Skyline Park Teacher's Guide

Cfwep.Org • Clark Fork Watershed Education Program

Skyline Park • Butte, Montana

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Chapter 1: Introduction and Welcome

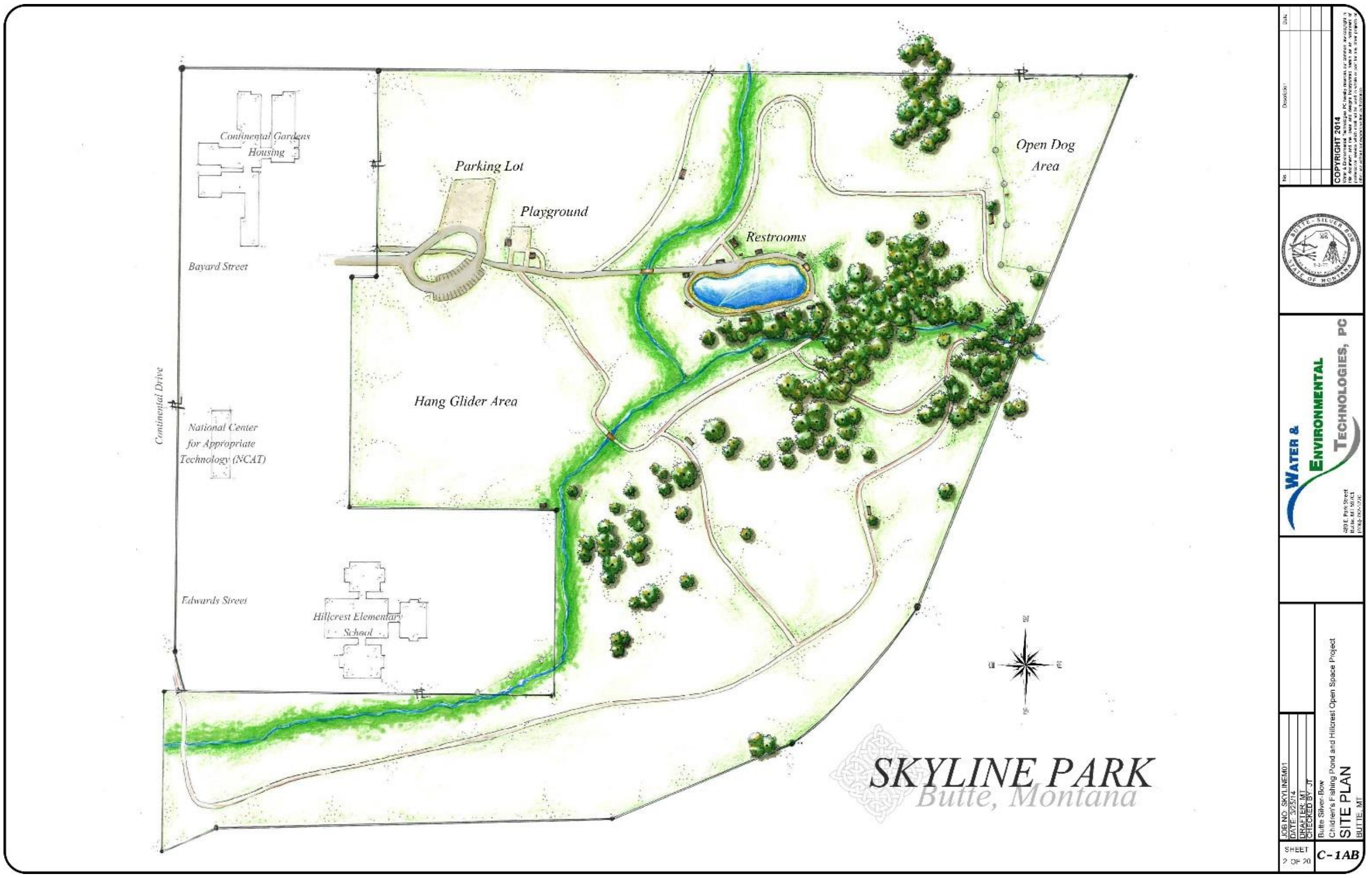
Ch1.1 Overview of Skyline Park

Introduction

Skyline Park is the result of collaboration between Butte-Silver Bow City/County government and the Skyline Sportsmen's Association to restore and develop the 57-acre parcel into a natural, passive recreational park and outdoor classroom. This outdoor classroom contains a children's fishing pond and is part of a natural wetland, which is supplied by Resse Canyon Creek and Tramway Creek. Funding for the project was provided by the State of Montana-Department of Justice's Natural Resource Damage Program.

Prior to funding, this site was a vacant lot, used by residents of Butte-Silver Bow as an informal ATV area. The area was filled with debris and infested with a host of noxious and nuisance weed species. For the first time in decades, the area is now serving to benefit Butte-Silver Bow, its schools and its residents. Skyline Park has been designed to provide an educational experience for a variety of users. Whether you are a teacher, student, or passer-by on the trail, you should be able to take in the educational opportunities provided by the site. A series of interpretive signs lead users to explore the wonders of the immediate environment.

Ch1.2 Map of Skyline Park



Ch 1.3 How to Use this Guide

For teachers, this guide provides everything needed to use Skyline Park as an outdoor classroom. The guide includes both content and activities. The content sections are intended to help the teacher enhance their own knowledge. While some of the information presented can and should be shared with students, the content is written at an undergraduate level for the teacher's benefit.

The activities are intended for teacher's to share with students, using some of the content knowledge to expand and elaborate on the activities. Each activity section includes objectives and guiding questions for students, brief background information, a list of materials, the procedure for conducting the activity, suggestions for extending the activity, and a list of resources. We have refrained from providing details about how long activities will take since each activity can be squeezed into one day or extended over several days. It is up to you, the teacher, and what your curriculum needs are.

The intention of the Cfwep.Org curriculum team is that all curricular areas will be explored through the science inquiry process. Skyline Park provides a unique opportunity for teachers to integrate all curricular areas including reading, writing, social studies, and science, while utilizing the park. Students will be able to complete multiple-step scientific studies and practice the science process skills throughout the course. Teachers can be as expansive as they wish within the park, evolving lessons into long-term projects, such as weather and seasonal monitoring, site maintenance, and further site improvement. The content included in the **Skyline Park Teachers' Guide** was developed by the Cfwep.Org curriculum team. Appropriate credit for other content is duly given within the guide.

Through comprehensive site study, students will become excellent stewards of their local environments. The content is designed to be place-based, meaning that the content is relevant to this particular site and its history. It is the hope of the project leadership team that Skyline Park will become an integral part of the science curriculum for teachers in the Butte school district.

We have also provided a glossary of important terms for both teachers and students to review. Most bolded words in the body of the guide are listed in the glossary. Lastly, we have included appendices that contain datasheets created by Cfwep.Org staff or others, supplements to activities, and additional information that illustrates certain points or procedures.

Skyline Park during its construction. Photo by: F. Ponikvar

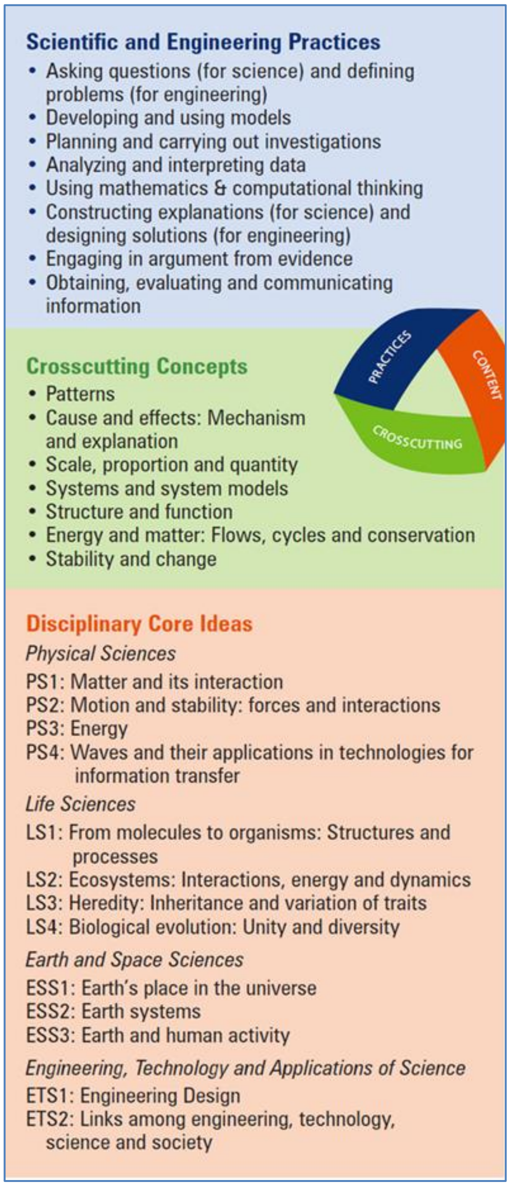
Chapter 2: About NGSS and Guide Alignment

Chapter 2.1 Background of NGSS and the K-12 Framework

Introduction

The Skyline Park Teacher's Guide has been developed from the perspective of science education as presented in the National Research Council's (NRC) report, A K-12 Framework for Science Education: Practices, Crosscutting Concepts, and Core Ideas. The Framework, as the report is now commonly called, outlines three dimensions of science education. The three dimensions attempt to move science education from a content-driven endeavor to a closer representation of the work of a scientist. The three dimensions are: Scientific and Engineering Practices; Crosscutting Concepts; and Disciplinary Core Ideas. The greatest change in the Framework and the resulting Next Generation Science Standards (NGSS) is the focus on Science and Engineering Practices and Cross-Cutting Concepts. The NRC called for a shift in science education, expecting educators to shift how science is delivered in classrooms, employing more experiential and research-driven pedagogical tools rather than relying heavily on vocabulary and memorization. This model attempts to bridge science and engineering, with students and teachers focusing more deeply in key content areas rather than attempting to cover great breadth of topics.

On the following page, a graphic representation of the three dimensions of the Framework is illustrated. The NRC intends that the three, while distinct and able to be presented in isolation, are meant to be integrated, or three-dimensional. Teachers should think about the pedagogical approaches necessary to illustrate not only a disciplinary core idea, but what practices will engage students to discover that core idea and what other areas of science does this core idea connect to (crosscutting concepts). It is noteworthy that the standards now focus more deeply on the content and concepts that are related across science disciplines as well as how scientists engage in their work, i.e., the science practices.



Scientific and Engineering Practices
- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics & computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating and communicating information

Crosscutting Concepts
- Patterns
- Cause and effects: Mechanism and explanation
- Scale, proportion and quantity
- Systems and system models
- Structure and function
- Energy and matter: Flows, cycles and conservation
- Stability and change

Disciplinary Core Ideas

Physical Sciences

PS1: Matter and its interaction
PS2: Motion and stability: forces and interactions
PS3: Energy
PS4: Waves and their applications in technologies for information transfer

Life Sciences

LS1: From molecules to organisms: Structures and processes
LS2: Ecosystems: Interactions, energy and dynamics
LS3: Heredity: Inheritance and variation of traits
LS4: Biological evolution: Unity and diversity

Earth and Space Sciences

ESS1: Earth's place in the universe
ESS2: Earth systems
ESS3: Earth and human activity

Engineering, Technology and Applications of Science

ETS1: Engineering Design
ETS2: Links among engineering, technology, science and society

<u>Overview of the Science and Engineering Practices</u>

The Next Generation Science Standards documents set forth the guiding principles for the science and engineering practices as follows:

- Students in grades K-12 should engage in all eight practices over each grade band.
- Practices grow in complexity and sophistication across the grades.

- Each practice may reflect science or engineering.
- Practices represent what students are expected to do and are not teaching methods or curriculum.
- The eight practices are not separate; they intentionally overlap and interconnect.
- Performance expectations focus on some but not all capabilities associated with a practice.
- Engagement in practices is language intensive and requires students to participate in classroom science discussions.

From NGSS and Lead States, 2013. Next Generation Science Standards, Volume 2, pp 48-50.

The practices, as their name implies, are meant to be visited and re-visited throughout a student's educational career. Just as a violist takes years of practice to develop her skills, so too does a scientist take years to develop hers. The National Research Council states, "*A focus on the practices (in plural) avoids the mistaken impression that there is one distinctive approach common to all science—a single 'scientific method'.*" With these conceptual changes about science and the practices of science in mind, teachers will need to further develop pedagogical skills to help students utilize the practices given any context, content idea, or classroom activity. The Framework document dedicates 81 pages to the discussion of the practices and their importance for creating a scientifically literate citizenry. For the purposes of this guide, the simple graphic on the previous page is presented. Teachers should review the Framework and NGSS documents in order to better familiarize themselves with the practices and the progressions of skill for each practice at particular grade-levels. The Framework and the NGSS documents illustrate grade-level learning progressions and illustrate the goals or student outcomes for each practice by grade 12.

The call to action regarding engaging students in the practices of science and engineering is a remarkable shift in science education. Teachers are now asked to complete authentic investigations and engineering activities with their students. Previously, in the elementary grade bands especially, students would engage in minor experimentation at times, but would most likely read about science rather than actually complete a scientific investigation. Authentic research experiences are now a critical component of classroom activities. Students who are engaged in research experiences within their local environments are more likely to meet the NGSS Performance Expectations. In addition, experiences that connect students to important issues within their community have demonstrated significant effects for student engagement and retention of scientific concepts. Skyline Park offers a unique opportunity for teachers to engage their students in an outdoor learning environment, while connecting them to the issues of environmental clean-up and restoration.

Overview of the Crosscutting Concepts

The crosscutting concepts, as their name implies, bridge across many disciplines of science and have application throughout both science and engineering. The National Research Council (NRC) expects the crosscutting concepts to become "touchstone" in the curricula, instruction, and assessments that are utilized throughout a student's educational career. The crosscutting concepts are fundamental to building scientific understanding and should be illuminated repeatedly.

The Next Generation Science Standards documents set forth the guiding principles for the Crosscutting Concepts as follows:

- Crosscutting concepts can help students better understand core ideas in science and engineering.
- Crosscutting concepts can help students better understand science and engineering practices.
- Repetition in different contexts will be necessary to build familiarity.
- Crosscutting concepts should grow in complexity and sophistication across the grades.
- Crosscutting concepts can provide a common vocabulary for science and engineering.
- Crosscutting concepts should not be assesses separately from practices or core ideas.
- Performance expectations focus on some but not all capabilities associated with a crosscutting concept.
- Crosscutting concepts are for all students.
- Inclusion of nature of science and engineering concepts.

From NGSS and Lead States, 2013. Next Generation Science Standards, Volume 2, pp 79-81.

The Next Generation Science Standards documents further elaborate on the Framework outline of the crosscutting concepts, giving a learning progression for each crosscutting concept across grade levels. Teachers should review the learning progressions as related to their particular grade band when building curricula for Skyline Park. The progressions can be found in the standards document: <u>Next Generation Science Standards, Volume 2, pp 81-89</u>, and also online at http://www.nextgenscience.org/next-generation-science-standards. Teachers utilizing Skyline Park as an outdoor learning center will find that the learning center lends itself to many of the crosscutting concepts easily, and with some creative effort, can probably be utilized to touch on all of the crosscutting concepts.

Overview of the Disciplinary Core Ideas

The Disciplinary Core Ideas (DCI's) are often referred to as "the content" portion of the Framework. The DCI's are intended to create depth of understanding related to a particular discipline, rather than attempting to cover a wide breath of ideas in each discipline. A student's understanding of the crosscutting concepts and the science and engineering practices should be reinforced by the repeated use of them in the context of instruction within the DCI's (NRC, 2012). Each dimension should be integrated into a three-dimensional approach, with none of the dimensions being taught in insolation. The Framework document outlines the DCI's and the learning progressions for each grade band. Volume One of the Next Generation Science Standards is organized by grade band and Disciplinary Core Ideas. Each grade level has one to two standards per DCI. For Example, the Kindergarten DCI's cover two main ideas in Physical Sciences: Motions and Stability and Energy; one in Life Sciences: From Molecules to Organisms; and two in Earth and Space Sciences: Earth's Systems and Earth and Human Activity. The Kindergarten DCI's do not cover Engineering, Technology and Applications of Science. Within each area, the NGGS further defines the performance expectation for each standard and illustrates which practices and cross cutting concepts that lend to facilitation of that particular DCI.

In no way do we intend to represent the Skyline Park guide as all-inclusive of the Disciplinary Core Ideas (DCI's) for grades K-8. Rather, the guide is particularly strong as related to the Life Sciences DCI's and particularly standards: LS1: From molecules to organisms: Structures and Processes; LS2: Ecosystems: Interactions, Energy, and Dynamics; and LS4: Biological Evolution: Unity and Diversity. The other strength of the guide is within the Earth and Space Sciences DCI, ESS2: Earth Systems, and ESS3: Earth and Human Activity. The DCI's of Physical Sciences and Engineering, Technology and Applications of Science are covered less extensively than the Life Science and Earth Science DCI's. However, the guide does cover some content in the Physical Sciences as related to energy within ecosystems (food chains and food webs) and within the Engineering, Technology, and Applications of Science as related to ETS2: Links among engineering, technology, science, and society. The guide does not discreetly cover overall engineering concepts, but discussion about the history of the park and the design of the park through interpretive signing will give students a general overview of the engineering design at the park and will enable teachers to elaborate upon sign content.

The following chart is a brief example of how the NGSS align to content presented in the Skyline Park guide. Each of the Scientific and Engineering Practices are likely to be utilized throughout the guide activities. Some practices will have greater emphasis than others and certainly we acknowledge that the engineering practices in particular are not fully addressed in this curriculum. In the interest of brevity, the practices are not outlined in a chart. Rather, it is assumed that teachers will be utilizing the various practices in order to reach the crosscutting concepts and DCI's.

The first chart is a reflection of the cross-cutting concepts that are likely to be addressed through guide content. For the purposes of the chart example, we used the cross-cutting concepts as reflected in grades 3-5. The second chart is an example of Performance Expectations (PE) that may be addressed through guide content. This guide is intended to be used by teachers in K-8 classrooms. However, the example examines PEs for grades K-5 and does not include the Middle School 6-8 (MS) performance expectations. Individual teachers should review the NGSS that are covered for their classroom. Recall that according to the NGSS documents, the as described are NOT intended to be a set of instructional tasks or assessments, rather the PEs are the outcome or final goal for the student once instruction is completed. How a teacher gets to the ultimate PE is up to his or her own creativity and passion. A teacher may use multiple activities and trips to Skyline Park to ultimately cover one particular PE. Recall, it is not our intention to present this information and alignment as if this guide is all that is needed to address a particular PE. Rather, we expect that teachers will utilize Skyline Park and its resources as one of many activities or lessons on the way to accomplishing a particular PE. Please refer to the appendix documents of the NGSS for interpretation of alpha-numeric and color coding of the standards or watch the instructional video referenced here: http://www.nextgenscience.org/how-to-read-the-standards.

In brief, to decode the Standards, the first number or letter indicates the Grade Level for the PE, the next two letters indicate the Content Area (Physical, Life, Earth, or Engineering, Technology and Applications of Science) and the last two numbers indicate the particular Disciplinary Content Idea; for example, the following Performance Expectation coding is interpreted as follows:

K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.

K-LS1-1

Indicates Kindergarten Grade Level

Indicates Life Science DCI #1: From Molecules to Organisms: Structure

Indicates Performance Expectation #1 for Life Science DCI #1

In some standards, there is more than one Performance Expectation per DCI.

Cross-Cutting Concepts Delivered in Skyline Park Guide	
Concept	**Skyline Park Activity Example**
Patterns **In grades 3-5**, students identify similarities and differences in order to sort and classify natural objects and designed products. They identify patterns related to time, including simple rates of change and cycles, and use these patterns to make predictions	Sorting, collecting, and identifying macroinvertebrates and utilizing a data key to predict stream health related to biotic index
Cause and Effect **In grades 3-5,** students routinely identify and test causal relationships and use these relationships to explain change. They understand events that occur together with regularity might or might not signify a cause and effect relationship.	Students complete riparian vegetation assessment, water quality, and macroinvertebrate biotic index calculations which directly tie restoration efforts to overall pond health.
Scale, Proportion, and Quantity **In grades 3-5,** students recognize that natural objects and observable phenomena exist from the very small to the immensely large. They use standard units to measure and describe physical quantities such as weight, time, temperature, and volume.	The pond life activity invites students to compare microscopic and macroscopic pond life organisms. Students will reflect upon the diversity of microscopic organisms and their relative size.
Systems and System Models **In grades 3-5,** students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. They can also describe a system in terms of its components and their interactions.	Students investigate the functions of a riparian area and develop a model of a riparian area that includes the constituent parts of the riparian zone and must accurately represent the functions of the riparian area. Students discuss damages to riparian areas and propose engineering solutions, including budgeting, for repairing a damaged environment.
Energy and Matter **In grades 3-5,** students learn matter is made of particles and that energy can be transferred in various ways between objects. Students observe the conservation of matter by tracking matter flows and cycles before and after processes and by recognizing that the total weight of a substance does not change.	Students investigate food chains and food webs that interconnect aquatic and terrestrial organisms found at Skyline Park. Students reflect upon different habitat zones that support various life forms and identify interconnected relationships between plants and animals.
Structure and Function **In grades 3-5,** students learn that different materials have different substructures, which can sometimes be observed, and substructures have shapes and parts that serve functions.	Students investigate aquatic micro-organisms and macro-organisms. Students are asked to observe macroinvertebrate body parts and predict the organism's eating and moving habits.
Stability and Change **In grades 3-5,** students measure change in terms of differences over time and observe that change may occur at different rates. Students learn that some systems appear stable, but over long periods of time they will eventually change.	Students complete vegetation analysis of forb sods. Through this investigation, students will observe the various life cycles of the forb sod plants. Teachers could maintain student data from year to year to compare types of plants that dominate the sods, die out, or come into succession with other plants. Students investigate pond health and the riparian area surround the pond.

Disciplinary Core Ideas Delivered in Skyline Park Guide	
Performance Expectations Kindergarten	**Skyline Park Activity Examples**
K-LS1-1 Use observations to describe patterns of what plants and animals(including humans) need to survive.	The macroinvertebrate collection activity lends itself well to this DCI as the macroinvertebrates are the likely food source for native cutthroat trout in the Skyline Park pond.
K-ESS2-2 Construct an argument supported by evidence for how plans and animals (including humans) can change the environment to meet their needs.	Students will make general observations about the park, including evidence of wildlife use throughout the park. Evidence can include burrowing by small terrestrial mammals. Students can describe that the burrow is a change made by the animal. Other examples may be human related by the very construction of the pond itself.
K-ESS3-1 Use a model to represent the relationship between the needs of different plants or animals and the places they live.	The build a riparian habitat activity fully executes this DCI. Students have to be thoughtful regarding the various parts and functions of a riparian habitat and what is necessary to ensure survival of the animals within that habitat.
K-Ess3-3 Communicate solutions that will reduce the impact of humans on land, water, air and/or other living things in the local environment.	The water quality activities can be utilized to help students think about non-point source pollution such as stormwater and how each person contributes to non-point source pollution. Students can describe ways they can individually reduce pollution at their homes and schools.
Performance Expectations First Grade	**Skyline Park Activity Examples**
1-LS1-1. Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.	Teachers could expand upon the pond life Aquatic Macroinvertebrates activity to include the Cfwep.Org activity Build a Macro and ask students to imagine various macroinvertebrate structures, such as exoskeleton, as possible candidates for mimicking.
Performance Expectations Second Grade	**Skyline Park Activity Examples**
2-LS2-2. Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.	The pollinator constancy exercise illustrates how different pollinators are attracted to different types of plants. Teachers can scale up the constancy activity to include study about how pollinators do their work. The forb sod biodiversity activity can be scaled up for students to imagine how seeds are being dispersed from the island.
2-LS4-1. Make observations of plants and animals to compare the diversity of life in different habitats.	Students will investigate the three habitat types at Skyline Park and record observations about each habitat type in their science notebooks or journals. Students are encouraged to make predictions about the types of animals found in the different areas.
2-ESS1-1. Use information from several sources to provide evidence that Earth events can occur quickly or slowly.	The Skyline Park signage include two signs related to Earth processes. The first is the Geologic sign regarding the Boulder Batholith and the formation of soil types for Skyline Park. The second is the 100-year Flood sign which describes the catastrophic flooding events of 1908. Both sources can be utilized by teachers and students as the jumping off point for discussion of how Earth's processes formed the Skyline park area.
2-ESS2-2. Develop a model to represent the shapes and kinds of land and bodies of water in an area.	The mapping activity lends itself wonderfully to this DCI. Students map the overall park area including biotic and abiotic features.
K-2-ETS1-2. Develop a simple sketch, drawing or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.	In the extension activities for macroinvertebrate identification, the Build a Macro activity helps student explore how different mouth and body parts of macroinvertebrates determine how those parts function. The teacher could further elaborate the activity to ask students to design body or mouth parts beginning with the problem of scraping food from the bottom for example.

Disciplinary Core Ideas Delivered in Skyline Park Guide	
Performance Expectations Third Grade	**Skyline Park Activity Examples**
3-LS1-1. Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction and death.	The Pond Life activities, micros, aquatic macroinvertebrates, and terrestrial life all share in common the idea of life cycles and further elaborate the nutrient or energy cycling through a system. Teachers could elaborate on the macroinvertebrate activities to include the metamorphosis process of the aquatic insects.
3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment.	The Riparian Habitat activities and the pond life activities are rich with examples of plants or animals that are particularly suited for a specific habitat or environment. The riparian area plant chapter outlines how sedges and rushes are particularly adapted to wet landscape as compared to their upland counterparts. Teachers should complete the mapping and note booking activities along with the pond life activities and help students connect the 'traits' of an organism to its landscape/environment.
3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.	The pond life activities particularly lend themselves to this PE. Students should discuss the various roles macroinvertebrates hold in the pond ecosystem. Additionally, plant types that are particularly well-suited for the pond area are not able to live in the upland areas of the park due to lack of water.
Performance Expectations Fourth Grade	**Skyline Park Activity Examples**
4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth behavior and reproduction.	Students who utilize the plants and pollinators activity will both observe the plant structures and variance between plants, but will also make predictions about the type of pollination syndrome a plant utilizes based on that structure.
4-ESS1-1. Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in landscape over time.	There is not a particular activity in the guide that directly connects to this PE. However, the Boulder Batholith signage and the Geology and Soils background chapter both describe the unique geology of Summit Valley. Teachers could expand the student activities to include predictions about connectivity between soils found on the East Ridge and those that are translocated through stream flow into Skyline Park.
4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth's features.	The mapping activity requires students to describe the patterns of the park area and can be expanded to include other major geographic features such as the Continental Divide/East Ridge.
4-Ess3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.	The Skyline Park design included planning for flooding events, utilizing the pond as a catch in times of high flow, thereby reducing water that flows into Hillcrest school. Students could investigate various engineering designs in place at the park and discuss how effective these solutions are.
Performance Expectations Fifth Grade	**Skyline Park Activity Examples**
5-PS3-1. Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth) was once energy from the sun.	The background information chapter on Pond Life and the extension activities regarding food webs allow students to explore this concept.
5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.	Traditional graphs about food webs and energy flow are presented on the park signs. Teachers should expand this content by having students represent their own food webs based on their observations in the park.
5-ESS2-2. Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.	The water quality activity includes information about the amount of fresh water available for human use. Teachers could expand this information to include graphical representation during background lessons.

Chapter 2.2 Skyline Park Guide and the Montana Content Standards for Science

Instruction

As of the publication of this guide in October 2014, Montana has not officially adopted the Next Generation Science Standards. However, Montana was part of the writing team for the NGSS, which consisted of 26 states and representatives from various stakeholder groups. Montana has also completed a cross-walk of the standards, which examines how well NGSS aligns to the current content standards. According to the Office of Public Instruction Science Coordinator, the writing team for this guide, and many local teachers who participated in the cross-walk investigation, the NGSS and the current MT Content Standards align very well, with the notable exception of including Indian Education For All (IEFA) content in the science standards. In general, the NGSS call for a higher standard of pedagogical approach by including the scientific and engineering practices. Montana's Science Content Standards use the phraseology, "through the inquiry method, students will be able…." in an attempt to address the nature of science and scientific practice. However, the NGSS are much more discreet and enable a teacher to illuminate the scientific and engineering practices clearly.

Resources

1. For more details about **the Framework and Understanding the vision for change in science** education, read the following: National Research Council. (2012) *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press. Available for free download: http://www.nextgenscience.org/framework-k%E2%80%9312-science-education.
2. **The NGSS Standards** documents have detailed descriptions about each standard and learning progression - NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press. Available for free download: http://www.nextgenscience.org/next-generation-science-standards
3. **Conceptual Shifts about NGSS** is an appendix that outlines how teachers will need to revise lessons to meet NGSS. http://www.nextgenscience.org/sites/ngss/files/Appendix%20A%20-%204.11.13%20Conceptual%20Shifts%20in%20the%20Next%20Generation%20Science%20Standards.pdf

4. **How to read the NGSS** is a support document that further describes color-coding and alpha-numeric coding for the standards. http://www.nextgenscience.org/sites/ngss/files/How%20to%20Read%20NGSS%20-%20Final%2008.19.13.pdf

Chapter 3: Building Your Content Knowledge

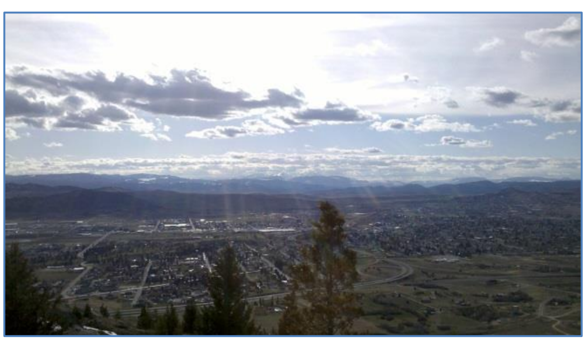
Chapter 3.1 History of Skyline Park Area

Introduction

Beautiful riparian habitat at Skyline Park. Photo by: A. Alvarado

Skyline Park was built in 2013-14 and sits in a natural wetland between Continental Drive and the East Ridge. The park includes an official, kids fishing pond and dog play park, as well as walking trails and a hang gliding landing site. It was designed and developed with grant money from the Natural Resource Damage Program, and through a partnership between the County of Butte-Silver Bow, the City of Butte and the Skyline Sportsmen's Association. Skyline Park is 57 acres, spanning the area behind Hillcrest School and Continental Gardens Housing. This area of land was previously available for unregulated use by all-terrain vehicle riders and dog walkers, and, unfortunately, for illegal dumpers.

Geographically speaking, Skyline Park is located in the Summit Valley in southwest Montana, and is part of the Clark Fork River and Columbia River watersheds. At present, two major creeks drain into the valley: 1) Silver Bow Creek and 2) Blacktail Creek. Many ephemeral creeks also help to drain the area during snowmelt and heavy rains.



A view of the Summit Valley, facing west, with Butte, Montana, shown nestled and basking in the afternoon sun. Photo by: A. Alvarado

Before Europeans arrived, the Native American tribes that frequently utilized the Summit Valley included the Salish, Kootenai and Pend d'Oreille Indians. Here they fished for large bull trout, collected supplies for tools, and gathered roots and berries. These areas were very important to the tribes for different reasons; the place-names given to the area are just one indication of how important the Summit Valley was to the tribes.

Others visited the area, such as French Canadian fur traders, described below. However, the major changes to the area came as prospectors struck gold in 1864 in Silver Bow Creek, and the first of Butte's mines was registered. Mining then became the primary way of life in the Summit Valley.

The French

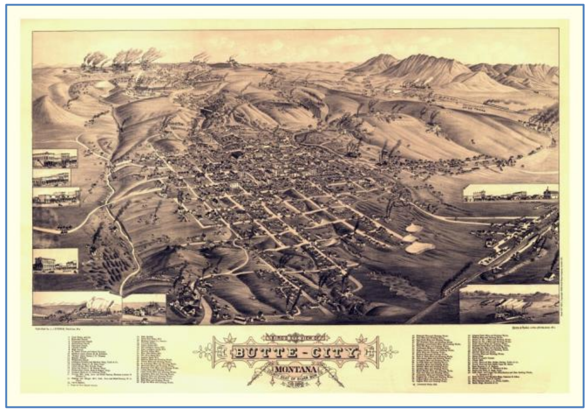
The first documented French man in Butte was Sieur De La Verendryer in 1742. He said, "This is indeed the land of the Shining Mountains." The French Canadians were the heart and soul of the Hudson Bay Fur Trading Company, bringing pioneering mountain men into the Summit Valley. Once here, the French Canadians settled on the Flats of Butte and they commonly worked as timber cutters. The mining operations consumed some 21 million board feet of timber between 1885 and 1900. The Flats hosted many homesteading French Canadian farms and dairies using the foot hills of the Highland Mountains for grazing. Many small farms and dairies served as Mile Houses – Nine Mile, Five Mile and Four Mile. The Mile Houses provided food, lodging and stables for teamsters and travelers before they made the arduous trip over the Continental Divide.

The Poor Farm

Butte's chief industry, mining, was a very dangerous occupation and resulted in many men contracting silicosis and dying from industrial accidents. Scores of women became widows with limited income to care for homes and children, so services for the poor were in great demand. The Silver Bow County Poor Farm Hospital was designed by C. S. Haire of Link and Haire Architects, and was constructed in 1902 to accommodate that need. The building is a classic style for a hospital of its time, and the grounds include a pest house and a burial site. It is the only surviving poor farm in the state. In the 1930s, the Poor Farm was converted to a long-term care facility for the elderly, and the complex is now occupied by the National Center for Appropriate Technology (NCAT; BSB Archives, VF1249).

Transportation

The sheer wealth created by mining in the Summit Valley Mining District drew all major roads and trails into Butte. The technological progress that sparked the need for copper – the electrification of America – spurred the growth of the city and made Butte a transportation destination. Every major railroad – the Union Pacific, the Northern Pacific, the Great Northern, the Chicago, Milwaukee and St. Paul, and the Butte, Anaconda and Pacific Railway – had stately stations, and multiple, daily trains carried passengers, freight and ore to and from the bustling city of Butte. The need to get goods and services to Butte to feed the mines and its workers, created rail and road innovations, such as electrification of the rail system and engineering feats in roads and highways, all designed to move materials over the Continental Divide. Butte is an important crossroad in the country's interstate highway system.



Historic map of Butte, MT, 1884.

<u>Resources</u>

1. **Butte Silver Bow Public Archives** is a wonderful resource for people of all ages. It was established in 1981 to maintain Butte's history. Part of its mission is to provide public access to the documents and manuscript collections at the Archives. The staff is available to help educators utilize archive resources. https://buttearchives.org/
2. **Butte History and "Lost Butte"** by Dick Gibson is an invaluable resource for learning about Butte's history. http://buttehistory.blogspot.com/
3. The **Butte Historical Society**'s webpage is another interesting place for students to visit and learn more about Butte's history. http://buttehistorical.com/index.html
4. The **<u>Montana Standard</u>** is another good source of recent history of Skyline Park. http://mtstandard.com/
5. **Citizens' Technical Environmental Committee** (CTEC) is a group of volunteer citizens who work with the EPA, state of Montana, and others to help inform residents about the Superfund process and cleanup decisions. This site offers contemporary history of our area, specifically, Butte's mining history and the resultant environmental damage. http://www.buttectec.org/
6. **Cfwep.Org**, formerly the Clark Fork Watershed Education Program, maintains a website full of information related to local history, watershed science, teacher curriculum, and more. www.cfwep.org

The Silver Bow County Poor Farm Hospital in 19xx. The building now houses The National Center for Appropriate Technology (NCAT). Photo: BSB Archives.

Chapter 3.2 Habitat Types of Skyline Park

Introduction

At **Skyline Park**, there are three distinct habitat types: 1) the **wetland habitat** (or area), 2) the **riparian habitat** (or area), and 3) the **upland habitat** (or area). Each habitat type is distinct with regards to: plant types found in each; the amount of water available; and levels of sun exposure. The habitat types are designated by informational signs along the walking trails, allowing students to make general observations and begin to understand the roles and functions of these different habitats.

Walking trail in Skyline Park. We see here the upland habitat in the foreground with its shrubs and grasses, and the riparian habitat in the background with its tall cottonwood trees and full willows. Photo by: A. Alvarado

In functional, natural ecosystems, these habitat types are interdependent and can be viewed as parts of a whole. That means that sometimes delineating these natural areas is not straightforward and, indeed, delineations may be inconsistent between resources and regions. At Skyline Park, we define the pond as the **wetland**, while the greener areas with the **ephemeral** (short-lived) creeks are defined as the **riparian habitat**. In other resources, these two features – the pond and the ephemeral creek areas – may be considered a wetland, without delineating between the two. Be sure to discuss such variations with students, as this is a great lesson in the dynamic nature of science and scientific investigations.

In general, different habitat types are distinguished from one another by subtle and not-so-subtle clues, such as elevation, plant types, soil types, and overall available moisture. Teachers utilizing the Skyline Park site can help students understand the interdependency between different habitats and, wherever possible, point out the differences between the habitats and how the plants and animals interact within each type.

The Wetland Habitat

In naturally-functioning, **wetland habitats**, ponds charge (fill) and recharge with groundwater and with surface water flows. During peak runoff in the spring, the wetland will absorb much of the excess water, helping to contain flood waters. During high water periods, the ephemeral Reese Canyon and Tramway Creeks feed the wetland and bypass the Pond. During dry periods, the wetland will recharge the streams and areas outside the wetland.

Reese Canyon Creek, one of the ephemeral creeks, during the spring with water running through the creek. Photo by: A. Alvarado

At Skyline Park, some these functions are human engineered. The pond is fully lined, disallowing groundwater to naturally recharge the pond during dry periods. Therefore, water will be pumped into the pond as needed to maintain adequate temperature and depth to support the stocked fish. Because of this restoration and engineering, the pond will now be able to absorb and trap more water in peak runoff than this area was previously able to accommodate. In fact, the construction of Skyline Park pond is helpful to nearby Hillcrest School as the pond serves as a catchment for seasonal stormwater runoff. In years past, the basement of Hillcrest School would flood during the spring months due to its location downstream from Reese Canyon Creek. Arial photographs of this area reveal that Hillcrest School was built precisely within the floodplain of Reese Canyon Creek.

Wetlands are somewhat difficult to define in specific terms as the scientific and political communities tend to have different impressions and definitions for wetland areas. However, the official definition of a wetland as published by the Army Corps of Engineers in 1987 is defined as follows:

> Wetlands are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

Using this definition of wetland, one can reasonably expect that throughout most of the year, the ground surrounding a wetland is boggy or marshy. There may be ponds that expand and contract throughout the seasons, but water remains in at least a small portion of the area. The plants and animals that inhabit a wetland are often the best indicators of wetland areas as described by the Army Corps of Engineers' definition.

Wetlands are extremely rich ecosystems, and are able to support a vast number of plant and animal species. It is estimated that the wetlands of the United States support over 5,000 plant species, 270 bird species and 190 amphibian species. Less than 2% of Montana is comprised of wetlands, yet 50% of bird species depend on these important areas. Eighteen of the 21 species of plants and animals listed as threatened or endangered in Montana are inhabitants of wetland or riparian areas.

Over the past 200 years, Montana has lost approximately 300,000 acres of wetlands. Typically, these areas are filled or drained for cropland or other human developments. In 1977, Section 404 of the Clean Water Act was created to help protect wetlands. It is now unlawful to add any fill material into a wetland without receiving authorization from the Army Corps of Engineers. The difficulty in protecting wetlands from development is inherent in the very nature of wetlands themselves. Some important wetlands are rather seasonal and may not meet the definition of saturation throughout the year. However, these wetlands, although somewhat temporary, still provide much needed resources for migrating and nesting birds, amphibians, and other wildlife, as well storage for water overflows.

Wetlands are not only valuable for sustaining wildlife populations, they are also critical to the functioning of healthy watersheds. A **watershed** is an area of land that drains or sheds its waters into a common network of streams or rivers. Wetlands help the functioning and maintenance of watersheds in the following ways:

- **Flood control**: Wetland plants retain more water in their roots, leaves and stems than drier land plants. Therefore, in times of heavy rain, wetlands absorb and hold water, reducing the likelihood and severity of flooding.
- **Sediment and microbe trap**: Since wetlands slow down the flow of water through the soil, pollutants from agriculture, disease-causing bacteria, and even heavy metals from mining can be trapped in wetlands. The roots of certain wetland plants actually secrete substances that kill harmful bacteria. Heavy metals chemically bind to concentrated peat, silt and clay that usually form the substrate of most wetlands. Incidentally, designers of wetlands can select different types of clay to absorb specific metals.

- **Water table recharge**: The slowed water flow of wetlands recharges the water table by seeping through the ground. This is very important in Montana as late summer weather is usually hot and dry, and in some areas, groundwater is the primary source of water for human and natural systems. Wetlands near streams and rivers are especially important as they supply a gradual water supply for water bodies throughout the year.

Grasses, sedges, and rushes are planted in the wetland bench area and act as filters for the pond and will eventually become home to wetland animals. Photo by: F. Ponikvar

- **Oxygen source**: Because of all the decomposing organic material in a saturated wetland, there is very little free oxygen. Wetland plants can actually transport oxygen from their leaves to their roots. They then release oxygen through their roots into the water and soil. This process is the primary source of oxygen in a wetland, and is crucial for virtually all wetland inhabitants.

New wetlands are being designed and constructed to clean water, filter sewage, and absorb industrial waste. Wetlands are being designed all over the country right next to paper mills, natural resource mines, and waste water treatment plants. Constructing man-made wetlands is often less expensive and more effective than building conventional treatment plants to do the same job.

At Skyline Park, the pond and surrounding area serve as this location's wetland area. The pond has been constructed specifically to filter the water and maintain fish habitat. Notice on the south side of the pond, there is a shallow area or 'bench' that is filled with **hydrophilic** plants. This **wetland bench** serves a specific function in that these plants will help to filter and trap algae growing in the pond. The plants will also help to maintain oxygen levels and provide habitat cover for shore birds, amphibians, insects, and fish fry. A generic diagram of typical placement of a wetland bench is shown in the figure above.

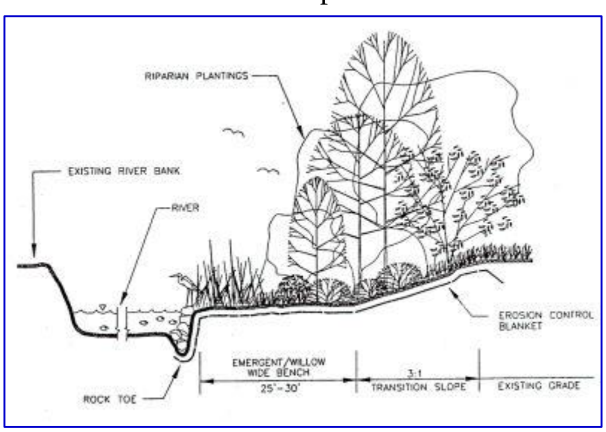


Diagram of a typical wetland bench.

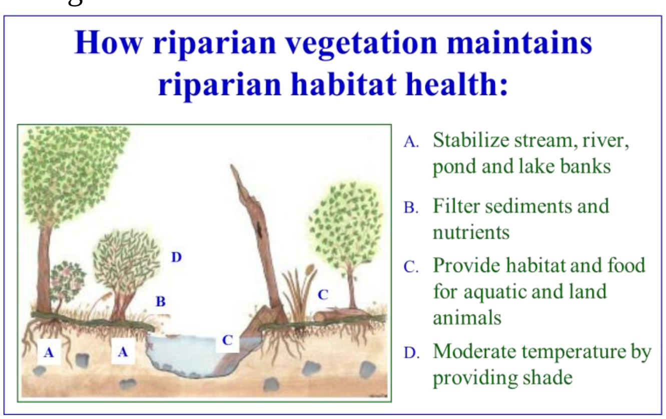
The Riparian Habitat

The **riparian habitat** includes all areas of land that are affected by or that have an effect on the water body it surrounds. In some sources, the riparian habitat may or may not include the wetlands, but most do include the floodplains and the **riparian zone**. In Montana, about 80% of our biodiversity is dependent upon our riparian habitats. In fact, high biodiversity of plants and animals in a riparian habitat is a measure of the health of the habitat.

The **riparian zone**, sometimes called the *buffer zone*, is defined here as the community of plants that grow right alongside the banks of the water body. Riparian zones are major determinants of the health of the riparian habitat. They are ecologically diverse, and contribute to the health of aquatic ecosystems by: filtering out pollutants; preventing erosion; stabilizing streambanks; providing shade (thus keeping waters cool); supporting biodiversity; and a few other critical roles. These roles are further explained below. The dominant riparian habitat plants in Skyline Park are cottonwoods, willows, rushes and sedges, which is similar to many riparian habitats in Montana.

It is typically very easy to identify the riparian zone because, if it is in a healthy riparian habitat, the zone appears as a ribbon of green along the banks of a river, stream, lake or pond (with the exception of the wintery season). In places that have dry seasons, like Montana, riparian zone vegetation is **only** found in the riparian zone. Since it is very moist around the banks of water bodies, the riparian zone supports **hydrophilic** plants. The term *hydrophilic* comes from the Greek words *hydro* meaning water and *philia* meaning friendship or loving. Riparian zone plants consist of vegetation that **requires** lots of water - more than upland plants do.

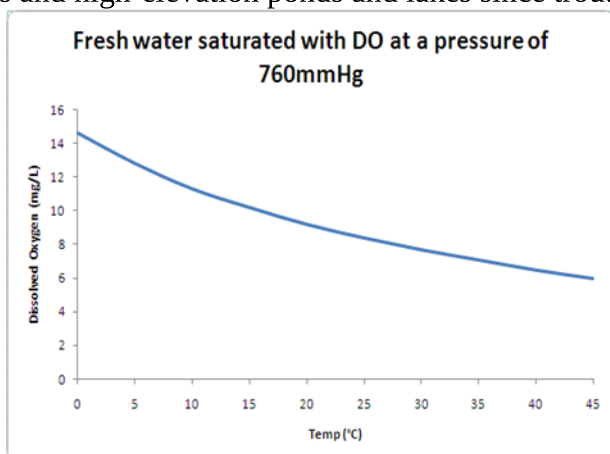
Two very important functions of the riparian zone is bank stabilization and erosion control. Since riparian zone plants send their roots deep into the soils surrounding the water, they form a complex web of roots that provide stabilization to the banks of water bodies (see figure to the right). During times of high runoff, riparian zone plants and their roots act as filters, trapping and storing sediments and nutrients that would otherwise cause turbid waters. **Turbidity**, which refers to the cloudiness of water, is a measure of water quality. In some streams and rivers, such as those in Montana, the higher the turbidity is the lower the water quality is. Of course, as streams drain into rivers, and smaller rivers drain into larger rivers, sediment loads increase which increases turbidity – consider the muddy Mississippi River which drains much of the land between the Appalachian and Rocky Mountains.



Ways riparian vegetation maintains riparian habitat health.

How do we know if a riparian habitat is healthy or unhealthy? Healthy riparian habitats are capable of performing key ecological functions, as described above. Consider how we assess human health; when we are sick or unhealthy, our body's functions do not perform within optimal ranges. In an unhealthy riparian system, we also find that it cannot perform its normal ecological functions within optimal levels. It may be able to perform some functions, but in unhealthy riparian habitats, either some functions do not occur at all or cannot be fully perform the function.

Riparian zone trees, shrubs, **forbs** and grasses also provide critical **microhabitats**, those smaller, specialized habitats within larger habitats. Organisms as small as **microbes** and as large as bears depend upon riparian zone vegetation for shelter and food. Moreover, the shade provided by riparian zone vegetation is very important for moderating water temperatures. This function is especially important for our Montana streams and high-elevation ponds and lakes since trout are particularly sensitive to high temperatures. As shown in the graph, as temperature increases, the amount of oxygen dissolved decreases. At 21° C or less (< 70° F), trout begin to experience distress; temperatures above 27° C (80° F) are considered lethal. In addition to the critical roles performed by the riparian zone, riparian habitats serve several other ecological functions, many of which act to protect water quality or maintain an ecological balance in a water body. For example, wetlands and floodplains provide 'storage' areas during peak runoff ensuring that flooding is minimized. It is not unusual, especially in Montana, for wetlands and floodplains to dry out over the hot summer months.



The relationship between temperature and the amount of dissolved oxygen in freshwater is shown in this graph. As temperature increases, the amount of oxygen dissolved in water decreases.

Riparian habitats are sensitive to environmental pressures because of their complex, interconnected ecosystems. As mentioned, they provide rich resources in the form of water, soils, and cooling shade. These resources are important not only for many plants and animals, but riparian habitats also tend to be attractive for humans as well. Urbanization of riparian areas results in habitat loss and significantly impacts these systems.

Restoration and preservation of riparian habitats is critical to maintaining biodiversity within a given landscape. Forest management practices and urban development policies are helping to curb some of the negative impacts caused by human activities. Skyline Park plays the dual roles of education and preservation; it is an example of citizens helping to preserve and protect a riparian habitat, and allows citizens to learn why it is important to preserve and protect other riparian habitats.

The Uplands Habitat

Upland habitats in Montana get about 40 cm (15.4") of precipitation annually according to Montana Fish, Wildlife, and Parks. The uplands are a transition area between prairie and forest. This habitat is dominated by shrubs, grasses, and forbs. Because of the terrain and decreased water supply in the upland areas, plants that grow here tend to be more drought-tolerant than those that grow in the riparian area. The upland and prairie ecosystems are home to many native plants, birds, and mammals.

Major threats to upland and prairie ecosystems are housing and business development and the resultant habitat fragmentation. As these areas are developed, rangelands become increasingly smaller, thereby, increasing the chance of adversarial human-animal interactions. Other impacts that have affected upland and prairie ecosystems are poor logging practices, invasive species encroachment, fire suppression, and improper grazing management, which have all lead to a significant reduction of suitable habitat for native plants and animals. Disturbed habitats are suitable to invasive and introduced (non-native) species. In many cases, invasive plant species result in habitat loss for animals and plants, and result in loss of important grazing lands for our native herbivorous animals. Students and teachers may wish to explore invasive plant species in more depth through Missoula County Weed District's kNOweeds Curriculum. This tool is an excellent resource regarding weeds and weed adaptations.

Resources

1. **Environmental Protection Agency - Wetlands** includes definitions, types, status and trends, and the Wetland Fact Sheet series. http://water.epa.gov/type/wetlands/
2. **Environmental Concern** is a non-profit that is dedicated to working with all aspects of wetlands. Their **Education** pages offer general information about wetlands, and **Wetlands 101** is an online course about the functions and value of wetlands. http://www.wetland.org/education_wetland101.htm
3. **Ducks Unlimited, Canada** has a 35-page guide called, **Teacher's Guide to Wetland Activities**. This guide includes everything from the water cycle and the importance of wetlands, to information on wetland food webs, and more. http://www.greenwing.org/dueducator/ducanadapdf/teachersguide.pdf
4. **My Science Box** provides "hands-on science curriculum for the adventurous teacher." It includes excellent extension activities for wetlands including a Hurricane Katrina case study about the importance of wetlands for flood control. http://www.mysciencebox.org/wetlands/logistics

5. The **US Forest Service** published in April 2000, Monitoring the Vegetation and Resources in Riparian Areas, a technical manual that provides information on three sampling methods used to inventory and monitor the vegetation resources in riparian areas. http://www.fs.fed.us/rm/pubs/rmrs_gtr047.pdf
6. One of the best resources for information about invasive weeds in Montana is available at the **Missoula County and Extension Weed District**. Their curriculum called, **kNOweeds**, is designed for grades K-12. http://missoulaeduplace.org/weed-curriculum.html
7. **Montana Fish, Wildlife, and Parks** teacher education website has a wide variety of resources for educators including links to **Project WILD** which offers conservation and environmental education programs and contain various extension activities for all three habitat areas described in this section. http://fwp.mt.gov/education/teachers/

Chapter 3.3 Pond Life

Introduction

Aquatic habitats, such as ponds and ephemeral creeks, typically support a higher abundance of life forms and a greater diversity of plant and animal species than drier habitats do. Similar to other aquatic habitats, ponds support many different kinds of animal life, ranging from microscopic rotifers and small fish to birds, mammals, reptiles and amphibians. Pond waters also support many different kinds of photosynthetic life forms from the plant and bacterial taxonomic groups. Protists, both animal-like and plant-like in form, are also found in abundance and in relatively high diversity, especially in a healthy pond. This chapter is intended to give you an overview of the many different kinds of life forms you may encounter at and near **Skyline Park** pond. First, however, we'll review how ponds are defined and described by the scientific community, and as well as discuss those features that make ponds different from other water bodies, especially lakes.

What is a Pond?

A pond can be defined as a quiet body of water, typically smaller than a lake, and shallow enough to allow rooted plants to grow completely across it. In contrast, lakes are deeper so plants cannot take root in them beyond the lakes' shallow shores. While there are several different types of ponds, the Skyline Park pond is most similar to a meadow-stream pond, as opposed to a bog or farm pond (Reid 2001). Meadow-stream ponds, according to Reid (2001), develop where a stream widens and the flow of water slows, typical of what happens in valleys. Also, pond water temperatures tend to be fairly uniform from top to bottom, and vary with air temperature. Lakes, on the other hand, vary in temperature by depth; the deep waters are colder than the shallow waters. Pond bottoms are usually covered with mud, and there is little wave action. With their larger surfaces, lakes tend to have more wave action.

Skyline Park pond. Photo by: A. Alvarado

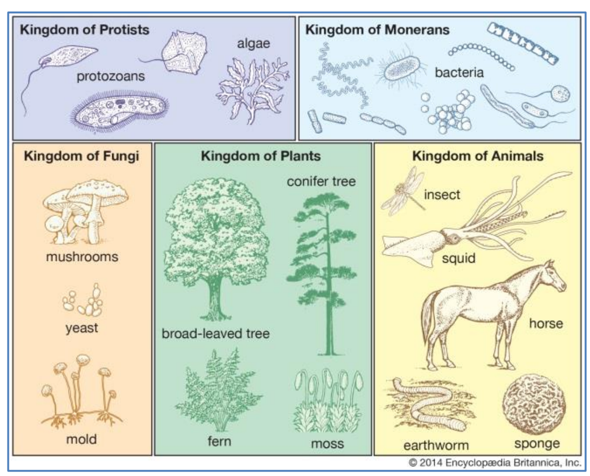
Lastly, ponds tend to vary greatly in dissolved oxygen (DO) levels within a 24-hour period because of the abundant aquatic plants living in them. At night when aquatic plants shut down photosynthesis, they use the DO available in the water for cellular respiration. While they perform cellular respiration all day, in daylight aquatic plants release more oxygen than they consume. So while photosynthetic organisms can increase DO in a pond during the day, they consume the oxygen at night. Lakes have fewer aquatic plants with roots in the water so their dissolved oxygen concentrations are more influenced by season and lake depth. In deep, stratified lakes, this difference may be big – plenty of oxygen near the top, but practically none near the bottom. If the lake is shallow and easily mixed by the wind, the DO concentration may be more consistent throughout the water column. Of course, official and scientific definitions of ponds and lakes are continuously being redefined (for examples, see USDA website). For our purposes, the descriptions given above are sufficient.

Important Note on Invasive Species

In order to maximize the health of the pond at Skyline Park, it is important that no plants or animals be intentionally introduced as it can damage the system and the animals already inhabiting it. Invasive plant species result in loss of habitat and nourishment for animals, and loss of habitat for native plants. Teachers may wish to explore invasive plant species in more depth with their students through the Missoula County Weed District's kNOweeds Curriculum. This tool is an excellent resource regarding weeds and weed adaptations. Other invasive species can include certain fish, crustaceans, mollusks, mammals, parasites and pathogens. For your reference, Montana Fish, Wildlife, and Parks has a complied list of these species on their website; please see *Resources* for more information.

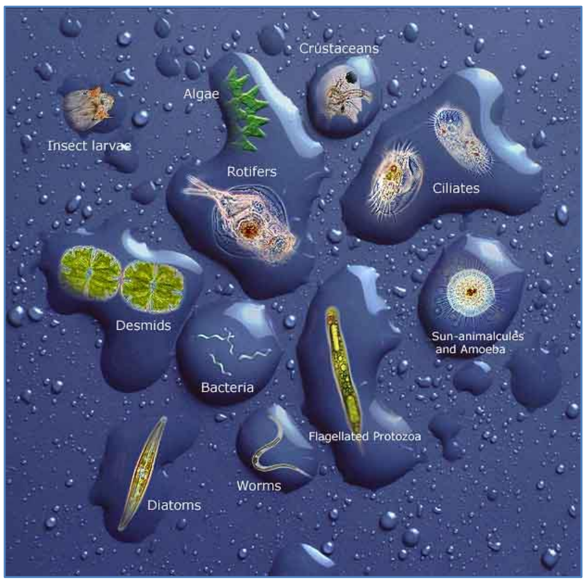
Overview of Pond Life Forms

Pond life is a fascinating science topic for students of all ages. There are so many different ways of grouping and talking about pond life forms that they can be introduced through multiple units. In this chapter, we discuss pond life forms by first grouping them by size: microscopic and macroscopic. The microscopic forms, also called **microbes**, can be seen using a regular compound microscope. The macroscopic forms range from those that are easily seen – for example, birds and mammals – to those that can be seen moving, but using a hand lens makes identification easier.



Five Kingdoms of scientific classification system.

Within these major groupings of microscopic life, we further grouped pond organisms into current taxonomic units as described by Encyclopedia Britannica: 1) Kingdom Monera, the bacteria, in this case both eubacteria and archeobacteria; 2) Kingdom Protista, animal-like, plant-like and fungal-like organisms; 3) Kingdom Fungi, the molds, yeasts and mushrooms; 4) Kingdom Plantae, the multicellular, photosynthetic organisms; and 5) Kingdom Animalia, the multicellular organisms that can move and must ingest nutrients. Kingdom Monera includes only microscopic types, while Kingdom Plantae typically only includes macroscopic types. However, some sources sometimes identify photosynthetic protists 'plants.' The other three kingdoms, Protista, Fungi, and Animalia have both microscopic and macroscopic types.



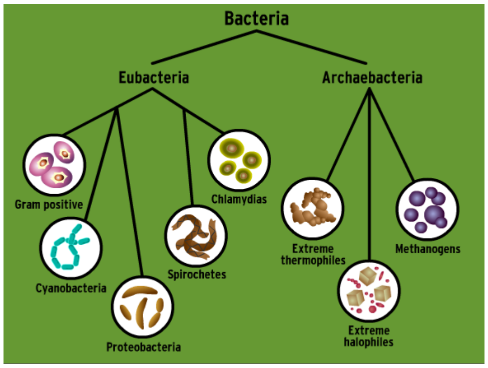
The diversity of life in a single drop of pond water.
Image source: www.microscopy-uk.org.uk

Microscopic Pond Life Forms

A single drop of pond water reveals a fascinating collection of microscopic creatures hustling and bustling about, finding food, avoiding predation, and reproducing. Many organisms in a drop of water are single-celled creatures – they are complete and independent life forms. However, a few are multicellular. Single-celled organisms include bacteria, some algae, and wide-variety of protozoa; multicellular organisms include algae, rotifers, daphnia, hydras and others. Many microscopic life forms are classified under Kingdoms Monera and Protista, but some are classified under Kingdom Animalia. Some microorganisms can be harmful to a system, while others can be helpful. Here we provide a brief survey of the most common types of microbes that you and your students may see in a drop or two of pond water from Skyline Park.

Pond Microbes from Kingdom Monera

Kingdom Monera includes all the bacteria, a very large group of single-celled organisms – the number estimated at about 5 x 10^{30} – that inhabit every part of Earth. Bacteria are the smallest creatures you will see in a drop of pond water with a compound microscope. Most bacteria are about 0.2 μm in diameter and 2-8 μm in length (Encyclopedia Britannica). Most bacteria are so small that 10,000 individuals lined up end-to-end would only equal about 1 cm. A compound microscope will allow you to see relatively well those bacteria that form colonies, but single-living bacteria will likely only be apparent as tiny, squirming dots or strands.



Two major groups of bacteria: 1) eubacteria and 2) archaebacteria. Source: http://www.brainpop.com/educators/community/bp-topic/bacteria/

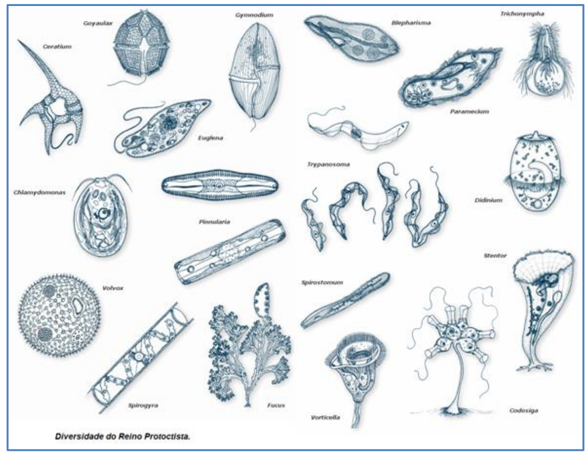
Bacteria are highly diverse, but most individual bacteria tend to appear in one of three shapes: 1) spherical-shaped bacteria called **cocci** (singular, coccus); 2) rod-shaped types called **bacilli** (singlular, bacillus); and 3) spiral-shaped ones called **spirilla** (singular, spirillum), **vibrios** (singular, vibrio) or **sprirochete** (singular, spirillum). The spiral forms and some types of bacilli have a flagellum at one or both ends, allowing them some directed motility. If your students do see bacteria, having students identify them to general shape works well, even though their shapes can sometimes be distorted.

One of the more common bacteria found in a drop of pond water are the aerobic phototrophs, those bacteria that convert light energy into sugar and oxygen through photosynthesis. Cyanobacteria, also known as blue-green algae because the bluish-green color they give ponds and lakes, are one example of photosynthetic bacteria in ponds. For a while cyanobacteria were classified as algae because they perform photosynthesis, but unlike eukaryotic algae, cyanobacteria lack a membrane-bound nucleus, so like other prokaryotes, they are considered bacteria. *Nostoc* is a cyanobacterium that forms large spherical colonies; they are common and can just be seen with the naked eye. Cyanobacteria are best known as being the first organisms to release oxygen into the atmosphere.

Bacteria are a vital food source for the other microbes that continuously feed on them. Bacteria also help to decompose dead organisms; the algae, protists and animals, as well as bacteria, that die and settle to the bottom of the pond would quickly accumulate and overcome the system were it not for the bacteria's decomposing actions. In addition, the importance of bacteria in recycling nutrients and making essential nutrients such as nitrate, phosphate, and sulfate, available to other organisms make bacteria indispensable for healthy, functioning ecosystems.

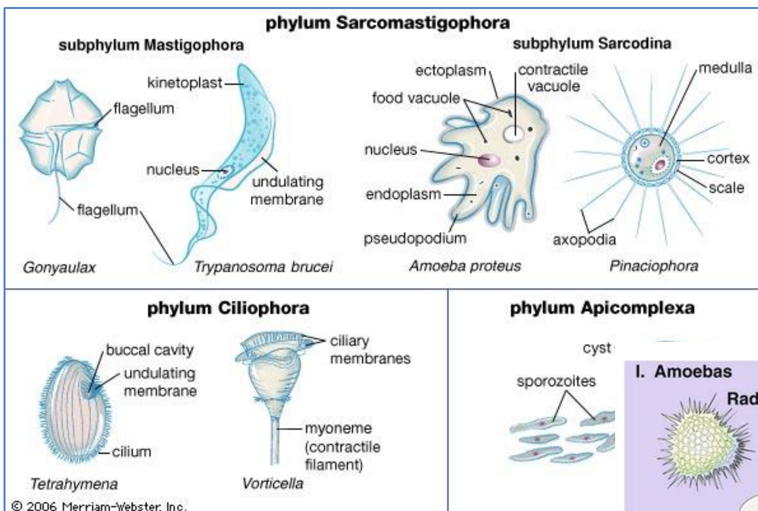
Pond Microbes from Kingdom Protista

The organisms included in the Kingdom Protista are among the most diverse and interesting microbes you will see in a drop of water. All protists have a nucleus, so they are classified as eukaryotes. Most are microscopic, but some are macroscopic; the largest member of this group is giant kelp that can reach about 10 m in length. The majority are unicellular, but some live in colonies, and a few are multicellular, such as the algae. The algae are autotrophic, making their own food; other protists are heterotrophic, such as the paramecium, which must obtain nutrients by ingesting other organisms entirely or ingesting just their fluids. All protists need some kind of watery environment; some live in seawater or freshwater, though others can live in moist soils, or in or on other organisms.

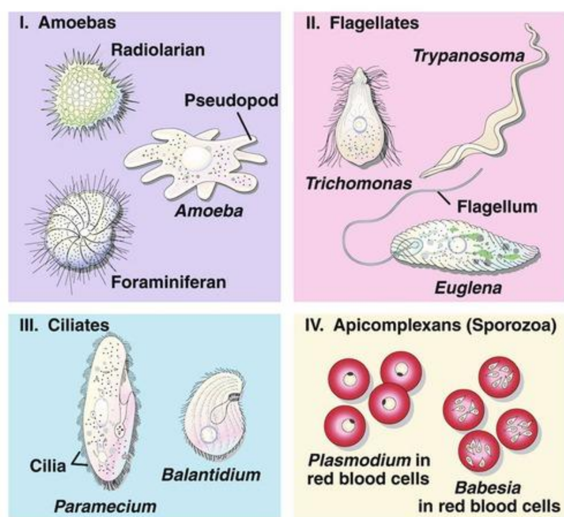


Diversity of living forms in Kingdom Protista. Image Source: http://www.clickescolar.com.br/reino-protista.htm

Protists are defined as those organisms that do not belong in the other kingdoms. There are three general groups of protists based on how they obtain nutrition: 1) **protozoans**, the animal-like protists that ingest their food; 2) **algae,** the plant-like protists that create their own food via photosynthesis; and 3) fungi-like protists, also known as **slime** and **water molds**, that



Representative protozoans. The phytoflagellate *Gonyaulax* dinoflagellates responsible for the occurrence of red tides. T zooflagellate *Trypanosoma brucei* is the causative agent of A sleeping sickness. The amoeba is one of the most common s Other members of the subphylum Sarcodina usually posses coverings. The phylum Ciliophora, which includes the cilia *Tetrahymena* and *Vorticella*, contains the greatest number o species, but is the most homogeneous group. The malaria-ca *Plasmodium* is spread by the bite of a mosquito that injects spores (sporozoites) into the bloodstream. © Merriam-Web



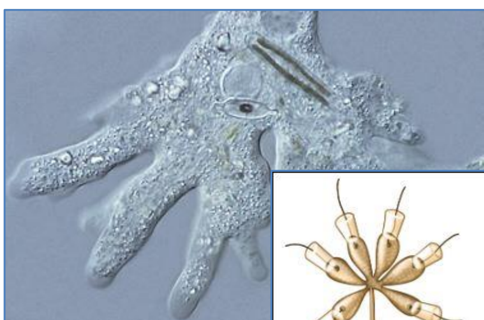
Four types of protozoans: 1) the amoebas or sarcodines; 2) the zooflagellates; 3) the ciliates; and 4) the apicomplexans or sporozoans. Image source: http://quizlet.com/17085111/micro-parasite-lab-final-images-only-flash-cards/

absorb nutrients from dead organic matter. Please note that since Protista is a group that is not based on evolutionary relationships, they are difficult to scientifically classify, and, therefore, some sources may list different groupings than we use here.

The Protozoans – Animal-like Protists

Protozoa which means "first animal," show similar characteristics to animals, as they hunt, gather and 'digest' other microbes for food. However, since they are unicellular, they are not classified with the multicellular animals of the Kingdom Animalia. Protozoa are found in soil and water, and are normal inhabitants of the guts of animals. They have been found in almost every kind of watery environment, including the frigid waters of the Arctic and Antarctic Oceans. They range in size from about 5 μm to 1 mm. A very small number of protozoan species can cause disease in people, such as those that cause malaria and amoebic dysentery (Microbe World).

There are four general kinds of protozoans based on how they move: 1) **sarcodines** or the amoebas that move with pseudopodia (extensions of cytoplasm); 2) **zooflagellates,** or just flagellates, that move with a whip-like flagellum; 3) **ciliates** that move with hair-like cilia; and 4) **apicomplexans** (previously known as sporozoans) that do not move and live as parasites. You may see the first three in a drop of pond water, but will likely not see the fourth group since they are parasites and reside within hosts. Let's do a brief overview of these four types of protozoans.



A micrograph of a naked food and contractile vacu pseudopods. Image sourc http://www.microscopy-uk.org.uk/mag/indexmag. croscopy-uk.org.uk/mag/artfeb01/m

The amoebas (sarcodines) are grouped into two types – the naked amoebas and the testate amoebas. The main difference between them is the shell-like body covering of the testate amoeba. Amoebas are famous for their locomotive behavior of extending pseudopods or "false feet" out toward the direction of travel, followed by the movement or streaming of their cytoplasm into the 'foot.' They also use pseudopods to entrap and engulf food items. While looking at them under the microscope, you can sometimes see small, struggling organisms inside the amoeba.

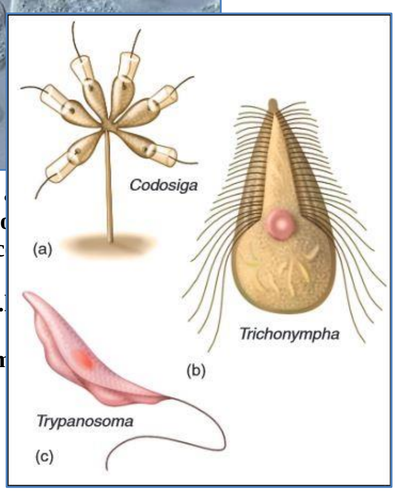


Diagram showing some of the diversity of forms in the zooflagellates. Image source: http://www.mhhe.com/biosci/genbio/tlw3/eBridge/Chp14/14_3.pdf

The **zooflagellates** are protozoans that are non-photosynthetic, animal-like flagellates that typically possess a **flagellum**, a whip-like structure that is used for locomotion, feeding and other purposes. Identification of flagellates can be difficult because they are very small and high magnification is required for a good view. They ingest food – bacteria, algae and other protozoa – by engulfing it in food vacuoles as the amoebas do, or by absorbing organic material through their plasma membrane. There are many different types of zooflagellates and we see considerable variation in form. They may be free-living, commensal, symbiotic or parasitic.

One group of zooflagellate of particular interest is Choanoflagellate, named for the *collared* flagellates, which use a flagellum for propulsion and to collect food. Choanoflagellate is most likely the group that gave rise to the sponges, and may be the group from which all animals arose. *Proterospongia* is considered the best living example of what the ancestor of animals may have looked like, though it is not the actual ancestor. A few zooflagellates cause disease, such *Trypanosoma* which causes African sleeping sickness and Chagas disease, and *Giardia*, which causes gastrointestinal illness.

The third kind of protozoan, the **ciliates** such as paramecium and blepharisma, is the most common and generally the largest-sized protozoan that you'll likely see in pond water. Ciliates are considered some the most complex of protozoans, especially considering they are unicellular. Feeding mostly on bacteria and protists, they use their cilia to move through the water and/or to create currents to bring food particles into their mouths. In general there are three kinds of ciliates based on how they move: 1) free-swimming ciliates, like paramecia; 2) crawling ciliates whose cilia can look like legs like those belonging to *Aspidisca* and *Euyplotes*; and 3) stalked ciliates like those belonging to *Stentor*. The most common ciliate, in fact the most common protozoan, you will see in pond water is the paramecium, one of the fastest moving protozoa.

A photo of a paramecium showing nucleus, mouth and water expulsion vacuoles. Image source: http://www.wired.com/2013/10/nikon-small-world-2013/#slideid-593739

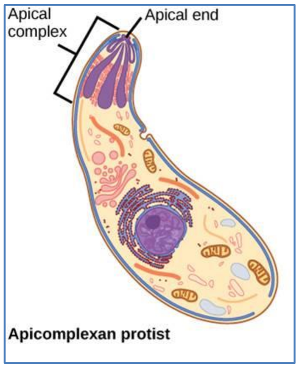


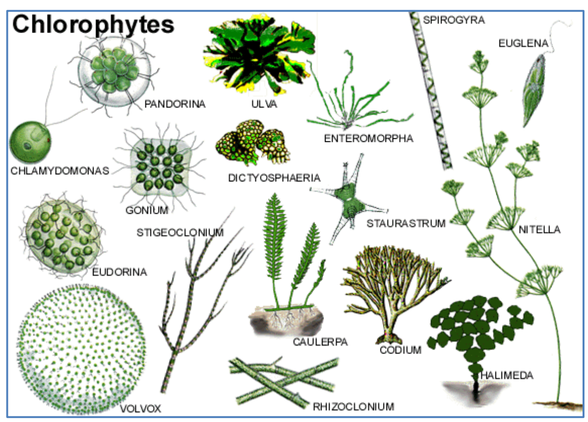
Diagram of an apicomplexan protist featuring the apical complex, a structure that all apicomplexans (formerly known as sporozoans) share. Image source: http://cnx.org/content/m44617/latest/?collection=col11448/latest

The **apicomplexans** were so named because of a shared structure called an apical complex. They were previously known as the sporozoans but that name was considered not specific enough of a description of what sets these creatures apart from other protozoans. Apicomplexans, most of which lack pseudopods, flagella or cilia, are spore-forming, intracellular parasites of animals. The apical complex is thought to function in the attachment to or penetration of host cells. These infectious agents are typically spread by insects in whose bodies they complete part of their life cycle. The species within this group vary between being parasites for just part of their lives to being parasitic all of their lives. You are not likely to see this creature in a drop of pond water since they are usually associated with their hosts. The best known apicomplexan is *Plasmodium*, the organism that causes malaria.

There are so many fascinating types of protozoans that a full year of study could be spent on just surveying all the different types. In addition, they are critical to a healthy aquatic habitat. While most protozoans feed mostly on bacteria, they play a key role in maintaining the balance of bacterial, algal, and other microbial life. They themselves are a vital source of food for each other and other larger organisms, and are the center of many food webs.

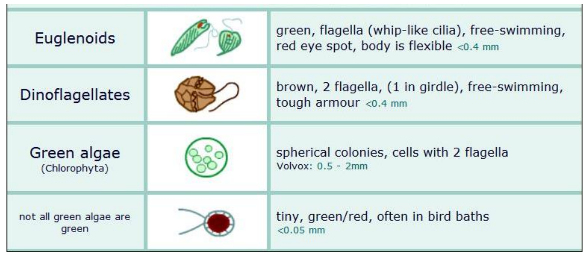
The Algae – Plant-like Protists

Microscopic algae are unicellular, plant-like protists that use chloroplasts to convert light energy into chemical energy through photosynthesis, subsequently releasing oxygen. In fact, about 75% of the planet's oxygen is produced by photosynthetic algae and cyanobacteria (Microbe World). Most algae are aquatic, but some inhabit soils and others join fungi in a symbiotic relationship to form lichens. There are some macroscopic, multicellular types of algae that will be discussed in the next section on macroscopic pond organisms. Here we will focus on the microscopic, freshwater algae.



Diversity of unicellular and multicellular photosynthetic algae. Image source: http://www.botany.hawaii.edu/BOT201/Algae/Bot%20201%20Chlorophytes%20page.gif

Algae are scientifically classified according to their structures and pigments, but here we group them by their major feature, which is more helpful for pond water investigators. There are four main types based on major features: 1) **flagellated algae**; 2) **non-flagellated algae**; 3) **filamentous algae**; and 4) **other algae** of various growth forms (which are not further discussed).

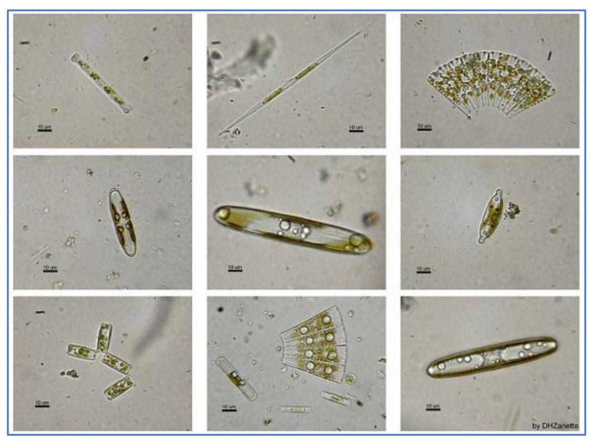


Euglenoids		green, flagella (whip-like cilia), free-swimming, red eye spot, body is flexible <0.4 mm
Dinoflagellates		brown, 2 flagella, (1 in girdle), free-swimming, tough armour <0.4 mm
Green algae (Chlorophyta)		spherical colonies, cells with 2 flagella Volvox: 0.5 - 2mm
not all green algae are green		tiny, green/red, often in bird baths <0.05 mm

Flagellated algae forms. Some of these are sometimes grouped into protozoa. The flagella of these creatures is only visible with strong magnification. Image source: http://www.microscopy-uk.org.uk/index.html.

The **flagellated algae** include Euglenoids, which can both photosynthesize and engulf food. Since it is a creature that is both animal-like and plant-like, you may come across some resources that consider *Euglena* to be protozoan. Euglenas can become so numerous in ponds that they may turn the water a bright green. They are easily recognizable by their green color and red eye spot. Other flagellated algae include the dinoflagellates, which are also free-swimming, but are brown in color. Some dinoflagellates can cause what are known as red tides, or harmful algal blooms, in which they release domoic acid, a neurotoxin that can harm aquatic animals. The green algae (Chlorophyta) form spherical colonies that include cells with two flagella. One type of flagellated algae that is grouped under green algae is Volvox; they are a favorite among microbe enthusiasts because of their beauty and visibility.

The **non-flagellated algae** include diatoms, desmids and green algae. **Diatoms** have got to be some of the most exquisite looking creatures on the planet! They are usually brownish, and have a two-part, silica-based cell wall called a **frustule**, upon which identification is based. They can be solitary or form colonies. Many diatom species are suspended in the water column moving at the mercy of water currents, while others are found attached to substrates. Diatoms are abundant in freshwater, making them an important food source in aquatic systems. Of all algae groups, diatom species are the most numerous (Encyclopedia.com).

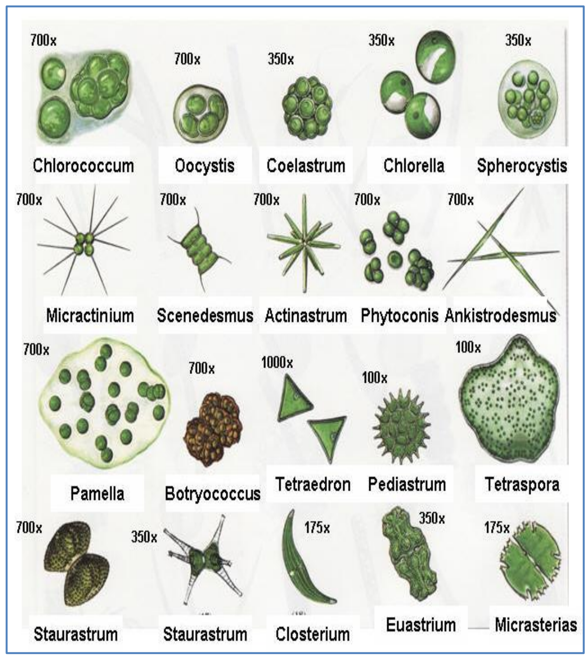


Diversity of freshwater diatoms. Image source: http://en.wikipedia.org/wiki/Diatom

Diversity of freshwater desmids, non-flagellated algae. Image source: http://www.microscopy-uk.org.uk/

Desmids are found mostly in freshwater. They are unicellular, but the cells in some types are divided into two compartments separated by a narrow bridge. They display beautiful, symmetrical shapes upon which identification is based. The shapes vary from circular, elongated, star-shaped and even moon-shaped species. Some are also 'decorated' with knobs and spines. They are green, lack flagella, and are mainly solitary, though some colonial varieties exist. There are also some desmids that form long filaments.

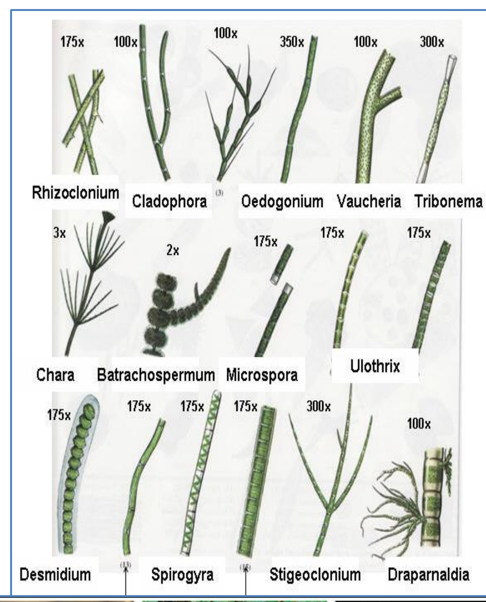
The last group of non-flagellated algae are also called **green algae**, and are classified as Chlorophyta (sometimes the division name, Chlorophycophyta, is used). This is a large group of green algae with very different cell sizes. They are all green, and do not move. Instead, they remain attached to a surface. A common type found in pond waters is Pediastrum, which forms colonies that look like a circle with spikes. Of special note, understand that there is continued confusion and debate about how to group these algae, especially with the added DNA evidence that is now becoming available. Don't be surprised if you come across resources that group them differently than we did here.



Diversity of non-flagellated green algae. Image source: http://classroom.sdmesa.edu/eschmid/Lecture11-Microbio.htm

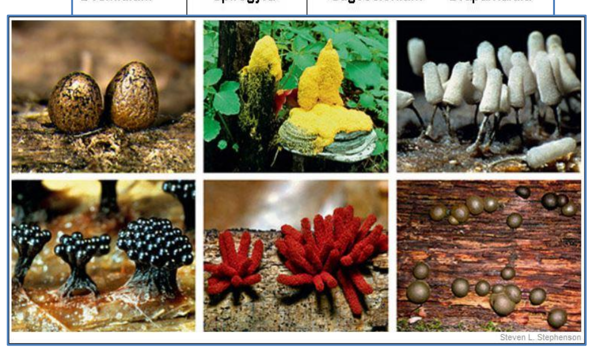
Algae are also grouped according to the pigments they contain; please note that not all of these groupings are found in fresh water. The three types of algae based on pigment are: 1) Chlorophyta, the green algae; 2) Rhodophyta, the red algae; and 3) Phaeophyta, the brown algae. All Chlorophyta contain green pigments and grow in filamentous, sheet-like, spongy or calcareous forms. Chlorophyta contains both unicellular and multicellular species, and most inhabit freshwater (~ 90%), though some marine species exist. The green algae are considered a close relative of terrestrial plants. Rhodophyta contain red pigments and mostly inhabit tropical marine environments. Most Rhodophyta are multicellular with a great deal of branching; this group includes the red to purple seaweeds. Phaeophyta contain brown and yellow pigments and are also mostly marine, though a few freshwater types exist. They are all multicellular, and include the brown seaweeds. Phaeophtya species called kelp can reach up to 30 m in length. Asian cultures feature both Rhodophyta and Phaeophtya in their foods (UC Berkeley, Natural History Museum).

The **filamentous algae** are unicellular algae cells that form long chains, threads or filaments. Some are non-branching while others will display branches. Filamentous algae grow along the bottom of a water body, or are attached to rocks or aquatic plants. As they grow, they float to the surface forming large mats commonly referred to as pond scum. There are many species, and typically more than one species will be present at the same time in a pond. A few types of filamentous algae you'll likely see in pond water are *Spirogyra*, *Zygnema*, and *Mougeotia*.



The Slime Molds, Water Molds and Downy Mildews - Fungi-Like Protists

Fungi-like protists are heterotrophic and feed mostly on decomposing organic materials. They have cell walls and use spores to reproduce, like plants. All types are motile at some point in their life cycle, like animals; some move by using pseudopods. In general appearance and habits, they are like fungi. They are three types of fungus-like protists: 1) **slime molds** (Myxomycota); 2) **water molds** (Oomycota); and 3) **downy mildew** (Oomycota). Slime molds tend to live in moist soils and on decaying plants; the water molds and downy

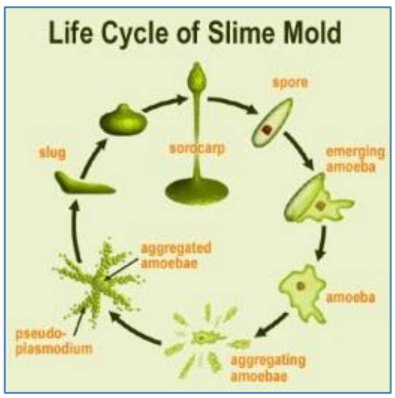


Diversity of slime molds found in forests. Image source: http://www.nytimes.com/2011/10/04/science/04slime.html?pagewanted=all&_r=0

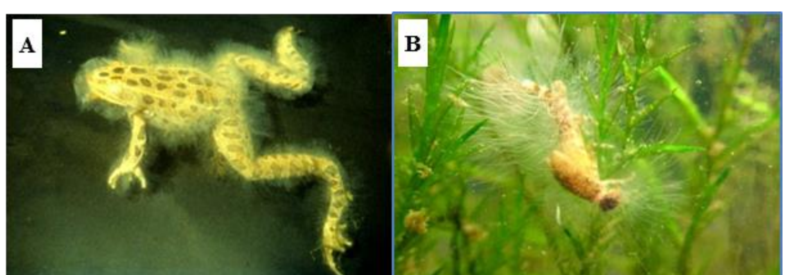
mildews grow as threads in water or moist places.

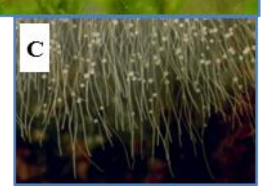
The **slime molds** have two distinct types: 1) the plasmodial (or acellular) slime mold, and 2) the cellular slime mold. About 60 species of slime molds live in freshwater out of the roughly 900 species known. The others are mostly found living in damp, organically rich habitats. All are motile, form spores for reproduction, and ingest food by engulfing it. They ingest bacteria, yeast, and bits of decaying plant and animal matter. Both plasmodial and cellular types have a life stage that consists of single cells that absorb nutrients, and both prefer cool, moist habitats, such as forests.

The main difference between the plasmodial and cellular types is what happens when they aggregate. The cellular slime mold spends most of its life as an independent, amoeba-like cell. When conditions turn unfavorable, they swarm and aggregate into an large, single mass. The mass produces a slimy covering and behaves like one organism, but each cell retains its cell membrane. At this stage it is called a slug due to its resemblance to the animal. When conditions improve, the slug stops moving and forms another structure that is ready to release spores like plant seeds. Each spore becomes a new amoeba-like cell. In contrast, the individual cells of the plasmodial slime mold lose their cell walls after aggregating, leaving a large mass with multiple nuclei floating in protoplasm.



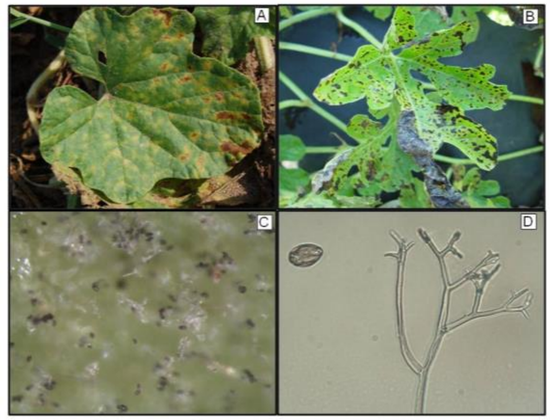
The life cycle of a cellular slime mold is a fascinating example of the diversity of lifestyles that one finds among the protists. Image source: http://www.arctic.uoguelph.ca/cpl/organisms/protists/terra/slime_molds_frame.htm





Images of water mold. A) Water mold infestation on a frog. B) Water mold on dead mayfly larva. C) Water mold close up. Image sources: A) http:// www.bsu.edu/ classes/ ruch/msa/ porteretal/3-37.jpg; B) http://commons. wikimedia.org/wiki/file: Water_mold.JPG. C) http://website.nbm-mnb.ca/ mycology webpages/NaturalHistoryOfFungi/Oomycota.html

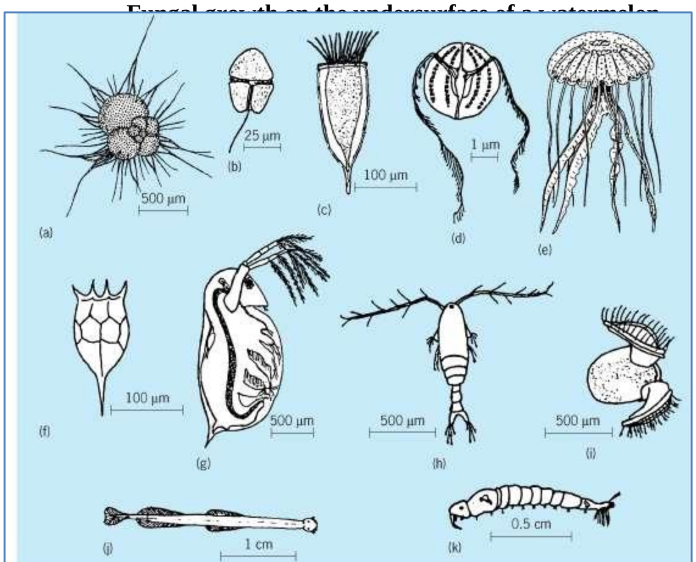
The other two types of fungus-like protists are **water mold** and **downy mildew**, both in the phylum Oomycota. They are filamentous protists that decompose and recycle decaying matter. Most of them are small, single-celled organisms. Unlike the chitinous cell wall of fungi, the cell walls of the oomycetes are partially composed of cellulose, like plants. The water molds are mostly aquatic; any body of water, fresh or salt, contains them in abundance. The downy mildew are all parasitic, infesting terrestrial plants. There are more than 500 species of oomycetes living in water and soil, or as parasites. The parasitic types infest algae, plants, animals or one another. In water, they can cause many problems for fish and amphibians, and on land they can wreak havoc on flowering plants. For example, a species of Oomycota caused the potato famine in Ireland in the 1800's.



Typical symptoms and signs of downy mildew. A) Yellow to brown angular leaf spots on squash. B) Black leaf spots with some leaf curling on watermelon (Photo: Dr. Mathews Paret). C)

Pond Microbes from Kingdom Animalia

Microscopic pond animals, most of which are commonly referred to as zooplankton, may look like protists, but they are not. By definition all organisms in the Kingdom Animalia are multicellular, while all animal-like protists are unicellular. There is a wonderful diversity of microscopic animals that can be observed in pond water, all going about looking for food, avoiding predation, and reproducing. The groups found include: segmented worms (microannelids); hydra (coelenterates); water fleas (microcrustaceans; Cladoceran); copepods (microcrustaceans); midges (dipterans); gastrotrichs; round worms (nematodes); flat worms (Platyhelminths); rotifers; water bears (tardigradas), and others. There may also be some larval forms of macroscopic arthropods that are microscopic in size during early life stages.



Representative zooplankton. (*a*) Foraminifera. (*b*) Dinoflagellate. (c) Tintinnid ciliate. (*d*) Ctenophore. (*e*) Cnidarian (scyphozoan jellyfish). (*f*) Rotifer. (*g*) Cladoceran. (*h*) Copepod. (*i*) Gastropod veliger larva. (*j*) Chaetognath. (*k*) Insect larva (*Chaoborus*). (*Parts a and e from L. H. Hyman, The Invertebrates, vol. 3: Protozoa through Ctenophora, McGraw-Hill, 1940*)

Microscopic animals found in freshwater. Image source: http://skaibook.com/119/page173.html

One of our favorite little critters are rotifers. A rotifer is a multi-cellular animal that resembles a protist, but is scientifically classified as an animal. Most species are adapted to freshwater, but a few marine species occur. It gets its name from the crown of cilia on top of its head that spins like rotors. The spinning action creates water currents that bring food to the organism. When feeding, it will stay anchored with its ‘foot,’ stretching its body in one direction or the other to capture food. When conditions are unfavorable, the rotifer will release its foot and migrate to a different location. They feed on algae, dead bacteria, and fish waste.

Typical rotifer with a clear crown of cilia. Image source: http://www.vanleeuwenhoek.com/His-Microscopic-World.htm

The microcrustaceans, which are distantly related to shrimp, crab and lobster, are another group of zooplankton that is among our favorites. Included in this group are daphnia, cyclops, and seed shrimp. For example, daphnia is a wonderful creature to study in detail since many species have translucent bodies, allowing for the observation of anatomical features, such as the beating heart and egg chamber. They beat their legs to produce a constant current that brings food to them. They are filter feeders that eat bacteria, single-celled algae, other protists, and organic detritus. They bear two sets of antennae; the second set powers most of their swimming. Microcrustaceans get their common name, water flea, because of the resemblance of their swimming motions to flea movements.

Another microscopic animal to watch for is the hydra, a relative of jellyfish, sea anemones and coral. Hydra is a carnivorous animal that is typically seen with its **basal disc** or foot attached to pond debris, plants, or stones, while it sways its tentacles in the water to capture food. The tentacles surround the mouth and are lined with sharp, toxin-bearing barbs called cnidocytes that attach to prey. Cnidocytes are the same stingers found in jellyfish, corals, and other cnidarians.

Most of the microscopic organisms discussed above – bacteria, protists and animals – form the **plankton** community in the pond. Plankton – both phytoplankton and zooplankton – are organisms that float in the water column, mostly at the mercy of currents. Please see Chapter 4.4, Pond Life – Microorganisms, for a more extensive discussion.

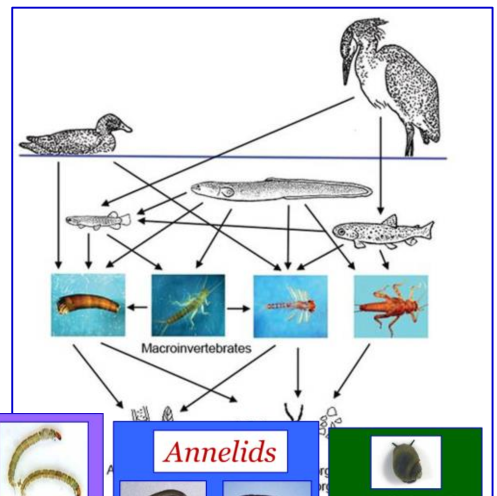
In summary, the diversity and abundance of microorganisms in pond water is astounding. Students can be exposed to many biological concepts by just looking at one drop of pond water under a microscope. The creatures include mostly single-celled organisms, but there are some multicellular ones present as well. The activities in Chapter 4.4, Pond Life – Microorganisms are provided to assist you and your students in exploring a drop of pond water.

<u>Macroscopic Pond Life Forms</u>

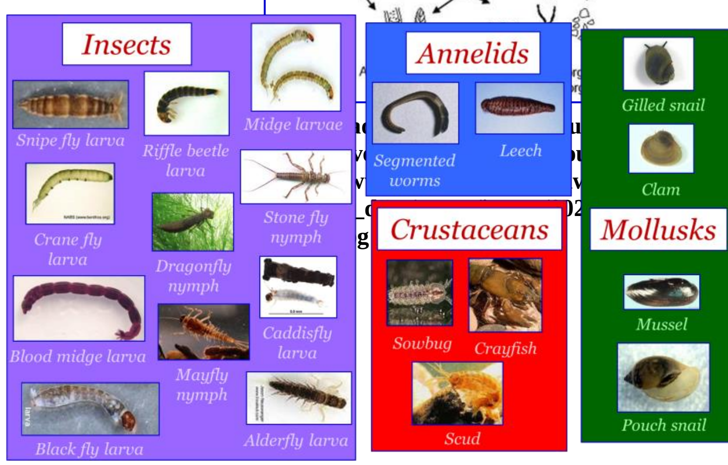
Macroscopic pond life forms include a wide diversity of organisms from all of the kingdoms. In this section, our main focus is on small invertebrates (Kingdom Animalia), followed by a brief description of some vertebrate life forms. Traditionally, the term *macroscopic* is not used when discussing vertebrates, but instead refers to invertebrates. However, here we will discuss both invertebrates and vertebrates for convenience.

Invertebrate Life Forms

Aquatic macroscopic organisms are typically referred to as aquatic macroinvertebrates. **Aquatic macroinvertebrates**, or aquatic macros for short, are defined as organisms without vertebrae (a backbone) that live in water for some or all of their lives, and are big enough to see with the naked eye, i.e., without a microscope. Some types may be very small, only a few millimeters in length, but they are still visible to the eye. These creatures are a critical part of the web of life of freshwater; without them, fish and water fowl would not have a vital and essential food source.



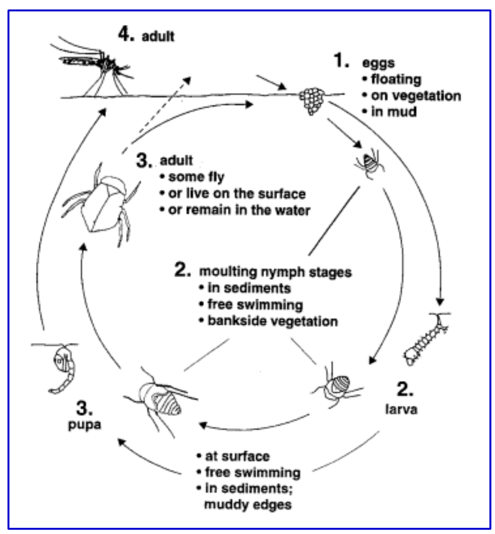
There are four general types of aquatic macroinvertebrates: 1) insects; 2) mollusks; 3) annelids; and 4) crustaceans. Many aquatic macros are immature forms of insects, many of which grow and develop in the water, sometimes for years, to emerge after metamorphosis as terrestrial adults. These include the stonefly, mayfly, caddisfly, crane fly, dragon fly, black fly, to name a few. In addition to the insects, mollusks like mussels, clams and snails; annelids like the segmented worms and leeches; and crustaceans like crayfish, sowbugs and scuds, are also aquatic macros. All of the organisms in the mollusk, annelid and crustacean groups remain aquatic all their lives.



Diversity of aquatic macroinvertebrates. Four types are presented: 1) insects of Class Insecta; 2) annelids of Class Annelida; crustaceans of Class Malacostraca; and 4) molluks of Class Mollusca

Aquatic macros are sometimes characterized into functional feeding groups, such as: shredders, collectors/filter feeders, scrapers/grazers, and predators. Shredders require a rich riparian zone and slow flowing water so that plant material can fall into the water and not be swept away. They chew on large pieces of leaves and woody material forming smaller vegetative particles. Collectors, or filter feeders, feed on the small particles produced by shredders, typically using special anatomical structures or behaviors that help them to collect the particles. Scrapers, or grazers, eat the thin layer of algae attached to rocks and plants. Lastly, the predators feed on live prey. Another common way to group these creatures for study is into functional groups based on movement, such as: clingers, climbers, crawlers, sprawlers, burrowers, swimmers and skaters. Both grouping methods are helpful when seeking out specific types of aquatic macros as they can direct you on where to search; for example, search the benthic habitat for burrowers, or near the riparian zone vegetation for shredders, and so on.

You can tell much about these creatures by just looking at their anatomy. For example, the dragonfly's mouth parts are large and lethal, shaped for carnivorous activities, such as eating bugs and small fishes. The black fly larvae have "filter fans" at the top of the head which they use to collect small particles of detritus. The flattened body, spread legs and eyes on the back of the head of some mayfly species suitably adapts these creatures to crawl between and live under rocks. This line of inquiry is great for teaching students about the relationship between form and function.



Macroinvertebrates in the insect group change their body shape as they grow through the process of metamorphosis. **Metamorphosis** is a biological process by which an animal develops from an immature (young) to a mature (adult) individual. The main difference is the ability of the mature form (adult) to sexually reproduce; immature macros by definition cannot yet reproduce. Other changes also occur leading to changes in habitat or behavior. Some insect groups go through **complete** (holometabolous) **metamorphosis**, while others develop through **incomplete** (hemimetabolous) **metamorphosis**. One of the primary differences between the two types is a pupal stage between the larval and adult forms in those displaying complete metamorphosis. With incomplete metamorphosis, the egg hatches into a nymph and then molts into an adult. In addition, the young of insects that display incomplete metamorphosis tend to look more like their adult counterparts and are called **nymphs**. In contrast, the young that display complete metamorphosis look markedly different from the adult forms; their young are called **larva** (plural larvae). Insects spend most of their lives in the aquatic juvenile stage, primarily feeding. The adult stage of these insects' life cycle typically consists of only a brief reproductive stage.

The types of macroinvertebrates found in a pond system are dependent upon oxygen levels, water quality, and food requirements. Recall that in a pond, dissolved oxygen (DO) can decrease and become quite low because ponds are typically not moving bodies of water, and therefore there is little opportunity for aeration. Aeration tends to happen only at the surface where there is oxygen exchange with the atmosphere. In addition, the abundance of aquatic plants decreases DO as they switch at night to cellular respiration and cease releasing oxygen. In streams and ponds where DO concentration is low, we expect that only those macroinvertebrates that have adapted to live in low-oxygen conditions can survive; an example of these are the non-gill breathing organisms that absorb oxygen through their skin.

Since water quality parameters can indicate the types of macroinvertebrates found in an area, aquatic macros are used as **biological indicators** of the health of an aquatic ecosystem. Among the aquatic macros, there are different types that can tolerate polluted waters and those that cannot – they are sensitive to pollution. Therefore, by sampling water bodies and collecting aquatic macros, predictions can be made about water quality depending upon what types were found. For example, many stonefly species are sensitive to pollution; finding a healthy population of them in a water body is usually indicative of healthy water. In contrast, midges are highly tolerant of pollution; if they make up the majority of organisms collected, this would indicate that the water may not be healthy. Please refer to Chapter 3.4, Water Quality for more information.

Vertebrate Life Forms

We expect to see several types of vertebrate organisms at Skyline Park, especially as the park's new vegetation becomes more established and matures. We will not go into too much detail about vertebrates since they are more commonly known and understood by teachers. Also, since the park is young, it may take a few years for a diversity of vertebrates to take up residence in this newly-restored habitat, with the exception of birds which can fly into the area. We highly recommend checking out Montana Fish, Wildlife, and Parks' **Montana Field Guide**; it is an excellent resource that can provide additional information and pictures on all of the animals discussed below (please see *Resources*).

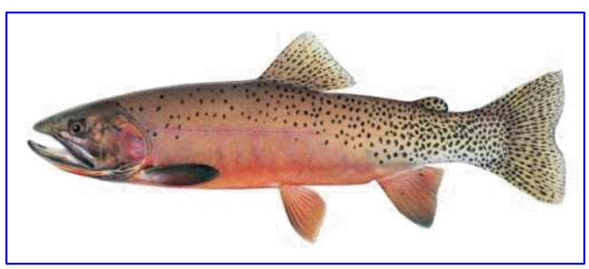
One natural assumption with respect to vertebrates is that a small diversity birds will take up residence at Skyline Park. We assume 'small' simply because of the park's size; it can only accommodate so many. Pond ecosystems provide a great habitat for a variety of birds, especially waterfowl, such as ducks and geese. Predatory birds, such as raptors and owls, may also visit the area, though the park may be too small to support too many individuals of large, predatory birds. There are plenty of mature trees already in the park to support songbirds, and it will be interesting to see if there are increases over time of song bird species utilizing the park as the new vegetation matures. A good bird guide is essential for observing and identifying birds; a favorite among birders is Field Guide to Birds of North America by R. T. Peterson. In addition to actual observations, evidence of wildlife such as feathers, tracks or prints, nests, and scat, can also be evaluated to determine what flying critters are using the park.

It is difficult to know at this point in time what reptiles and amphibians the park will support. Most of the snake species that prefer riparian habitats, such as the common gartersnake, also prefer low elevation. There are some species that prefer dry, upland habitats, such as the gophersnake. Time will tell what snake species, if any, call Skyline Park home. Pond habitats are typically home to many amphibians. Ponds provide a key component in amphibian development because their early life stages must occur in water. Perhaps the Columbia spotted frog, the painted turtle, long-toed salamander, and western toad will find their way into the pond by way of a waterfowl with amphibian eggs adhering to its body.

Ponds and their associated riparian habitats provide an ideal home for small mammals. However, it is typically not common to observe these animals because they are primarily nocturnal – they sleep during the day and are active at night. Holes and tunnels made by small mammals may be observed, and these are good features to indicate as they can be used for evidence of wildlife. Small mammals we expect will occupy Skyline Park include deer mice, voles, shrews, muskrats, pocket gophers, woodrats, jumping mice, chipmunks, squirrels, weasels, and rabbits. These small mammals are an important component of any ecosystem as they are great seed dispersers and serve as food for predatory animals.

Another group of animals that occupy pond habitats are the large mammals. Large mammals that may be observed in the park include raccoons, skunks, beavers, fox, coyote and deer. Perhaps one day we will even hear about sightings of some of the largest of the large mammals - elk, moose and black bears. Animal prints, or tracks, and scat can be reviewed to determine what large mammals are using Skyline Park.

The Washoe Park Trout Hatchery in Anaconda has stocked the pond at Skyline Park with native Westslope cutthroat trout (*Oncorhynchus clarkia lewisi*). The Washoe Hatchery raises the state's only stock of Westslope cutthroat trout, Montana's state fish. This hatchery has been active for over a hundred years and produces over one million cutthroat trout eggs each year. Westslope cutthroat trout are native to Montana, and are classified as a species of concern. They are under threat mostly because



Westslope cutthroat trout; image by J. Tomelleri. Image source: http://fieldguide.mt.gov/detail_AFCHA02088.aspx

of habitat degradation and loss, and hybridization with rainbow and/or Yellowstone cutthroat. Westslope cutthroat trout require water that is cold and clear as they require lots of dissolved oxygen and are sensitive to fine sediment. They feed mostly on zooplankton and aquatic insects.

In conclusion, there are endless hours, days, weeks and months that can be spent observing and studying pond life. From the smallest to the largest of creatures, pond habitats offer many opportunities to explore the diversity of life. Whether just going to the park to do observations – taking notes and drawing pictures – or going to collect and study micro- and macro- organisms close up and personal, educational opportunities are plentiful!

Resources

1. Pond Life: A Guide to Common Plants and Animals of North American Ponds and Lakes by George K. Reid (2001); a Golden Guide book published by St. Martin's Press, NY.
2. Pond Water Zoo: An Introduction to Microscopic Life by Peter Loewer (1996); published by Simon and Schuster, NY.
3. Montana Fish, Wildlife, and Parks, Montana Field Guide; http://fieldguide.mt.gov/
4. **NRCS. *Riparian Assessment Using the NRCS Riparian Assessment Method*. September 2004.**
5. http://www.buzzle.com/articles/microorganisms-in-pond-water.html
6. **NRCS. *Stream Visual Assessment Protocol*. December 2008.**
7. Government of Western Australia, Department of Water. *Water facts: 2nd edition, Water and Rivers Commission.* October 2001. http://nynrm.sa.gov.au/portals/7/pdf/landandsoil/17.pdf
8. Flathead National Forest, Swan Lake Ranger District. http://www.fisheriessociety.org/AFSmontana/SSCpages/westslope_cutthroat_trout.htm
9. **A Guide to the Natural History of Freshwater Lake Bacteria** (2011) by R. J. Newton, S. E. Jones, A. Eiler, K. D. McMahon, and S. Bertilsson published in Microbiology and Molecular Biology Review [75(1): 14–49] is a primary resource for freshwater bacteria. It is highly technical, but if you are interested, it provides a very nice overview of current research in this area.
10. **Microorganisms Present in Pond Water** http://www.buzzle.com/articles/microorganisms-in-pond-water.html
11. **Microbe World** includes some great information about all types of microbes, such as bacteria, fungi, protists and viruses. http://archives.microbeworld.org/microbes/types.aspx
12. The website, **Micrographia**, is an excellent source for researching and investigating microbes. In addition to wonderfully detailed graphics, they include descriptions for most types of microscopic organisms. This is the general link - http://www.micrographia.com/index.htm; and this is the link specifically for freshwater life - http://www.micrographia.com/aadirpgs/specall/specgen/spegen01.htm#freshwaterlink

13. This helpful resource developed by the **University of California Museum of Paleontology** provides research-based work being done on palentology and evolution. This link is for K-12 teacher resources. http://www.ucmp.berkeley.edu/education/teachers.php
14. London's **Natural History Museum** (http://www.nhm.ac.uk/index.html) and the **American Museum of Natural History** (http://www.amnh.org/) have amazing websites full of accurate and current information about a plethora of topics.

Chapter 3.4 Water Quality

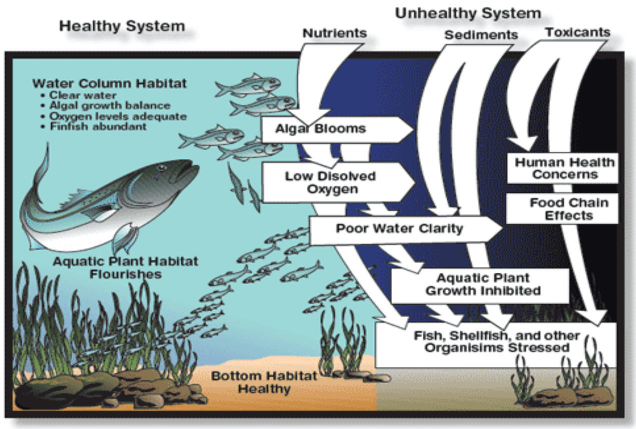
Introduction

Healthy aquatic ecosystems are biologically diverse, supporting a variety of life including fish, macroinvertebrates, algae, and other microorganisms. Biodiversity, defined as the number and types of organisms, is an indicator of stream and pond health. In general, the greater the variety and abundance of life within and around a water body, the healthier the water quality tends to be. When the diversity and abundance of organisms decrease, we can usually assume there were impacts to the water body that affected the quality of the water.

Potential Impacts for Skyline Park Pond

There are two sources of potential impacts to this area: 1) urban activities, and 2) historic mining practices. With regard to effects resulting from urban activities, Reese Canyon Creek and Tramway Creek pick up pollutants from a variety of sources as they make their way from the East Ridge over the landscape to the **Skyline Park** area. As the water drains from the surrounding landscape, these creeks pick up pollutants from a variety of sources. One potential impact to these urban creeks includes water running off of impervious surfaces, such as roads and parking lots. This water runoff can contain many contaminants like herbicides, oil, and garbage, all of which drain directly into streams. Following summer storms, runoff from hot roads and parking lots can cause rapid increases in stream temperatures that can produce thermal shock and death in many fish. The runoff of sand and salt, both of which are used to help remove snow from roads, can also contaminate streams, causing changes in water quality. Lastly, development and construction near waterways can lead to stream bank erosion and increases in the amount of sediments in streams and rivers.

Though mining never occurred directly at the site, the impacts of historic mining practices were evident throughout the clean-up of Skyline Park. During the mining heyday of Butte, tailings and waste piles were stacked throughout the city and often used as fill material for a variety of building projects, including providing the bed material for roadways and railroads. Tailings, which are crushed rock that look fine-grained in texture, are sources of sedimentation that increase turbidity and affect water chemistry. Tailings also contain pollutants of concern such as copper, arsenic, zinc, lead and cadmium. All of these metals can be toxic to pond life in excessive quantities.



This figure shows some of the effects of common pollutants. For example, when the sand used on the streets washes into the water, this can cause poor water clarity (high turbidity), which can then inhibit aquatic plant growth and stress aquatic organisms.

Reese Canyon Creek and Tramway Creek are ephemeral streams, meaning that they are not supported by a regular water flow (i.e. base flow) throughout the year. These creek beds usually contain water during periods of high runoff such as during spring melt or heavy rainstorms. Water quality in an ephemeral stream is a direct reflection of the surface over which the stream flows. Water quality in these water bodies may fluctuate greatly depending on time of year, quantity of runoff, and changes in the landscape. For example, if construction occurs near Reese Canyon and Tramway Creeks, one may notice increased sediment in the runoff due to ground disturbance.

Water quality in Skyline Park is influenced both by natural conditions within the pond and by human actions. The pond substrate (bottom material), the soil conditions surrounding the pond, and water sources that fill the pond are examples of natural conditions that influence it. Since the local geology and landscapes are fairly fixed, the influences of some of these natural conditions (pond substrate and soil) are difficult to change or control.

The water sources that fill the pond are easily influenced by human actions, both positively and negatively. For example, in order to maintain healthy temperatures and water levels, groundwater will be regularly pumped into the pond during the warm summer months. This will maintain a consistent water level and keep the Pond cooler than it would be otherwise. ~~In contrast, water draining into the pond from Reese Canyon and Tramway Creeks can have negative effects on water quality. For example, property owners adjacent to the park may use excessive fertilizer that flushes into the waterways during heavy storm periods. This fertilizer will be carried by the creek systems and find its way into the pond. The excessive nutrients~~

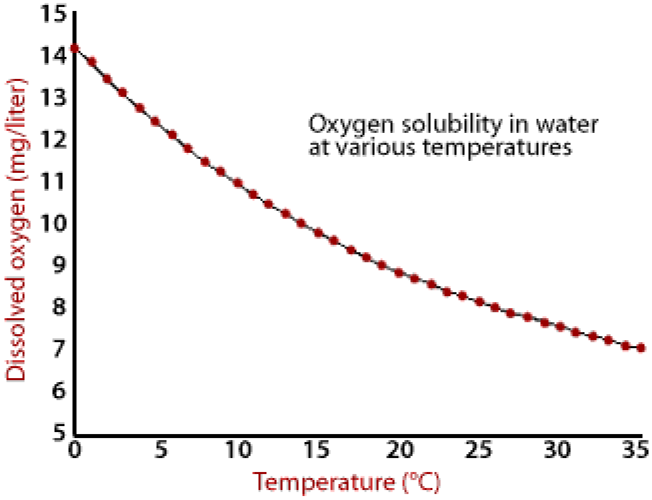
~~provided by the fertilizers can result in plant and algae overgrowth, which will decrease the amount of available dissolved oxygen, which could lead to fish kills within the pond.~~

<u>Water Quality Criteria</u>

Standards for water quality are criteria set by government agencies that must be met in order to ensure healthy, balanced aquatic ecosystems. Water quality parameters, such as temperature, pH, dissolved oxygen (DO) and turbidity, to name a few, all have standards designed to ensure healthy drinking water as well as to protect aquatic life. In the following section, we describe these parameters, their healthy ranges, and explanations for their importance for overall pond health.

Temperature

Within ponds, temperatures will fluctuate throughout the day. Unlike a moving body of water, the temperature of a pond will be slightly warmer and have a greater variance between daytime and nighttime temperatures. Most pond organisms are adapted to this fluctuation and are able to tolerate the range of temperatures found in a pond, provided the overall average temperature remains within the normal range. Deeper areas of the pond will maintain a cooler temperature and provide resting areas for fish during the heat of the day. If the pond is too shallow, not shaded by trees, or is not regularly fed by cooler groundwater sources, fish are not likely to survive the warm summer months. Skyline Park's pond is stocked with native Westslope cutthroat trout from the Washoe Fish Hatchery in Anaconda, MT. Westslope cutthroat require cool temperatures, i.e. below a maximum temperature of 20˚C. Westslope cutthroat are sensitive to high water temperatures and begin to metabolically suffer at temperatures above 20˚C, with their optimal range being between 7˚C and 16˚C (Bear, et. al 2005). The actual temperature is not what harms the fish; it is the accompanying decrease in DO that impacts the fish. Gases are less soluble in water at higher temperatures, leading to lower DO concentrations in warmer water because the oxygen gas has escaped the water into the air.



Dissolved Oxygen and Temperature Relationship. As temperature increases, DO decreases. Graph and further information available at: http://www.cotf.edu/ete/modules/waterq3/wqassess3f.html

Dissolved Oxygen

Fish and aquatic macroinvertebrates are dependent upon dissolved oxygen (DO) within the water. In general, gill-breathing organisms require higher levels of DO than organisms that are able to absorb oxygen through their bodies. For example, the Westslope cutthroat trout utilizes capillary-rich gills for breathing, and therefore requires high concentrations of DO. In contrast, organisms that are tolerant of low DO conditions, such as the blood midge, are able to absorb oxygen through their integument (skin). Additionally, the blood midge is able to retain and store oxygen within its system due to the presence of oxygen-binding hemoglobin.

In a pond, DO conditions can drop to critical levels because ponds are typically not moving bodies of water, so there is little opportunity for aeration. Aeration tends to happen only at the surface where there is oxygen exchange with the air. The typical rolling of a river or stream in riffle sections allows a greater amount of water surface to be exposed to the air, thereby increasing aeration.

Other pond life utilizes DO as well. During the night hours, aquatic plants switch from **photosynthesis**, in which they release oxygen as a by-product into the water, to **respiration**, in which plants take up oxygen from the water. Should there be overgrowth of aquatic plants and algae in the pond, the amount of available DO is further decreased by respiratory activity at night. To make matters even more difficult, when plants and algae die off, organisms that decompose plant materials use oxygen in their metabolism, further depleting DO.

In summary, ponds that are well shaded by trees and shrubs are better suited to maintaining healthy DO due to better temperature regulation. Additionally, DO levels are connected to balanced plant growth in the pond. Too much plant growth spells trouble for DO. Overgrowth of plants in a pond system is typically due to excessive nutrient loading, i.e. high levels of nitrogen and phosphorus.

Nutrients

Nutrients, as defined by the United States Geological Survey (USGS), are "elements or compounds essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium" (USGS, 2007). Sources of nutrients include fertilizers (applied to yards, golf courses, and agricultural lands), septic systems, and animal wastes.

Nitrogen is typically in the form of ammonia or nitrate, and usually originates from animal or human wastes entering directly into the pond. Ammonia is toxic to fish and macroinvertebrates above 0.1mg/L. Users of Skyline Park should clean up after their pets in order to ensure the best water quality possible.

Nitrogen and phosphorous are fertilizers or nutrients for aquatic plants and algae. This fertilization can lead to overgrowth in the pond, similar to over-fertilizing one's lawn. When plant overgrowth occurs, dissolved oxygen (DO) conditions become depleted during evening hours when plants and algae respire. Additionally, when the algae and aquatic plants die off and begin to decompose, DO is further depleted by microscopic decomposers, which also require oxygen.

Turbidity

Excessively cloudy or dirty water is also harmful to gill-breathing animals. Extremely turbid water is analogous to heavy smog for humans. The Westslope cutthroat trout and gill-breathing macroinvertebrates are intolerant of extreme turbidity, as the particulates will clog the gills, rendering them ineffective for oxygen exchange. This symptom in macroinvertebrates is analogous to humans who struggle to breathe when the air is not clear. Turbidity is increased by runoff from surrounding areas if there is not sufficient vegetation to catch eroding sediments. The plants surrounding the pond, both the upland plants and riparian area plants are important for controlling erosion. Wetland plants can also act as bio-filters for sediment. Should invasive plant species begin to overpopulate the landscape, erosion will increase because noxious and invasive weedy species typically do not hold soil as well as their native counterparts.

pH

Literally translated, pH means power of hydrogen. In chemical terms, pH is the measure of the acidity or alkalinity of a solution. It is formally a measure of the activity of dissolved hydrogen ions ($H+$). In solution, hydrogen ions occur as a number of cations including hydronium ions ($H3O+$). In pure water at 25 °C, the concentration of $H+$ equals the concentration of hydroxide ions (OH^-). This is defined as "neutral" and corresponds to a pH level of 7.0. Solutions in which the concentration of $H+$ exceeds that of OH^- have pH values lower than 7.0 and are known as acids. Solutions in which OH^- exceeds $H+$ have a pH value greater than 7.0 and are known as bases (or alkaline solutions).

pH is used as a water quality indicator. For aquatic life, the healthy range of pH is 6.0-8.5. In streams and ponds where pH falls outside of this range, macroinvertebrates and fish begin to die. Because pH is an indicator measurement, if pH is out range, it is likely that there are other problems with water quality. In other words, there is typically another issue that is influencing the pH measurement. For example, waters affected by pesticide use may have a lower pH, depending on the type of pesticide.

Metals

In the Butte area, metals of concern are arsenic (Ar), cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn). The soils throughout Butte contain these metals simply because of the area's geology, which is composed of a granite batholith. Under normal circumstances, these metals are below the ground where they do not interact with air and water. In our area, however, historic mining exposed these metals to air and water. Waste rock and tailings were deposited throughout the landscape of Butte. Although many of the valuable metals were extracted from the rock, some were left behind and are now located in the various waste piles. Many of these areas have been remediated through Superfund and are now capped in place, ensuring that the metals will not make their way into waters throughout Butte. There are some areas that are still exposed such as beneath rail beds, where tailings and waste rock were used for fill material when the railroad was built. As remediation continues across uptown Butte, some areas of waste are still adding limited amounts of metals to the overall stormwater profile. In time, these areas will be remediated and will not contribute metals to stormwater. In the meantime, Butte-Silver Bow is taking precautions to prevent metals from entering our waterways by installing filters in storm drains throughout Butte. These filters are called hydrodynamic devices or HDD's, which capture sediments and trash, allowing cleaner water to move through the device and into the streams. Additionally, Butte-Silver Bow has invested in upgrading water infrastructure such as supply pipes and stormwater tunnels.

The current mining operations have protocols in place that ensure that metals do not find their way into the stream from the mine property. These protocols include on-site stormwater management, such as catch basins which ensure that any erosion occurring on-site is mitigated and captured. In-time remediation is another control measure used by Montana Resources, which means that areas that have recently been mined will be remediated, or capped immediately following the mining activity. This method ensures that waste rock is not exposed to air and water post-mining.

Under normal circumstances, Skyline Park may be slightly higher in metal concentrations than a pond located in a different region. This slight elevation is due to the normal substrate (bottom) conditions of the pond, which is decomposing granite. This substrate condition is unlike a limestone substrate condition; granite has companion metals associated and will likely lead to slightly acidic conditions within the water. This is in contrast to a limestone substrate pond, which would have slightly basic conditions and lower metal concentrations. This difference is simply due to the way that granite and limestone are formed and their composition within the Earth.

At this pond site, a liner was installed during construction to further mitigate metals levels. This liner will prevent the water from eroding the granite substrate and will ensure that the pond is a closed system. Some metals may make their way into the pond through stormwater discharge. However, metals should remain within acceptable ranges for pond life.

The World Water Monitoring kits recommended in the activity sections enable one to measure the following parameters: temperature, dissolved oxygen, pH, and turbidity. These measurements allow students to gain a rudimentary understanding of pond health. If teachers wish to expand the water quality monitoring, there are other resources available from Cfwep.Org.

Resources

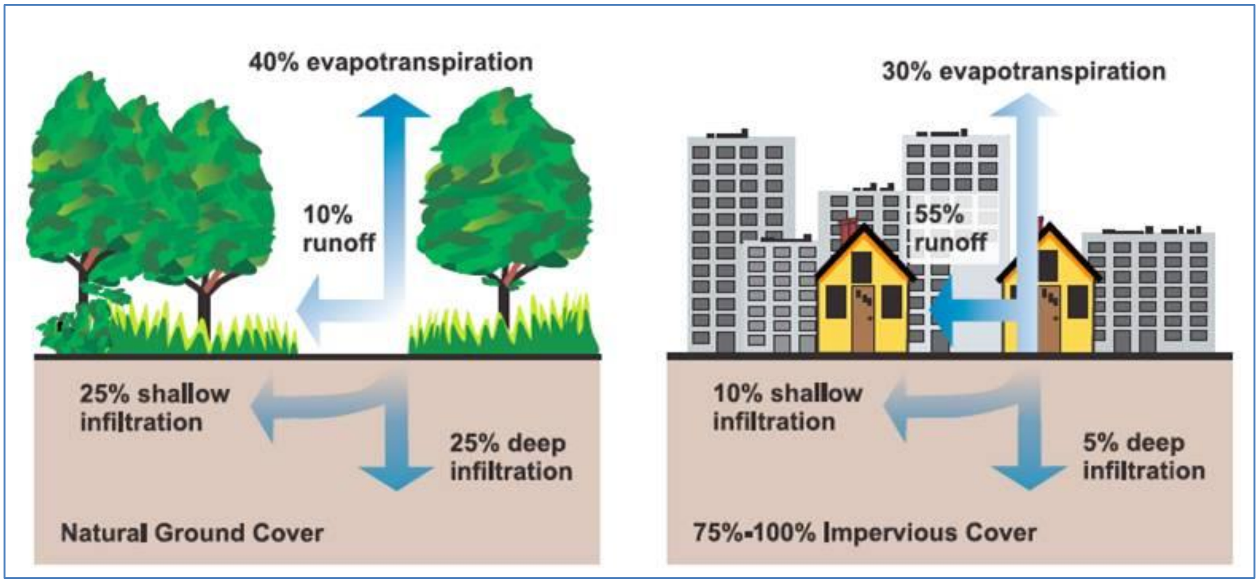
1. Thermal Requirements of Westslope Cutthroat Trout
   http://wildfish.montana.edu/docs/ThermalStudy%20_FinalReport.pdf
2. Pond Water Quality Conditions
   http://extension.psu.edu/natural-resources/water/ponds/pond-management/pond-construction/water-quality-concerns-for-ponds
3. Information about nutrients
   http://toxics.usgs.gov/definitions/nutrients.html
4. 2012 Water Quality Standards Circular
   www.deq.mt.gov/StateSuperfund/PDFs/DEQ7_2012.pdf
5. A Citizen's Guide to Understanding and Monitoring Lakes and Streams
   http://www.ecy.wa.gov/programs/wq/plants/management/joysmanual/dissolvedoxygen.html
6. USGS water quality and dissolved oxygen
   http://ga.water.usgs.gov/edu/dissolvedoxygen.html

Chapter 3.5 Stormwater

Introduction

In **Skyline Park**, the area is meant to represent natural landscape conditions. The Park includes wetland areas, upland areas, and the pond. The Park’s trailways are mostly gravel and there are very few asphalt features. Precipitation that occurs during a storm event falls on the Park’s landscape and is readily absorbed into the ground. In other words, these surfaces are **pervious**. Very little **impervious** surfaces exist in Skyline Park. The asphalt trail around the pond and the parking lot area are impervious and do not allow water to percolate into the ground.

What is important about pervious and impervious surfaces?
In our built landscapes, the amount of impervious surface greatly increases as we build homes, businesses, sidewalks, roads, and parking lots. In a natural landscape, the pervious surfaces are able to absorb water from storm events fairly effectively. However, when we build upon the



Comparison of infiltration, runoff, and evapotranspiration between natural and urban landscapes. Illustration courtesy of www.epa.gov

landscape, the water from storm events, also known as **stormwater,** is not able to be absorbed by the ground and eventually flows into streams and wetlands. In fact, it is estimated by the Department of Environmental Quality (DEQ) and the EPA that a city block generates five times as much runoff as a natural landscape of the same size.

Stormwater Definitions

In general terms, stormwater is precipitation that falls on the landscape during a storm event. This definition includes all surfaces and all landscapes, and does not define any problems. However, stormwater that falls within a built landscape is distinctly different than water that is falling within the natural landscape. According to the Environmental Protection Agency (EPA), "stormwater runoff is generated when precipitation from rain and snowmelt events flows over land or impervious surfaces and does not percolate into the ground. As the runoff flows over the land or impervious surfaces (paved streets, parking lots, and building rooftops), it accumulates debris, chemicals, sediment or other pollutants that could adversely affect water quality if the runoff is discharged untreated."

This definition further adds the distinction of waters that are falling on built landscapes and that accumulate pollutants, not simply water that falls during storm events. Although the park has natural features, the areas surrounding the park, which are conveying water into the pond, are part of an urban landscape. For this chapter, we will examine stormwater in the sense that the EPA has defined it. Throughout the United States and certainly in Butte, stormwater is not treated before it reaches the area's waterways. Some municipalities have implemented capture systems and basic filtration systems, but as a general rule, municipal storm water is untreated. We will examine some of Butte's stormwater management systems later in this chapter.

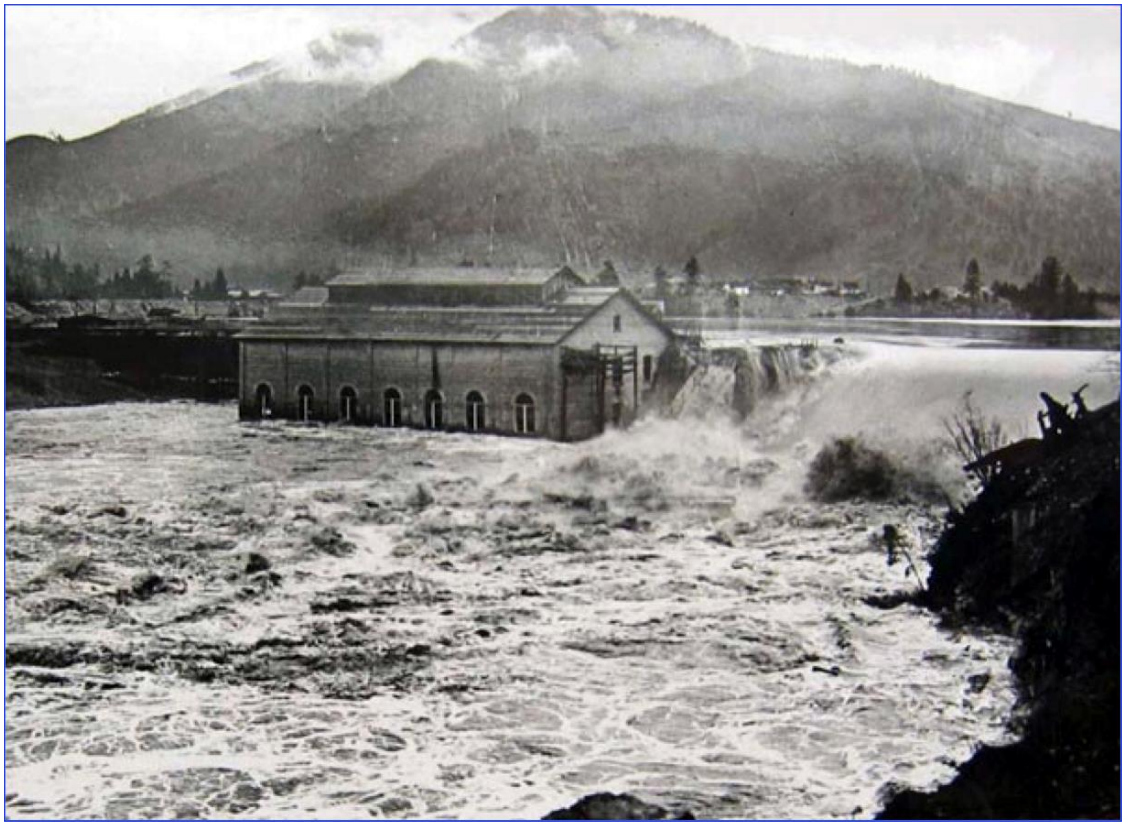
Stormwater Pollution

Stormwater runoff accumulates from the entire body of roofs, sidewalks, and streets within an urban landscape. It is conveyed through storm drain systems, typically at very high flow and velocity. As the waters traverse the landscape and do not percolate into the ground, the water picks up a multitude of pollutants along its journey to the creek. These pollutants include: oil and gas; litter; sediment; animal waste; pesticides; fertilizers; and any other chemicals left behind on streets or rooftops. Everyone contributes to stormwater pollution in some way. This type of pollution is considered **non-point source** pollution because not one person or entity is singly responsible for the source of pollution. Rather, everyone is contributing, which makes stormwater extremely troublesome. In fact, according to the EPA, "the most recent National Water Quality Inventory reports that runoff from urbanized areas is the leading source of water quality impairments to surveyed estuaries and the third-largest source of impairments to surveyed lakes." Why is stormwater pollution so bad? Consider that each citizen of Butte is contributing to stormwater in some fashion. Therefore there are over 36,000 people who are adding pollution. Now consider that along the Clark Fork River from Butte to Missoula, there are the communities of Butte, Anaconda, Deer Lodge, Drummond, and Missoula as well as numerous small communities in between. If each community is also adding their share of polluted stormwater, the pollution effect is multiplied five times over! Scale this idea up to a global view and add all of the communities along the Clark Fork River to the Columbia River and eventually to the Pacific Ocean. It's no small wonder that humankind has created the Great Pacific Garbage Patch (see Resources for more information).

Stormwater and Flooding

In the urban landscape, stormwater is conveyed along impervious surfaces such as the streets and curbsides typically into underground storm drains. These drains dump into either catchment basins, wetlands, or directly into the area's creeks. Because the storm drains are typically concrete tunnel systems, they convey water at a high velocity. The tunnels were initially constructed to move water quickly from the streets and ensure that flooding did not occur within a given neighborhood. However, because the water is no longer draining across a pervious landscape system, the volume of water that is dumping directly into the creek is much higher than would have been conveyed in the natural setting. This high volume of water overwhelms creeks quickly, which can lead to increased flooding in the creek. In addition, any failure along the tunnel conveyance structure, such as excessive sediment build-up within the tunnel, will result in backups and flooding within neighborhoods.

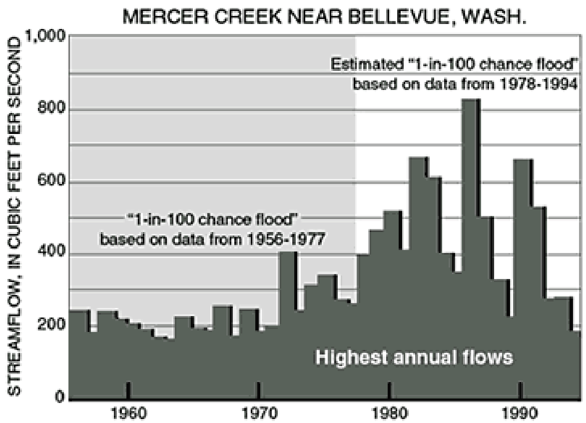
100-Year Flood Events



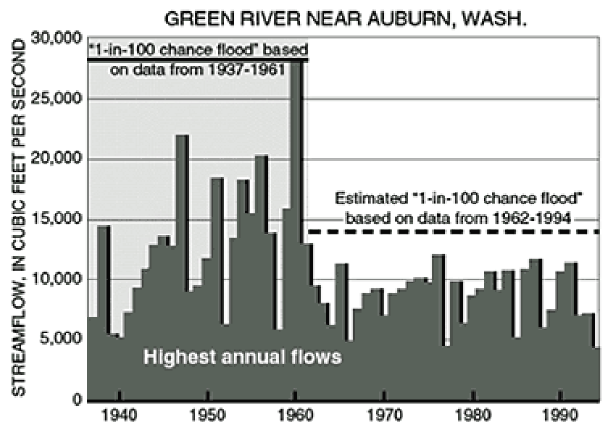
Milltown Dam during the 1908 flood, which was considered a 100-year flood event.

Seasonally, our area receives excessive snowfall and rainfall. During these periods, our streams, wetlands, and rivers become overwhelmed with water. Additionally, the ground becomes saturated and is literally unable to absorb any more water. At this time, a hydrologist may claim that the area is experiencing a **100-year storm or flooding event**. A 100-year flood is defined as stream flows that meet or exceed the highest recorded stream flow for an area. In the case of the storm event, the 100-year storm implies precipitation accumulation that meets or exceeds the highest recorded accumulation for an area in one given event.
The name implies that this extreme condition happens once every 100 years. However, the name leads to a common misconception. A more accurate term according the United States Geological Survey (USGS) would be **100-year recurrence level.** This term implies that statistically, the amount of rainfall and the resulting in-stream flows typically occur or reoccur every 100 years. However, any given year can have a 100-year flood event or storm. In other words, a 100-year flood or storm could occur two years in a row. Statistically speaking, the probability of a 100-year flood event or storm occurring in any given year is only 1%.

The **100-year storm event** does not always indicate a **100-year flood event.** Many factors can influence whether or not a given area will flood. In the case of urban landscapes, an area receiving 100-year storm precipitation amounts may have a significantly higher chance of experiencing a 100-year flood event than perhaps an area that is not covered with impervious surfaces. For example, this graph from the USGS website illustrates the effects of various changes within a watershed that can positively or negatively impact the magnitude of a 100-year flood event. In this example, the amount of runoff dramatically increases as development increases. For the community in the example, this means that the amount of water conveyed in a 100-year flood event is significantly higher than prior to development. This increase could mean disastrous consequences for the community and the communities downstream. The chart on the right illustrates how the magnitude of water conveyed in a 100-year flood event can be decreased, in this case by building a dam.



Rapid urban development in the Mercer Creek Basin since 1977 has increased the estimated magnitude of the "1-in-100 chance flood" as Bellevue, Wash.



The completion of Howard Hanson Dam on the Green River has decreased the magnitude of the "1-in-100 chance flood" as Auburn, Wash. since 1961.

Graphics courtesy of USGS.

Butte Area Drainages

Along the Butte Hill, working from West to East, we have seven drainage divides. If we imagine water falling on Uptown Butte, it will make its way to the lowest sections of Summit Valley via one of these drainages. The seven drainages are: West Side; Missoula Gulch; Idaho Street; Montana Street; Buffalo Gulch; Anaconda Road-Butte Brewery; and Warren Avenue. Some of the waters in the northern sections of Anaconda Road-Butte Brewery and Warren Avenue are conveyed to the Berkeley Pit. Please consult the guide appendix for the Butte Hill Drainage Basin map provided by Butte-Silver Bow GIS department.

Summit Valley is surrounded by mountains, which also convey water via drainage divides into the lower areas. To the south, the Highland Mountains drain waters via Blacktail and Basin Creeks. To the east, water falling on the East Ridge will either drop off the east side into the Whitehall area and eventually drain to the Atlantic Ocean, or will fall towards Butte and be conveyed through many drainages easily identified along the ridge. In the case of Skyline Park, the two key drainages that feed the park are Reese Canyon Creek and Tramway Creek. This geography lesson is intended to give you an idea of the various pathways water travels across the Butte landscape.

Stormwater Management

In urban landscapes, management of stormwater runoff volume is critically important to managing flood magnitude. Communities also need to control the amount and types of pollution that stormwater carries. Although 100-year storm and flood events are statistically rare occurrences, everyday pollution is unfortunately not rare. Effective management processes include planning for both flooding and pollution control.

In Butte, stormwater and sewage are conveyed separately. This system is considered a “Municipal Separate Sewer and Stormwater System” or MS4. In Montana, all MS4 communities are regulated by the EPA and the DEQ. These communities are required to implement stormwater best management practices and storm water control systems. Our stormwater is carried separately from our sewer through various conveyance structures including open ditches, underground tunnels, and concrete-lined conveyance structures. Additional features include catch basins and retention ponds that are designed to slow flow and allow for percolation. Unlike our sewer water, stormwater is not treated before discharge to the creek. Another common misconception is that the grate located in the street is the sewer. Rather, this is the storm drain. Your sewer is buried in the street and is likely a large pipe rather than a tunnel. Sewer water is conveyed through these underground pipes to our sewage treatment plant and treated before discharge into Silver Bow Creek. In contrast, storm drains lead directly to receiving water bodies such as Blacktail Creek and Silver Bow Creek. There are retention basins and ponds throughout Butte that also receive storm drain waters. However, with a few exceptions, storm drain water throughout Butte is untreated and released directly to our creeks.

Our community is located within an EPA Superfund Site. Due to this location and the additional regulations involved with Superfund, some of our stormwater is captured and fortunately never released to Silver Bow Creek. These waters are able to be conveyed to the Berkeley Pit where water is eventually treated at the Horseshoe Bend Water Treatment Plant. However, the amount of stormwater we are able to capture and re-direct to the Berkeley is only a tiny fraction of the stormwater that is conveyed across the Butte landscape. Waters falling on areas outside of the capture area are likely to meet Silver Bow Creek, Blacktail Creek, or wetlands eventually. Many historic mining dump sites across the Butte Hill have been remedied, meaning these areas have vegetated caps that ensure soils stay in place rather than eroding. The following photos illustrate a cap remedy for the waste piles. Curbing around the capped areas helps to ensure that water does not run across capped sites. Rather, water is re-directed around the sites.

Buffalo Dump located on the corner of Main and Buffalo streets prior to remedy. Photo by: F. Ponikvar.

Buffalo Dump following remedy. The site was graded, capped with topsoil and planted with grasses. Photo by: F. Ponikvar.

Water flowing across recently mined areas and areas that are not capped are likely to convey heavy metals. These areas require additional stormwater management controls. For example, Montana Resources contains all of their stormwater to their property by utilizing conveyance systems throughout the property, catchment basins, retention ponds, and stormwater ditches. These structures ensure that water does not leave the mine property. Some of Montana Resources' stormwater is directed into the Berkeley Pit and some is captured in a retention pond near the concentrator.

In an effort to control sedimentation from the Butte Hill runoff, hydrodynamic devices or HDDs were installed at the bottom of a few select drainages including at the bottom of Montana Street at Warren avenue, at the bottom of Buffalo Gulch, and at the bottom of the Anaconda Road-Butte Brewery drainage. The HDD is not intended to be a filtration system in the usual sense as it only is functional as long as the device is not overwhelmed by excessive flow or clogged with sediment. It also is only able to capture **suspended load**, in other words, particulate and garbage that can be carried, but not dissolved in the water. Finer sediments are not captured by the HDDs as the system relies upon gravity in order to drop out the sediments. The finer particles are typically too light to drop into the HDD and are carried through. The **dissolved load**, or materials that are dissolved in the water such as pesticides, fertilizers, and other chemicals are not filtered through the HDD.

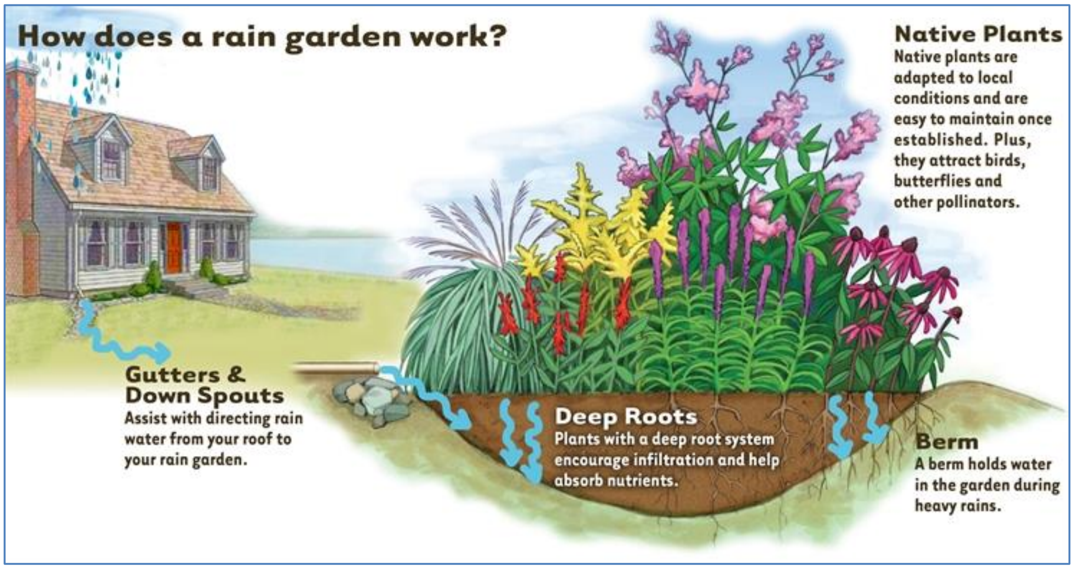
Butte Silver-Bow crews vacuuming clogged storm drains.

Cover of HDD located in the Webster Garfield School parking lot.

In addition to installing HDDs and new conveyance structures for stormwater, Butte Silver-Bow has implemented municipal stormwater management regulations. These regulations include permitting, which ensures that contractors have plans for stormwater management pre- and post-construction. During construction, the contractors or homeowners must comply with stormwater best management practices (BMP's). Some examples of BMP's are: silt fencing around dirt

Trash collected in a stormwater tunnel. The trash collected in the HDDs must be extracted regularly, or the HDD will not function.

piles; protecting storm drain inlets with straw waddles or other obstruction methods; and ensuring that concrete washout is handled properly and not discharged down the storm drain. Architecture plans must include stormwater controls and demonstrate that the site will not discharge any more water from the site than prior to building. For commercial construction, newly constructed parking lots include oil and water separator devices buried under the lots, which capture oil draining from the lot surfaces prior to release into the municipal storm drain system. Landscaping and/or rain gardens around commercial buildings often serve the dual purpose of beautifying the property and also increases the amount of pervious surface which allows for increased water absorption.



Graphic courtesy of the Watershed Coordination Council http://www.watershedcouncil.org/learn/rain-gardens/

What can the average citizen do to reduce stormwater pollution?

Good housekeeping is probably the most important way that you can help minimize stormwater pollution. Good housekeeping rules are as follows:

- Only rain in the drain. Recall that stormwater is not treated, therefore do not dump anything down the storm drain, most especially do not dump household chemicals, paints, or yard waste.
- Keep fertilizers and pesticides in their place. In other words, use only when absolutely necessary and in controlled fashion. When utilizing a broadcast spreader for fertilizing, ensure that the granules are only sprinkled on lawn areas and do not sprinkle sidewalks or driveways needlessly. Make sure that you apply the fertilizer according the package instructions and water in the fertilizer as directed.
- Clean up pet wastes. Pet waste contributes greatly to stormwater pollution as the waste contains both high nitrogen content and bacteria.
- Wash your car at the car wash or on your lawn. Commercial car washes have drainage systems that connect to the sewage system. This water is conveyed to the water treatment plant. In comparison, when you wash your car on the street, you likely use more water than the commercial car wash, and the soaps and road chemicals on your car run into the storm drain.

- Point downspouts from your roof into your lawn or garden. Many residential downspouts point to an alleyway or sometimes to an adjoining sidewalk. Locate your downspouts and point them to an area that is pervious such as your lawn or garden. This procedure will give you the added benefit of watering areas that you normally sprinkle.
- Decrease your impervious surfaces. Around our homes, we often have sidewalks and paved driveways. Where possible, install rain garden barriers or gravel ways that allow water to percolate rather than run off into the drain.
- Minimize litter and trash around your home. Make sure that trash if placed in its proper place. When the wind blows trash into your property, try to clean up right away.
- Remind others of the good housekeeping rules for stormwater.

For Skyline Park, stormwater management is critical to stream health. The waters that flow from the ephemeral streams within the park are likely only conveying water during the wet spring periods and much of this water has made its way through the urban landscape of Butte. In addition, the waters falling within the park boundaries also convey to the Pond somewhat. People utilizing the park will need to follow good housekeeping rules in order to ensure healthy water quality for the streams and pond.
Teachers utilizing Skyline Park may wish to extend the good housekeeping rules to the schoolyard or play areas around their schools. Students and teachers can inventory how well their school manages stormwater and suggest changes that can help decrease runoff and minimize pollution sources from the school. Recall that we all contribute to stormwater pollution, therefore every small action to decrease runoff and pollution is needed.

Resources

1. Facts about stormwater and stormwater management from the EPA
   http://water.epa.gov/polwaste/nps/urban_facts.cfm
2. General information about stormwater regulations and the National Pollution Discharge Elimination System (NPDES)
   http://cfpub.epa.gov/npdes/home.cfm?program_id=6
3. Montana Department of Environmental Quality MS4 information
   http://deq.mt.gov/wqinfo/MPDES/StormWater/ms4.mcpx
   USGS Website, Water Science for Schools page has many interesting links, videos, and photos about non-point source pollution and stormwater controls.
   http://water.usgs.gov/edu/watercyclerunoff.html
4. NOAA's website on Ocean Service Education offers great information about the compounding effects of stormwater for the ocean.
   http://oceanservice.noaa.gov/education/tutorial_pollution/03pointsource.html
5. National Geographic Education Site about the Great Pacific Garbage Patch
   http://education.nationalgeographic.com/education/encyclopedia/great-pacific-garbage-patch/?ar_a=1

6. Information about 100-year flood events, how urbanization can increase flooding, and methods for controlling floods
   http://water.usgs.gov/edu/100yearflood.html
7. Short video clip of a hydrodynamic device
   http://www.conteches.com/products/stormwater-management/treatment/cds.aspx
8. Cfwep.Org provides in-class stormwater education and routinely enlists students in helping to mark storm drains and assist with creek clean-up. To request a visit to your classroom by Cfwep.Org staff, please visit our website at: www.cfwep.org and send us an email. We'd love to visit!

Chapter 3.6 Seed Island Plants and Pollinators

Introduction

At **Skyline Park**, native plant species are represented throughout the park. These native plants will attract many insect and animal pollinators. Park developers used seed dispersal islands to naturalize this area. The seed dispersal island is an area approximately 30 m^2 located along the fence line of the park's northern boundary. It is located strategically in order to help native plants re-colonize areas that were previously disturbed by excessive ATV use. Seed islands are used in a variety of restoration settings, including mining waste caps, excessive erosion, over-grazed areas, and areas plagued by weeds.

The island consists of a grouping of plants, approximately 200 individuals total, that are typically found living together in natural ecosystems. The island was constructed by growing forb sods (or mats) approximately 1 m^2 in size, which were laid side by side along the fence. Each mat is distinctly different from its neighbors, containing different species of plants. Common to each mat is the presence of native forbs, containerized sapling trees, and in some cases shrubs. This

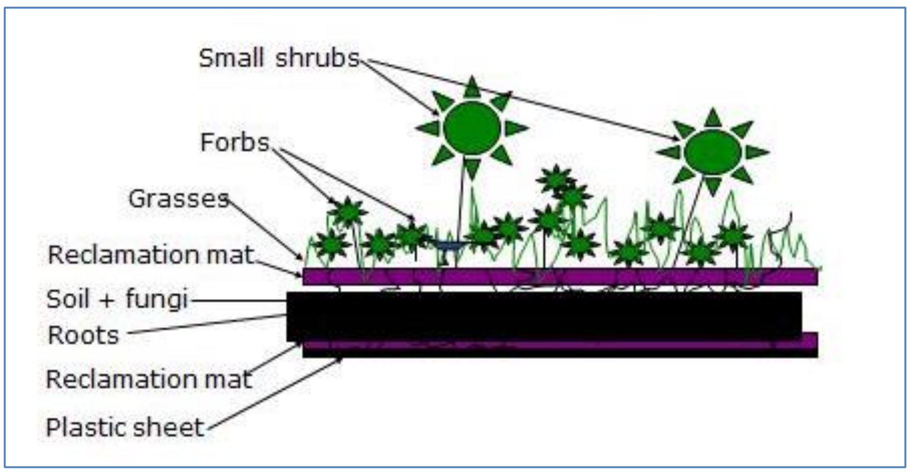


Diagram of a Seed Island provided by Kriss Douglass

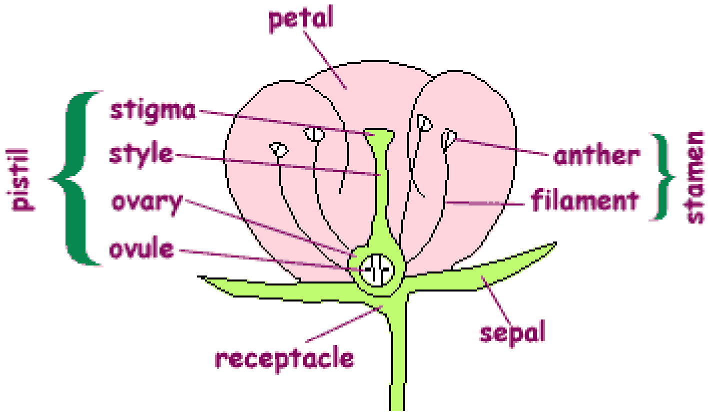
difference allows for various types of plants to establish in succession over the years to come. After 10 or more years, the island will be a significant source of seeds that can disperse throughout the park and surrounding area. **Native plants** typically need three to five years to establish in an area. They are slow to take up resources from the soil and require time to develop healthy root systems. The wildflower sods contain native plants which are cyclic, allowing for the decomposition of different species at various times throughout the growing season, thereby ensuring that the soil is continuously naturally enriched. Because of this cyclical nature and the fact that the plants themselves provide nutrients for the dispersal island, the sods will not require fertilization. Once the plant community is well established within the island, wind and animals naturally disperse plant seeds.

Forb sods develop roots that are non-rhizomous. Notice that the roots are thinner and have more hair-like structures allowing the plant to gain nutrients and water. Once the forbs die off, the roots decompose and add richness to the soil. Photo by Kriss Douglass

Pollination

Pollination refers to the transfer of **pollen** from one plant's flower to another plant's flower, or from one flower to another flower within the same individual plant. Pollen is the male **gamete** (reproductive cell) in plants, and is transferred to the structures containing the female gametes, or **ovaries**. Flowers are the structures that produce both male and female gametes. Flowers range widely in their shapes depending on how they are pollinated. Flowers may be small or large, colorless or colorful, odorless or odorous. When pollen reaches the **stigma** (see figures below), a pollen tube grows down the style to the ovary, where the pollen's genetic material is deposited, and the ovum is fertilized. The ovary then develops into one or more **seeds** and their accompanying **fruit**.

The stigma and anther of a flower. http://diagnostics.montana.edu/Graphics/FlowerStigmaAnther.gif



The parts of a flower.
http://www.palaeos.com/Plants/Lists/Glossary/Images/Flower.gif

Pollination is achieved in many ways among different plant species, but most plants are pollinated passively by the wind, or actively by animals. A wind **pollination syndrome** means that the wind blows pollen randomly, and chance dictates whether the pollen lands on an appropriate flower. In contrast, pollination syndromes involving animals can be enormously diverse. The majority of animal-pollinated plants are insect pollinate, in which an insect actively carries a flower's pollen to another flower. However, birds, rodents and other mammals can also participate in pollination.

Many plants and their pollinators co-evolved, meaning that they have evolved adaptations suited to one another. Pollination is a type of **mutualism**, or a symbiotic interaction between two species that is mutually beneficial. The mutualism can be either diffuse, among lots of plant species and lots of pollinator species, or between specific pairs of species. The floral characteristics of many plant species allow them to attract general classes of pollinators, rather than specific pollinator species. Flower shape, size, color, odor, and amounts of pollen and nectar all vary depending on the type of pollination.

Pollinators Are Important for the Environment

Because many pollinators and plants exhibit a mutualistic relationship and depend on one another for success, it is necessary for both the pollinator and the plant to be present in the local environment. In cases where one or the other is absent, biodiversity of the area decreases, which can negatively impact the site's ecology. For example, if a plant's pollinator is eliminated by insecticide use, the plant's population will decline and be unavailable as food and shelter for animals such as birds and mammals.

Most allergy-causing plants are wind pollinated because for wind pollination to be successful, a huge amount of pollen must be produced by one plant in order for some of it to find its way randomly to another plant's **stigma**. Large amounts of pollen in the air sometimes overstimulate our immune system and cause allergies. Flowers that are tiny, numerous, and lack petals, such as willow **catkins**, are usually wind pollinated.

Animal pollination, or directed pollination is considered to be more recently derived, meaning it is a more recent evolutionary innovation. Directed pollination may be evolutionarily advantageous because plants do not have to produce a very high volume of pollen. For example, if a plant relies on a bee to carry pollen directly to the stigma of another flower, the plant only needs to produce a small amount of pollen, which requires less energy.

When trying to predict a plant's pollinator, we can observe the characteristics of the flower. For example, it is common for bees to pollinate round yellow flowers, while birds such as hummingbirds usually pollinate red flowers with long **corollas**, or floral tubes. Butterflies are attracted to red, blue, and purple tubular flowers. Moths or bats typically pollinate white, smelly flowers that are open at night.

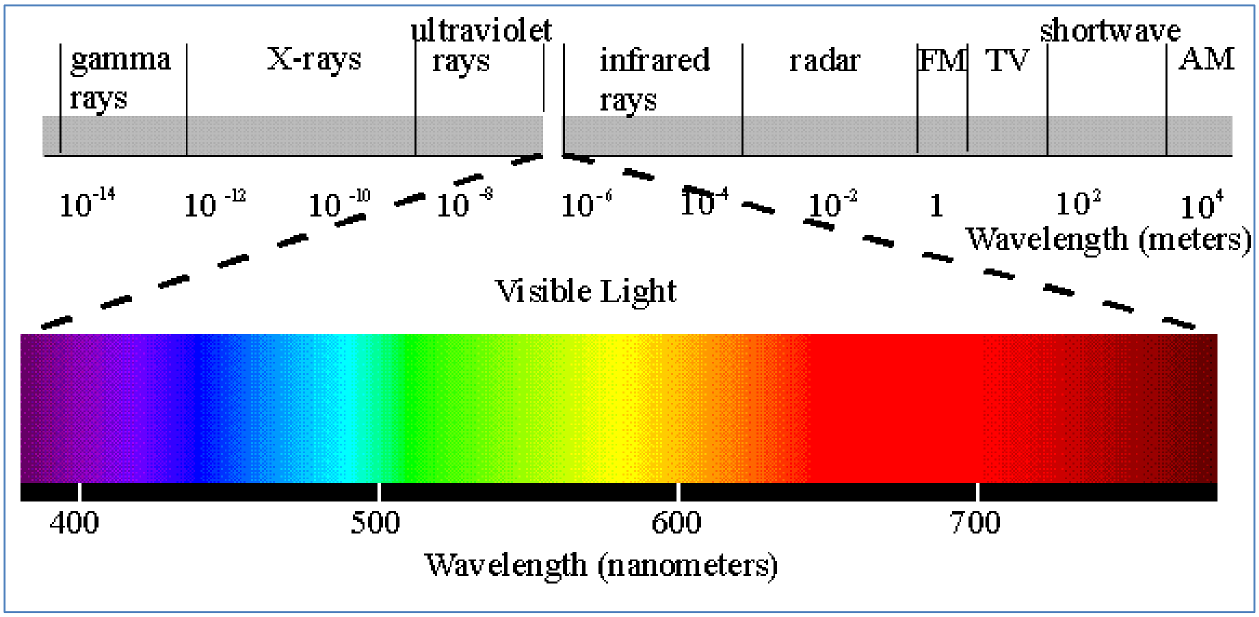
<u>Bird and Insect Pollinators</u>

Bird pollinators are attracted to flowers that are:

- Tubular and have petals that re-curved to be out of the way;
- Tube-, funnel-, and cup- shaped;
- Strong enough to support perching;
- Brightly colored: red, yellow, or orange;
- Odorless (birds have a poor sense of smell);
- Open during the day;
- Produce a lot of nectar that is deeply hidden with pollen designed to dust the bird's head/back as the bird forages for nectar.

Most insects cannot see red, but birds can. Bees and many other insects see the yellow part of the spectrum best, but unlike us or other vertebrates, can also see ultraviolet (UV) light (see figure below). Plants take advantage of bees' ability to see UV by exhibiting UV patterns on their flowers that point toward the part of the flower containing nectar. Butterflies are unique among insects in that they can see across the spectrum all the way from red to UV light. A quick Google search of "UV patterns and flowers" yields thousands of stunning photos. The following figure illustrates flowers in white light and UV light conditions.

Osteospermum seen in UV light. Photo by Tom Blegalski/TTBphoto, from geneticarchaeology.com.



Visible light spectrum. Image from: http://www.dnr.sc.gov/ael/personals/pjpb/lecture/lecture.html

We have generalized some of the characteristics that plants exhibit to attract pollinators, but these are not strict rules. In gardens, you will commonly see bees and birds travel amongst both red and purple flowers, such as bee balm and blue larkspur. However, these rules apply fairly well in habitats with native, uncultivated plants.

Resources

1. **For more depth and pictures of plants and pollinators**, please refer to the Cfwep.Org website curriculum at www.sciencepartners.info and visit the Plants and Pollinators online module.
2. A quick Google search for '**Plants and UV colors'** yields thousands of photo results and resources related to these phenomena. Our favorite photo resource is listed at: http://www.naturfotograf.com/UV_flowers_list.html#ASTERACX
3. For more detail about pollination syndromes visit: http://www.fs.fed.us/wildflowers/pollinators/birds.shtml

Chapter 3.7 Geology and Soils

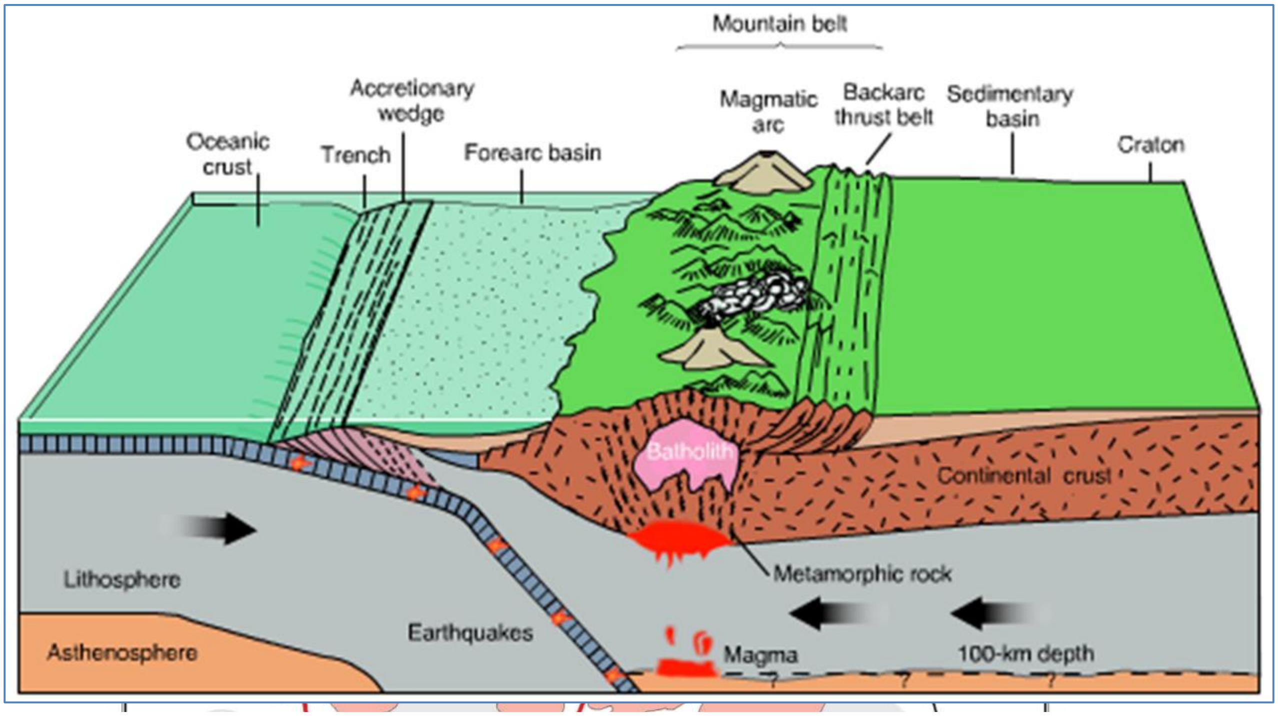
Introduction

Skyline Park is surrounded by mountains- to the south is the Highland Mountain Range, to the east is the East Ridge, in the far west, Timber Butte, and to the north the Butte Hill. This valley is called the Summit Valley, likely named by Europeans because of its high elevation. These mountains are part of the Continental Divide, and water falling in the Summit Valley eventually ends up in the Pacific Ocean. In contrast, water that falls just on the eastern side of the East Ridge or on the southern side of the Highland Mountains ends up in the Atlantic Ocean. The Summit Valley is the headwaters region for the Clark Fork River and one of three headwaters regions for the Columbia River.

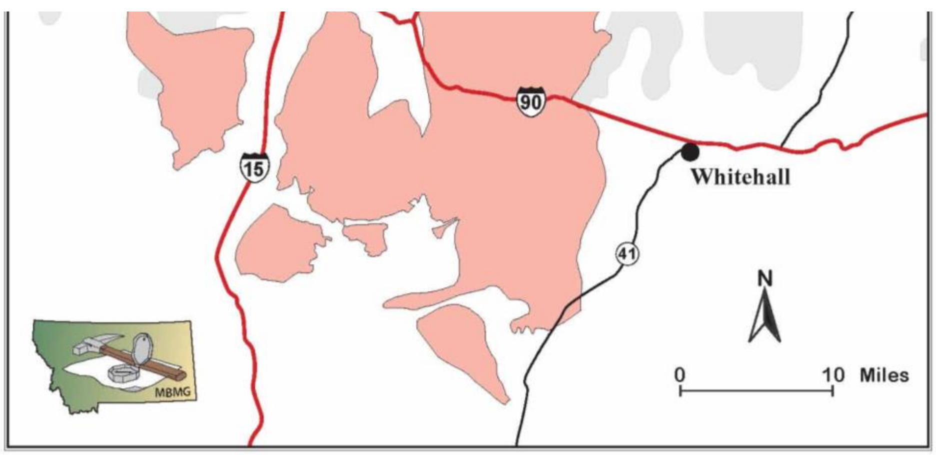
The geology of this area dictates the soil types found here, which in turn influences the nature of the plant communities that can grow, aspects of water quality, stream bed and pond substrates, and the presence of high value ores. In other words, geology influences everything!

Skyline Park Geology

The city of Butte sits atop a large granite formation called the **Boulder Batholith.** The Boulder Batholith was formed when two tectonic plates collided between 80 and 75 million years ago. The denser oceanic plate sunk under the lighter continental plate. This formed a **subduction zone** that allowed **magma** to rise into the continental crust. Some of the magma reached the



Graphic of tectonic plates forming subduction zone and batholith. Graphic from: //highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/0072402466/30425/19_32.swf::Fig.%2019.32%20-%20Ocean-Continent%20Convergent%20



Extent of the Boulder Batholith. Image courtesy of MT Bureau of Mines and Geology

surface, forming volcanos. The magma then cooled quickly and formed volcanic rock. The magma that remained underground cooled slowly and formed the batholith and its many associated ore bodies.

After millions of years of erosion, some of the granite (quartz monzonite) that makes up the Boulder Batholith can be seen. While in Skyline Park, glance over to the East Ridge just below the statue of Our Lady of the Rockies, and you will see rounded granite boulders typical of the Boulder Batholith. Below is a picture from atop the Continental Divide on Homestake Pass showing these boulders.

Granite boulders on Continental Divide near Pipestone on Homestake Pass.

A granite batholith is typically mineral rich with ore veins formed during the slow, underground cooling process. **Minerals**, naturally occurring inorganic substances composed of specific **elements** ordered in a specific way, fill the voids in the cooling magma. These voids are scattered throughout the batholith and resulted in veins of minerals. The Boulder Batholith is rich in copper, gold, silver, molybdenum, and lead. Copper is by far the most abundant of these minerals. Most hard-rock mining operations are located within batholiths because they often have a rich mineral composition.

At Skyline Park, you are close to the **Continental Fault** that runs through Butte. Faults are within the Earth's crust and result from the action of tectonic plates. The Continental Fault allows for groundwater upwelling, which feeds vegetation. In Skyline Park, groundwater is pumped to maintain the pond.

This aerial photo illustrates the park before the restoration of area. On the left (east edge of park) runs the Continental Fault.

Geologists would prefer calling watersheds "rocksheds" because water is continuously eroding the landscape and transporting rocks and soil from one place to another. Near Skyline Park, the East Ridge is continuously shedding decomposing granite. Because of this, the soils within Skyline Park have a sandy appearance and quickly absorb water. In addition, granite soils are naturally more acidic- close to 6.0pH rather than 7.0, which would be neutral.
While valuable ore minerals like copper are present in the Boulder Batholith, other compounds are also found. For example, iron pyrite is common within the granite boulders along the East Ridge. When iron pyrite is exposed to air and water, it undergoes weathering and breaks down into iron oxide and sulfuric acid. This sulfuric acid production is called **acid rock drainage.** In

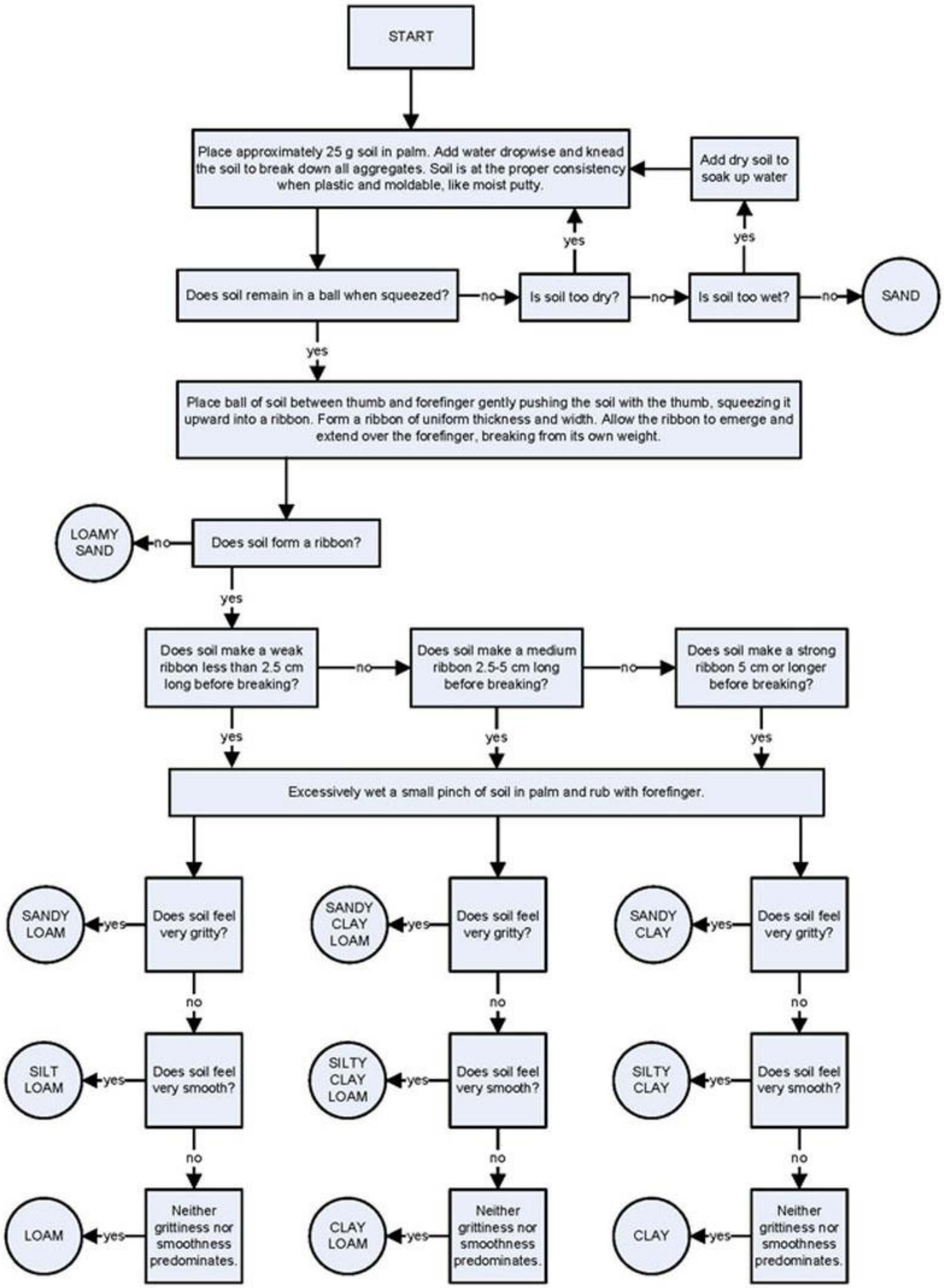
areas with high concentrations of iron pyrite, soils will sometimes be too acidic to support vegetation, especially in areas that have been disturbed. In disturbed areas, more iron pyrite is exposed to air and water than would naturally occur and the resultant acid rock drainage from mine waste piles can devastate waterways and upland soils. In contrast, in natural landscapes undisturbed by mining, relatively small amounts of iron pyrite are exposed to air and water and so acid rock drainage is not a problem. The acid rock drainage that does occur in these natural, undisturbed landscapes is balanced by surrounding soils. Under Superfund, many Butte area mine dumps have been capped to reduce the amount of iron pyrite exposed to air and water, thus preventing acid rock drainage.

The soils of Skyline Park favor upland plant communities that are drought tolerant and prefer slightly acidic soils. These upland plant communities may naturally have fewer species of plants than plant communities not located atop a batholith. Plants in Skyline Park must also be capable of enduring Butte's extreme winter temperatures.

Soils in the wetland and riparian areas are typically higher in nutrients, have a neutral pH, have more water, and hold water longer than upland soils. Wetland soil conditions allow a greater diversity of plant species to establish in wetland and riparian areas.

Many home gardeners know that soil texture, color, and structure dictate how well their garden grows. Gardeners prefer rich, dark, loamy soil over soils that are sandy or contain too much clay. Soil texture helps determine the water-holding capacity of the soil because areas between soil particles either hold water, or allow water to flow through. Soils containing a lot of clay hold more water and do not allow for percolation into deep groundwater. In fact, clay liners are often used to prevent water seepage in constructed ponds and water retention basins. Soils that are excessively sandy do not hold much water at all, and convey water quickly to deep groundwater. Sandy soils can be used as filters in some constructed stormwater percolation areas because the sands retain oils and other harmful pollutants, while allowing clean water to percolate into groundwater.

The following diagram is a soil texture chart developed by the United States Geologic Survey (USGS) and will help you identify soil texture.



In addition to soil texture, we can use soil color to identify soil type. Soil color is dictated by a variety of factors including the presence of various minerals, clays, and decomposing plant material. Soil scientists use a Munsell color chart to help them identify soil type and composition. For the purposes of a basic color study within the park, project WET has an excellent lesson on soil color. In this lesson, students create their own chart with colors corresponding to different soil types. See the resource section for a link to this activity.

We can also examine soil structure to determine the soil type. The soil structure is also dictated by the presence or absence of clay, sand, and organic materials. Soil structure may vary by location. For example, compacted soil structure is likely near the surface where animals and humans regularly compact the soil. The following diagram illustrates the various soil structures.

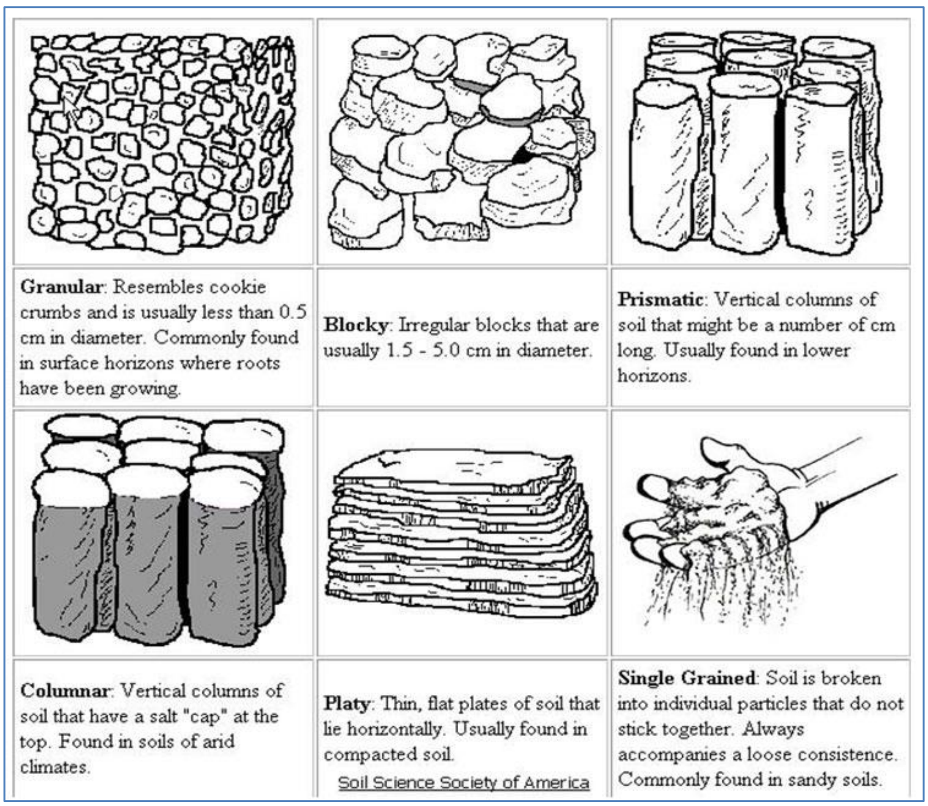


Image from URL:
http://www.soils.umn.edu/academics/classes/soil2125/doc/s3chap1.htm

Resources

1. The Montana Bureau of Mines and Geology website has a multitude of maps and links including "exploring earth science with kids". http://www.mbmg.mtech.edu/
2. Batholith formation and graphics www.highered.mcgrawhill.com
3. United States Geological Survey (USGS) website for teachers. This site includes many schoolyard activities for geology. http://education.usgs.gov/lessons/schoolyard/index.html
4. Natural Resources Conservation Service site about soils and soil types http://www.nrcs.usda.gov/wps/portal/nrcs/main/or/soils/
5. Cfwep.Org's Science Partnership Website contains two modules: Landforms and Soils which both can be utilized within the classroom to further deepen understanding of the area's basic geology and soil profile. www.sciencepartners.info
6. Project Wet Soil Color Chart. www.projectwet.org
7. Smithsonian page on soils and educator's resources for teaching about soils http://forces.si.edu/soils/02_02_03.html

Chapter 3.8 Restoration of Skyline Park

Introduction

Historic mining practices have heavily impacted the Clark Fork River watershed. These impacts include loss of key riparian areas from Butte to Missoula, degradation of upland habitats from air pollution, and loss of fishing and other recreational opportunities. The damages to this watershed were extensive and unparalleled in the United States in terms of the acreage of land area damaged. In 1983, the citizens of Montana filed a lawsuit against the Atlantic Richfield Company (ARCO) for damages to the Clark Fork River watershed, specifically to recover damages for injuries to water, soils, fish and wildlife, and the public’s use and enjoyment of resources.

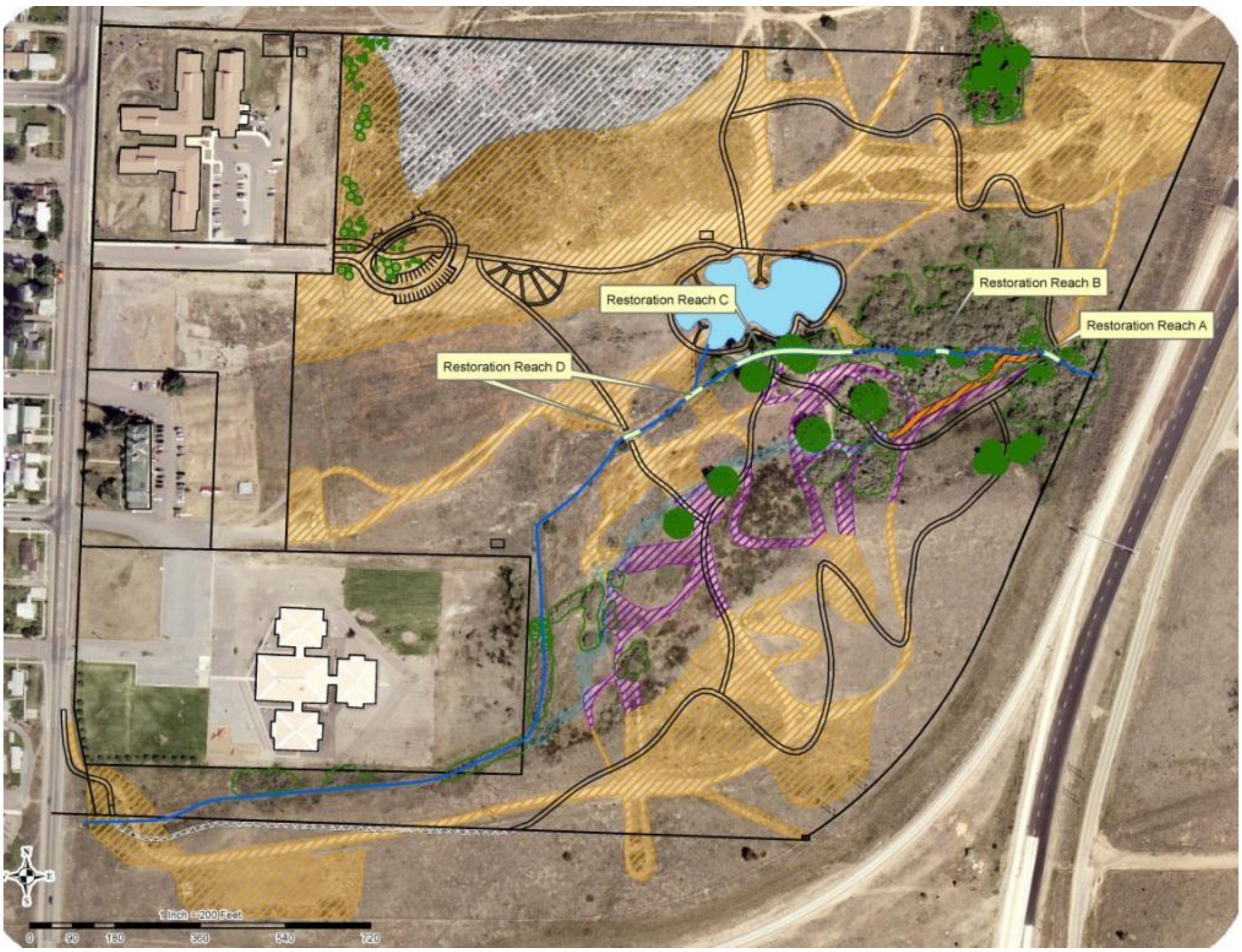
In 1990, the Natural Resource Damage Program (NRDP) was created to prepare the state’s lawsuit against ARCO for damages to the Upper Clark Fork River Basin (UCFRB). The NRDP is part of the State of Montana’s Department of Justice and is now responsible for overseeing the settlement dollars. The State of Montana and ARCO settled the lawsuit through a series of agreements made in 1999, 2005, and 2008. NRDP has administered annual restoration grant projects from the 1999 partial settlement. These grant projects have totaled over $112 million and include projects that will improve water, fish and wildlife resources, public drinking water supplies, and natural resource-based recreational opportunities such as hunting, fishing, hiking, and wildlife watching. Please see the NRDP website at https://doj.mt.gov/lands/ for more detailed information.

The Skyline Park project was an effort to restore lost resources within in the Butte area and is an example of projects that the NRDP has funded. Prior to constructing the park, community members had very few fishing opportunities immediately within the area.
The Skyline Park project was a joint effort between Butte Silver-Bow and Skyline Sportsman’s Association. The project partners submitted a proposal to the Natural Resource Damage Program in 2010 for park construction. The partners were successfully awarded a grant in 2011, construction design and planning began in 2011, and the park was completed in 2014.

Eroded channel of Reese Canyon Creek prior to the Skyline Park project. Photo by: F. Ponikvar.

Before Restoration

Restoration is the process of returning a damaged resource back to its original state biologically, structurally, and functionally. In other words, think of the word root 'restore', which means 'to bring back or return'. Prior to building the park, the public used this parcel of land as an informal recreation site for hiking, biking, dog walking, hang gliding, unauthorized ATV riding and motorbike riding. However, the area had also been used for undesirable purposes like uncontrolled off-road vehicle riding, illegal dumping, and teen drinking. The natural resource features had deteriorated significantly, including damage and erosion to the stream channel caused by motorized vehicles, vandalism, and noxious weeds.



Map detailing restoration areas of the park.

Restoration Activities

Stream restoration at Skyline Park addressed the heavily impacted lower stretch of Reese Canyon Creek. The first 500 ft of stream (from the interstate to just above the grove of cottonwoods) remained in fair condition with an intact channel and dense riparian vegetation with the exception of crossings created by motorized recreation vehicles. The crossings captured much of the creek's flow and formed off-channel gullies. The next 600 ft of Reese Cancyon Creek had been heavily impacted by motorized vehicle use and channel diversion. Restoring the stream channel included reconstructing the lower 600 ft reach, improving channel and floodplain structure and function between and above the Hillcrest School property, and re-vegetating the riparian corridor. Open space restoration included the upland areas, which were planted with a native grass mix, and open upland areas that were planted with native grass, forb and shrub species. Within these areas, there was variety in seeding and planting, allowing for additional diversity of plants and habitat.

After reconstructing the stream channel, appropriate vegetation was planted in the surrounding area. The rechanneling also helps control runoff through the park and to the Hillcrest School site. Though Reese Canyon Creek is an ephemeral stream, meaning that it only holds water during high runoff periods, water flows during high runoff must be managed and contained to eliminate flooding downstream.

Installation of wetland sods. Photo by: F. Ponikvar.

Wetland sods were selected by the park designer, John Trudenowski in order to create natural habitat surrounding the pond. The sods also will help mitigate algal blooms, filter water, and provide habitat.

Trail construction. Photo by: F. Ponikvar.

Trails throughout the site are constructed of gravel, except for the handicap accessible trails surrounding the pond and adjoining the parking area. Using gravel ensures that stormwater is conveyed to groundwater rather than running off of impervious surfaces.

While exploring Skyline Park, be sure to observe the cement bridges, which were made from old mine cap covers. These bridges are a creative and unique display of the reuse and recycling of materials at Skyline Park.

After Restoration

The Skyline Park project has repaired, replaced, and restored the riparian and upland areas, which has not only has benefited the resource, but has also provided outdoor education opportunities for teachers and students in the Butte area. Restoring the riparian and upland vegetation improves fish and wildlife habitats. The project also eliminated noxious weeds and restored native vegetation. Establishing a trail system and re-vegetating unwanted trails improves recreation opportunities and protects vegetation and creeks from off-road use. Restoration of the park will continue post-construction as native plant communities establish and come into balance with one another. It will be exciting to observe the natural state of the park continue to evolve and develop. Community members who use Skyline Park must maintain its beauty by making sure to throw away litter, dispose of animal waste in the bins provided, exclude motorized vehicles from the park, and prevent introduction of invasive species into the pond.

Teachers who use this site as an outdoor education opportunity should consider creating a photo journal with their students. The photo journal provides a unique opportunity for students to review photos from the past and compare those to today. The key to the photo journal is to simply take a photo from the same place (or places) in the park at the same time of the year (possibly late spring) each year. Of course, be sure to label and archive the pictures for future comparisons. See the resources section below for a link to the activity.

Resources

1. Natural Resource Damage Program website. This site offers historical background to the lawsuit and many links to additional resources. https://doj.mt.gov/lands/
2. Answers to Superfund newspaper available for download at www.cfwep.org
3. Nature journaling and photo journaling with students from the Smithsonian http://www.smithsonianeducation.org/educators/lesson_plans/journals/smithsonian_siyc_fall06.pdf

CHAPTER 4: ACTIVITIES

Ch. 4.1 Science Note Booking

Start GREEN BOX

Student Objectives

- Students will be able to use a science notebook for recording observations about Skyline Park.

Guiding Questions for Students

- What do you want to know or find out about the park?
- In general, what do you notice about the park? What types of plants and animals are here?
- How will you collect data or information about the park?

End GREEN BOX

Background Information

Scientists regularly use a notebook for keeping observations, tracking data, designing experiments and recording findings. In this exercise, students will use science notebooks for recording general observations about the park and possibly for constructing new questions to explore following their visit to the park. A complete science notebook includes the following parts:

- Question, Problem, Purpose
- Prediction
- Developing a Plan
- Observations, Data, Chart, Graphs, Drawings, and Illustrations
- Claims and Evidence
- Drawing Conclusions
- Reflection – Next Steps and New Questions

For this activity, we will focus our attention on the questions we have about the park and the observations we make. Students can choose to illustrate or photograph some of their observations. This activity will prepare students to think about future research questions that they may pursue later at the park.

Activity 1.1: My Science Work: Science Note Booking About Skyline Park

Materials

- Notebook
- Pen or pencil
- Colored pencils (optional)
- Camera (optional)

Procedure

1. Walk through the park with your students along the trails. At the various signs, instruct students stop to read the content of the signs.
2. Instruct students to take a moment to record any observations about the particular area that they notice.
    a. Be sure students include descriptive words that allow a reader to create a picture of what they are recording. For example, rather than writing, "I saw many birds." They should write, "I saw ten birds. They appeared to be about the same size as a robin and were blue in color."
    b. Encourage students to use as many adjectives as they can to describe what they are seeing, and to include the relative size of things with phrases such as "bigger than," "smaller than," and "about the same as," in order to describe size.
3. Students should also record the relative location of objects they are recording. For example, they may observe trees and state, "The large cottonwood trees are located within about 5 meters of the pond."
4. If they are observing animals such as insects, encourage them to think about any behavior they may notice.
    a. For example, they might record, "There were two bees landing on the red flowers next to the fence. The bees seemed to be only going to the red flowers and were not seen on the white flowers."
    b. Another observation may be, "There were two frogs on the south edge of the pond. They remained in the shallow area while I was watching them and were only partly underwater."
5. As you and your class walk through the park and observe things happening there, have students write down any questions that come to mind.
    a. For example, they may be wondering how many fish are in the pond or what how the fish survive in the pond. Perhaps they wonder why there are not any willow trees by the park entrance or what type of rock they have found.
        i. Encourage students to write down any questions that come to mind, since these questions can become a research project for later.

6. Lastly, also encourage students to make a drawing of at least one item they observed in the park, if not more.

Extensions

- This activity is limited to making observations and does not require students to explore the other aspects of the scientific process. Students should engage in further questioning based on their observations and attempt to design a research question and study to explore.

Resources

1. **National Research Council's** book, *A Framework for K-12 Science Education: Practices, Crosscutting, Concepts, and Core Ideas*, includes a section on the scientific practices. This section illustrates the importance of using notebooks as a tool for science education.
2. **Michael Klentschy**'s book, *Using Science Notebooks in Elementary Classrooms,* is also an excellent resource with easy to use sentence starters for elementary students. The book is available as a PDF at http://static.nsta.org/files/PB209Xweb.pdf.

Ch 4.2 Skyline Park History

Start GREEN BOX

Student Objectives

- Practice creative writing skills by writing a fictional story of the history of Skyline Park using observations and evidence from the site.
- Demonstrate research skills by exploring various media for factual history stories related to Skyline Park, the areas surrounding the park, and Butte in general.

Guiding Questions for Students

- Based on your observations at Skyline Park, what historical events may have affected this site?
- Based on your research of Skyline Park and its surrounding areas, who or what had major influences in shaping the natural landscape here?
- Is there anything about the history of this area that surprised you?

End GREEN BOX

Background Information

If you do not know your history, you cannot know yourself. Salish Tribe Elder

History tells us about people and events that came before us, teaching us about ourselves and who and what influenced our lives. History lends itself well to scientific inquires since our understanding of all natural phenomenon is greatly enhanced by knowing who and what interacted with and affected the phenomenon in question. Even the methods, tools and theories used in science have a history to them; knowing about how these were created and developed helps students better understand how to do science.

As described in Chapter 3.1, History of Skyline Park Area, the Summit Valley was home to American Indians, and was visited by people of several other cultures. In the 1740's French Canadians from the Hudson Bay Fur Trading Company came looking for pelts, eventually settling here as timber cutters for the mines. Without a doubt, the mines had some of the greatest impacts to this area. In addition to the environmental impacts, mining also resulted in many other industries and development in the Summit Valley, paving the way for railroad expansion, small businesses and more. Mining also brought many peoples from many cultures to Butte giving it international flavors and decors. Poor farms were also a feature of the Valley as many miners suffered accidents and died, leaving poor widows and their children behind.

Activity 2.1: Write Your Own History for this Site

This activity encourages students to create their own fictional histories about Skyline Park and the surrounding areas based on observation and evidence.

Materials

- Science Notebooks, or sheets of paper and clipboards
- Pens or pencils
- Drawing tools or cameras

Procedure

1. Instruct students that they will be writing a fictional story about Skyline Park**.**
2. Walk around the park with your students and instruct them to make general observations about what they see in and around the park, and write these in their notebooks.
    a. Their initial observations may be superficial; encourage them to look again and again and again. With time they will see what they missed.
3. After the walk-about, have students sit down and write their stories.
    a. Ask students to create a fictional story about what historical events, both natural and human-made, might have influenced the park and surrounding areas.
    b. Direct students to use direct observations and evidence at the site and the surrounding areas as a basis or foundation for their story.
    c. Drawings and/or photographs are encouraged to allow students to document their evidence.
    d. As they build their fictional histories, do encourage students to take creative license with the evidence and let their imaginations fill in the blanks.

Activity 2.2: Create a Timeline for this Area

Timelines with text and graphics are great visual tools to orient students to when and where they are. We find that scientific practices, content and cross-cutting concepts are enhanced by orienting students to **their place** - the geological, environmental, and human history of where they live.

Materials

- Science Notebooks or sheets of paper
- Pens or pencils
- Library or internet access for research
- Computer access for presentation development

OR

- Poster-size or legal-size paper
- Fine- to medium-point markers, glue and scissors for posters

Procedure

1. After reviewing their initial observations and notes, instruct students to conduct scholarly research on Skyline Park, using resources on Butte Silver Bow's website, Cfwep.Org's website, Butte Silver Bow Public Archives, the local or school's library, etc.
    a. Students can work in groups to do one of the following: geological, cultural, environmental and industrial history. Students are required to provide proper credit and citations.
    b. Graphics are highly encouraged; students are responsible for crediting the producer of all graphics, including themselves.
2. Student groups can then present their work to the class using posters or handouts, or some other oral and graphical presentation. We also encourage them to submit a bibliography or reference list.
    a. Examples of timelines can be found in the appendices. Appendix 1a and 1b show an example of an environmental/natural history timeline for the Clark Fork watershed; Appendix 2a and 2b show an example of an industrial/civilization timeline also for the Clark Fork watershed.

Extensions

- Working in groups, have students create one fictional story by combining their individual story with other students' stories.
- Encourage students whose families have been in Butte for some time to interview family members about memories or thoughts from the area. Other elders in the communities can be interviewed as well. These reflections can be recorded and potentially submitted to the Butte Silver Bow Public Archives.

Resources

1. **Butte Silver Bow**'s website is user-friendly and a good place to start research on Skyline Park. http://www.co.silverbow.mt.us/
2. **Butte Silver Bow Public Archives** is a wonderful resource for people of all ages. It was established in 1981 to maintain Butte's history. Part of its mission is to provide public access to the documents and manuscript collections at the Archives. The staff is available to help educators utilize archive resources. https://buttearchives.org/
3. The **Butte Historical Society**'s webpage is another interesting place for students to visit and learn more about Butte's history. http://buttehistorical.com/index.html
4. The <u>Montana Standard</u> is another good source of recent history of Skyline Park.
5. For geological history, one of the best local resources is the **Montana Bureau of Mines and Geology (MBMG)** on Montana Tech's campus. Start on their web page, then let the fun begin! http://www.mbmg.mtech.edu/
6. **Cfwep.Org**'s website offers many resources for teachers including historical information about the Clark Fork watershed. www.cfwep.org

Ch. 4.3 Mapping Skyline Park

Start GREEN BOX

Student Objectives

- Observe natural and human features at the Skyline Park site.
- Graphically represent natural and human-made features on a student-created map.
- Explore and document how the field site changes over time.

Guiding Questions for Students

- Where is north?
- How large is our study site?
- What are some of the major features you notice in this site?
- What other features border our study site?
- Why do we want to map this site?

End GREEN BOX

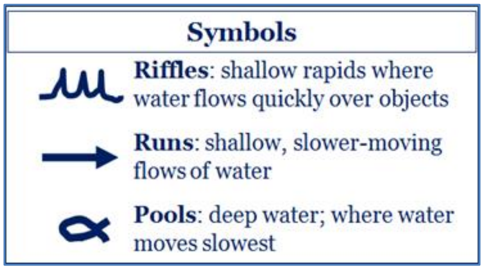
Background Information

A great way to introduce students to an outdoor site that will be used for scientific study is to have them create their own map of the site. By drawing a map, students will be required to make very detailed observations of the site; understand how site features are distributed in space; and appreciate the relationship between features located on the site. Map drawing can also help students develop skills in reading and math, and help build spatial sense and visual literacy. It especially helps students develop skills related to representation and scale. These are all skills that students will use in varied situations. Lastly, students should be able better comprehend how to read maps by creating their own map as they learn to appreciate map characteristics.

As described on Cfwep.Org's teacher professional development website, Montana Science Partnership (www.sciencepartners.info), a **map** is a geographic representation of objects or facts that are observable in our universe. Maps are pictures that communicate a sense of place and document the features of that place. There are two broad categories of maps: **reference maps** and **thematic maps**.

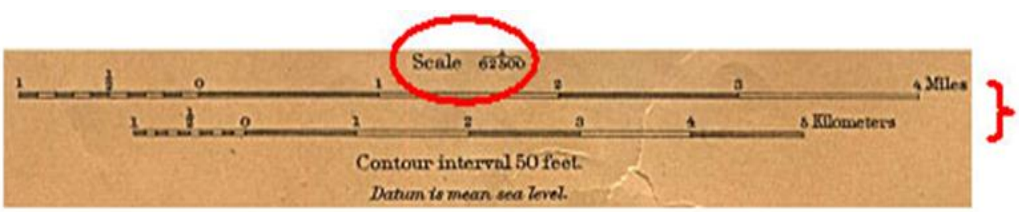
Reference maps show you where objects are located in the environment. They are called *reference maps* because they are used as a reference to find specific sites. A road map is a reference map used by travelers to find roads and destinations. There are two main types of reference maps that we use regularly: the **planimetric map** and the **topographic map**. Maps that display public information – subway routes, the layout of a city building, walking trails, stream restoration plans – are often **planimetric**. The type of reference map that includes location and elevation information is called a **topographic map**. In contrast, **thematic maps** show information about locations by documenting how events or objects are distributed across the landscape. They are called *thematic maps* because they focus on a specific theme. A map of the temperatures around Montana on a given day would be an example of a thematic map. Since maps are created for many reasons, it is important for students to depict those features thatare most relevant to their study. To help orient students to the task at hand, students should answer the following questions before creating their maps: Why am I making this map? Who is this map for? What is this map going to be used for? In brief, for this situation, we encourage students to create a map of the field site so that it can serve as a resource for them in their future science studies of this outdoor laboratory.

Maps of all kinds are a basic tool in science that allows scientists to discover relationships between different phenomena. In addition, using and studying maps of natural areas can help students better understand changes in landscapes over time. All maps include the following basic information: legend, scale and reference frame. The **legend** explains what the symbols, which represent real-world things, mean; picture at right shows a simple example of a legend. The **scale** is the ratio between the distance on the map and the actual, real-world distance it represents; more information on scales and maps is provided below. Lastly, the **reference frame** is a system of coordinates used to show the orientation of a map; the most common ones used typically indicate north, south, east and west.



Example of a legend for a map, showing the symbol used on the map and the explanation of the symbol.

All maps are drawn with a different **scale** that is much smaller than the area of land, water, or sky being represented. Obviously a true-to-scale map of Yellowstone Park would not fit on a standard sheet of paper like the map you were shown. A map scale is the ratio between the distance on the map and the actual, real-world distance it represents. Many maps present the scale as a ratio called the representative fraction or **ratio**. For example on the figure below, we can see on this scale from a topographic map, the representative fraction of the map is 1/62,500 (red circle):



Example of a scale from an old topographic map.

This means that a distance of one inch on the map is equivalent to 62,500 inches on the ground. As 62,500 inches is approximately 0.99 miles, on this map one inch is roughly equal to one mile of actual distance. This same scale could be presented as a representative ratio of 1:62,500. This map also had a graphic scale (shown in the red parenthesis), a diagram that illustrates the representative fraction. Many maps produced in the United States today present the scale of maps in both English and metric units.

We suggest that students work in groups of about three or four students for this activity in order to share ideas and tasks. Additionally, you may want to consider having student groups create maps for different features. For example, one group of students could create a general map that includes trails and other natural and human-made features; another group of students can make a map of vegetation types; and a third group can create a map of geology or soil types. In addition or alternatively, as a group you may all decide to break the study site into smaller maps, for example, mapping just the pond area or just the uplands area. Prior to creating their own maps of the site, students should study the map on the park's sign and discuss the relationship and basic geographic features surrounding the Skyline Park site.

Activity 3.1: Where is That? Mapping the Skyline Park Site
This activity is intended to help students develop a basic understanding of the purpose of map making for scientific study and develop those associated skills. It should also assist students in getting a general idea of the Skyline Park site's features in preparation for other activities.

Materials

- Science notebooks or sheets of drawing paper
- Pencils for fine writing
- Crayons, colored pencils, markers, etc., for drawing
- Rulers
- Measuring tapes
- Compasses

Procedure

1. Ask students to make observations of the important features at the site. Instruct them to think about which features should be represented on their map, why those features are important, and what relationships they want to illustrate on their map.
2. Next have students create symbols to represent the features they want to characterize, and to create a legend that identifies each symbol for their map.
3. Students should then measure the boundaries of the site and distances between features, then use those measurements to draw the site to scale.
4. Have students select a reference frame for their map. A common reference frame used for maps is a compass.

5. Students should divide mapping tasks among group members. Each group needs:
    - Map designer (1 person): draws features, scale, etc., on the map;
    - Table recorder (1 person): fills in a table of environmental features to be characterized and helps to create the legend of map symbols;
    - Field observers (2 – 3 people): locate and observe features and measure distances.
6. As a group, walk the field site and identify important features of the site:
    - **Biotic features:** trees, bushes, insects, birds, wildlife, fish, people, etc.
    - **Abiotic features:** buildings, walkways, fences, bridges, tables, statues, shadows, sun, snow, etc.
    - **Potential safety risks:** broken glass, sharp wire, etc.; discuss how to avoid these risks.
7. Within their group, students decide what features to include and what symbols will represent the different features. At the bottom of the map, students should create a legend that explains what each symbol represents.
8. Using a compass, students can determine their reference frame (N, S, E and W) and add it to a bottom corner of the map.
9. Using a meter tape and/or by pacing, students should estimate the length and width of the site. Ask students to determine an appropriate scale for the map depending on the size of the area, and then use a ruler to draw the scale in metric units.
10. Lastly, have students draw the important features to scale on their map, and to describe aspects of the important features in their table that are not conveyed by the map alone.

This map should be considered a work in progress. We recommend that teachers instruct students to continually update their maps as they work through the other site activities included in this guide.

Cfwep.Org would like to thank Dr. Michelle Anderson from the University of Montana-Western for this activity.

Extensions

- Either in the field or in the classroom, have students compare the maps and tables produced by different groups and consider some or all of the following questions:
    - Which features were common and which differed between maps?
    - Why are certain types of plants and wildlife found at this site while others are not?
    - How does the presence or absence of living organisms relate to features listed on the maps and tables? For example, if you found birds, where were they living?
    - Would your map or table look different if you created it during a different season?
    - Would you consider any of the plants or wildlife you found undesirable?
    - Does the map you created meet your original stated purpose?

- After students have completed discussions about their maps, teachers could explore Google Earth images of the site and compare the images to the student-generated maps.

Resources

1. United States Geological Survey (USGS) has several resources for educators related to mapping. For example, **Mapping Your School Yard** is a series of lesson plans that guide you through the process of creating a map of your schoolyard and other field studies. (http://education.usgs.gov/schoolyard/index.html). USGS also provides geography teacher packets at http://egsc.usgs.gov/isb/pubs/pubslists/edu.html.
2. **Me on the Map** from the Utah Education Network is a 2nd grade lesson plan that uses a wonderful book called, *Me on the Map*, by Joan Sweeny. The book uses simple, eye-catching drawings to show how maps can represent everything from your bedroom to your street, to your town and so on, all the way up to the universe. http://www.uen.org/Lessonplan/preview.cgi?LPid=5713
3. **National Geographic-Education** provides lesson plans that are keyed to grade level, concepts and geography standards. http://education.nationalgeographic.com/
4. **Mapping and Geography** from the Geological Society of America provide their own lesson plans as well as helpful links to other lesson plans. http://www.geosociety.org/educate/LessonPlans/i_map.htm
5. **Resources for Earth Science and Geography Instruction** from Central Michigan University is a website that contains links which are organized alphabetically around the sequence of topics typically taught in an introductory earth science or physical geography class. Links are also available for environmental science, earth science/geography education. http://webs.cmich.edu/resgi/
6. **Montana Maps and Spatial Data**, from the Natural Resource Information System (NRIS) is a website with maps and mapping data specific to Montana. It hosts information on everything from what fish are found in different streams to where major pollution sites are found. It may take a while to get used to the mapping tools, but it is worth it. http://nris.mt.gov/
7. **Montana View** is a consortium of universities, non-profit organizations and government agencies working within Montana to advance the availability and timely distribution of remotely sensed data. Click on the Education page to find some Montana-specific Google Earth exercises using digital data. http://www.montanaview.org/default.aspx
8. **Perry-Castañeda Library Map Collection** from the University of Texas at Austin may be the best single source for publically available, easy to view, downloadable maps. This site includes historical maps, weather maps, maps with math applications, national park and historic site maps and much more from the US and the World. http://www.lib.utexas.edu/maps/

Ch 4.4: Pond Life – Microorganisms

Start GREEN BOX

Student Objectives

- Describe that all life forms are made up of cells – from single-celled bacteria found in ponds to human beings, who are made up of trillions of cells.
- Gain experience observing the shapes, sizes, movements, and other features of pond microorganisms using a microscope.
- Describe and identify forms of microscopic pond life.
- Explain the roles of pond microorganisms in the pond web of life (transfer of energy).

Guiding Questions for Students

- What kinds of organisms did you observe?
- Which organisms were most common?
- Did you notice diversity among the organisms? Explain your answer.
- Are there any features that are shared among organisms? Are there any features that are unique to only one or two organisms?
- How are the organisms behaving and are they interacting with each other?
- Do these organisms remind you of any other organisms? If yes, what about them reminds you of others?

End GREEN BOX

Background Information

Ponds are typically defined as wetlands because of their transient existence in natural systems. What do we mean by transient existence? They do not last long, especially, considering other geological and ecological features. To further answer this, let's consider the succession of ponds. How do ponds form and how do they end? Sometimes they form from lakes after hundreds or thousands of years of sediments filling the lake which allows for rooted plants to take hold until they can root from shore to shore. When this happens, the lake becomes a pond.

Most lakes were formed during the last glacial period when large basins or bowls were formed through erosive forces of glacial movements and then filled with water from melting glaciers. Of course, if the bowl is small, the water body skips the lake stage and starts at the pond stage. Sediments keep filling the pond (bowl), allowing for more and more plants, and bigger and bigger plants to take hold, eventually filling the pond until it functions more like as a marsh or wetland. If continually recharged with groundwater, they may remain as pond-like marshes for long periods of time. Since the pond at **Skyline Park** is human-engineered it is unclear how long this pond will last – certainly, at least a few hundred years.

Pond water offers many exciting opportunities for scientific study. Beneath the smooth, placid surface of the water lives a bustling microscopic world of bizarre organisms living their lives. They move, hunt, eat, defend, reproduce and eliminate waste – just like most other living creatures. Many of these organisms are **plankton**, consisting of drifting microscopic plants (**phytoplankton**), animals (**zooplankton**), bacteria (**bacterioplankton**) and viruses (**virioplankton**) that inhabit oceans, seas and bodies of fresh water. Plankton float along at the mercy of the tides and currents. In fact, their name is derived from the Greek word, *planktos*, which translates to "drifter" or "wanderer."

Plankton are the most abundant form of life in the oceans, and in most other aquatic systems. All other aquatic life is dependent upon plankton for food. While you can also find **microorganisms**, also called **microbes**, living in the pond's sediments (and these, too, are worthy of study), in this guide we are going to focus on plankton, those organisms that are drifting in the water. Detailed descriptions of the different types of microbes found in freshwater are provided in this guide in Chapter 3.3: Pond Life. Discussions regarding how to categorize and group these creatures are also included.

The first step in helping students study and appreciate pond microorganisms is to expose them to the diversity of life that can be found in a **single drop of pond water**. We recommend you do this by showing them videos of these creatures in action. There are several brief video clips available from which to choose. We have provided a few of our favorites as a start. The next step would be to have them collect pond water and see these creatures live. Therefore, this activity consists of two parts. The first part is done in the classroom and involves showing the students video clips of pond life. The second part is done both in the outdoors - for the collection of pond organisms - and in the classroom – for the observations of organisms through a microscope. This activity also includes instructions for making a simple plankton net to increase the concentration of microbes in pond water samples.

Activity 4.1, Part 1: Observing the Diversity of Pond Life in Videos

For this part of the activity, the goal is to expose students to the diversity of microscopic life forms found in a drop of pond water.

Materials

- Short video from the internet (see *Resources* list)
- Art supplies, such as crayons, markers, colored pencils, etc.
- Science notebook, Exam Blue Book or sheets of 8.5" x 11" of paper, folded in half

Procedure

1. Show student the video clip(s) of pond microorganisms.
2. Show students the same video clip(s) a second time.
    a. This time ask students to write down questions and thoughts about what is seen in the video in their science notebook.
    b. For more direct student guidance, see "Guiding Questions for Students" (in green box) for suggestions.
3. Show the video clip(s) a third time.
    a. This time freeze the frame on specific creatures. Try to showcase at least one type each major group of organism.
    b. Ask students to draw the creatures, including as much detail as possible.
    c. At this point, do not worry about identifying the creatures.

Activity 4.1, Part 2: Collecting Pond Microorganisms and Observing the Diversity of Pond Life Using a Microscope

For the second part of this activity, the goal is to show students evidence that these organisms do in fact live in a drop of pond water by having them collect the pond water themselves and observe the live organisms through a microscope.

Materials

- Specimen bottle with lid for pond water collection
- Hand lens (several)
- Microscopes (4x and10x magnification works great; 40x also works well)
- Microscope slides and cover slips
- Eye droppers
- Tweezers
- Tissue or filter paper (for absorbing excess water from slide)
- Plankton nets (optional; see instructions below for making a net)

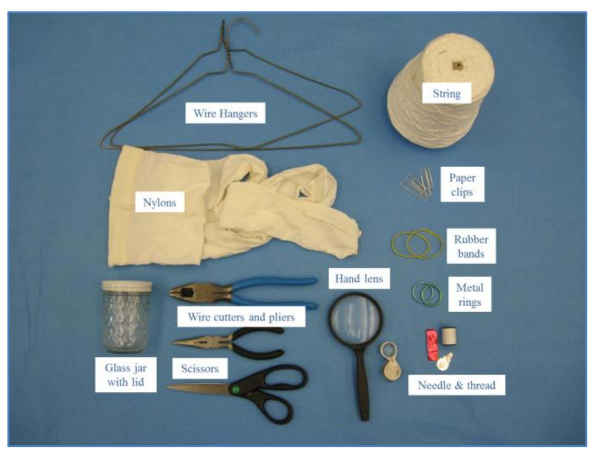
Procedure

1. Instruct students to collect samples of pond water.
    a. Collect water from the surface, including floating aquatic plants or 'scum.'
    b. Collection jars should be completely clean and free of detergents (detergents contain chemicals that kill the organisms).
    c. If you'd like, use a plankton net (instructions on making one below) to increase and concentrate the number of organisms collected.
    d. Collect small bits of algae and aquatic plants, and add to the jar of pond water. Many creatures reside right on the algae and plants.

2. At this point, students can use their hand lens to get a general view of squiggling and squirming life forms. This observation can be done at the pond site. Encourage discussion among students about what they are seeing. Ask if they recognize any creatures from those they saw in the videos.
3. Once back in the classroom, have students prepare **wet mounts** (slides with cover slips) for viewing with a microscope.
    a. Using an eye dropper, place **one drop** of water onto a slide.
    b. Use tweezers to avoid putting fingerprints on the cover slip, then gently lower the cover slip at an angle from one end of the drop of water to the other end.
    c. For more detailed instructions on creating the perfect wet mount, please see the video from **MicrobeHunter Microscopy Magazine** (see *Resources* section). This resource also includes how to deal with highly mobile creatures and provides suggestions for slowing their movements.
4. View sample under microscope. For a quick review of how to use a microscope for yourself or for your students can be found in **Appendix 3**.
    a. The best type of microscope to use for observing pond life is a compound microscope with two or three powers (e.g., 4X, 10X and 40X).
    b. Place slide on microscope stage.
    c. View sample under low magnification at first to find and focus on creatures; then zoom in closer and adjust the focus.
5. Recording observations and data
    a. In their science notebook, have students record as many organisms as they can find in **one** drop of water.
    b. Instruct students to draw and identify as many of their creatures as possible.

Activity 4.1, Part 3: Making a Plankton Net

If you want to increase your chances of collecting a diverse and abundant community of pond microbes, use a plankton net to do your pond water collection. This is an optional activity since you can still collect some organisms by simply collecting water in a jar.



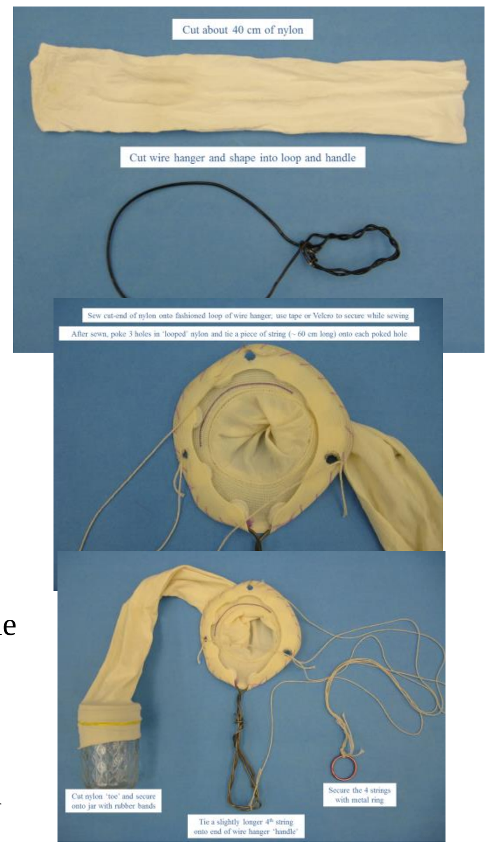
Materials you will need to make a plankton net.

Materials

- Wire hanger
- Old pair of nylon panty hose
- Wire cutters
- Pliers
- Small glass jar
- Scissors

- String or paper clips
- Rubber bands
- Metal rings
- Hand-held magnifying lens
- Needle and thread

<u>Procedure</u>



1. Cut about 40 cm of nylon from one of the nylon legs.
2. Untwist the wire hanger and bend the two ends of the wire together at about half their length to create a loop of about 12-15 cm in diameter.
3. Use the remaining wire to make a handle (see picture at right). You might need to cut some of the hanger off with the wire cutters.
4. Pull the thigh end of the nylon leg over the wire loop, fold it over, and sew the edge over with the needle and thread. Try using Velcro or tape to secure the nylon onto the loop while sewing.
5. Cut three pieces of string about 60 cm long. Poke three holes through the nylon that was sewn onto wire loop. Run each string through the holes and tie them over the wire (see picture at right).
6. Tie a fourth string onto the handle. Gather all the strings and secure them onto a metal ring. This creates the lead with which to drag the net through water. If no string is available, create a 'string' of paper clips instead.
7. Cut the toe portion of the nylon and pull it over the jar opening. Secure with a rubber band. The plankton net is now ready for use.

This net can be used near shore with the handle or can be tossed further out using the metal ring and string. Just submerge the net into the water, and drag it along or hold it still for a couple of minutes. When it is pulled up, check the contents of the jar with a hand magnifying lens.

<u>Extensions</u>

- Using the "Pond Life in Jar" worksheet provided in Appendix 4a, have students try to identify each organism using an identification guide such as found at Microscopy-UK's website or other website, as well as the book, <u>Pond Life</u> by G. K. Reid (see *Resources*). For your convenience, an answer sheet for this worksheet is provided in Appendix 4b.

- Have the students choose three (or more) distinct organisms to draw in detail and on which to conduct background research. Ask them to write about the habits and habitat of the organisms.
- Have students construct data tables of types of organisms and estimates of numbers found.
- Students can also choose at least 4 organisms for which there are good counts and create a bar graph as a class that compares types and counts across multiple samples, i.e., each student's drop of pond water is one sample.
- Ask students to determine the ratio of producers (photosynthetic organisms) to consumers (those that feed on other organisms). To keep it simple, organisms that appear green can be grouped as producers. Those that are not green can be grouped as consumers.
- Challenge students to engineer their own plankton nets by providing them with all the necessary materials in addition to

Resources

1. **Videos:**
   - ♦ **The Invisible World:** short clips of microbes from pond water; no creatures are ID, making this a great video clip to use at the start for simple observations and diagraming; the video contrasts creatures using colors which helps to show the detailed features; please caution students that their water samples will not look like this because of they are not using stains; this would be a very good video to have students draw their catalog of pond creatures from and then check their pond water to see how many of these are seen; toward the end it does show macroscopic insect larvae, tadpoles and a frog (6:45 minutes); http://youtu.be/fLiUg1-BSUI
   - ♦ **Pond Life** by Nikon's Microscopy U: the Source for Microscopy Education, Digital Image and Video Gallery,: we love this webpage's video clips of specific organisms at high magnification; so many of details are visible, allowing students the opportunity to really study them up-close and personal; http://www.microscopyu.com/moviegallery/pondscum/
   - ♦ **Animalcules in Pond Water:** short clips of microbes assembled from the observation of a few drops of pond water; each organism is identified and featured for a few seconds (9:45 minutes); **http://youtu.be/X0hdW37Ue_c**
   - ♦ **Life in a Drop of Water:** includes how to collect water and prepare slide; also does comparison of human cell versus single-celled creatures; survey of major types of microbes found in pond water; the organisms are identified (23:34 minutes); http://youtu.be/_cpBK2t0Yeo
   - ♦ **The Hidden Life in Pond Water**: short clips of microbes assembled from pond water; the visuals in this video are very good; please note that the ID of most critters is included; narrated (4:41 minutes); http://youtu.be/tIMJWWpOrjw

2. **Pond Life** (Golden Guide) by George K. Reid (2001); ISBN-13: 978-1582381305: this book is wonderful, very affordable, and includes basics of pond habitats and pond life identification.
3. **MicrobeHunter Microscopy Magazine,** Making a wet mount microscope slide: this website includes a video showing how best to make a wet mount slide; the first 6.5 minutes are specifically about the best way to make slides for observing pond water. http://www.microbehunter.com/making-a-wet-mount-microscope-slide/**.**
4. **Microbus:** this webpage is a wonderful resource for those just starting out using microscopes, but they also have an advanced section. Go to the info page to choose your level; **http://www.microscope-microscope.org/microscope-info.htm**.
5. **Microscopy-UK:** we love this website because this resource includes many activities and information related to work done with microscopes; **http://www.microscopy-uk.org.uk/index.html**; for *Pond Life Identification Kit* go to http://www.microscopy-uk.org.uk/index.html; for very young students, use http://www.microscopy-uk.org.uk/index.html, which is a virtual pond dip; just click on the critter and information regarding size, where they are found and special notes pops up.
6. Science Net Links, Association for the Advancement of Science (AAAS): brought to you by professional scientists, this website has some ideas for activities related to pond life; check out, Pond 1: Pond Life, http://sciencenetlinks.com/lessons/pond-1-pond-life/ ; and Pond 2: Life in a Drop of Pond Water, http://sciencenetlinks.com/lessons/pond-2-life-in-a-drop-of-pond-water/.
7. Science Learning Network, Inquiry Resources from Museum of Science in Boston (1996): this link is for directions to make a plankton net, similar to what is described here: http://legacy.mos.org/sln/sem/mic_life.html.
8. Molecular Expressions: Digital Video Gallery, Streaming Video and Download - Pond Life: this web page includes a great collection of videos that shows both micro- and macroorganisms; there are videos on common species of protozoans, rotifers, algae, gastrotrichs, nematodes, flatworms, annelids, arachnids, dipterans, crustaceans (including micro crustaceans): http://micro.magnet.fsu.edu/moviegallery/pondscum.html.
9. Freshwater Microscopic Organisms from nwnature.net: includes high-quality pictures of microscopic pond organisms; http://www.nwnature.net/micro_org/index.htm.
10. Digital Learning Center for Microbial Ecology, Michigan State University, Microbe Zoo: Water World, Pond: this website is a good resource for students; it includes very brief descriptions of major groups of organisms, and links to specific organisms within each group; the authors of this site focus on the relationship between the organism and the habitat within the pond that the organism resides; http://commtechlab.msu.edu/sites/dlc-me/zoo/zwpmain.html#algae
11. The Biology Corner: this resource includes worksheets for pond identification, and many other topics and ideas; http://biologycorner.com/worksheets/identifypond.html.

Ch. 4.5 Pond Life – Aquatic Macroinvertebrates

Start GREEN BOX

Student Objectives

- Understand the importance of aquatic macroinvertebrates in the riparian habitat.
- Gain experience collecting aquatic macroinvertebrates, and identifying those that live in Skyline Park pond.
- Describe the types and numbers of aquatic macroinvertebrates collected.
- Gain skills in using metrics to determine water quality based on aquatic macros that serve as biological indicators.
- Explain the roles of pond macroinvertebrates in the pond web of life (transfer of energy).
- Explain that young aquatic insects are very different in how they look and how they behave compared to the adult form.

Guiding Questions for Students

- What kinds of organisms did you observe?
- In comparing body parts of the creatures collected, are there common body parts macros share and body parts that are unique to only one or two macros?
- What differences did you observe between the communities of macroinvertebrates inhabiting the pond compared to those inhabiting the stream? (Naturally, this question will only apply to seasons during which the stream has water.)

End GREEN BOX

Background Information

Aquatic macroinvertebrates need many of the same water quality conditions that trout do in order to survive in the pond. Once the macroinvertebrate community establishes itself in Skyline Park pond, the organisms will continue to live and reproduce as long as the water quality remains healthy. One of the methods scientists use to measure pond, lake, stream or river health is to examine the diversity of macroinvertebrate life within the area. This is because aquatic macros serve as good **biological indicators** of the health of streams, rivers, lakes and ponds.

Biological indicators are certain plants and animals whose presence or absence is an indication of the health in an aquatic environment. Notice that only certain plants and animals are good biological indicators. In other words, since some macros are highly sensitive to pollution, such as the stoneflies and mayflies, and others are highly tolerant of pollution, such as black flies and midges, they can be used as indicators of healthy water. Of course, there are many that fall between these levels of tolerance. Considered together, the ratio of tolerant to intolerant (sensitive) organisms can indicate the overall water quality of a body of water.

There are four general types of aquatic macroinvertebrates that are used as biological indicators: 1) insects; 2) mollusks; 3) crustaceans; and 4) aquatic worms. The insect larvae are those that have six legs, two pair of wings and two pair of antennae. Some of these features are not present in the larval form, and appear only when they are adults after the young go through metamorphosis – more on this soon. The mollusks include animals with shells such as clams, snails, and mussels. The crustaceans include the scuds, sowbugs and crayfish (crawdads). Lastly, the worms include flatworms, leeches, and other segmented annelids.

As mentioned, insects are one group of animal that go through **metamorphosis** as they develop from young to adult. Recall that in complete metamorphosis, the egg hatches into a larva and then into a pupa and finally into an adult. The egg hatches into a nymph and then molts into an adult in incomplete metamorphosis. Also, the young of insects that display incomplete metamorphosis tend to look more like their adult counterparts and are called nymphs. In contrast, the young that display complete metamorphosis look markedly different from the adult forms; their young are called larva (plural larvae). Insects spend most of their lives in the aquatic juvenile stage primarily feeding. The adult stage of an insect's life involves only a brief reproductive role.

Activity 5.1, Part 1: What's That Squirming and Swimming in the Water? Collection and Identification of Pond Macroinvertebrates

For this part of the activity, the goal is for students to collect aquatic macroinvertebrates from the pond and to practice identifying the macros using a dichotomous key.

Materials

- Science notebook, Cfwep.Org's datasheet, Collection and Identification of Pond Macroinvertebrates – Part 1 (see **Appendix 5a**), or sheets of paper
- Pen or pencil
- D-ring for collecting macros
- 3-5 plastic dish tubs
- 3-5 ice cube trays
- Plastic spoons
- Plastic pipettes
- A dichotomous key - we recommend, Key to Life in the Pond, from the University of Madison (see *Resources* at end of this activity for the web link)
- Water monitoring kits (optional; please see Chapter 7: Water Quality for instructions)

Procedure

1. Use a D-ring net to collect pond macroinvertebrates. Be sure to collect from the bank side, the open water, as well as from the bottom of the pond where possible. Do not enter the pond to do the collection; do it from the shore.

2. Place collected organisms into individual dish tubs with enough water to keep them alive for later identification and counting. If small fish or amphibians happen to be gathered in the net, allow students a quick look and return the animals to the pond. Both can be quite sensitive and should be handled with care.
3. Once the samples have been collected, students can use the ice cube trays to sort their macroinvertebrates.
    a. Sorting should be done by basic observation of similarities and differences between macros. Identification with the dichotomous key comes later.
    b. Make sure that students are not focusing solely on the larger organisms. Point out to them the less obvious, smaller organisms for collection.
    c. Students should also be looking for a variety of types of organisms and not simply collecting the same ones.
4. Allow students to sort the macros from the sample tubs for at least 10 minutes or until they have found 100 organisms between all the sample dish tubs.
    a. We suggest students work in teams of two to three per team.
    b. Each student, however, should record the data in their own science notebook as they will need it later for Part 2 of this activity.
5. Once students have collected and sorted their samples, student teams should work through their dichotomous key to identify the organisms in the ice cube trays.
    a. Simply demonstrate to students how to use the key using one or two of the organisms they collected. Students typically learn how to use the dichotomous key quickly.
    b. It is not expected that students identify to the species, genus or even the family taxonomic level. The level of identification present in the dichotomous key is all that is needed.
    c. Have students record their pond organisms in their science notebooks. The students should include the type of organisms and the number of each.
6. Gather all teams together to combine the data to get total numbers and types for the day's collection.
7. Lastly, have students make some general observations about the pond macros and record their observations in their science notebooks.

Activity 5.1, Part 2: What are Those Macroinvertebrates Telling Us? Aquatic Macros as Biological Indicators

For this second part of the activity, the goal is to demonstrate how the community of aquatic macroinvertebrates found in ponds (or other water bodies) can be used to assess water quality using the macros as biological indicators.

Materials

- Cfwep.Org's datasheet, Aquatic Macros as Biological Indicators – Part 2 (see **Appendix 5b**),
- Pen or pencil
- Calculator (optional)

Procedure

1. Review the instructions of the first page of the datasheet with the students. Inform them that they will be calculating two indices for water quality: Biological Index Score (BIS) and EPT which uses insects from the orders, **E**phemeroptera (mayflies), **P**lecoptera (stoneflies) and **T**richoptera (caddisflies; both the case-builders and the net spinners).
    a. If Cfwep's datasheet was not used, instruct students to carefully transfer their data from their science notebook or sheets of paper to Cfwep's datasheet, Collection and identification of Pond Macroinvertebrates – Part 1, into column *A* and to calculate the sum of *A*.
2. Next, instruct the students to calculate values for column *B*.
    a. Students need to multiply the number of organisms found of a particular type by its multiplier in the middle column.
    b. Explain that some creatures might be severely affected by polluted waters while others may be able to tolerate quite a bit of pollution. For example, the stone fly is very sensitive to pollution so they only have a multiplier of "1," whereas, aquatic worms are highly tolerant of pollution so their multiplier is "9." The creatures range from very sensitive (e.g., multiplier of 1), to somewhat sensitive (e.g., multiplier of 3), to somewhat tolerant (e.g., 6), and to highly tolerant of pollution (e.g., 9).
    c. Demonstrate the procedure used to calculate *B* values with one or two examples of the organisms from their science notebooks.
    d. Next, have students calculate the sum of B.
3. To calculate C, students need to bring down to the bottom of the page, the number of stoneflies, mayflies and both caddisflies, and then calculate the sum of those.
    a. Allow each student to complete the first page.
    b. When done, students should have values for *A*, *B*, and *C*.

4. Next, transfer the sums of columns, *A*, *B* and *C* to Cfwep's datasheet, Aquatic Macros as Biological Indicators – Part 2 (see **Appendix 5b**)
    a. Instruct students to transfer their values for *A*, *B*, and *C* from page one to page two.
    b. Review with them the calculations they need to complete in order to obtain their BIS and their EPT score.
    c. Have each student do their own calculations.
5. After all students complete their calculations, instruct them to determine the predicted water quality based on the key of values listed on the data sheet (e.g., water quality 'very good,' 'good,' 'fair,' or 'poor').
6. Have students compare their values to each other and come to consensus on the water quality of the pond.

Activity 5.2: Who's My Mommy? Matching Aquatic Insect Young with their Adult Form
This activity introduces the concept of metamorphosis by having students match larval forms of insects to their adult forms.

Materials

- Laminated pictures of young and adult forms of aquatic insects; plan for each team (2 students) to work with a picture of one young form and the matching adult form
- Wooden skewers or chopsticks for pictures of young forms
- Clear tape or push pins
- Answer key (for instructor)
- If creating your own pictures, a coding system for answer key

Procedure

1. Download and print the aquatic insect pictures from Cfwep.Org's website (http://www.cfwep.org/?page_id=437). (To make it easier to do this lesson more than once, we highly recommend that you laminate your insect pictures.)
2. Securely tape skewers/chopsticks onto the backs of the pictures of the young insects.
    a. If skewers are used, we recommend cutting off the sharp tips of the skewers with pruning shears.
3. Prior to arrival of students, tape or pin pictures of the adult forms on the walls all around your room.
4. Distribute pictures of young forms with the sticks to each pair of students (teams of two are recommended).
5. Tell the students that they will be answering the question, "Who is My Mommy?" and explain that they will be trying to find the adult form that created the young form.
6. Before they begin, tell them to look carefully at the pictures they are holding and then to look around the room at the pictures that are posted. Ask them:

   a. **Question**: What is the biggest difference between the insects you are holding in your hands and the ones that are hung up?
   b. **Answers**: In addition to any observations that they may make, try to lead them to the answer WINGS.
   c. **Question**: What are some things that are similar between the two sets of pictures?
   d. **Answers**: This will depend on the picture, but they may list such features as: eyes, antenna, tails, etc.

NOTE: At this point, you are just trying to get them to practice observation skills, as well as compare and contrast skills.

7. Next, have them go about the room to look for their "mommy."
8. This may take anywhere from 15 to 20 minutes – as long as the kids are having fun with it, let it go on as long as needed.
9. Once several teams have made a decision, ask them:
   a. **Question**: What features did you use to make your decision?
   b. **Answers**: They will likely state that they based their decision on color, presence of legs, wing buds, eyes, etc. This is great! It is exactly the types of cues scientists use, in addition to features pertaining to genetics, physiology, behavior, etc.
10. It is okay for other teams that have not yet made their decision to hear these discussions.
11. When a team gets a correct match, have them stand next to their "mommy" as an aid for others to find their 'moms.'
12. Stress the point that <u>the young really look very different from the adults</u>.
13. End the game and introduce lesson on aquatic insect life cycles, and complete and incomplete metamorphosis.

This activity may not be easy for the students as far as getting the right answers immediately. That's okay – the 'right' answer does not matter – it is the practice of observational skills and compare-and-contrast skills that matters. Adult forms can look drastically different from young forms and it is typically only knowledgeable people that know both the adult and young form of an insect. Aim toward keeping students on task and focusing on what criteria they are using to make their decisions.

<u>Extensions</u>

- If the water quality of the pond is less than "very good," have students write predictions of what they think the problems may be in this system, and how they can verify their predictions. For example, ask them what additional information they would need to verify their predictions.
- Ask students to pick one pollution sensitive organism and one pollution tolerant organism and do research on these creatures. Ask them to explain why one is sensitive and the

other is not. Their explanation should include how the anatomy of the creature predisposes it to either tolerate or be sensitive to pollution.

- Collect macros two to three times over the school year and ask students to compare using graphs how the community changes over time.
- Review with students general invertebrate life stages. Then ask them to conduct in-depth research on a chosen organism in which they would include anatomy, life habits and life stages.
- If water quality data was collected, ask students to 'tell a story' using their water quality data and biological indicator assessments.

Resources

1. **Project Wild - Aquatic** provides many lessons and activities intended for use both in the classroom and in outdoor settings. http://www.projectwild.org/projectwildwebsite/aquatic/
2. **Key to Life in the Pond**, from the University of Madison is the dichotomous key that Cfwep.Org prefers to use because of how easy it is for students of all ages to utilize. http://clean-water.uwex.edu/pubs/pdf/pondkey.pdf
3. **Freshwater Macroinvertebrates from Streams in Western Washington and Western Oregon** is a laminated, colored field guide by Michael R. Clapp. Use this key as a supplement to the University of Madison key to verify the identification of organisms. Unlike the University of Madison key, this one includes information on color, size and distinguishing features. This site also has other helpful information and links related to the Pacific Northwest. http://www.nwnature.net/index.html
4. **Macroinvertebrates of the Pacific Northwest: A Field Guide** by Jeff Adams and Mace Vaughan, published by The Xerces Society. This field guide is printed on durable, water resistant paper. The images are representative of 56 common and readily visible groups of macroinvertebrates encountered in wadeable streams of the Pacific Northwest. General information is included regarding the identification and natural history of each group. http://www.xerces.org/publications/identification-guides/macroinvert-pnw/
5. The **Kentucky Division of Water** has provided educators an online macro identification system that groups macros according to their sensitivity to pollution, and identifies them to Family taxonomic level and provides general descriptions. http://kywater.org/ww/bugs/intro.htm
6. **Nwnature.net** offers wonderful resources including a power point slideshow and ID practice sets. http://www.nwnature.net/macros/resources.html
7. **Aquatic Insect.Net** by Jan Harmrsky has some of the most beautiful photos of aquatic insects, crustaceans, mollusks, mites, worms, as well as hydras and ciliates.These photos show lots of close-up details of these magnificent creatures. http://www.aquaticinsect.net/

Ch. 4.6 Pond Life – Terrestrial Animals

Start GREEN BOX

Student Objectives

- Describe the relationships between commonly found terrestrial animals, including predator-prey relationships.
- Explain how energy is transferred among terrestrial organisms, including plants and animals, by describing one of the many food chains found in Skyline Park.
- Understand how pollution may influence one of the park's food chains, and what happens when one or more organisms are removed from the food chain.
- Make predictions about types of animals that will utilize the pond area.

Guiding Questions for Students

- What food sources are available to terrestrial animals at Skyline Park?
- What types of animals do you expect to see in and near the pond?
- How does energy move through a typical riparian food chain?
- Which animals are considered the consumers? Which of those are the predators?
- What are some of the behaviors that terrestrial animals display?

End GREEN BOX

Background Information

Riparian habitats are home to a diverse number of **terrestrial** (land) animals. In order for an animal to survive and thrive, a habitat must include **conspecifics**, food, water, shelter (cover), and space. Energy moves through a riparian habitat through the plants and animals that inhabit the aquatic and terrestrial ecosystems. Plants and animals feed on each other and are able to survive because of each other. Plants are the **producers** that convert water, carbon dioxide and sunlight (photons) into sugar, releasing oxygen as a byproduct. It is the producers that provide food for the terrestrial animals, and form an essential link in a food chain or the central part of a food web. **Herbivores** feed on plants. **Carnivores** feed on other animals. **Omnivores** feed on both plants and animals. All of these animals are known as **consumers**, meaning they must eat or consume food. They form the links leading out from the primary producer link in a food chain or the outer sections of a food web. More details on the different types of terrestrial animals that are found in a riparian ecosystem and creatures that are expected to inhabit Skyline Park are provided in Chapter 3.3, Pond Life.

Activity 6.1: Crunch Game! The Aquatic Food Chain Game

This activity is a game based on a food chain game called, Chomp: the Fast and Furious Food Chain Card Game by Gamewright. We have modified the Chomp Game so that it is based on a local food chain of the Clark Fork watershed.

Materials

- 5 bald eagle cards
- 10 bull trout cards
- 11 minnow cards
- 8 macroinvertebrate cards
- 5 plankton cards
- 2 pollution cards
- 4 rainstorm cards

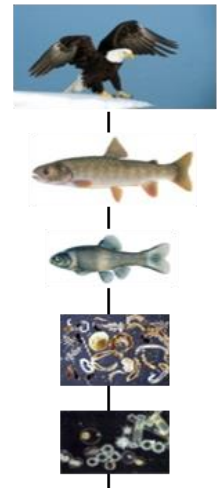
Cards were printed from the following resources:

- Bald eagle: http://mnh.si.edu
- Bull trout: http://www.fs.fed.us/r6/fishing/regional/fishresources/images/bull.jpg
- Minnow: http://fwp.mt.gov/mtoutdoors/images
- Macroinvertebrates: http://www.nzfreshwater.org
- Plankton: http://oceanworld.tamu.edu/students/fisheries/fisheries2.htm
- Pollution: http://www.dostquangtri.gov.vn; http://www.enviroblog.org/pollution.jpg

Procedure

1. Prior to visiting pond and starting content lessons, ask students to describe and depict in their science notebooks what they expect to see around the pond before visiting it. Direct students to give their drawing a title and to clearly label components of their drawing.
2. At the pond, have students reflect and write about how their expectations were met or not met, and what they should and should not have included in their drawing.
3. Discuss the food chain with students. Specifically, talk about the organisms in the **Crunch Game** (bald eagle, bull trout, minnow, macroinvertebrates and plankton).
4. Discuss the effects of pollution on the food chain.
5. Divide the students up into groups of three to five.
6. Explain the cards and the rules (view figures at right for images for cards):

a. **Cards and Crunching Order**



   i. **Bald Eagle** (can crunch Bull Trout, Minnow, Macroinvertebrate, and Plankton)
   ii. **Bull Trout** (can crunch Minnow, Macroinvertebrates, and Plankton)
   iii. **Minnow** (can crunch Macroinvertebrates and Plankton)
   iv. **Macroinvertebrat**e (can crunch Plankton)
   v. **Plankton** (cannot crunch anything)

   Action Cards

   vi. **Rain Storm Card:** Be the first player to slap another card and shout Rain and you get all the cards.
   vii. **Pollution Card:** All cards get set aside.

7. Students play the game.
   a. Become familiar with crunching order (Bald Eagle, Bull Trout, Minnow, Macros, Plankton) and special cards.
   b. Remove explanation cards.
   c. Shuffle the deck and deal the cards equally to each player (place any remaining cards to the side).
   d. In unison, all players turn over the top card in their pile.
   e. The first player to slap the card lowest in the food chain and shout CRUNCH wins the round. The winner collects all the cards that their card can crunch and places them in their discard pile. If your card could not be crunched, place it in your discard pile. **NOTE**: if the lowest card is yours, you cannot crunch.

Example of figures to be used for Crunch cards.

Example:

- Four players turn over a bald eagle, bull trout, bull trout and minnow. Only the bald eagle and the bull trout can crunch, since the minnow is the lowest on the food chain. The player that slaps the minnow card and shouts CRUNCH, wins the round. If the player that slaps the minnow card is the player with the bald eagle card, they would collect all the cards. If the player that slaps the minnow card is the player with the bull trout card, they would collect the minnow card and the other players would put their card in their discard piles.

8. Play continues; all players turn over the next card in their pile.
9. When your pile runs out, shuffle your discard pile, place it face down in front of you and continue playing.

Bad Crunches

- Slap another player's card that is higher on the food chain.
- Slap another player's card that is the same as yours.
- Slap your own card.

If you make a bad crunch, put the top card of your pile face down in the playing area. The winner takes both of your cards along with any other card they crunch. If there is no winner of the round, your card stays in the center and the winner of the next round takes the card.

Possible Scenarios

- All cards turned over are the same.
  - Since you cannot eat your own kind, each player puts their card in the discard pile.
- All but one player turn over the lowest creature on the food chain.
  - The player with the highest creature on the food chain takes all the other cards.
- Both pollution and a rain storm card are played.
  - Pollution prevails and all cards are set aside.

Breaking a Tie

If two or more players crunch at the same time, set aside the cards. Each player then plays the next card in their deck. The first to slap the lowest card and shout CRUNCH wins all the cards. They also get all the cards from the previous round that they could crunch. The ones they cannot crunch are given to the player of the cards to place in their discard pile.

Ending Game

If all your cards get crunched, you are out of the game. Keep playing until only two players have cards. The players then count their cards and the winner is the player with the most cards.

10. After the game is done, talk about the consequence of removing certain cards or creatures and how it might change the overall food chain.

<u>Extensions</u>

- Use pre-test and post-test (same questions) to assess gains in content knowledge prior to and after visit and activity.
- Deepen prior activity by doing research in the classroom on food chains and food webs. Ask students to explain the differences and the relationship between the two.
- Students can cast animal tracks found at Skyline Park. Please see the *Resources* list below for a web link address for casting instructions.
- Students can deepen their knowledge on individual species by doing more background research on an organism of their choice.

- Students can start a nature journal where they draw and make observations of plants and animals found at Skyline Park.

Resources

1. The **United States Geological Survey** (USGS) provides wonderfully, east-to-read instructions for creating animal casts. http://education.usgs.gov/kids/assets/tracks.pdf
2. Instructions for playing the original game, Chomp: the Fast and Furious Food Chain Card Game can be found at http://www.gamewright.com/gamewright/pdfs/Rules/Chomp-RULES.pdf
3. The original game, Chomp: the Fast and Furious Food Chain Card Game by Gamewright is available for purchase at http://www.gamewright.com/gamewright/index.php?section=games&page=game&show=64

Ch. 4.7 Water Quality at Skyline Park

Start GREEN BOX

Student Objectives

- Measure water quality parameters on water samples collected from Skyline Park using various equipment and supplies.
- Discuss the various water quality parameters and how they impact aquatic life.
- Learn about aquatic life and drinking water standards criteria for healthy water.
- Compare and contrast the water quality parameters actually measured against aquatic life standards.

Guiding Questions for Students

- Why is water, and consequently, water quality, so important?
- Based on general observations, what possible impacts could be affecting the water quality of Skyline Park pond?
- Why would we want to collect data on the quality of the water in the pond?
- If the water quality is poor, what would you predict about the kinds of life forms that live in the water?

End GREEN BOX

Background Information

Water is the *stuff of life*. What do we mean by that? We mean that all life on Earth is dependent upon water for its existence. Does this mean that ALL life, no matter where it is in the universe, requires water in order to survive? Since we do not know what is happening in the entire universe, we can only base our answers on what we know about life on Earth. According to our experiences and scientific knowledge to date, the scientific community would collectively claim, "Yes! All life on Earth requires water to exist." Of course, science is all about keeping the doors of inquiry open, so scientists are continually challenging and testing this premise. So far, the consensus is that water is the giver of life and is required for the processes of life to occur.

Organisms on Earth consist of about 70-80% water. What vital functions does water serve in living organisms? All biochemical and cellular processes require water to occur; from metabolism to cellular replication, from nutrient transportation to defecation and urination, from respiration to reproduction, water is required to carry out all these functions. So basic and fundamental it is for water to be involved in these processes that textbooks do not even bother to mention the role of water. It is just treated as the basic medium in which all biochemical reactions take place.

The existence of water, in and of itself, however, does not mean that all life can be supported. While all life requires water to survive, not all water can support all life. In other words, the nature or quality of the water will affect what life is supported. One fascinating local example of the relationship between water quality and the type of life supported comes to us in the form of Berkeley Lake. Berkeley Lake is the body of water that formed after the pumps at the Berkeley Pit, an open pit mine, were shut down and the pit filled with groundwater. We can easily consider this one of the most inhospitable water bodies in the United States. Yet, it still supports life. According to research scientists, Drs. Andrea and Don Stierle, they have identified more than 100 types of microbes in the lake that include bacteria, algae and fungi. Through natural selection and adaptation, these microbes are able to survive in this unique and toxic ecosystem. In fact, some of these microbes have only been found to exist in Berkeley Lake. Some of these life forms do not just survive, but thrive in this environment.

Pond water offers many opportunities for microbes and multicellular animals to survive and thrive. To understand which ones will do well or have the potential to do well in Skyline Park pond, we can start with the study of water quality **parameters –** those factors that can be measured and that help explain the behavior of a system. Here we present two options for collecting water quality data using two different tools: 1) World Water Monitoring Day kits available for purchase; and 2) Vernier Lab Quest units and probes available from Cfwep.Org.

When using the World Water Monitoring Day (WWMD) test kits, there are some strengths and weaknesses in the quality of the data collected. On the positive side, the kits are easy to use, provide quick results, and are comparable to the thousands of other study sites using them. The downside is that the data collected is limited in scope and accuracy, and thus limits what conclusions can be drawn from the data. The Vernier Lab Quest units and probes are more accurate than the WWMD test kits, though they are not intended for professional scientific study. They require more training to use on the part of the teacher and students. Training for teachers may be arranged with Cfwep.Org staff. Notably, this equipment was designed for educational purposes at the elementary and secondary levels. The primary limitation of these units is that they are not always available since Cfwep.Org uses them during the year in their educational programs.

Activity 7.1, Option 1: Water Quality Data Collected with World Water Monitoring Day Kits

This activity is intended to provide students a basic lesson on collecting and interpreting water quality data using. This option focuses on using the World Water Monitoring Day (WWMD) Kits for data collection and contributing student data to WWMD's world-wide database.

Materials

- Science notebooks or Cfwep.Org's datasheet, Water Quality with World Water Monitoring Day Kits (see **Appendix 6**)
- **World Water Monitoring Day** kits for measuring pH, turbidity, temperature, and dissolved oxygen (see *Resources* for ordering information)

- WWMD Fact Sheets for each student (see *Resources*)
- 3 cups for each group of students and/or sealed containers for transport to classroom
- Copies of the USGS Water Quality Primer for each student (optional)
- Most recent WWMD Year in Review Report (optional; see *Resources*)

Procedure

1. Prepare students for the field by reviewing water quality measurements and discussing healthy water quality standards.
2. Review the data collection procedures and have students practice using the monitoring kits. For practice, students can test various solutions, such as tap water, pop (flavored soda), lemon juice, etc.
3. Once in the field, collect water quality data for each of the parameters as per WWMD instructions from at least two to three locations in the park: 1) pond's open water; 2) water near the pond's shore; and 3) water from creeks or standing pools (during runoff season).
   a. Allow several groups of students to collect data at each location in order to have enough samples.
   b. If possible, collect data for several times of day for several days, utilizing the same locations and same times.
4. If uploading data to the WWMD website, have students transfer data from their science notebooks (if that method was used) to the WWMD datasheets.
   a. Take great care to be sure that students fill out the data sheets completely and accurately.
5. Upload Data to WWMD website. Directions for uploading data can be found at http://www.worldwatermonitoringday.org/.
6. Once class data has been collected, review the Water Quality Standards for Montana sheet (see **Appendix 7**) and discuss the values collected by the class.
   a. Are the values for the site within the healthy range?
   b. What factors could be affecting water quality at the site?
7. Using the WWMD year in review report, write average water quality values listed in the report for Montana on the board, along with the average values for one to two other locations outside of Montana.
   a. In classroom discussions, ask students to develop hypotheses to explain observed differences in average values. Some possible hypotheses: differences in local climates (e.g. high elevation versus low elevation sites); differences in population densities; different local or regional environmental laws or practices; different levels of human development.

Activity 7.1, Option 2: Water Quality Data Collected with Vernier Lab Quest Units and Probes - Digital Equipment Borrowed from Cfwep.Org

This activity is also intended to provide students a basic lesson on collecting and interpreting water quality data using; however, the data collection described here is conducted using Vernier units and probes.

Materials

- Science notebooks or Cfwep.Org's datasheet, Water Quality with Vernier Lab Quest Units and Probes (see **Appendix 8**)
- **Vernier Lab Quest Unit** and **probes** for measuring pH, temperature, dissolved oxygen, conductivity, turbidity, and GPS coordinates, as well as assorted solutions for using probes (available from Cfwep.Org)
- WWMD Fact Sheets for each student (see *Resources*)
- 3 cups for each group of students and/or sealed containers for transport to classroom
- **Hach Colorimeter** for measuring dissolved copper (optional; available from Cfwep.Org)
- Copies of the USGS Water Quality Primer for each student (optional)
- Most recent WWMD Year in Review Report (optional; see *Resources*)

Procedure

1. Follow Steps 1 and 2 from activity Option 1 (described above).
2. Once in the field, collect water quality data for each of the parameters as per instructions provided from Cfwep.Org, following procedures under Step 3 above.
3. Once class data has been collected, follow Steps 6 and 7 above.

Extensions

- Using the Pollution Tolerance Index (PTI) Data Sheet (see **Appendix 9**), which shows macroinvertebrates according to how sensitive they are to pollution, have students make predications of what macroinvertebrates might be present based on the water quality parameters measured. For example, if low pH and low dissolved oxygen were measured for the site, one might predict that mainly **Group 3** macroinvertebrates will be present and very few, if any, macroinvertebrates would be found from **Group 1.**
  - Note that after completing the aquatic macroinvertebrate activity (Chapter 4.5), students can go back to see if their predictions were right. If that activity was already completed, they can go back and explain why they found the macros they did as it relates to the water quality data just collected.
- Conduct follow-up or seasonal water monitoring at the same site locations during the same times, and compare the data over time, creating graphs to show trends and patterns.
- Ask students to compare various water-based solutions, such as: a salt water solution; tap water; bottled water; soda; water samples from a local water body; 6) tap water mixed with a tablespoon of dirt; Berkeley Pit water (available from Cfwep.Org); mine **tailings**

mixed with water (available from Cfwep.Org); water samples from students' taps or wells.

- If you found water quality parameters that did not meet aquatic life standards, have students write two to three hypotheses about what may be causing the poor water quality results, and a few paragraphs making suggestions for mitigating the problems. We highly encourage this to be a research paper so that students can make educated guesses regarding their hypotheses.

Resources

1. **Montana Watercourse**'s Volunteer Monitoring Guidebook is an excellent resource for teachers that would like to start a long-term water monitoring program at their school. This guidebook includes lots of information, including scientific background on water and water resources, protocols for developing water monitoring programs, and ways in which the data collected can be shared with other water monitor volunteer groups. The guidebook is free and available as a PDF file. http://mtwatercourse.org/media/downloads/VMGuidebook_2009ReprintFinal.pdf
2. **World Water Monitoring Challenge** is "an international education and outreach program that builds public awareness and involvement in protecting water resources around the world by engaging citizens to conduct basic monitoring of their local water bodies." **World Water Monitoring Day** (WWMD) kits are easy-to-use, kid-friendly, water monitoring kits that are available for purchase. We recommend purchasing the 'class kits' as you'll save quite a bit of money with this option. These kits can be used for data collection of pH, temperature, dissolved oxygen (DO), and turbidity. In addition, students can upload their water quality data to the WWMD site. Datasheets, fact sheets and activity sheets are also available at this site. http://www.worldwatermonitoringday.org/
3. Explore water quality resources at **Cfwep.Org**. Here you will find detailed lesson plans and student worksheets for the WWMD curriculum as well as other resources pertaining to water quality. www.cfwep.org; http://www.cfwep.org/?page_id=439
4. **Project WET** has a wonderful web site full of resources for educators. Their mission is to educate children, parents, teachers and community members about the importance of water and to help empower community action to solve complex water issues. http://www.projectwet.org/
5. **National Extension Water Outreach Education** is an organization representing a collaborative effort of the United States Department of Agriculture (USDA) Cooperative State Research, Education, and Extension Service (CSREES) and other public and private clean and safe water partners to identify Best Education Practices (BEPs), promote the use of BEPs for water-management education, and to improve access to education resources and strategies. http://wateroutreach.uwex.edu/index.cfm

Ch 4.8 Riparian Habitats

Start GREEN BOX

Student Objectives

- Design and create a model of a healthy riparian habitat.
- Describe the importance of biodiversity for riparian habitat health.
- Discuss the usefulness and limitations of models.

Guiding Questions for Students

- What do you think are the best indicators of a healthy riparian habitat?
- Does Skyline Park have healthy or unhealthy riparian habitats?
- If both healthy and unhealthy features are present, which features are healthy and which are unhealthy?
- After finishing the riparian habitat model, discuss the limitations of your model with respect to the real natural habitat and the benefits of your model for understanding riparian habitats.

End GREEN BOX

Background Information

Skyline Park includes three habitats – the wetland habitat, the riparian habitat and the upland habitat – as described in Chapter 3.1. The **riparian habitat** is an especially important habitat because of its importance in maintaining healthy water quality, supporting biodiversity and managing flood waters, to name a few. Many factors, both natural and human, can affect a riparian habitat, and these affects can either have negative or positive impacts on the health of the area. Some examples of negative impacts that can lead to unhealthy conditions include: urban pollution, excessive sedimentation, high water temperatures, and overabundance of aquatic plants.

Activity 8.1: Design and Build Your Healthy Riparian Habitat

For this activity, the goal is for students to design and create a model of a typical, healthy riparian habitat. It is recommended that this activity be done in the classroom because of the many materials involved. Also, the longer students can work on their models, the better. When we do this activity, we do it in combination with associated lessons. We also provide students with about 30 minutes to work on their model each day for three to five days. As the students learn about riparian habitats and their inhabitants, they keep adding to their model. Students are also encouraged to present their model and explain the features they included.

Materials

- Styrofoam – flat, 1-1.5 cm thick pieces are best; square pieces work well to build height
    - Because of the high cost of Styrofoam, Cfwep.Org staff save Styrofoam from packing materials included in items shipped to the office and homes; alternatively, you can contact companies or organizations that receive many large, shipped items and ask them to collect and save them for you.
- Tooth picks (for assembling Styrofoam and other materials)
- Chenille stems (also known as fuzzy wire; previously known as pipe cleaners)
- Pom-poms
- Diversity of colored feathers
- Water-based markers
- Fast-drying, non-toxic glue
- Scotch tape
- Miscellaneous items: streamers, packing foam, old cake decorations, beads, rocks, and more.
- Plastic containers, about the size of dish tubs, with lids for holding and storing materials

Procedure

1. Explain to students that they are going to build a healthy, riparian habitat. If you have already covered this information, ask them what they think they need to include. If not, provide them guidance. Time permitting, they should include the following in their model:
    - ✓ Water
    - ✓ Riparian zone bushes and trees that provide shade for the water
    - ✓ Rushes and sedges at stream banks
    - ✓ Rocky stream bottom
    - ✓ One or more aquatic insects (6 legs originating from thorax; antennae originating from head)
    - ✓ One or more aquatic annelids (worm-like; no legs, no antennae)
    - ✓ One or more aquatic crustaceans (10 legs or more; antennae)
    - ✓ One or more aquatic mollusks (two shells like a clam or one shell like a snail)
    - ✓ One or two trout species; must include adipose fin as well as other fins
2. Show students all the materials that are available to them for creating their model. Inform them that they should use the flat Styrofoam as their base.
3. Review the features that they should include in their model, while asking them why these particular features are important.
4. Students are encouraged to include more than what is listed above as long as they describe the feature or organism and its role in the riparian habitat.
5. Instruct students to keep in mind that they will present their models to the class and describe each feature they included.

6. After the students have completed their model, have them present to their class what they have done and how the features they included work in the system.
    a. If time does not allow for each student to present, they can alternatively write a report about their habitats and its inhabitants.
7. Lastly, after they see a natural, living riparian habitat, students are encouraged to consider the limitations of models versus natural systems, and the usefulness of models for learning. This can be done through small group discussions or in a written report.

Extensions

- Using the resources provided below under the *Resources* section, conduct a riparian assessment activity with your class at Skyline Park.
- Make observations and notes of the riparian area over time, noting the differences between seasonal vegetation and animal use.
- Take students to visit an unhealthy, or damaged, riparian area and have them make observations and comparisons between a healthy and unhealthy riparian habitat. You can then further discuss and relate the types of macros observed with water quality values..

Resources

1. Visit Cfwep.Org for riparian assessment datasheets as well as many other resources. www.cfwep.org.
2. Cows and Fish, also known as the Alberta Riparian Habitat Management Society, is a non-profit society striving to foster a better understanding of riparian habitats. This site has information for all parties who are concerned with promoting and conserving healthy riparian habitats. This resource is very good for building content knowledge, but it also includes activities and riparian assessment instructions. http://www.cowsandfish.org/.
3. For riparian assessments, check out these workbooks at Cows and Fish under these links:
    - ✓ For streams and small rivers: Riparian Health Assessment for Streams and Small Rivers Field Workbook (http://www.cowsandfish.org/publications/documents/StreamsandSmallRiversRHAWorkbook2009.pdf)
    - ✓ For lakes, ponds, wetlands and sloughs: Riparian Health Assessment for Lakes, Sloughs and Wetlands Field Workbook. http://www.cowsandfish.org/publications/documents/LakesandWetlandsRHAWorkbook2009.pdf.
4. Riparian Assessment Using the NRCS Riparian Assessment Method at Natural Resources Conservation Service. Environmental Technical Note No. MT-2 (Rev.1), November 2012. This document focuses on stream and river riparian habitats; however, it provides a good resource for understanding general processes. Review or download this PDF file from: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_050752.pdf

5. Stream Visual Assessment Protocol at Natural Resources Conservation Service, December 2008. http://www.learnnc.org/lp/editions/mudcreek/6395

Ch. 4.9 Native Plants at Skyline Park

Start GREEN BOX

Student Objectives

- Make predictions about which types of plants you will find growing in the upland area versus those found growing in the riparian area.
- Practice identifying the types of plants found growing at Skyline Park using common plant identification keys and/or guides.
- Quantify the diversity of plants in seed dispersal islands and evaluate structural components of the riparian habitat.
- Identify the ground cover, understory and canopy of vegetation at Skyline Park.

Guiding Questions for Students

- What are two reasons that upland plants are different from riparian area plants?
- Why is structural diversity of vegetation important in an ecosystem?
- Why is biodiversity of vegetation important in an ecosystem?

End GREEN BOX

Background Information

At **Skyline Park**, one primary goal has been to provide both biological diversity (biodiversity) and structural diversity of vegetation. One way to promote biodiversity is to encourage native plants, which are plants that evolved and adapted over time to this particular type of environment. For example, seed pod dispersal islands, also called *seed mats* or *seed islands*, are one method used to re-vegetate some of the park's land with native plant species. The seed pod dispersal island used at Skyline Park consists of forb sods, containerized saplings, and seeds. About 28 forb sods of about 1 m^2 were planted, laid in plots of 4 sods each. Each sod includes a mix of native forbs and grasses. The forb sods, along with other vegetation, were grown at Montana Tech's Gless/Sawyer Greenhouse. The sods were then planted. One of these islands can be observed along the western edge of the park near the fence. For more detailed information about these seed islands and the forb sods, please see Chapter 3.6.

Another goal of the park's designers was to promote structural diversity of vegetation. To do this, many of the mature trees and shrubs were left in place, especially near the riparian habitats. In other areas of the park, new trees, shrubs, and other understory vegetation and ground cover have been planted. This will ensure that plants of varying heights and widths are present to provide a diversity of foods and habitats for wildlife. One way to study structural diversity of plant communities is to evaluate three layers of vegetation: the canopy or overstory layer, the understory layer and the ground cover layer.

The **overstory layer**, also called the canopy, is the highest vegetative layer. For our activity, we have defined the overstory as any vegetation over 30 m tall, in order to accommodate for student heights. The primary vegetation found in a healthy overstory is mature trees that fill the sky with leaves. During the growing season, overstory leaves intercept much of the sunlight available to the lower layers. Typically less than 50% of the total amount of sunlight can pass through the overstory to plants in the lower layers. In a deciduous forest, the overstory is typically the last layer to show green in the spring. Since the overstory trees receive sunlight throughout the growing season, they can wait longer to deploy their leaves. This reduces the risk of the young tender leaves being destroyed by a late freeze and allows the lower layers to receive sufficient sunlight.

Just beneath the overstory is the **understory layer**. We define the understory as any vegetation between 0.5 and 30.0 meters tall. The primary vegetation found in the understory includes tree saplings, small shade-tolerant trees, shrubs (bushes), and tall **herbaceous plants**. The understory can be thought of as a tree sapling staging ground. In a mature forest, many saplings can claim enough nutrients and sunlight to reach the understory. However, further growth is typically impractical as the saplings cannot obtain enough additional nutrients from established overstory trees to grow any higher. Therefore, many saplings slow their growth and wait in the understory until a mature overstory tree dies. When a mature tree dies and opens a gap in the overstory, all of the saplings waiting in the understory rush upward. There is typically only room for one new tree in the overstory. All saplings that committed to the growth race, but failed to reach the overstory, gradually weaken and eventually die. The understory typically provides an abundance of food for animals such as deer and bears. In fact, many plants of the understory depend on wildlife digesting their fleshy fruits and distributing seeds in their feces.

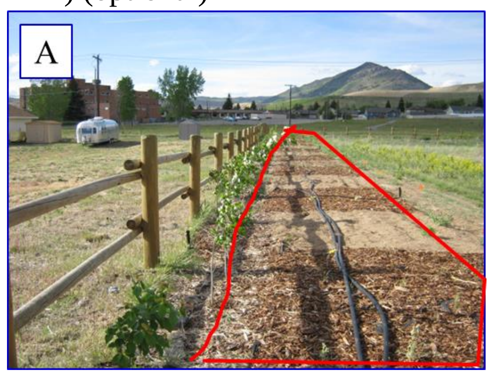
The **ground cover layer** is the layer closest to the ground. We define ground cover as any vegetation from the ground up to 0.5 meters tall. The primary plants of the ground cover include tree seedlings, herbaceous plants, and grasses. Plants of the ground cover are typically the first plants to turn green in the spring. These plants have to deploy their leaves early in the growing season to capture direct sunlight to kick-start their growth cycle. Once the understory and overstory layer plants have deployed their leaves, very little sunlight remains for plants in the ground cover layer; one of the reasons that many plants in the ground cover layer have short life cycles. For our activities, ground cover also includes bare ground and rocks. We also ask that students identify **pollution-tolerant** plants (tufted hairgrass and saltgrass), moisture-loving plants (sedges and rushes) and bare ground with mine **tailings**.

The activities described below include having students evaluate how well the seed mats are doing with regards to supporting biodiversity of plant species. Students will also assess the structural diversity of riparian vegetation. Both activities should help students appreciate the importance of complex plant communities in supporting wildlife biodiversity.

Activity 9.1: Measuring Biodiversity Success of Forb Sods
This activity teaches students the basics of collecting data on plant biodiversity. Here they will focus on the biodiversity of the forb sods which are one component of the seed pod dispersal islands used to re-vegetate some areas of Skyline Park.

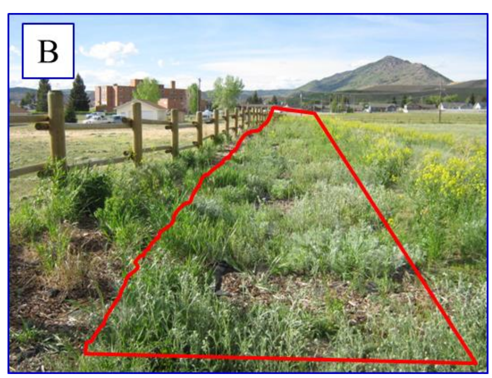
<u>Materials</u>

- Science Notebook, sheets of paper, OR Cfwep.Org Datasheet, "Forb Sod Biodiversity Study – Part 1"
- Pens or pencils
- Meter rulers or meter tape (to form grids)
- <u>List of Native Forbs and Shrubs Planted at Skyline Park</u> (see **Appendix 10**)
- <u>Common Native and Invasive Wetland Plants in Montana</u> (see *Resources*) or other plant identification guide (optional)
- <u>Montana Noxious Weed List (2013)</u> (see **Appendix 11**) (optional)
- Cfwep.Org Datasheet, "Forb Sod Biodiversity Study – Part 2" (see **Appendix 12b**) (optional)



<u>Procedure</u>

1. Locate the vegetation plots that run along the west fence that divides Skyline Park from the Continental Gardens Housing parking lot.
   a) The picture at right shows these plots. The picture labeled, *A*, shows what the plots look like prior to the vegetation filling out the area. You can see square plots of mulch and square plots with brown mesh fabric.
   b) This picture labeled, *B*, shows how the plots look after much of the vegetation has grown and filled in the area.
2. Select an area of study, using the meter tapes or rulers to delineate your study plot. We recommend studying one grid consisting of four 1-m^2 forb sods, so about 4-m^2 study plot.
3. Use Cfwep.Org's Datasheet, "Forb Sod Biodiversity Study – Part 1" or the students' Science Notebooks to collect data.
4. Have students number their first study plot, "Study Plot #1, or identify it in some other way. Next, for just that study plot, ask students to determine if grasses and/or forbs are present, indicating on their datasheets, "Y" for *yes* or "N" for *no*.
   a) If they find grasses in their study plot, ask them to determine if the grasses are



all the same type or different. Be sure they have a good argument for either choice. For example, the leaves look different or are slightly different in color.

b) If they observe differences, ask them to: 1) indicate how many different kinds of grasses they see; 2) determine how many individuals of each grass type they see.
c) If they find forbs in their study plot, ask them to determine if the forbs are all the same or different. If they observe differences, ask them to: 1) indicate how many different kinds of forbs they see; 2) determine how many individuals of each forb type they see.

5. Another option for this activity is to have students attempt to identify the forbs they have observed using a plant identification key. This option is best done when flowers are present since flowers are one of the primary features needed to identify forbs correctly.
   a) Use one or more of the identification guides listed in the *Materials* section or see the *Resources* list.
   b) Students can enter their data in their carefully-labeled Science Notebooks or on Cfwep.Org's Datasheet, **"Forb Sod Biodiversity Study – Part 2."**
   c) For plants that cannot be identified, but are clearly a different type from the rest, have students check weed identification books/lists.

Activity 9.2: Where's the Structural Diversity?

This activity is designed to teach students about collecting data on the structural diversity of riparian habitats and is intended to be used near the ephemeral streams, even if water is not present.

Materials

- Science Notebook or sheets of paper, OR Cfwep.Org Datasheet, "Structural Diversity – Part 1" **and** "Structural Diversity – Part 2"
- Pens or pencils
- Meter rulers or meter tape (to form transects)
- Cfwep.Org's Plant Guide for Students (see **Appendix 13** for quick view of the guide; see *Resources* to print guide)
- Helige-Truog kits OR pH strips and cups for slurries
- Other plant identification guides (optional)

Procedure

1. Set out a tape measure 30 m in length along the greenline (see glossary of Chapter 5) of the stream; it does not matter if water is present in the stream.
    - **a.** If water is present, we recommend setting the line about 0.5 meters from edge of water for safety concerns.
    - **b.** The meter tape should follow the curves of the stream – this is considered "Line 1" (see the figure above). Additional lines can be set sequentially; i.e., another 30 m line following the first *along the greenline*. This would still be Line 1, but Sample 2.
    - **c.** Alternatively, you can set another line 5 meters from Line 1, going away from water. This is "Line 2."

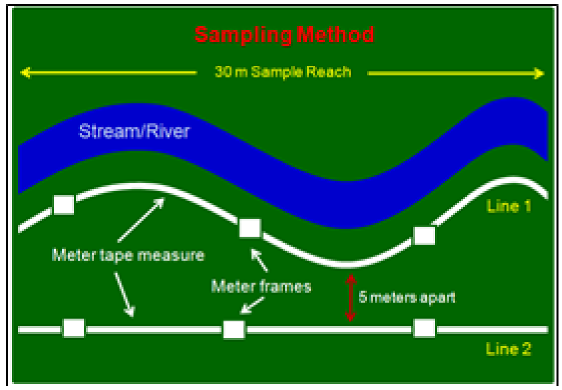


Diagram showing set up to assess the structural diversity.

2. Starting at the 3-m point of the tape and for every 3 meters after that (i.e., 6-m point, 9-m point, etc.), have students determine the vegetation type in the ground cover layer, the understory layer and the overstory layer (see figure).
3. After they decide of the type of vegetation, students should enter their data on the datasheet, <u>Riparian Vegetation Assessment, Structural Diversity</u> (Parts 1 and 2) (see Appendix 13a and Appendix 13b) or in the Science Notebooks. For guidance in how to complete the data sheets, please see Appendix 14a, which shows an example for completing <u>Structural Diversity, Part 1</u> and Appendix 14b, which shows an example for completing <u>Structural Diversity, Part 2</u>.
    - **a.** Only one category of plant type can be scored for each layer.
    - **b.** The plant types and codes for each layer are as follows:

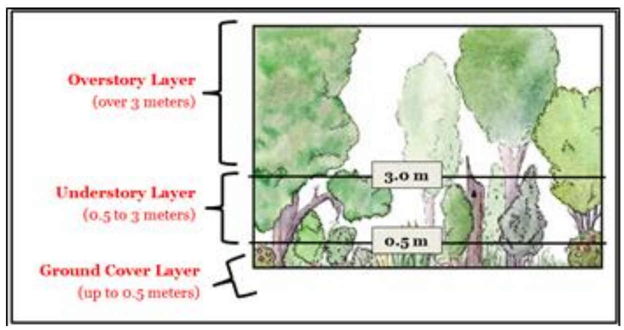


Diagram showing overstory, understory, and ground cover layers.

Ground Cover Layer	
SR	Sedges and rushes
G	Grasses and forbs (good)
P	Pollution tolerant (tufted hairgrass & saltgrass)
B	Bare/disturbed ground
T	Tailings
R	Rock

Understory & Overstory Layers	
C	Coniferous
D	Deciduous
M	Mixed (coniferous and deciduous)
(–)	Understory or Overstory is absent

4. When assessing understory and overstory vegetation along the greenline, instruct students to envision an imaginary line extending vertically from the meter point. If this vertical line intersects the canopy of a shrub or tree, then the data should be recorded as being on the sample point.
    a. If no shrub or tree is encountered, a dash (—) should be placed in the in the column on the data form.
5. Instruct students to leave the tape measures where they are so that you can review their work, especially the points where they indicated bare soil or tailings.
    a. Instruct students to test the pH of the soil to verify which category it best fits.
    b. If the pH indicates acidic soils, the category should be marked as "tailings" and not bare soil.
    c. If the pH is near neutral, the category should be marked as "bare".
6. Following the completion of greenline data collection, instruct students to complete the calculations on the datasheet, Structural Diversity – Part 2 or in their Science Notebooks. (This can also be done later in class).
7. To summarize the data for the three structural layers, have students do the following calculations:
    a. Count the number of hits of living vegetation in the ground cover layer; this excludes bare ground, tailings or rocks; divide each hit by total number of points/stations.
    b. Second, calculate percent of stations (meter points) that had any type of living vegetation at each layer. For example, if six stations had 'SR,' 'G,' and/or 'P,' the ground cover would be '60%' living vegetation (if 10 stations were studied).
    c. Next count the number of hits in the other two layers: understory and overstory. Divide each hit for each layer by the total number of points/stations. For example, if seven meter positions had understory, then Understory would be 70%, and so on.
    d. Healthy levels would be close to the following: ground cover is ~40%; understory is ~40%; and overstory is ~20%. In unhealthy habitats, you may see ~ 90% ground cover, ~10% understory and ~0% overstory. Because there are no leaves in the canopy blocking shade, the low growing plants can take over the habitat.
8. To summarize the data for just the ground cover layer, have students do the following calculations:
    a. Sum the number of hits for each different type of category that was observed.
    b. For example, if the category 'sedges/rushes' (SR) was observed two times, put a '2' next to SR for the appropriate line. (Note: This means 20% of ground cover is sedges/ rushes if there are 10 stations.)
    c. Students should calculate percentages for all ground cover categories.

9. Follow up the data summaries with discussions about healthy and unhealthy structural diversity.

Extensions

- If students identified plants, the student-created plant identification pages can be collected into a class binder for plant identification for the site. Year-to-year comparisons may be valuable to assess which plants tend to be thriving on the site and which plants may not be as successful.
- Have students take pictures of the various plant types during two or all seasons. Teachers can then use the pictures to illustrate plant life cycles.
- If weeds are dominating parts of the site, students can estimate how much area is covered by weeds as compared to the area covered by native plants. Students and teachers can research various weed-control methods to determine which method may be most effective for controlling weeds, and then write a report to submit to Butte Silver Bow County Personnel.

Resources

1. Information on **structural diversity** and **plant layers** was modified from descriptions obtained from the following web page: http://www.mightytrees.com/science/foreststrat.html.
2. The **Montana Weed Control Association** has brought many partners together to develop a wonderful website that focuses on strengthening and supporting noxious weed management efforts in Montana. They include weed identification and management resources, as well as up to date research on noxious weeds. http://www.mtweed.org/index.php
3. **Montana Noxious Weed Education Campaign** is brought to us by the Montana Department of Agriculture, Agricultural Sciences Division, and is a statewide noxious weed awareness and education program. Included in this website is teacher curriculum as well as various weed identification resources. http://www.weedawareness.org/
4. Through the **Montana Department of Agriculture**'s Montana Noxious Weed Education webpages, you can find printable, weed identification cards, in addition to many other resources. http://agr.mt.gov/agr/Programs/AgClassroom/k-8projects/noxiousweededucation/learningandbulletinboard.html
5. One of the best resources regarding native and invasive plant species is available at the USDA's Natural Resources Conservation Service (NRCS), **PLANTS Database**. Here you will find detailed descriptions about various species of invasive and noxious plants and weeds, as well as detailed information on native plants. Check out the topic, *Fact Sheets & Plant Guides* as well as *Introduced, Invasive, and Noxious Plants,* for a listing of all plants. When you find the plant you are looking for, you can click on the (pdf) or (doc) format for a printable version of the *Plant Guide* for that particular plant. http://plants.usda.gov/java/

6. Thomas J. Elpel's book, Botany in a Day: The Patterns Method of Plant Identification, is a plant identification method based on the fact that species of plants within the same family usually have similar characteristics and features. Instead of learning new plants one at a time, students can learn plant identification by looking at plant family patterns.
7. This site developed by **Birmingham Grid for Learning** in the United Kingdom, includes activities to help students familiarize themselves with the life cycle of plants from seeds to dispersal, as well as an online-based plant identification program. This site is great for helping students get an idea of how plant identification is done in the classroom before heading out to the field. Bring in some samples from your backyard or near school, and allow students the opportunity to practice these skills. http://www2.bgfl.org/bgfl2/custom/resources_ftp/client_ftp/ks2/science/plants_pt2/index.htm
8. **Go Botany** brought to us by the **New England Wild Flower Society** is another great online-based plant identification tool. They include a 'simple key,' a 'full key,' and a 'dichotomous key' for helping students learn to identify plants. https://gobotany.newenglandwild.org/
9. **Cfwep.Org**'s Plant Guide For Students, is available on our web site (www.cfwep.org), and is a general identification guide of generalized plants, including a guide to help distinguish between bare ground and mine tailings. It is intended to be used to guide students to complete a study of structural diversity.

Ch. 4.10 Native Plants at Skyline Park

Start GREEN BOX

Student Objectives

- Practice making observations about plants and their pollinators at Skyline Park.
- Describe the types of pollinators that visit plants within the park and how their pollination syndrome works.
- Record data and create graphs regarding the frequency of visits by pollinators for various plants.

Guiding Questions for Students

- Do you think it would make sense for insects to specialize on flower types or not? Why?
- Might it be more advantageous for some species to specialize and not others? (Think of advantages for either strategy, random or specialized.)
- Based on what you know generally about insect vision and pollination, can you predict what flowers pollinators of different species might prefer?
- Might you expect different behavior from bees versus butterflies? Why?

End GREEN BOX

Background Information

As one of the primary producers in the ecosystem, plants play a very important role in natural habitats. Plants, algae, and photosynthetic bacteria are the only life forms that can convert light energy from the sun into food for their metabolic processes. These photosynthetic organisms are also responsible for putting oxygen in our atmosphere, and for providing food and shelter for wildlife and humans. In this activity, our focus will be on the vascular plants found on land.

Activity 10.1: Calling All Buzzers, Flappers, Slurpers and Crawlers: Please Pollinate Me

The purpose of this exercise is to test whether or not certain pollinators visit flowers randomly, or specialize on certain flower species or types, a phenomenon known as pollination constancy Before data collection can begin, students should familiarize themselves with the different flower species available on site, with the help of the teacher. Colors and shapes of each flower species should be defined before any data are taken. For example, if flowers have two colors, such as daisies, as a group you should either decide what the dominant color is for that species, or if it seems appropriate, define it as its own color, white/yellow. Usually though, flower colors will fall easily into the following categories: white, yellow, orange, red, pink, purple, or blue. Shape categories are either radially symmetric or bilaterally symmetric – radial or bilateral for short. Pictured here are a few common pollinators native to Montana: PHOTOS FOR GUIDE IN GRAPHICS FOLDER

- Calliope Hummingbird
- Ant

- ♦ Bee
- ♦ Northern Crescent Butterfly
- ♦ Painted Lady
- ♦ Yellow Swallowtail

Materials

- Science notebook
- Pen or pencil
- Student-created datasheet to record plant and pollinator visiting
- Plant ID guide
- Hand-lens (optional)

Procedure

1. Prior to making observations within the site, teachers should cover the information provided in the background section of the manual. Teachers should also help students create a draft data sheet in their science notebooks for collection of observation data at the site. The data sheet should include the following parameters: plant name, flower color pollinator, number of visits.
2. Instruct students to work with a partner--one will observe and one will be the data recorder.
3. Identify an area of the park to observe pollinators. Students will need boundaries to work within and should be encouraged to narrow their focus somewhat in order to follow the pollinator.
4. Find a pollinator (bee or butterfly, usually) and follow that individual pollinator exclusively for as long as possible.
5. While following the pollinator, the observer keeps an eye on the insect while giving the reporter the data on flower species, shapes, and colors available in the designated areas. There may be several types and colors of flowers in a given study area, but the pollinator may not visit all of the available flowers listed.
6. Observe how far pollinators travel between flowers. Do they go to the next immediate flower, or skip over some flowers? Some of these observations will be more measurable than others, but the observer should give as much information as possible. To do the proper analysis, the minimum information recorded should be flower species, shape, and color, in the order visited.
7. After a set period of pollinator- watching (determined by the teacher, but at least a half hour), reassemble as a class to analyze the data. A separate analysis for each bee or butterfly comparing the numbers of flowers visited of each color available, to the expected number if the insect were choosing flowers randomly. The expected numbers are just the total number of flowers visited, divided by the number of categories.

8. Determine: Did the bee show pollination constancy or not?
To figure it out, we make a table comparing the actual numbers with the expected values, which are calculated based on the proportions of flower types in the patch:

Color	Observed	Expected
White	5	3
Yellow	8	3
Orange	3	3
Red	0	3
Purple	1	3
Yellow	1	3
Total	**18**	**18**

- ✓ You see the two totals in the "observed" and "expected" columns have to be the same. This is because our expected numbers are based on the same number of visits that we observed. Because we need to know the expected values of random visits based on the number of visits the bee actually made (=18 in this example), we divide that number of visits into the total number of categories (=18/6=3). (It's perfectly fine if this number is a decimal, even though it happened to come out evenly in this example.) No matter how many plants are in the particular study are, the totals for the observed and expected columns are the total visits observed. The colors available for visit are determined by observation of the study area. Students should record the types of colors <u>available</u> in the study site, prior to observing a pollinator.

9. Depending on the level of your students, this can be taken a step further and analyzed with a chi-square test, available online here: http://www.graphpad.com/quickcalcs/chisquared1.cfm

- ✓ Simply type in your category names (in this case, colors) and your observed and expected values in the table, and the page will calculate the statistical result for you. A statistically significant result means that these distributions can be stated to be different from each other, meaning the bee is not choosing flowers randomly. After you click the "calculate now" button, you will see the "P value" at the top of the page. In this case, $P=0.009$. The generally accepted cutoff for statistical significance is $P<0.05$, which means that we accept less than a 5% chance that the data we have are from a random distribution. Because $0.009<<0.05$, we are fairly confident that the bee is demonstrating a true preference for yellow.
- ✓ If you don't want to get into statistics with younger children, you can simply look at the values and point out the big differences - in this case, mainly white, yellow, red

and purple. We would say that the bees appear to prefer white and yellow, and avoid red and purple. Thus the conclusion would be that this bee has some pollinator constancy for color.

10. In a given class you will do this test for several individual bees (or other pollinators). Look at all the results together and talk about whether it seems as though bees in general show flower constancy, or not. The same test can be run on shapes to see if shape, independently of color, affects bee behavior.

Questions to ask after data are collected and analyzed:

1. If pollinators appear to show constancy, what might be an explanation for this? You can think about this in two ways. First, there may be an answer that has to do with immediate benefit for the insect. But also think about the long term, i.e. an evolutionary benefit. These two ways of thinking about behavior are known as "proximate" and "ultimate" causes, respectively.
   - ✓ Proximately, it may be more efficient for a pollinator to use a single search image when locating flowers. Insect brains, like human brains, are not good at looking for a lot of things at once.
   - ✓ Ultimately, flower constancy has a benefit for plants, because it ensures transfer of pollen to the right species. This benefits the bees too in the long term because pollination is a mutualistic relationship: if the bees do not properly pollinate the flowers, there will be fewer flowers around in the next generation, which means fewer resources for the descendants of these bees.
2. Do all bees prefer the same color, or do different individual bees favor different colors? Why or why not?
3. What data are missing that might affect our conclusions? This is especially important to discuss if the data are not strong in showing a trend toward color preferences. That is, all analyses such as this rely on certain assumptions. What assumptions are we making in this observational study? Examples of these are assumptions about spatial distribution of flowers, relative numbers of flowers of each color available, relative flower sizes of the different colored flowers, different levels of rewards in different flower species, and interactions with other pollinators.

Extensions

- Ask students to make predictions about which type of pollination syndrome a particular plant in the garden will use based on basic observations.
  - o Reference materials from http://www.fs.fed.us/wildflowers/pollinators/birds.shtml
  - o Students observe the plant types in the study site and predict which type of pollination syndrome the plants require. Students make predictions about what type of pollinator they expect will work with each plant or whether they think

their plant will use an animal pollinator. Once the predictions are made, students defend their reasoning.

- Another possibility for further extension of this activity is to have student choose a plant in the park as their research plant. Each student observes their chosen plant in the garden for color, flower type, and overall plant structure. Students conduct research of their plant from various websites and books, then report back to the group about their findings.

Resources

1. Visit the following additional picture links for common pollinators of Montana:
   - ✓ **Butterflies:**
     - http://www.insectimages.org/search/action.cfm?q=Carterocephalus
     - http://www.insectimages.org/search/action.cfm?q=Lycaena
     - http://www.insectimages.org/search/action.cfm?q=Phyciodes
     - http://www.insectimages.org/search/action.cfm?q=colias
     - http://www.thebutterflysite.com/montana-butterflies.shtml (link to the butterflies of Montana and distribution by county)
   - ✓ **Hummingbirds:**
     - http://fieldguide.mt.gov/detail_ABNUC51020.aspx
     - http://fieldguide.mt.gov/detail_ABNUC48010.aspx
   - ✓ **Black chinned hummingbird:** http://fieldguide.mt.gov/detail_ABNUC45020.aspx
   - ✓ **Calliope hummingbird:** http://fieldguide.mt.gov/detail_ABNUC48010.aspx
   - ✓ **Rufous hummingbird:**
     - http://fieldguide.mt.gov/detail_ABNUC51020.aspx
     - http://www.fs.fed.us/wildflowers/pollinators/birds.shtml
2. For more information about pollination syndromes, visit: http://www.fs.fed.us/wildflowers/pollinators/birds.shtml
3. For more in-depth background and information about plants and pollinators, visit the Cfwep.Org website and our partner website at **www.sciencepartners.info**

CHAPTER 5: GLOSSARY

Abdomen: When referring to the Class Insecta, the abdomen is the posterior of the three body regions of an adult insect. It is composed of 11 segments. The abdomen houses the respiratory, digestive and reproductive systems. On some terrestrial insects, the abdomen (and thorax) have small holes called spiracles that are used for breathing.

Abiotic: Non-living, or never having lived. Abiotic factors would include soil, water, air, temperature, and sunlight. Examples of abiotic things include rocks, a bicycle, and cement.

Abundance: The degree to which individuals of a certain species are present.

Acid: An acid is traditionally considered any chemical compound that, when dissolved in water, gives a solution with a hydrogen ion activity greater than in pure water, i.e., a pH less than 7.0. Put another way, an acid is a compound which donates a hydrogen *ion* (H^+) to another compound (called a *base*). Common examples include acetic acid (in vinegar) and sulfuric acid (used in car batteries). A solution that has a pH less than 7.0 is acidic.

Acid mine drainage (AMD): Acidic water that is created when sulfides in a rock are exposed to air and water and, through a natural chemical reaction, produce sulfuric acid. Water that drains over these rocks can have a low pH, meaning it is acidic. Acidic water can cause cellular damage and interfere with body functions in plants and animals.

Annelids: A type of aquatic macroinvertebrate that has a body formed of numerous rings or annular segments, and without jointed legs. Includes segmented aquatic worms and leeches.

Aquatic: Meaning "of the water", but not the water itself. For example, macroinvertebrates that live within a stream are *aquatic macroinvertebrates*; plants that live and grow within a stream are *aquatic plants*.

Aquatic ecosystem: An ecosystem includes the biotic and abiotic (living and non-living) factors in a given area. In and aquatic ecosystem, this includes the water, soils, and organisms that live in the water. Examples include streams, rivers, lakes, ponds, oceans, swamps, and bogs.

Aquatic macroinvertebrates: Animals without backbones (*e.g., insects, worms, crustaceans, mollusks, etc.*) that are big enough to be seen with the naked eye and that inhabit streams, rivers or other bodies of water during some, most, or all of their lives.

Archaea: Organisms classified in one domain of the three-domain system (Bacteria, Archaea, Eukarya). Archaea are unicellular microbes that lack a cell nucleus and membrane-bound organelles. They differ from Bacteria in their cell wall and protein structure and composition. Archaea are often found living in extreme environments, in which case they are called extremophiles (extreme-loving).

Arsenic: A natural element and poisonous substance present in Earth's soils. It is found in many kids of rock, especially ores that contain copper or lead.

Arthropods: Invertebrate animals of the phylum Arthropoda; these include the insects, crustaceans, arachnids, and myriapods. Arthropods are characterized by a chitinous exoskeleton and a segmented body to which jointed appendages are articulated in pairs.

Bacteria: Organisms classified in one domain of the three-domain system (Bacteria, Archaea, Eukarya). Bacteria are unicellular microbes that that lack a cell nucleus and membrane-bound organelles. Bacteria play an important role in ecosystems as they decompose a wider range of earth material than any other microbe group. Some bacteria can also fix (convert) nitrogen into forms that plants can use.

Bald eagle: A bird of prey found in North America. Found near open bodies of water with abundant food sources. Has a varied diet, but mainly consumes fish.

Basic: In chemistry, a base is commonly thought of as any chemical compound that, when dissolved in water, gives a solution with a *pH* higher than 7.0. Examples of simple bases are sodium hydroxide (baking soda) and ammonia. Bases can be thought of as the chemical opposite of *acids*. A reaction between an acid and base is called neutralization. Bases and acids are seen as opposites because the effect of an acid is to increase the hydronium ion (H_3O^+) concentration in water, whereas bases reduce this concentration. Bases react with acids to produce water and salts (or their *solutions*).

Benthic: Referring to the bottom of a river, stream, sea, pond, or lake, or to the organisms that live there.

Bioassessment: Also called biological assessments, these types of assessments evaluate the condition or "health" of an ecosystem using direct measurements of biological indicators, and integrate the cumulative impacts of chemical, physical, and biological stressors on organisms.

Biodiversity: *Bio* meaning 'life' and *diversity* meaning 'variety.' The variety of living things, such as plants, animals, and other organisms, present in a particular area. The particular area can be as small as one valley, or as large as an entire planet.

Biofilm: Any group of microorganisms that form densely packed communities attached to a hydrated surface.

Biological indicators: *Bio* meaning 'life' and *indicators* meaning 'attracts attention.' Also called bioindicators, these are organisms used as markers of ecosystem quality, especially with respect to pollution. Typically, assessments are based on the presence or absence of particular life forms. An organism's sensitivity to, or tolerance of, pollution often dictates its use as a biological indicator. For a great website that delves deeper into types of indicator species and differing environmental conditions, please visit: http://science.jrank.org/pages/3553/Indicator-Species.html.

Biomass: Biological material derived from living, or recently living organisms. This term often refers to plants or plant-based materials.

Biotic: Living or having lived. Examples of biotic factors in a pond or stream include a frog, fish, leaf, tree, or piece of wood.

Biotic index: A "score" used to indicate the relative health of a water body, judged by the amount and type of aquatic life that dwells in it.

Bug: The true bugs are classified in the phylum Arthropoda, class Insecta, order Hemiptera. Informally, many insects and other arthropods are called *bugs*; some folks even call bacteria *bugs*. Scientifically, only hemipterans are bugs.

Bull trout: A char of the family Salmonidae native to northwestern North America. Bull trout need cold water, clean gravel beds and deep pools. Small bull trout eat insects and as they grow larger their diet consists mainly of fish.

Canopy cover: In relation to plants, canopy cover refers to plants that provide shade and the shade they provide. In riparian habitats, the canopy cover is essential for keeping the water cool during the hot months. Also referred to as the overstory.

Carnivores: Animals or plants (i.e. insect- and invertebrate-eating plants) that obtain their energy mostly or exclusively by feeding on animal tissue through predation or scavenging. Examples include large wild cats such as lions and tigers and the Venus fly-trap.

Colloid: Substance that consists of particles dispersed throughout another substance. Are too small to see using an ordinary compound light microscope, but cannot pass through a semipermeable membrane.

Colony: A group of one species of animals or plants growing or living in one place, typically for mutual benefit.

Colorimeter: A device that directs a beam of light of a particular wavelength through a solution and measures the amount of light that is absorbed by the sample.
Compost: Organic matter that has decomposed.

Conductivity: Electrical conductivity or specific conductivity is a measure of a material's ability to conduct an electric current. The conductivity of a solution of water is highly dependent on its concentration of dissolved salts and sometimes other chemicals, which ionize in the solution. Electrical conductivity of water is used as an indicator of how salt-free or impurity-free the sample is; the purer the water, the lower the conductivity. Conductivity is measured in units called microSiemans per centimeter (μS/cm).

Coniferous plants: Trees and shrubs that produce seeds in cones (gymnosperms) and have needle or scale-like leaves. Most coniferous plants are evergreen, meaning they have green leaves on the tree all year. The leaves are shed, but not all at once. One common exception found in Montana are the larch trees (Western and Alpine larch), which shed their leaves in fall.

Conspecifics: Another organism of the same species.

Consumers: Organisms that obtain their energy from other organisms through ingestion (eating) and digestion, in contrast to producers.

Coordinates: Geographic coordinates are represented by numeric values that correspond to a particular position on a map. Coordinates are oriented by the cardinal directions of North, South, East, and West.

Copper: A chemical element used as a conductor of heat and electricity amongst other things.

Crustaceans: An invertebrate animal with several pairs of jointed legs, a hard, protective outer shell, two pairs of antennae, and eyes at the ends of stalks (e.g., scuds, crayfish or crawdads, and sowbugs).

Culture: In biology, the development and nurturing of bacteria, tissue cells, etc. in conditions suitable for growth, often an artificial medium containing nutrients.

Deciduous plants: Trees, shrubs and non-woody (herbaceous) plants that produce seeds through flowers rather than cones. Deciduous trees and shrubs shed their leaves seasonally, typically in fall. Deciduous non-woody plants die back in fall.

Dichotomous key: A tool used in plant or animal identification. The dichotomous key is a series of questions, and each question is a choice between two characteristics. The identity of an organism is determined through eliminating characteristics that do not apply to a given specimen.

Dissolved oxygen: A relative measure of the amount of oxygen that is dissolved or carried in a liquid. It can be measured with a dissolved oxygen probe such as an oxygen sensor in liquid media, usually water. In aquatic environments, oxygen saturation is a relative measure of the amount of oxygen (O_2) dissolved in the water. Dissolved oxygen is measured in standard solution units such as milliliters of O_2 per liter of solution (ml/L), or milligrams of O_2 per liter of solution (mg/L, also referred to as parts per million or ppm). Dissolved oxygen is used as a *water quality indicator*. Montana streams and rivers typically have a DO concentration of about 6-10 mg/L. Lower DO values can harm trout populations. DO levels lower than this range could also indicate pollution; for example, sewage effluent, or too many nutrients in a stream cause algae to grow in abundance, and the algae take up the oxygen during respiration (during dark hours). For more information, visit http://www.worldwatermonitoringday.org/.

Divide: A ridge of high land that separates one watershed from another watershed.

Domain: Highest classification rank of organisms. There are three categories: Eukarya, Bacteria, and Archaea.

Duff: Layer of the forest floor containing partly decayed organic matter.

Ecosystem: A community of plants, animals and microorganisms that live, feed, reproduce and interact in the same area or environment. Also, a natural unit consisting of all plants, animals and microorganisms (biotic) in an area functioning together with all of the non-living, physical (abiotic) elements of the environment.

Ephemeral: Short-lived; in reference to streams/creeks, means that water is only present in creek seasonally.

EPT Index: E-P-T is an acronym for **E**phemeroptera (mayflies), **P**lecoptera (stoneflies), and **T**richoptera (caddis flies). These three insect orders are moderately to very sensitive to pollution, and are used as indicators of water quality. The EPT Index uses the ratio of their abundance to total abundance to determine a relative abundance.

Eukarya: Domain of life containing eukaryotes, which are organisms that have membrane-bound organelles in their cells. Kingdoms of life within this domain are: plants, animals, fungi, and protists.

Filter feeder: An animal that filters and feeds by straining suspended matter and food particles from water.

Food chain: A linear depiction of the transfer of energy in which organisms in an ecosystem are grouped into nutritional levels, and are shown in succession to represent the flow of food energy and the feeding relationships between them. Typically represented by arrows; for example, trees and shrubs (producer) → giraffe (herbivore) → lion (carnivore). Most food chains have only about four to five links. If one animal or plant food disappears, other animals in the food chain may be impacted.

Food web: Used to depict a more realistic representation of energy transfer within an ecosystem as compared to food chains; a food web is many food chains linked together. It is more realistic because it shows the essential producers of energy at its center, and the consumers radiating out from it and interacting with each other as well as the center.

Forbs: Herbaceous (non-woody stems) flowering plants that are not graminoids (grasses, sedges and rushes). The leaves of forbs are broader than those of grasses. Most wildflowers, herbs, succulents and ferns are considered forbs.

Fungi: Simple, aerobic organisms that are able to break down resistant materials such as cellulose. They dominate in acidic, sandy soils, and in fresh organic matter.

Gills: A gill is an anatomical structure found in many aquatic organisms.It is a respiration organ whose function that extracts oxygen from water and excretes carbon dioxide. The microscopic structure of a gill is such that it presents a large surface area to the external environment.

Graminoids: Herbaceous grasses (family Gramineae or Poaceae), and grass-like plants such as sedges (family Cyperaceae) and rushes (family Juncaceae).

Grasses: Plants having narrow leaves, hollow stems, and clusters of very small, usually wind-pollinated flowers. Grasses (family Gramineae or Poaceae) include many varieties of plants grown for food and ground cover. Wheat, maize, sugar cane, etc., are all grasses.

Greenline: The first strip of vegetation along the stream. Also, the first perennial vegetation that forms a linear grouping of community types on or near the water's edge. Most often, it occurs at or slightly below the bankfull stage – the water level of steams or rivers when they are at their fullest.

Ground cover: As used by Cfwep.Org, the layer of vegetation (plants) that extends from the ground to 0.5 meters high. Typically, ground cover consists of grasses and forbs, but can also include very small shrubs and tree seedlings. The plant community of the ground cover layer that is of interest to us includes sedges, rushes, grasses, forbs, pollution tolerant species (tufted hairgrass and saltgrass), bare/disturbed ground, and rocks.

Habitat: The environment where an organism, or groups of organisms, normally live or occur (like a riparian habitat). The place where an organism is most likely to be found and where they tend to live, obtain energy, and reproduce.

Head: When referring to the Class Insecta, the head bears the antennae, eyes and mouthparts. Insects use the antennae to detect odors or as tactile (touch) organs. Antennae are very variable in form and size. Mouthparts also vary depending on the feeding behavior of the insect; mouthparts can be used for chewing, sucking, rasping, or can be undeveloped.

Herbaceous plants: Also known as non-woody plants, because the stems of herbaceous plants remain green throughout the growing season, never becoming woody. These plants are typically found in the ground cover layer, but tall grasses can extend into the understory layer.
Herbivores: Animals that consume plant material as their primary source of energy. Also, any animal that feeds mostly on grass and other plants; horses and cows are herbivores.
http://science.jrank.org/pages/3553/Indicator-Species.html

Hydrophilic: From the Greek *hydros* which means water, and *philia* which means friendship or loving; used here with respect to riparian zone plants which require lots of water to survive and thrive, so they are found along the banks of water bodies.

Inorganic: Composed of matter other than plant or animal.

Insects: All insects have: six legs, at one point in their lives; three body regions or parts; one pair of antennae; and one or two pairs of wings at maturity; wing buds may be present in young insects. Some insects such as ants, except queen ants, and fleas do not have wings.

Insect body parts: Insects have 3 body parts: the *head*, the *thorax* and the *abdomen*. Please see each for exact definitions of each.

Ion: An electrically charged atom or molecule. A positive or negative charge occurs because the number of protons (positively charged) and electrons (negatively charged) in an atom or molecule is unequal.

Iron pyrite: Also known as fool's gold due to its similarity in color and shape, is not an element or metal but an ore. In Butte, waste rock contains iron pyrite. Iron pyrite reacts with oxygen and water to form sulfuric acid and rust, and is associated with *acid rock drainage*.

Kingdom: A group of closely related phyla. The second highest taxonomic rank below domain.

Larva (pl. larvae): A larva is a distinct juvenile form many animals undergo before metamorphosis into adults. Animals with indirect development such as insects, amphibians, or cnidarians typically have a larval phase in their life cycle.

Layers of the plant community: As defined by Cfwep.Org and others, the layers include: ground cover layer (0-0.5 m), understory layer (0.5-3.0 m), and the overstory (canopy) layer (over 3.0 m).

Legend: An explanatory list of the symbols on a map or chart**,** also called a key.

Loam: Soil composed of mostly sand, silt, and clay good for growing plants because they contain more nutrients, moisture, and humus.

Macroinvertebrates: Animals without backbones, for example, insects, worms, crustaceans, mollusks, etc., which are large enough to be seen with the naked eye.

Metamorphosis: A biological process by which an animal develops from an immature (young) to a mature (adult) individual. The main difference is the ability of the adult to sexually reproduce; immature animals by definition cannot yet reproduce. Several other physical, biochemical and behavioral changes also occur, sometimes leading to drastic differences between adults and immatures.

Microbes: Microscopic organisms, or those living creatures that cannot be seen with the naked eye and require a microscope or a magnifying lens to see. Also known as microorganisms.

Microhabitat: In ecology, a very small, specialized habitat, such as clumps of grass, shady areas of trees, space between rocks, pools of water, and others. It is the smallest part of the environment that supports distinct flora (plants, bacteria, algae) and fauna (animals).

Microorganism: A microscopic organism, by definition, not visible to the naked eye and requiring a microscope to view, such as a bacteria, fungus, protozoa or virus. Also known as microbes.

Microscope: A compound light microscope is a scientific tool that includes: an objective lens, stage, eyepiece, arm, and fine and course focus adjustment knobs. Microscopes are used to see microscopic organisms (microbes) and other objects invisible to the naked eye.

Minnow: Any of many species of small fish. Minnows are an important food source for larger fish and other animals.

Mollusks (alternate spelling molluscs): A highly diverse phylum of bilaterally symmetrical invertebrates with a soft unsegmented body, a mantle, and usually a protective shell in one, two, or three pieces (e.g., clam, snail, mussel, octopus, squid, cuttlefish).

Native plants: Plants that under natural conditions survive and thrive in a particular habitat or environment. Native plants are adapted to their natural environment, and have coevolved with other inhabitants of that environment.

Neutral: In pure water at 25 °C, the concentration of H^+ equals the concentration of hydroxide ions (OH^-). This is defined as "neutral" and corresponds to a pH level of 7.0.

Nonpoint source pollution: Nonpoint source (NPS) pollution is water pollution affecting a water body from diffuse sources, rather than a point source that discharges to a water body at a single location. NPS pollution may derive from many different sources with no specific solution to rectify the problem, making it difficult to regulate. According to the U.S. Environmental Protection Agency (EPA), nonpoint source pollution is the leading cause of water pollution in the United States today, with polluted runoff from agriculture the primary cause. Other significant sources of runoff include hydrological and habitat modification and storm water runoff. Another important cause of NPS pollution is urban runoff of items like oil, fertilizers, and lawn chemicals. As rainfall or snowmelt moves over and through the ground, it picks up and carries away natural and human-made pollutants. These pollutants are eventually deposited into bodies of water.

Omnivore: An animal that obtains its energy from feeding on both plants and animals. Humans and some rodents are examples of omnivores.

Organic: Of or relating to an organism or living entity.

Organism: A living thing that can function on its own, such as a plant or animal.

Overstory: As used by Cfwep.Org, vegetation (plant) layer that extends over 3 meters high. Overstory is typically made up of mature trees, however, some shrubs could grow tall enough to fit into the overstory. Also referred to as a canopy.

Parameter: One of a set of measurable factors such as temperature and pressure; can be varied in an experiment. Also any of a set of physical properties whose values determine the characteristics or behavior of something, such as parameters of the atmosphere: temperature; pressure; and density.

Petri dish: A shallow cylindrical glass or plastic dish with a lid used to culture cells.

pH: The measure of the *acidity* or *alkalinity* of a solution. It is formally a measure of the activity of dissolved hydrogen ions (H^+). In solution, hydrogen ions occur as a number of cations including hydronium ions (H_3O^+). In pure water at 25 °C, the concentration of H^+ equals the concentration of hydroxide ions (OH^-). This is defined as "neutral" and corresponds to a pH level of 7.0. Solutions in which the concentration of H^+ exceeds that of OH^- have a pH value lower than 7.0 and are known as *acids*. Solutions in which OH^- exceeds H^+ have a pH value greater than 7.0 and are known as *bases* (or alkaline solutions). pH is used as a *water quality indicator*. The typical pH of Montana streams and rivers is about 7-8.8.

Phylogenetic: Of or relating to the evolutionary history of a kind of organism.

Planimetric maps: A type of reference map that display public information. For example, subway routes, the layout of a city building, walking trails, stream restoration plans, are often called planimetric.

Plankton: The community of passively floating, drifting, or somewhat motile organisms occurring in the upper layers of bodies of water; primarily comprised of microscopic algae and protozoa. These organisms include phytoplankton, zooplankton, bacterioplankton, and virioplankton. Aquatic macroinvertebrates and small fish consume and depend upon plankton for food.

Point source pollution: A point source of pollution is a single identifiable localized source of air, water, or other form of pollution. The sources are called point sources because in mathematical modeling, they can be approximated as a mathematical point to simplify analysis. Examples include water pollution from an oil refinery wastewater discharge outlet, or air pollution from the Anaconda smelter stack.

Pollution: The introduction of contaminants (chemical, trash, etc.) into an environment that cause harm or discomfort to the ecosystem (physical system and/or living organisms).

Pollution tolerance: The ability of a plant or animal to survive under adverse conditions. Pollution tolerance is directly related to how *tolerant* or resistant the organism is to pollution and/or other environmental impacts. Examples of pollution-tolerant macroinvertebrates are blood midges and leeches. Examples of pollution tolerant grasses include tufted hairgrass and saltgrass.

Pollution tolerance index (PTI): An index of invertebrate counts used to assess presence or absence of pollution-intolerant (pollution sensitive) and pollution-tolerant (pollution insensitive) species. In general, a high PTI score indicates presence of more sensitive species and better water quality.

Predators: An organism that lives by preying on other organisms.

Primary producers: Living organisms that create energy by converting light (photons), water and carbon dioxide into sugar, and release oxygen as a byproduct; they do not consume (eat) other organisms for their energy. Primary producers are essential for *consumers* to exist, and form the center of all *food webs* and the foundation of all food pyramids.

Prokaryote: A unicellular organism lacking a nucleus and membrane-bound organelles.

Protista: A *eukaryotic* organism having a nucleus, but lacking other features specific to plants, animals, or fungi.

Raptorial feeder: Feeding on large prey, typically as large as can be handled; compare to filter feeder that takes small prey and is typically non-selective.

Reference frame: A system of coordinates used to show the orientation of a map.

Reference maps: These types of maps show where objects are located in the environment. They are called *reference maps* because they are used as a reference to find specific sites. A road map is a reference map used by travelers to find roads and destinations.

Riparian: A riparian zone or riparian area is the interface between land and a stream, river, lake or other body of water. Riparian zones are significant in ecology, environmental management, and civil engineering because of their role in soil conservation and biodiversity, and the influence they have on aquatic ecosystems. Riparian areas are ecologically diverse and contribute to the health of an aquatic ecosystems by filtering out pollutants, preventing erosion, stabilizing stream banks, providing shade, and supporting biodiversity. In places that have dry seasons, like Montana, riparian vegetation is only found in the riparian zone.

Riparian habitat: Includes aquatic ecosystem, riparian zone, and flood plains and wetlands. Healthy riparian habitats filter water, stabilize stream banks, support biodiversity, recharge groundwater, and keep waters cool through shading.

Rush: Grass-like or sedge-like plant growing in very moist soils. Rush stems are solid and round-shaped. The stem is the primary way to distinguish rushes from sedges and grasses. Flowers of the rush are typically located along the top part of the stem.

Saltgrass (*Distichlis spicata*): A specific type of pollution tolerant grass that is able to tolerate soils that are heavy in salts, such as copper salts.

Scale: The relationship between the actual size of a place and its size as shown on a map.

Sedge: Grass-like or rush-like plant growing in very moist soils. It has narrow grass-like leaves and spikelets of inconspicuous flowers. Features distinguishing members of the sedge family from grasses or rushes is that members of the sedge family have triangular stems (with occasional exceptions), and their leaves are spirally arranged in three ranks (grasses have alternate leaves forming two ranks).

Seed pod dispersal islands: Also known as *seed mats* or *seed islands*. Sod mats of native plant species that are grown under controlled conditions and known to naturally have close associations with each other. They are similar to grass sod or grass mats because the plants are held together by the roots, and/or a thin, organic material. Similar to grass sod, seed pod dispersal islands are used to establish an area more quickly than attempting to re-vegetate from seeds; they also help to minimize soil erosion.

Segmented: When speaking of animals, having the body divided into successive *metameres* or segments, as in earthworms or lobsters.

Shrub: A woody plant, relatively low (smaller than a tree), with several stems arising from a single base; a bush.

Soil: The mixture of minerals, gases, liquids, organic matter, and organisms that can support plant life.

Soil horizons: Layers running parallel to the soil surface that make up soil types. The layers range from rich, organic upper layers to underlying rocky layers and are typically classified using color, particle size, and texture.

Soil profile: A vertical section of the soil from the ground surface downwards to where the soil meets the underlying rock; showing the different horizons or layers.

Soil types: The different sizes of mineral particles (finely ground rock) in a particular sample.

Solution: A mixture of two or more similar substances, which may be solids, liquids, gases, or a combination of these.

Structural diversity: In relation to plant communities, structural diversity refers to having plants of varying heights and shapes, such as short ground cover, tall grasses, full bushes and shading trees. In healthy riparian habitats, we tend to see high structural diversity which lends to better wildlife habitat surrounding streams and rivers. We look at three layers in structural diversity: 1) ground cover, 2) understory and 3) overstory. In general, the ground cover consists of grasses, sedges, rushes and forbs; understory consists of shrubs and tree saplings; and overstory consists of mature trees.

Tailings: Crushed iron pyrite resulting from the mining process; considered a toxic waste. Tailings are fine-grained wastes that can be easily carried off and dissolved by water, forming sulfuric acid. Tailings also contain various heavy metals such as iron, lead, zinc, copper, and arsenic.

Taxonomy: The classification in which different living things, organisms, that are related by putting them into groups.

Terrestrial: Living or growing on land, as opposed to in or on water. Terrestrial animals live predominantly or entirely on land.

Thematic maps: These types of maps show information about locations by documenting how events or objects are distributed across the landscape. They are called *thematic maps* because they focus on a specific theme. A map of the temperatures around Montana on a given day is an example of a thematic map.

Thorax: When referring to the Class Insecta, the thorax is the middle of the three body regions of an adult insect. It is composed of three segments called (from head to abdomen), the prothorax, the mesothorax and the metathorax. It bears three pairs of legs – one on each segment – and usually two pairs of wings, if the wings are present at all. Some insects have only one pair of wings. In some insects, spiracles can also be found on the thoracic region (as well as the abdominal region), which are used for gas exchange.

Topographic map: A type of reference map that includes information about locations and elevations.

Total maximum daily load (TMDL): TMDL is a regulatory term in the U.S. Clean Water Act (CWA), describing a value of the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. This process incorporates both point source and nonpoint source pollutants within a watershed.

Tree: A woody plant with an erect, perennial trunk and a fully-formed crown of foliage. At maturity, diameter of the trunk should be at least three inches at breast height and achieve a total height of at least 12 feet.

Tufted hairgrass (*Deschampsia cespitosa*): A specific type of pollution-tolerant grass that is able to tolerate low pH soils. It grows in bunches with "tufts" of seed heads.

Turbidity: Literally means *cloudy*, and typically refers to a solution made cloudy by sediment or insoluble matter in a solution- the cloudier the water, the higher the turbidity. Cloudiness is caused by suspended matter in water such as clay, silt and organic matter, and microbes. Turbidity is determined by measuring the amount of light that can pass through water. Turbidity is used as a water quality indicator and the unit of measure is a nephelometric turbidity unit (NTU). Sources of increased turbidity in water include wastewater discharge, natural resource extraction, and bank erosion. Water that looks clear will usually have NTU < 2; water that looks cloudy will have NTU between 2 and 10; water with NTU > 10 is very muddy, and little to no light can penetrate the water.

Understory: As used by Cfwep.Org, the layer of vegetation (plants) that extends from 0.5 m to 3 m high. Typically, this layer consists of shrubs and shorter trees, but may include some high-growing, deciduous, herbaceous plants, such as grasses.

Water cycle: Earth's water is always moving, and the water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth. The water cycle is truly a "cycle," with no beginning or end. Water can change states among liquid, vapor, and ice at various places in the water cycle, with these processes taking as little time as the blink of an eye and as long as millions of years.

Watershed: An area of land that drains or sheds its waters into a common network of streams or rivers. Watersheds are separated from each other by ridges of high land called divides.

Weathering: The process of rocks, minerals, and soil breaking down when subject to the forces of the atmosphere and water.

Wetland bench: A shallow area or 'bench' that is filled with hydrophilic plants. Wetland benches filter and trap algae growing in the pond.

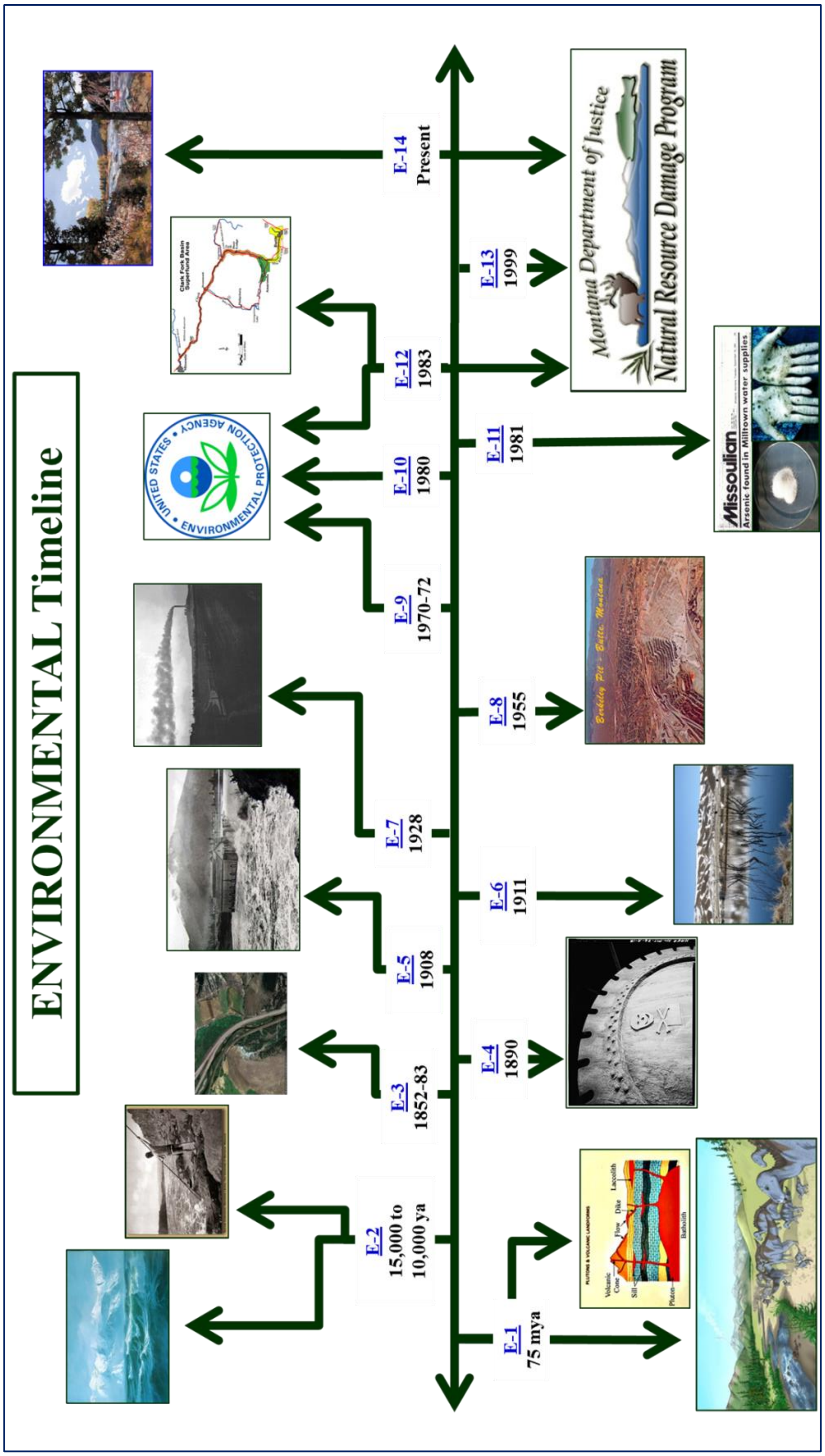
CHAPTER 6: APPENDICES

Appendix 1a: Example of an **Environmental/Natural History Timeline.** The numbers of each event (e.g., E-1, E-2, etc.) corresponds to the point on the graphic-based timeline shown in Appendix 1b. This example can be used with Activity 2.2: Create a Timeline for this Area.

Environmental/Natural History Timeline		
E-1.	**75 million year ago**	Dinosaurs, like Maisaurus, "Montana's dinosaur," ran free. A volcanic uprising, known as a batholith, deposited vastly rich deposits of minerals and metals into veins over a mile deep from the surface of a large area in southwest Montana, with present-day Butte at the batholith's center.
E-2.	**15-10,000 years ago**	The era of the last Ice Age. Glacial Lake Missoula, an inland sea larger than present-day Lake Erie and Ontario combined, stretched from an ice dam in Idaho all the way across much of western Montana. The dam broke near the end of the age, carving landscapes from Montana all the way to the Pacific. Salish Indian culture tells of this "Great Flood" in its creation stories.
E-3.	**1852-1883**	The Clark Fork watershed begins to undergo a series of changes as transportation routes cut-off the river's access to many of its floodplains and valleys.
E-4.	**1890**	Citizens in Butte pass the nation's first environmental law, an air quality ordinance banning the "open roasting" or crude smelting of ores within the city's limits. Natives who once utilized the Deer Lodge Valley for gathering plants are no longer able to do so because of the changes to the vegetation caused by smelting and mining.
E-5.	**1908**	In June of this year, the Clark Fork River basin experienced the largest flood ever recorded by scientists in our area. Over a month of consecutive rain, one large storm, and mountain snow melt resulted in natural disaster.
E-6.	**1911**	The Upper Clark Fork River's structure and natural character further change when mining companies build a large settling pond near Warm Springs to trap sediments and wastes flowing downstream.
E-7.	**1928**	The U.S. Forest Service begins a series of land trades with the Anaconda Copper Mining Company. Anaconda traded timber lands it owned in western Montana for land near its Anaconda smelter that the Forest Service claimed was damaged by smelting practices.

Environmental/Natural History Timeline		
E-8.	**1955**	The amount of disturbance to the headwaters of Silver Bow Creek and to the Clark Fork River vastly increased when mining practices changed in Butte from underground to open pit mining. The Berkeley Pit is born.
E-9.	**1970-1972**	US President Richard Nixon establishes the Environmental Protection Agency (EPA) in 1970 to safeguard our nation's air, land and water. A new Clean Air Act is passed in 1970; the federal Clean Water Act was passed in 1972.
E-10.	**1980**	The federal Superfund Law is passed, authorizing EPA to identify parties responsible for contamination of abandoned industrial sites and to compel those parties to clean them up to protect public and environmental health.
E-11.	**1981**	High levels of arsenic are found while testing the drinking water in the household wells of residents of Milltown, Montana. The contamination is tied to the toxic sediments behind the dam.
E-12.	**1983**	By this time, the EPA had added all areas of the Upper Clark Fork River affected by the Anaconda Company's historic mining, processing and smelting operations to the National Priorities List of Superfund sites. The Clark Fork sites begin in Butte, include Anaconda, and continue downstream to Milltown, roughly seven miles from Missoula, making this complex the largest continuous environmental cleanup site in the United States. The State of Montana files a lawsuit against ARCO, which inherited the Anaconda Company's contamination responsibility the same year, for damages to and Montana residents' lost use of natural resources which included land, water and wildlife.
E-13.	**1999**	The State of Montana settles a portion of its claims against ARCO for natural resource damages; the Salish-Kootenai Tribe also settles with ARCO for damages to its aboriginal territories in the Upper Clark Fork. Restoration begins on Silver Bow Creek.
E-14.	**Present**	Remediation and restoration work continues within the Upper Clark Fork River's Superfund site. Federal, state and county agencies work together through this process.

Appendix 1b: Example of a graphically-based **Environmental/Natural History Timeline**. The numbers of each event (e.g., E-1, E-2, etc.) corresponds to the text-based timeline shown in Appendix 1a. This example can be used with Activity 2.2: Create a Timeline for this Area.

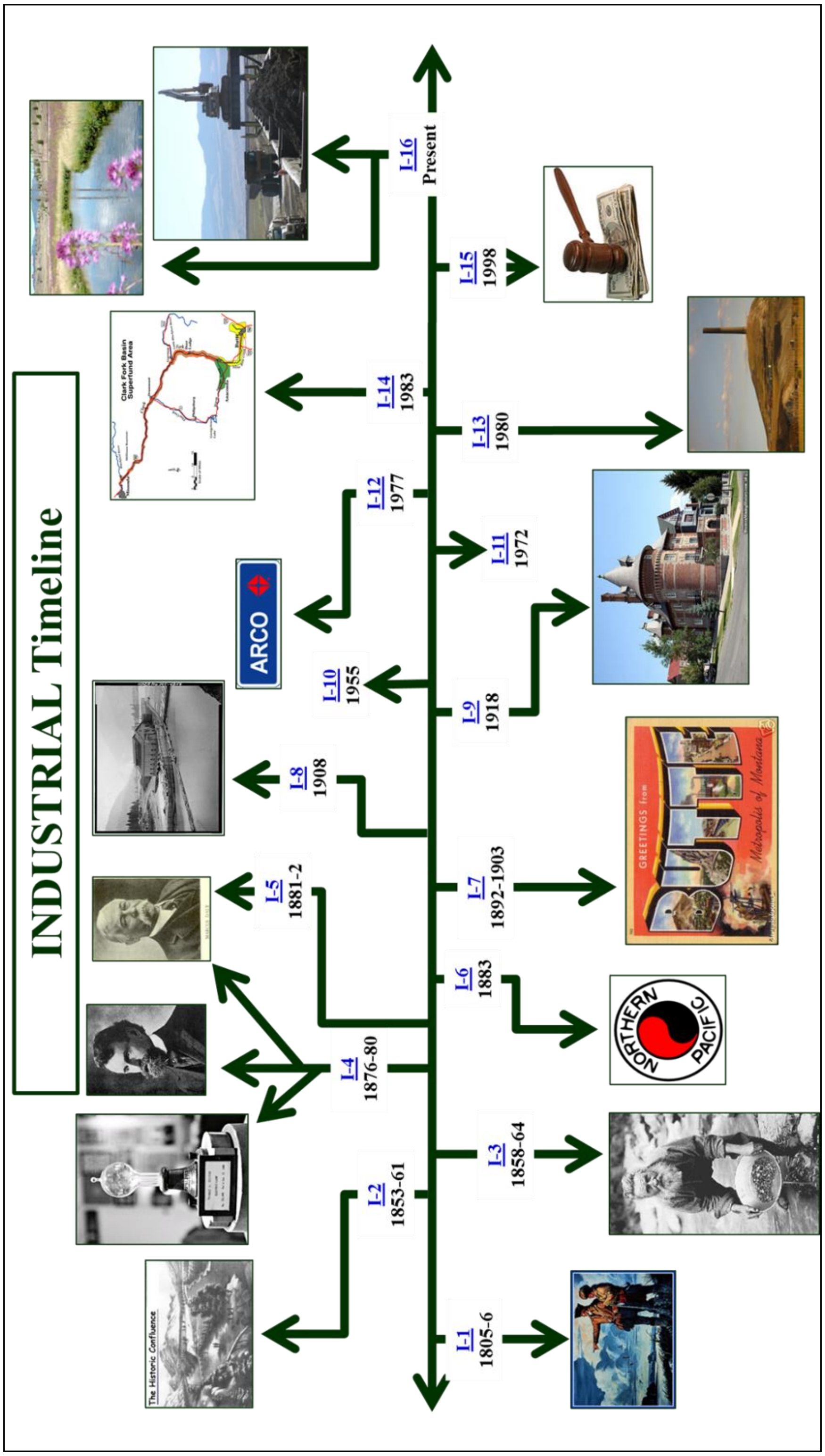


Appendix 2a: Example of an **Industrial/Civilization Timeline.** The numbers of each event (e.g., I-1, I-2, etc.) corresponds to the point on the graphic-based timeline shown in Appendix 2b. This example can be used with Activity 2.2: Create a Timeline for this Area.

Industrial/Civilization Timeline		
I-1.	**1805-1806**	The Lewis and Clark expedition documents its excursions across Montana, marking the first time the area had been traveled, mapped and documented by European settlers. French explorers traveled within the lower Clark Fork River region in this time period, as well.
I-2.	**1853-1861**	Lt. John Mullan, contracted by the United States government, surveys and constructs a "military road" between Fort Walla Walla, Washington and Fort Benton, Montana. This route, however, was never really used for its original purpose, and instead became an important travel route for early settlers, miners, and trappers.
I-3.	**1858-1864**	The first gold strikes hit Montana: Gold Creek in 1858; Bannack and Virginia City in 1862-63; and Silver Bow Creek in Butte in 1864.
I-4.	**1876-1880**	Alexander Bell invented the telephone and Thomas Edison invented the electric incandescent bulb and electrical transmission line. These inventions soared the demand for the conductor metal, copper. Butte mining interests battled over the wealth in the ground, and who could get it out the fastest and in the most quantities.
I-5.	**1881-1882**	Marcus Daly founded the Anaconda Company by purchasing the Anaconda Mine in Butte in 1881. In 1882, he incorporates the town of Anaconda as the site of his smelting and reduction works.
I-6.	**1883**	The Northern Pacific Railroad is completed near Gold Creek as the Pacific Northwest's first transcontinental railroad, linking Butte and the Clark Fork to the rest of the nation by train.
I-7.	**1892-1903**	Butte is truly "The Richest Hill on Earth." Unparalleled deposits of copper in Butte, an unlimited demand for it across a booming America, and a "War of the Copper Kings" make Butte the world's largest producer of copper of the era. Daly dies in 1900, but his company grows with help from Standard Oil (Rockefellers).
I-8.	**1908**	Copper King William A. Clark completes his Milltown Dam, a lumber mill and hydroelectric facility in January near Bonner. This dam, made of rock and timer, is the first hydroelectric facility on the Clark Fork. This is one of Clark's last big developments before the Anaconda Company takes over all mining in Butte by 1915.
I-9.	**1918**	Marks the peak of Butte and Anaconda's mining heyday. Anaconda Company soon begins funneling its money and interest to its mines in Chile; Butte mines and Anaconda's production from ores declines.

Industrial/Civilization Timeline		
I-10.	**1955**	Anaconda Company begins open pit mining in its new Berkeley Pit in Butte. In the underground mines, ore is too low in copper to continue profitable mining operations, and over 1,000 miners are out of work.
I-11.	**1972**	Anaconda Company begins treating its water from the Butte concentrator before releasing it to Silver Bow Creek. This is the first time in its mining history that water from the Butte operations is treated before reaching Warm Springs.
I-12.	**1977**	Oil giant, Atlantic Richfield Corporation (ARCO) purchases the struggling Anaconda Company, which is in trouble after losing its biggest producing mine in Chile to its national government.
I-13.	**1980**	ARCO halts smelting operations in Anaconda, putting thousands of people out of work. The Berkeley Pit and all Butte mining operations cease in 1982.
I-14.	**1983**	ARCO turns off the underground pumps in the Kelley Mine, allowing the Berkeley Pit to begin filling with water.
I-15.	**1998**	Several hundred people are employed in remediation and restoration (clean-up), of the Upper Clark Fork's Superfund sites.
I-16.	**Present**	Even more people are employed in the Upper Clark Fork's "green collar" workforce, as work spans from Butte all the way to Milltown, where Clark's historic dam is now gone. Butte's heritage as The Mining City continues with Montana Resources' Continental Pit, a copper-molybdenum mine, employing over 300 people. Good environmental management at the mine protects Silver Bow Creek and the Clark Fork River from further damage.

Appendix 2b: Example of a graphically-based **Industrial/Civilization Timeline**. The numbers of each event (e.g., I-1, I-2, etc.) corresponds to the text-based timeline shown in Appendix 2a. This example can be used with Activity 2.2: Create a Timeline for this Area.

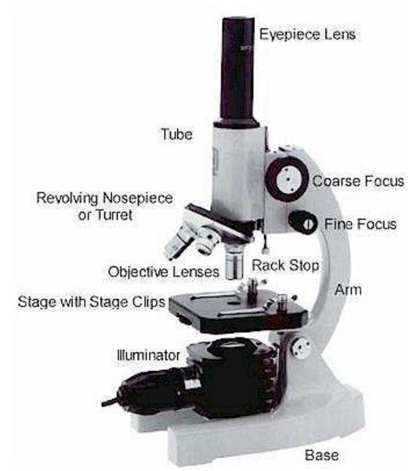


Appendix 3: Quick and easy guide to using a microscope. **Source:** http://www.microscope-microscope.org/microscope-home.htm.

The Compound Microscope

Parts and Specifications

Historians credit the invention of the compound microscope to the Dutch spectacle maker, Zacharias Janssen, around the year 1590. The compound microscope uses lenses and light to enlarge the image and is also called an optical or light microscope (vs./ an electron microscope)**.** The simplest optical microscope is the magnifying glass and is good to about ten times (10X) magnification. The **compound** microscope has two systems of lenses for greater magnification: 1) the ocular, or eyepiece lens that one looks into, and 2) the objective lens, or the lens closest to the object. Before purchasing or using a microscope, it is important to know the functions of each part.



Eyepiece Lens: the lens at the top that you look through; they are usually 10X or 15X power.

Tube: connects the eyepiece to the objective lenses.

Arm: supports the tube and connects it to the base.

Base: the bottom of the microscope, used for support.

Illuminator: a steady light source (110 V) used in place of a mirror. If your microscope has a mirror, it is used to reflect light from an external light source up through stage's bottom.

Stage: the flat platform where you place your slides. Stage clips hold the slides in place. If your microscope has a mechanical stage, you will be able to move the slide around by turning two knobs. One moves it left and right, the other moves it up and down.

Revolving Nosepiece or Turret: this is the part that holds two or more objective lenses and can be rotated to easily change power.

Objective Lenses: usually you will find three or four objective lenses on a microscope. They almost always consist of 4X, 10X, 40X and 100X powers. When coupled with a 10X (most common) eyepiece lens, we get total magnifications of 40X (4X times 10X), 100X, 400X and 1000X. To have good resolution at 1000X, you will need a relatively sophisticated microscope with an Abbe condenser, and oil-immersion is typically required. The shortest lens is the lowest power; the longest one is the lens with the greatest power. Lenses are color coded and, if built to DIN standards, are interchangeable between microscopes. The high power objective lenses are retractable (i.e., 40XR). This means that if they hit a slide, the end of the lens will push in (spring loaded), thereby, protecting the lens and the slide. All quality microscopes have achromatic, parcentered, parfocal lenses.

Rack Stop: this is an adjustment that determines how close the objective lens can get to the slide. It is set at the factory and keeps students from cranking the high power objective lens down into the slide and breaking things. You would only need to adjust this if you were using very thin slides and you weren't able to focus on the specimen at high power. (Tip: If you are using thin slides and can't focus, rather than adjust the rack stop, place a clear glass slide under the original slide to raise it a bit higher.)

Condenser Lens: the purpose of the condenser lens is to focus the light onto the specimen. Condenser lenses are most useful at the highest powers (400X and above). Microscopes with in-stage condenser lenses render a sharper image than those with no lens (at 400X). If your microscope has a maximum power of 400X, you will get the maximum benefit by using a condenser lenses rated at 0.65 NA or greater that can be mounted in the stage and work quite well. A big advantage to a stage mounted lens is that there is one less focusing item to deal with. If you go to 1000X then you should have a focusable condenser lens with an NA of 1.25 or greater. Most 1000X microscopes use 1.25 Abbe condenser lens systems. The Abbe condenser lens can be moved up and down.

Diaphragm or Iris: Many microscopes have a rotating disk under the stage. This diaphragm has different sized holes and is used to vary the intensity and size of the cone of light that is projected upward into the slide. There is no set rule regarding which setting to use for a particular power. Rather, the setting is a function of the transparency of the specimen, the degree of contrast you desire and the particular objective lens in use. Typically, it is easier to view specimens with the iris shining less light through, thus creating more contrast.

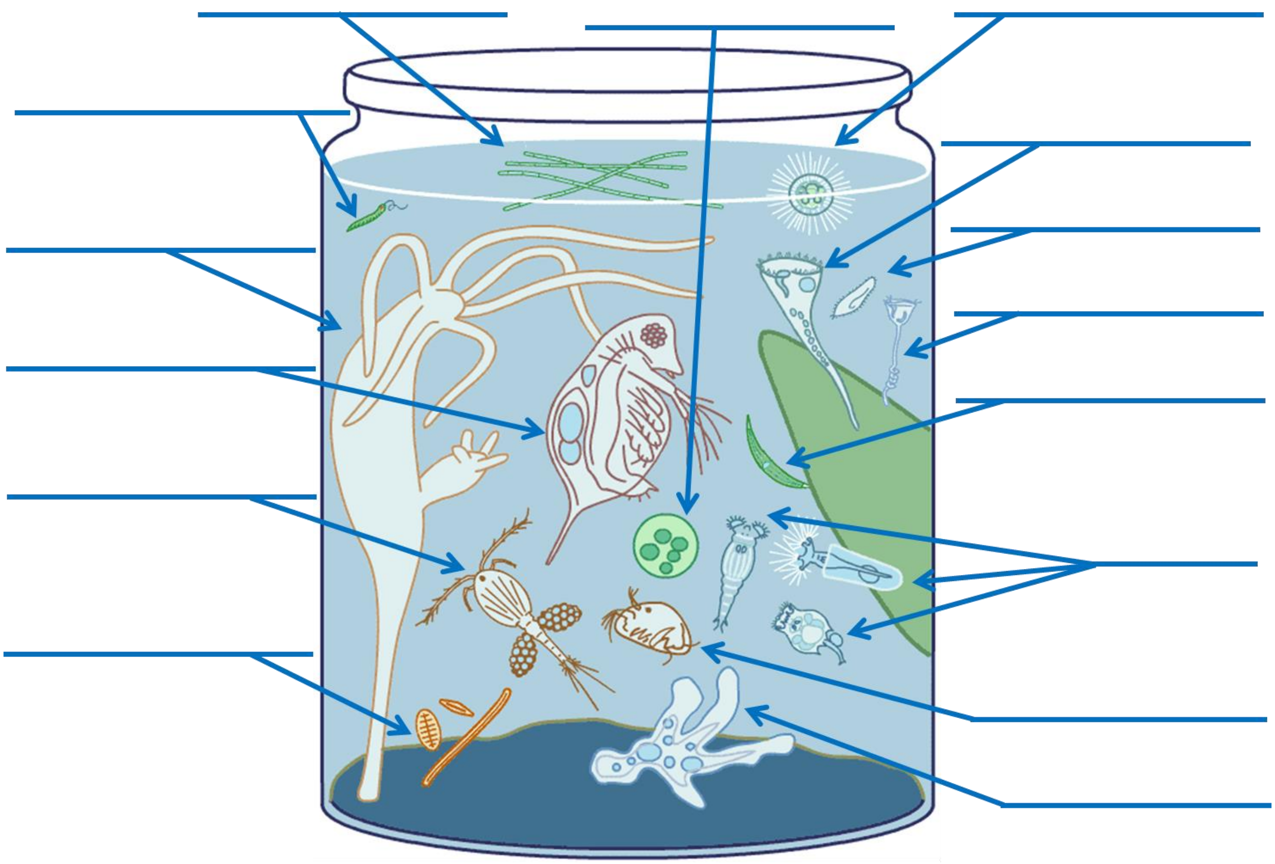
How to Focus Your Microscope: the proper way to focus a microscope is to start with the lowest power objective lens first, and while looking from the side, crank the lens down as close to the specimen as possible without touching it. Next, look through the eyepiece lens and focus upward only until the image is sharp. If you cannot get it in focus, repeat the process again. Once the image is sharp with the low power lens, you should be able to simply click in the next power lens and do minor adjustments with the focus knob. If your microscope has a fine focus adjustment, turning it a bit should be all that's necessary. Continue with subsequent objective lenses and fine focus each time.

What to look for when purchasing a microscope: If you want a real microscope that provides sharp crisp images then stay away from the toy stores and the plastic instruments that claim to go up to 600X or more. There are many high quality student grade microscopes on the market today. They have a metal body and all glass lenses. One of the most important considerations is to purchase your instrument from a reputable source. One dealer that we can highly recommend is Microscope World. They offer a wide variety of instruments at very competitive prices.

Appendix 4a: Worksheet for an extension of Activity 4.1: Wanderers, Drifters and Floaters, Oh My!.

POND LIFE IN A JAR

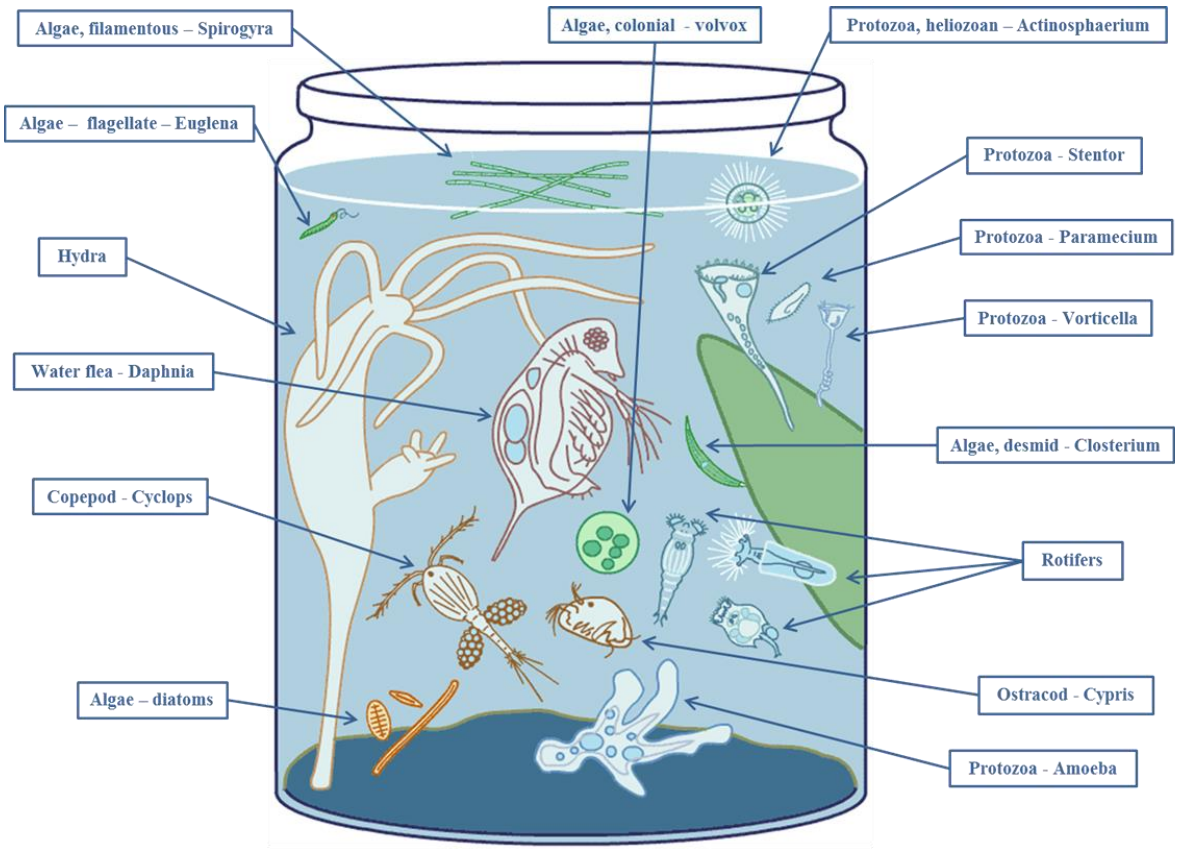
Instructions: Identify each creature pictured and write its name on the appropriate line.



Modified from original diagram located at: http://www.microscopy-uk.org.uk/index.html; original image by Wim van Egmond

Appendix 4b: Answers for worksheet for Activity 4.1: Wanderers, Drifters and Floaters, Oh My!

POND LIFE IN A JAR – Answer Sheet



From: http://www.microscopy-uk.org.uk/index.html; image by Wim van Egmond

Appendix 5a: Datasheet example for collecting data related to Activity 5.1, Part 1: Collection and Identification of Pond Macroinvertebrates

Collection and Identification of Pond Macroinvertebrates - Part 1

Instructions: 1) Count number of organisms for each major group identified in your sample (your ice cube tray); record in column ***A*** ; 2) Add counts from other teams to your counts; 3) Total column ***A*** ; 4) Multiply number of organisms in each major group by *Assigned Biotic Index* value; record in column ***B*** ; 5) Add column ***B*** ; 6) Turn to back of page (page 4) to complete calculations.

Major group	Number of Organisms in Sample	Assigned Biotic Index (tolerance index)	Biotic Value for Group
	A		**B**
Stoneflies (*P*)		1	
Mayflies (*E*)		2	
All Caddisflies (not net spinner; *T*)		2	
Gilled Snails		3	
Dobsonflies, Fishflies, Alderflies		4	
Dragonflies		4	
Crane Flies		4	
Watersnipe Flies		4	
Water Penny Beetle Larvae		4	
Whirligig Beetles		4	
Net Spinner Caddisflies (*T*)		5	
Other Beetles		5	
Black Flies		5	
Midges		6	
Damselflies		6	
Water Mites		6	
Crayfish		6	
Clams		6	
Scuds		7	
Other Snails (not gilled)		7	
Leeches		7	
Sowbugs		8	
Aquatic Worms		9	
TOTALS	**Sum of A =**		**Sum of B =**

TO OBTAIN "C" (for next page) **Write here numbers from shaded boxes above:**	
Stoneflies (*P*)	
Mayflies (*E*)	
All Caddisflies (not net spinner; *T*)	
Net Spinner Caddisflies (*P*)	
Total	**Sum of C =**

Bring Sum of **A**, **B** & **C** to page 2.

Appendix 5b: Datasheet example for collecting data related to Activity 5.1, Part 2: Aquatic Macros as Biological Indicators

Aquatic Macros as Biological Indicators - Part 2

Instructions: 1) Transfer your calculated sums of *A* , *B* and *C* from page 3 to the boxes below; 2) Calculate the Biotic Index Score as instructed below; place final score in box; 3) Calculate the EPT Index Score as instructed below; place final score in box; 4) Formulate and write conclusion at bottom.

Sum of A	

Sum of B		Sum of C	

How to Calculate Your Biotic Index Score

Directions:
1) Divide "B" by "A" to get *BIS*

$$\mathbf{BIS} = \frac{\mathbf{B}}{\mathbf{A}}$$

BIS = Biotic Index Score
A = Sum of Organisms in Sample
B = Sum Biotic Values

Your Calculated Score

BIS =

Biotic Index	
0.00 - 4.50	Very Good (non-impacted)
4.51 - 5.50	Good (slightly impacted)
5.51 - 7.00	Fair (moderately impacted)
7.01 - 10.00	Poor (severely impacted)

How to Calculate Your EPT Index Score

Directions:
1) Sum all the mayflies, stoneflies & caddisflies to get "C" (done on page 3)
2) Divide "C" by "A" to get *EPT to Total Ratio*

$$\mathbf{EPT} = \frac{\mathrm{C}}{\mathrm{A}}$$

E = Ephemeroptera (mayflies)
P = Plecoptera (stoneflies)
T = Trichoptera (caddisflies)
A = Sum of Organisms in Sample
C = Sum of mayflies, stoneflies & caddisflies

Your Calculated Score

EPT =

EPT Index	
0.5 or more	Good (slightly to non-impacted)
0.25 - 0.49	Fair (moderately impacted)
0.24 or less	Poor (severely impacted)

Conclusion

BIS indicates that this site is ______________________________.

EPT indicates that this site is ______________________________.

Appendix 6: Datasheet example for collecting data related to Activity 7.1, Option 1: Water Quality with World Water Monitoring Day Kits.

WATER QUALITY with WORLD WATER MONITORING DAY KITS

Parameter	Unit of Measure	Site # _____	Site # _____	Site # _____
Date	__/__/__			
Location				
Air Temperature				
Turbidity				
Water Temperature				
Dissolved Oxygen (DO)				
pH				

You're not finished yet! Make sure to enter your data at the WWMD data base online. Your data proves you monitored and allows for a global snapshot of the world's water quality.

Other Parameters	Unit of Measure	Site # _____	Site # _____	Site # _____

Notes:

Page __________ of __________

Appendix 7: Water quality standards for creeks and rivers. This information can be used to supplement Activity 7.1, both Option 1 and 2: Water Quality with World Water Monitoring Day Kits, and Water Quality Data Collected with Vernier Lab Quest Units and Probes.

WATER QUALITY STANDARDS FOR MONTANA

	Measure	Aquatic Life Standard	Human Health Standard
Parameters	**H_2O Temperature** (°C)	< 20°C (68°F)	
Parameters	**pH** (standard units)	> 6.5	
Parameters	**Conductivity** (µS/cm)	50 - 300	
Parameters	**Turbidity** (NTU)	< 10	
Parameters	**Dissolved O_2** (mg/L; ppm)	> 6.5	
Metals	**Copper** (µg/L; ppb) (@ 25 mg/L water hardness)	< 3.79	< 1300
Metals	**Iron** (mg/L; ppm)	< 1.0	< 300
Metals	**Aluminum** (mg/L; ppm) (pH 6.5 - 9.0)	< 0.087	
Nutrients	**Nitrate** (mg/L; ppm) (as NO_3^--N)		< 10.0
Nutrients	**Nitrite** (mg/L; ppm) (as NO_3^--N); (at pH 7.5)		< 1.0
Nutrients	**Ammonia** (mg/L; ppm) (as NH_4^+-N)	< 13	
Nutrients	**Phosphate**(mg/L; ppm) (as PO_4^--N)		
Others of Interest			
Metalloid/Metals	**Arsenic** (µg/L; ppb)	< 150	< 10.0
Metalloid/Metals	**Cadmium** (µg/L; ppb) (@ 25 mg/L hardness)	0.097	< 5.0
Metalloid/Metals	**Lead** (µg/L; ppb) (@ 25 mg/L hardness)	< 0.545	< 15.0
Metalloid/Metals	**Zinc** (µg/L; ppb) (@ 25 mg/L hardness)	< 37.0	< 2000

Values taken from: Circular DEQ-7 Montana Numberica Water Quality Standards, August 2010

Appendix 8: Datasheet example for collecting data related to Activity 7.1, Option 2: Water Quality with Vernier Lab quest Units and Probes.

WATER QUALITY with VERNIER LAB QUEST UNITS AND PROBES

Water Quality

Dissolved O_2 *(mg/L)* (Vernier)	
Air temp *(°C)* (Vernier)	
H_2O temp *(°C)* (Vernier)	
pH *(standard units)* (Vernier)	
Conductivity *(µS/cm)* (Vernier)	
Turbidity *(NTU)* (Vernier)	*Average =*
Latitude (Vernier)	
Longitude (Vernier)	
Nitrate *(ppm)* (test strip)	
Nitrite *(ppm)* (test strip)	
Ammonia *(ppm)* (test strip)	
Others (*indicate units*):	

Turbidity (NTU)	
Sample 1	
Sample 2	
Sample 3	
Sample 4	
Sum	
Average	

For average, divide "Sum" by number of samples.

Normal Range of Values in Healthy Western Montana Streams

pH = 6.5 to 8.5 standard units

Conductivity = 50 to 300 µS/cm

Dissolved O_2 = 6.0 to 10.0 mg/L
(*Note: Trout need ≥6 mg/L*)

Turbidity = 2 to 10 NTU
(*Note: drinking water must be <1 NTU*)

Converting Temperatures
F to **C** = 0.555 x (**F** Temp - 32)

Notes:

Appendix 9: Groupings of aquatic macroinvertebrates according to how sensitive or tolerant they are to pollution. This sheet corresponds to an extension activity described in Chapter 4.7.

Pollution Tolerance Index (PTI) Data Sheet

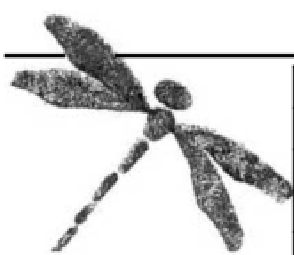
Name: ______________________ Location: ________________________
Date: __________________

Group One Taxa Pollution Sensitive	**Group Two Taxa** Somewhat Pollution Tolerant	**Group Three Taxa** Pollution Tolerant
☐ Stonefly (Plecoptera)	☐ Crayfish (Decapoda)	☐ Aquatic Worm (Oligochaeta)
☐ Caddisfly (Trichoptera)	☐ Sowbug (Isopoda)	☐ Midge Fly larvae (Nematocera)
☐ Water Penny (Coleoptera)	☐ Scud (Amphipoda)	☐ Blackfly larvae (Simulidae)
☐ Rifle Beetle (Coleoptera)	☐ Aderfly larva (Sialidae)	☐ Leech (Hirudinea)
☐ Mayfly (Ephemeroptera)	☐ Fishfly larva (Corydalidae)	☐ Pouch Snail and Pond Snails (Gastropoda)
☐ Gilled Snail	☐ Damselfly (Zygoptera)	☐ Other Snails (Gastropoda)
☐ Dobsonfly (Hellgrammite)	☐ Watersnipe Fly larvae (Athericidae)	
	☐ Crane Fly (Nematocera)	
	☐ Beetle larvae (Coleoptera)	
	☐ Dragon Fly (Anisoptera)	
	☐ Clam (Bivalvia)	

Total Group One Taxa: ☐ **x 3** Total Group Two Taxa: ☐ **x 2** Total Group Three Taxa: ☐ **x 1**

PTI = ☐ + ☐ + ☐

Pollution Tolerance Index (PTI) = ☐



PTI	**Stream Quality**
>23	Excellent
17-23	Good
10-16	Fair
<10	Poor

Use the table to the left to figure out Stream Quality from your PTI total.

Stream Quality: ☐

55

Appendix 10: List of common and scientific names of native forbs and shrubs planted at Skyline Park in 2014.

CODES FOR PLANT LIST		
FORBS		
CODES	**COMMMON NAME**	**SCIENTIFIC NAME**
ACMI	Yarrow	*Achillea millefolium*
Allium 1	Onion 1	*Allium species*
ANMI	Rosy pussytoes	*Antennaria microphylum*
AST/OXY	Milkvetch/locoweed	*Astragalus/Oxytropis* species
ERCO	Cutleaf daisy	*Erigeron compositus*
HEVI	Golden aster	*Heterotheca villosa*
SHRUBS		
CODES	**COMMMON NAME**	**SCIENTIFIC NAME**
ARTR	Big sage	*Artemesia tridentata*
CHVI	Green rabbitbrush	*Chrysothamnus viscidiflorus*
PUTR	Bitterbrush	*Purshia tridentata*
RIAU	Golden currant	*Ribes aureum*
RICE	Wax currant	*Ribes cereum*
ROWO	Wood's rose	*Rosa woodsii*
SYAL	Snowberry	*Symphoricarpos albus*

NATIVE FORBS AND SHRUBS PLANTED AT SKYLINE PARK										
CODE	**Planted 5/22/2014**					**Planted 5/28/2014**			**Planted 5/29/2014**	
	Plot 1	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**	**Plot 8**	**Plot 9**	**Plot 10**
ACMI	3	0	1	0	6	3	2	0	3	3
Allium 1	5	8	3	3	0	0	0	0	5	5
ANMI	0	0	1	6	1	2	2	2	2	1
AST/OXY	1	0	0	0	3	1	1	2	2	0
ERCO	3	0	1	0	0	2	2	2	4	2
HEVI	6	0	0	1	2	1	3	2	3	4
TOTAL Forbs	**18**	**8**	**6**	**10**	**12**	**9**	**10**	**8**	**19**	**15**
ARTR	3	1	4	2	2	4	0	2	2	0
CHVI	2	1	1	0	1	0	3	3	2	2
PUTR	0	2	1	0	2	2	3	4	2	2
RIAU	1	2	1	2	2	0	3	2	3	2
RICE	0	2	4	2	2	3	0	4	2	2
ROWO	4	2	1	2	1	5	4	3	2	1
SYAL	0	2	3	2	2	2	3	3	2	2
TOTAL Shrubs	**10**	**12**	**15**	**10**	**12**	**16**	**16**	**21**	**15**	**11**

Appendix 11: List of noxious weeds of particular concern for Montana from the Montana Department of Agriculture.

Montana Noxious Weed List
Effective: December 2013

PRIORITY 1A These weeds are not present or have a very limited presence in Montana. Management criteria will require eradication if detected, education, and prevention:

- Yellow starthistle — *Centaurea solstitialis*
- Dyer's woad — *Isatis tinctoria*

PRIORITY 1B These weeds have limited presence in Montana. Management criteria will require eradication or containment and education:

- Knotweed complex — *Polygonum cuspidatum, P. sachalinense, P.* × *bohemicum, Fallopia japonica, F. sachalinensis, F.* × *bohemica, Reynoutria japonica, R. sachalinensis,* and *R.*× *bohemica*
- Purple loosestrife — *Lythrum salicaria*
- Rush skeletonweed — *Chondrilla juncea*
- Scotch broom — *Cytisus scoparius*

PRIORITY 2A These weeds are common in isolated areas of Montana. Management criteria will require eradication or containment where less abundant. Management shall be prioritized by local weed districts:

- Tansy ragwort — *Senecio jacobaea, Jacobaea vulgaris*
- Meadow hawkweed complex — *Hieracium caespitosum, H. praealturm, H. floridundum, and Pilosella caespitosa*
- Orange hawkweed — *Hieracium aurantiacum, Pilosella aurantiaca*
- Tall buttercup — *Ranunculus acris*
- Perennial pepperweed — *Lepidium latifolium*
- Yellowflag iris — *Iris pseudacorus*
- Blueweed — *Echium vulgare*
- Hoary alyssum — *Berteroa incana*

PRIORITY 2B These weeds are abundant in Montana and widespread in many counties. Management criteria will require eradication or containment where less abundant. Management shall be prioritized by local weed districts:

♦ Canada thistle	*Cirsium arvense*
♦ Field bindweed	*Convolvulus arvensis*
♦ Leafy spurge	*Euphorbia esula*
♦ Whitetop	*Cardaria draba, Lepidium draba*
♦ Russian knapweed	*Acroptilon repens, Rhaponticum repens*
♦ Spotted knapweed	*Centaurea stoebe, C.maculosa*
♦ Diffuse knapweed	*Centaurea diffusa*
♦ Dalmatian toadflax	*Linaria dalmatica*
♦ St. Johnswort	*Hypericum perforatum*
♦ Sulfur cinquefoil	*Potentilla recta*
♦ Common tansy	*Tanacetum vulgare*
♦ Oxeye daisy	*Leucanthemum vulgare*
♦ Houndstongue	*Cynoglossum officinale*
♦ Yellow toadflax	*Linaria vulgaris*
♦ Saltcedar	*Tamarix spp*.
♦ Flowering rush	*Butomus umbellatus*
♦ Eurasian watermilfoil	*Myriophyllum spicatum*
♦ Curlyleaf pondweed	*Potamogeton crispus*

PRIORITY 3 Regulated Plants: (NOT on MONTANA LISTED NOXIOUS WEEDS) These regulated plants have the potential to have significant negative impacts. The plant may not be intentionally spread or sold other than as a contaminant in agricultural products. The state recommends research, education and prevention to minimize the spread of the regulated plant.

♦ Cheatgrass	*Bromus tectorum*
♦ Hydrilla	*Hydrilla verticillata*
♦ Russian olive	*Elaeagnus angustifolia*

Appendix 12a: Datasheet example for collecting data related to Activity 9.1, Part 1: Measuring Biodiversity Success of Forb Sods

FORB SOD BIODIVERSITY STUDY - PART 1: How Many Types Are Here?

Name(s): ____________________________ **Date:** ______________________

Instructions: Starting at a plot site that includes four (4) forb sods/mats, determine if any grasses and forbs are present. Next count the number of individual grasses. Then count the number of different kinds of forbs and the number of individuals of each type. Repeat this for each study plot area.

Numbers of Plants Present in Seed Pods						
Study Area #	Present (Y or N)?		Grasses		Forbs	
	Grasses	Forbs	If *Yes*, # of different kinds of grasses (unk = unknown)	If *Yes*, # of individuals	If *Yes*, # of different kinds of forbs (unk = unknown)	If *Yes*, # of individuals
				Type 1 = ______ individuals		

Notes

Appendix 12b, Pg. 1: Datasheet example for collecting data related to Activity 9.1, Part2: Measuring Biodiversity Success of Forb Sods – Page 1.

FORB SOD BIODIVERSITY STUDY-PART 2: What Types Are There?

Name(s): ________________________ **Date :** _____________________

Instructions: Identify as many of the forbs growing in the seed pod dispersal islands. For each plant type identified, do the following: in Column B, indicate how many plots (from FORB SOD BIODIVERSITY STUDY-PART 1) on which the plant was found; in Column C, calculate the percentage of plots; in Column D, indicate the total number of individuals of that type that were found. For those plants that you cannot identify, assign it a number, such as "Unknown #1, Unknown #2, etc. When done identifying all possible plants, assign an "Abundance Rank." The plant with the most number of individuals, gets a Rank of 1; the one with the second highest number of individuals, gets a Rank of 2, and so on.

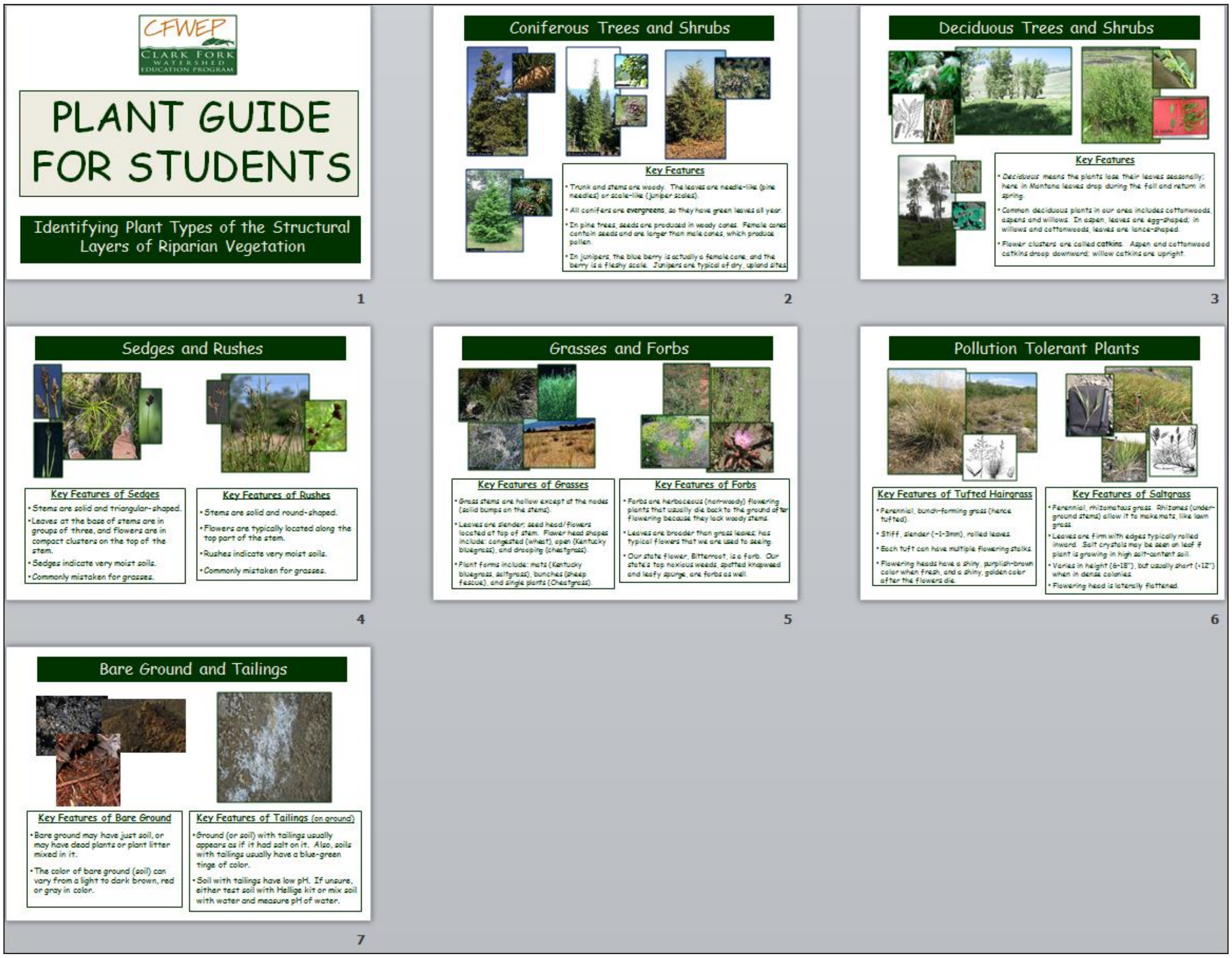
Forb Presence / Absence Data

Column A	Column B	Column C	Column D	Column E
Forb *Scientific Name* - Common Name The following forbs were planted.	**Found on how many plots?**	**% of Plots** (Column B / total #of plots)	**Total # of individuals**	**Abundance Rank**
Achillea millefolium - Yarrow				
Allium species - Onion spp.				
Antennaria microphylum - Rosy pussytoes				
Astragalus/Oxytropis species - Milkvetch/locoweed				
Erigeron compositus - Cutleaf daisy				
Heterotheca villosa - Golden aster				
Shrub *Scientific Name* - Common Name The following shrubs were planted.	**Found on how many plots?**	**% of Plots** (Column B / total #of plots)	**Total # of individuals**	**Abundance Rank**
Artemesia tridentata - Big sage				
Chrysothamnus viscidiflorus - Green rabbitbrush				
Purshia tridentata - Bitterbrush				
Ribes aureum - Golden currant				
Ribes cereum - Wax currant				
Rosa woodsii - Wood's rose				
Symphoricarpos albus - Snowberry				
Plant *Scientific Name* - Common Name Other plants not listed above.	**Found on how many plots?**	**% of Plots** (Column B / total #of plots)	**Total # of individuals**	**Abundance Rank**

Appendix 12b, Pg. 2: Datasheet example for collecting data related to Activity 9.1, Part2: Measuring Biodiversity Success of Forb Sods – Page 2.

Plant *Scientific Name* - Common Name Other plants not listed above.	**Found on how many plots?**	**% of Plots** (Column B / total #of plots)	**Total # of individuals**	**Abundance Rank**

Appendix 13: Quick view of Cfwep.Org's Plant Guide For Students. Please visit Cfwep.Org's website to download this guide in a printable PDF format.



Appendix 13a: Datasheet example for collecting data related to Activity 9.2, Where's the Structural Diversity?, page 1.

RIPARIAN VEGETATION ASSESSMENT

Name(s): ______________________ **Date :** ______________________

Instructions: To create transect of study, lay a meter tape up to 30 meters, either near a stream or 5 meters from a stream bed; indicate in box below at right the general location of the transect. Starting at the 3-m position, indicate what plants are present as ground cover, understory and overstory.

STRUCTURAL DIVERSITY

Station (Point) No.	Meter position	Site Name:		
		Ground Cover (<0.5 m)	Understory (0.5-3.0 m)	Overstory (>3.0 m)
1	3 m			
2	6 m			
3	9 m			
4	12 m			
5	15 m			
6	18 m			
7	21 m			
8	24 m			
9	27 m			
10	30 m			

Check (√) General Location:

Near stream: ☐

5 m from stream: ☐

Other (describe below):

____

____

____

CODES

Ground Cover Layer

SR	Sedges and rushes
G	Grasses and forbs (good)
P	Pollution tolerant (tufted hairgrass & saltgrass)
B	Bare/disturbed ground
T	Tailings
R	Rock

Understory & Overstory Layers

C	Coniferous
D	Deciduous
M	Mixed (coniferous and deciduous)
(—)	Understory or overstory is absent

When **hummocking** is observed, denote ground cover type followed by: " **/ H** " (e.g., G/H is grassy area with hummocks).

When the station lands at the **base of a shrub or tree**, place a slash (/) on the field form.

Appendix 13b: Datasheet example for collecting data related to Activity 9.2, Where's the Structural Diversity?, page 2.

RIPARIAN VEGETATION ASSESSMENT

STRUCTURAL DIVERSITY DATA - PART 2

Summarizing Study Area's Structural Diversity and Ground Cover Biodiversity

Question: What is the study area's structural diversity?

INSTRUCTIONS: Divide the number of points within the layer that had plants present by the number '10,' which is the total number of points studied. For example, if all 10-m points/stations had understory, then Understory = 100% (10/10); if 3 of the meter points had overstory, then Overstory = 30% (3/10). **Very important:** For ground cover layer, **do not include occurrences of** *B*, *T* or *R* since these are NOT plants.

Layer	Total Number of Points in that Layer with Plant(s) Present	Percentage (%) for Site (#of occurrences / 10)
Ground Cover		
Understory		
Overstory		

Question: What is the biodiversity of the ground cover layer?

INSTRUCTIONS: Add the number of stations (points) that had each type of cover. For example, if sedges were found at 3 points, put '3' next to 'SR'. This means 30% of ground cover is 'sedges/rushes' since there are a total of 10 stations/points.

Ground Cover			
Type	**Code**	**Total Number of Occurrences for Site**	**Percentage (%) for Site** (#of occurrences / 10)
Sedges and rushes	SR		
Grasses and forbs	G		
Pollution tolerant	P		
Bare/disturbed ground	B		
Tailings	T		
Rock	R		
Base of tree or shrub	/		

Appendix 14a: Example of how to compete the datasheet for Activity 9.2, Where's the Structural Diversity?, page 1.

RIPARIAN VEGETATION ASSESSMENT

Name(s): Cape Able Student **Date :** September 13, 2014

Instructions: To create transect of study, lay a meter tape up to 30 meters, either near a stream or 5 meters from a stream bed; indicate in box below at right the general location of the transect. Starting at the 3-m position, indicate what plants are present as ground cover, understory and overstory.

STRUCTURAL DIVERSITY

Site Name:

Station (Point) No.	Meter position	Ground Cover (<0.5 m)	Understory (0.5-3.0 m)	Overstory (>3.0 m)
1	3 m	G	C	C
2	6 m	G	D	D
3	9 m	SR	D	—
4	12 m	G	—	—
5	15 m	G	D	—
6	18 m	SR	D	—
7	21 m	R	—	—
8	24 m	G	C	C
9	27 m	B	—	—
10	30 m	G	D	M

Check (√) General Location:

Near stream: √

5 m from stream:

Other (describe below):

CODES

Ground Cover Layer

SR	Sedges and rushes
G	Grasses and forbs (good)
P	Pollution tolerant (tufted hairgrass & saltgrass)
B	Bare/disturbed ground
T	Tailings
R	Rock

Understory & Overstory Layers

C	Coniferous
D	Deciduous
M	Mixed (coniferous and deciduous)
(—)	Understory or overstory is absent

When **hummocking** is observed, denote ground cover type followed by: " **/ H** " (e.g., G/H is grassy area with hummocks).

When the station lands at the **base of a shrub or tree**, place a slash (/) on the field form.

Appendix 14b: Example of how to compete the datasheet for Activity 9.2, Where's the Structural Diversity?, page 2.

RIPARIAN VEGETATION ASSESSMENT

STRUCTURAL DIVERSITY DATA - PART 2
Summarizing Study Area's Structural Diversity and Ground Cover Biodiversity

Question: What is the study area's structural diversity?

INSTRUCTIONS: Divide the number of points within the layer that had plants present by the number '10,' which is the total number of points studied. For example, if all 10-m points/stations had understory, then Understory = 100% (10/10); if 3 of the meter points had overstory, then Overstory = 30% (3/10). **Very important:** For ground cover layer, **do not include occurrences of** *B*, *T* or *R* since these are NOT plants.

Layer	Total Number of Points in that Layer with Plant(s) Present	Percentage (%) for Site (#of occurrences / 10)
Ground Cover	8	80%
Understory	7	70%
Overstory	4	40%

Question: What is the biodiversity of the ground cover layer?

INSTRUCTIONS: Add the number of stations (points) that had each type of cover. For example, if sedges were found at 3 points, put '3' next to 'SR'. This means 30% of ground cover is 'sedges/rushes' since there are a total of 10 stations/points.

Ground Cover

Type	Code	Total Number of Occurrences for Site	Percentage (%) for Site (#of occurrences / 10)
Sedges and rushes	SR	2	20%
Grasses and forbs	G	6	60%
Pollution tolerant	P	0	
Bare/disturbed ground	B	1	10%
Tailings	T	0	
Rock	R	1	10%
Base of tree or shrub	/	0	

Appendix 15a: Plant identification worksheet, page 1.

Plant Scientific Name:

Is this plant invasive or native to Montana? (circle one)

Invasive Native

Plant Common Name(s):

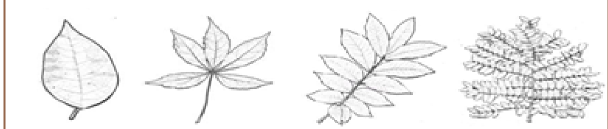
What is the ecosystem type? (circle one)

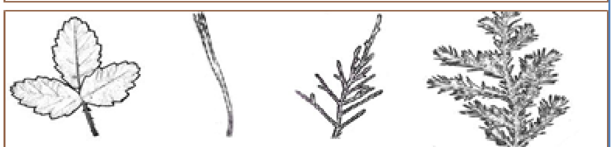
Riparian Upland Forest

LEAVES

Draw a picture or place a photo here

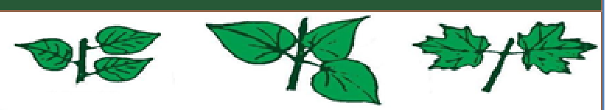
Leaf Type: (circle one)





Leaf Edge: (circle one)

Leaf Arrangement: (circle one)



WHOLE PLANT

Draw a picture or place a photo here

STEM

Draw a picture or place a photo here

What is the stem shape? (circle one)

Round Flat Triangular Square

Student researcher name(s):

Appendix 15b: Plant identification worksheet, page 2.

Plant Scientific Name:

Flowers and Berries	Seasonal Changes
Draw a picture or place a photo here	Explain how plant changes from season to season

Soil Observations	Kinds of Plants Near By
Is the soil moist or dry? (circle one) Moist Dry Other soil observations:	
	Do animals seem to be using this area and the plants? (circle one) Yes No

General Observation and Questions