>

## KEY TO POLLINATION SYSTEM CODES

- **WI** (wind)
- **F-M** (bee-like flies)
- **BE** (bees)
- **MO** (moths)
- **BT** (beetles)
- **F-S** (carrion & dung flies)
- **BU** (butterflies)
- **BI** (birds)
- **BA** (bats)
BIRD IDENTIFICATION

Bird identification is a skill learned through conscientious practice and experience. Bird ID involves much more than matching a color illustration in a book with what is seen through binoculars. Often birds are heard, not seen. Birds seen often are only a silhouette, or a form dashing across the road.

Below is a proven method of bird identification. By focusing in on how birds differ in size, shape, bills, wings, tails, legs and feet, head shape, color markings, song, behavior, habitat, and range, bird identification becomes easier.

BILL
This is the first characteristic to focus on (your eye will automatically pick up on the other characteristics and the bill tells much about the bird). Concentrate on the following characteristics: length (e.g. relative to head), width (e.g. conical, thin), and curvature (e.g. straight, curved down or up).

SIZE
Use bird “yardsticks.” Pick a series of birds you know of different sizes (e.g. sparrow, robin, pigeon, raven). Compare the size of your unknown bird to the sizes of your yardstick birds.

SHAPE
This is one of the most readily observed characteristics for identification. A bird’s shape integrates a number of characteristics of the bird (e.g. relative lengths of bill, head, body, wings, and tail; whether the bird holds its tail up or down; etc.). Practice working with silhouettes.

WING
Length (e.g. sticks out past the tail), width (e.g. broad, narrow), shape (e.g. bent back), and how the wings are held (e.g. V-shaped) are key features.

TAIL
Length (e.g. longer than body), shape (e.g. pointed at end, forked, etc.), and how the tail is held (e.g. up, down) are important characteristics.

LEGS AND FEET
Are the legs long or short, are the feet strong and clawed or relatively weak, are the toes webbed or not?

HEAD
Look at general shape of the head (e.g. flattened or round), look for a crest, etc.

FIELD MARKS
These are specific color and pattern characteristics that can be used to differentiate among similar species. These include wing bars, eye rings, colors, spots, streaks, white outer tail feathers, etc. (see handout).

Be cautious with field marks, for they are numerous, often complex, vary with age and sex, and are often difficult to see. Narrow your choices down by using size, shape, habitat, range, and behavior before concentrating on field marks.
**BEHAVIOR**

Behavioral features important to notice include tail flicking (e.g. up to down or down to up), flight pattern (e.g. up and down like woodpeckers), degree of “nervousness”, feeding manner (e.g. scratching with both feet on the ground like towhees), exact feeding location (e.g. tree-tops, lower foliage, trunk, etc.)

**RANGE**

When you are getting close to identifying your bird, you can limit your choices down further by eliminating (tentatively, for you never know when a bird may be out of its usual range) those birds that don’t occur in area.

**HABITAT**

Many bird species are specific to a particular habitat. Knowing the preferred habitat of a species helps you find the species; knowing what habitat you are in, helps you limit your number of choices of species. Habitat types may be general (e.g. Desert scrub, riparian, grassland, pinyon-juniper, coniferous forest) or may be very specific such as particular tree species, etc.

**SONG**

Song often is all you get from a bird for identification, or at least knowing songs saves you a lot of brush-beating and neck-creening. Without a knowledge of birds song identification, you will miss most of the birds. In addition, some birds can only be identified easily by song (e.g. the *Empidonax* flycatchers).

Learning bird songs may be a difficult undertaking, but it will pay many dividends later. Using cassette tapes while looking at a picture of the bird will get you started, but you will need to follow-up by watching a wild bird singing its song to really learn to associate the song with the bird.

You may be able to attach a human phrase to the bird’s song (e.g. "Who cooks for whoo" for the white-winged dove). More than anything, it takes practice.

**GOOD SOURCES**

**Bird Identification:**

**Bird Songs:**
- National Geographic’s Bird Sounds records
- Peterson’s A Field Guide to Western Bird Songs
- Keller’s Bird Songs of Southeastern Arizona and Southern Texas

**Bird Medleys From:**
- *Solitudes—Vol. 5: Dawn on the Desert*

**Bird CD ROM:**
- *Birds of North America* by Thayer Birding Software
### BIRD CENSUS OF PIMA COMMUNITY COLLEGE, WEST CAMPUS

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>TOTAL</th>
<th>TALLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardinal, Northern</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dove, Inca</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dove, Mourning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dove, Rock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dove, White-winged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finch, House</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flicker, Northern</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flycatcher, Ash-throated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gnatcatcher, Black-tailed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hummingbird</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killdeer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mockingbird, Northern</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phainopepla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phoebe, Say’s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrrhuloxia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quail, Gambel’s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadrunner, Greater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sparrow, Black-throated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sparrow, House</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sparrow, White-crowned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starling, European</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrasher, Curve-billed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Towhee, Canyon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verdin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodpecker, Gila</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wren, Cactus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTHERS (write names below)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL SPECIES**

**TOTAL INDIVIDUALS**
TEETH: Mammals have four kinds of teeth; from front to back they are:

INCISORS: often chisel-shaped; used for biting off pieces of food; nippers

CANINES: long and pointed; used for holding, piercing, and tearing flesh

PREMOLARS: shape and use reflects diet -- flat for crushing/grinding in herbivores, sharply ridged for cutting/slicing in carnivores, variable in omnivores.

MOLARS: shape and use reflects diet as in premolars above. Not deciduous (not shed and replaced, i.e. no "baby" set).

[CARNASSIALS]: modified last upper premolar and first lower molar, which oppose one another like scissor blades for shearing. Occur in Order Carnivora (dogs, cats, bears, weasels, etc.); especially well-developed in the Cat family.

DENTAL FORMULA: gives the number of each tooth type on one side of the skull (right or left) for both the upper and lower (Upper/Lower). Used to identify mammal skulls.

Example:

\[
\begin{array}{c|c|c|c}
\text{Upper} & \text{Lower} \\
3 & 1 & 4 & 2 \\
3 & 1 & 4 & 3 \\
\end{array}
\]

This mammal has 3 upper and 3 lower incisors, 1 upper and 1 lower canine, 4 upper and 4 lower premolars, and 2 upper and 3 lower molars in one side of the skull for a total of 42 teeth in its head.

Diet may be indicated by the dental formula as indicated in the examples below:

<table>
<thead>
<tr>
<th>Dental Formula</th>
<th>Type of Feeding</th>
<th>Representative Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1, 0/0, 1/1, 3/3</td>
<td>Bark, nuts, roots</td>
<td>Beaver, porcupine, many squirrels</td>
</tr>
<tr>
<td>2/1, 0/0, 3/2, 3/3</td>
<td>Browsing (twigs)</td>
<td>Rabbits, hares</td>
</tr>
<tr>
<td>0/3, 0/1, 3/3, 3/3</td>
<td>Grazing (grass)</td>
<td>Deer, bison, sheep</td>
</tr>
<tr>
<td>2/2, 1/1, 2/2, 3/3</td>
<td>Omnivory</td>
<td>Humans</td>
</tr>
<tr>
<td>3/3, 1/1, 4/4, 2/3</td>
<td>Predation</td>
<td>Dogs (incl. coyotes, fox), bears</td>
</tr>
<tr>
<td>3/3, 1/1, 3/2, 1/1</td>
<td>Strict Carnivores</td>
<td>Cats (Felis; incl. mt. lion, bobcat)</td>
</tr>
</tbody>
</table>

EVERGROWING INCISORS OF RODENTS AND LAGOMORPHS: Rodents (mice, squirrels, beaver, etc.) and Lagomorphs (rabbits, hares, pika) have evergrowing incisors. Lagomorphs, however, have a second set of peg-like upper incisors behind the first set unlike rodents. Note: rabbits (e.b. cottontails) have altricial young that cannot move well after birth, whereas hares (e.g. jackrabbits) have precocial young that are able to move well soon after birth.

VISION: Carnivores and omnivores tend to have eyes facing forward for binocular vision (greater depth perception for capturing prey) and herbivores tend to have eyes more toward the sides of their head to improve peripheral vision (can see in a wider arc around them for predator detection)

INTRODUCTION

From the deer pounced upon by the mountain lion to the ant snapped up on the tongue of a horned lizard, predator-prey relationships command our attention. Witnessing the actual event of predation is rare; therefore, scientists studying predator-prey relationships often must resort to examining the aftermath (carcasses, feces, and pellets).

Owls are a major nocturnal predator, especially on small mammal populations. Owls tend to swallow their prey whole. The "mouse" slides down the esophagus and into the stomach (proventriculus in birds) where acids begin to breakdown the meat. The fur and bones are undigestible. The "mouse" goes to the muscular gizzard for mashing to expose new surfaces to the stomachs acids. Finally, all the meat has been dissolved and passed into the long, tortuous passageways of the intestines for absorption and use by the owl. The remaining fur and bones are packed into a neat pellet and regurgitated. This is a nice way to reduce weight for flight. Other birds that take in a lot of undigestible parts (fur, feathers, scales, bones, insects shells, etc.) in their diet also regurgitate pellets (e.g. other birds of prey, fish-eating birds, beetle-eating birds, etc.).

Therefore, by identifying the pellet parts, one may study the diet of the bird on a day-by-day basis. It is much easier to collect the pellets below the bird's roost than to chase the bird around waiting to see what it eats. We will study the pellets from the Common Barn Owl (Tyto alba) (14-20" in height) that occurs throughout most of the U.S. including Tucson. The pellets have been obtained from and fumigated by a company that specializes in selling owl pellets (Genesis).
OWL PELLET LAB DATA AND QUESTIONS

1. Pair up and obtain one pellet, one tray, two tweezers, and a magnifying glass.
2. Using your hands, break apart the pellet, and separate the skulls and jaws from the rest.
3. Identify each skull and/or pair of jaws using the Key provided and record your results.
4. Use remaining time to rebuild your animal using the Vole Stick Sheet

SPECIES AND NUMBER OF INDIVIDUALS FOUND IN THE OWL PELLET:

• _______________________________________
• _______________________________________
• _______________________________________
• _______________________________________

QUESTIONS

What information can be obtained from owl pellets if you had every pellet dropped by a single owl for a year? Be complete.

Can one use the relative proportions of prey items in the pellets (e.g., 50% voles and 50% deer mice) to determine the relative proportions of the prey populations in the wild (e.g., the vole and deer mouse population are the same size)? Explain your answer.

Assuming one pellet per day is regurgitated (varies in actuality), how many prey items would your owl eat in a year?
KEY TO SKULLS FOUND IN OWL PELLETS
SEE DEFINITIONS OF TERMS USED ON NEXT PAGE

1. a. Teeth absent .................................................. Aves
   b. Teeth or tooth sockets present .............................. Mammalia -- 2

2. a. Skull without a diastema (a space between incisors and other teeth)(Fig. 1) ...... -- 3
   b. Skull with a diastema; incisors evergrowing ........................................ 2

3. a. Zygomatic arches (Fig. 1) not present on skull; teeth reddish brown at tips ......................... Family Soricidae: Shrews
   b. Zygomatic arches present; teeth white .................................................... 4

4. a. Skull containing well-developed upper and lower canines (Fig. 2); hard palate extending beyond the level of the last tooth by more than the length of that tooth .................. Family Mustelidae: Weasel
   b. Skull with poorly developed canines; hard palate extending beyond the level of the last tooth by less than the length of that tooth .................. Family Talpidae: Moles

5. a. Skull containing small peglike teeth immediately behind the upper incisors; skull with a cluster of holes (perforations) in the anterior portion of the maxilla (Fig. 3) ........................................... Family Leporidae: Rabbits and Hares
   b. With no teeth immediately behind the upper incisors; anterior portion of the maxilla of the skull without perforations .............. Order Rodentia: Rodents -- 6

6. a. Four lower molariform teeth and 4 or 5 upper molariform teeth (pull out molariform teeth to count) ....................................... Suborder Sciuromorpha -- 7
   b. Three lower molariform teeth and 3 or 4 upper molariforms ................................ Suborder Myomorpha -- 8

7. a. Skull lacking postorbital process (Fig. 4) or process small and blunt; skull less than 100 mm; 1st upper cheek tooth with 2 cusps (Fig. 5) ......................... Family Geomyidae: Pocket Gophers
   b. Skull with distinct sharply-pointed postorbital process .................................. Family Sciuridae: Squirrels & relatives

8. a. Upper molars with 3 longitudinal rows of cusps (Fig. 5) .......... Family Muridae -- 9
   b. Upper molars with 2 longitudinal rows of cusps ...................... Family Cricetidae -- 10

9. a. First upper molar longer than combined lengths of other two molars ............................ Genus Mus: House Mouse
   b. First upper molar shorter than combined lengths of other two molars .......................... Genus Rattus: Rat

10. a. Molariform teeth rows less than 4 mm in length .... Subfamily Cricetinae: Deer Mouse
    b. Molariform teeth rows more than 5 mm in length .................. Subfamily Microtinae: Voles
SKULL TERMS FREQUENTLY USED IN KEY

Figure 1. Side view of upper skull showing diastema, zygomatic arch, incisors, and molariform teeth.
   Incisors: front teeth       Molariform Teeth: back teeth in rodents/rabbits/hares
   Diastema: the space between incisors and molariform teeth

Figure 2. Top view of upper skull showing zygomatic arches and postorbital processes (the projections into the holes created by the zygomatic arch.

Figure 3. View of chewing surface of molariform teeth showing two or three rows of longitudinal cusps.

   two rows of longitudinal cusps
   three rows of longitudinal cusps
Geological Detective Story

Assignment:

Number the layers, with layer 1 being the oldest (note blank spots to write in numbers).
List the sequence of events (including all forces and geological structures) that built this road cut.