DENVER BOTANIC GARDENS

January 14, 2020

Final Report
Denver Botanic Gardens: Water in the West
POGG1
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Denver Botanic Gardens has completed the multi-phase effort to develop, design and implement a new exhibition, *Welcome Home: Meet Your Habitat*, in its Science Pyramid venue.

GRANT EXPENSES – $44,750

Incentives/Stipends	750.00
Focus group participants	
Outsourced Services	$30,173.90
Curriculum development	
Exhibition casework	
Digital design development	
Ecosystem tubes - custom fabrication	
Graphic design (field guides)	
Supplies/Materials – Programs	2,871.72
Casework (additional)	
Ecospheres	
Business Meeting Food/Bev	110.95
Focus group refreshments	
Consultant	2,000.00
Focus groups	
Translation	1,144.39
English to Spanish	
Sign Fabrication	7,699.04
Exhibition graphics	
TOTAL	$44,750.00
Amount invoiced to date	$18,360.72
Balance Due	**$26,389.28**

TASK 1: DEVELOP EXHIBIT

➢ FOCUS GROUPS (Sub-Task)

The Gardens hosted two focus groups in the Science Pyramid to gather visitor feedback and reactions to the exhibition's current physical space, as well as input on visitor understanding of water issues in the West. This includes feedback on the kind of educational messaging around water issues they feel would be useful or would resonate with them.

Laureen Trainer conducted the first focus group on March 31, 2018. The second focus group, held on June 16, was conducted in Spanish for a group not familiar with the Gardens; they had not been to the Gardens previously. This was a shift in original plan and required bringing in an additional facilitator to lead the session in Spanish, but given the Gardens' priorities to engage and serve an ever more diverse audience, making certain to connect with Spanish native speakers was an important component of hearing from our audience in advance of content decision-making. For the past four years the Gardens has been dedicated to bilingual educational signage and wayfinding.

Among important takeaways:

> Visitors had low knowledge, *but high interest in the ways they can adapt to meet future demands on the water supply*. In addition, there was *interest in, but little understanding of issues of climate change and water that are specific to Colorado*: droughts, floods and semi-arid climate.
>
> There was *low knowledge and low interest among focus group members with issues concerning biodiversity. What participants don't understand at this point is the connection between water, ecosystems, and biodiversity*.

From a design standpoint, the feedback on how the new exhibit would best communicate science related to the natural world has been instrumental as we make decisions concerning this aspect of exhibition development. *Participants preferred naturalistic representations, including real specimens*, with connections to local efforts and issues.

In addition to input from both English- and Spanish-language focus groups, the Gardens created an online survey (SurveyGizmo) to gather information about public understanding of the environment, water issues, and planted landscapes in the state of Colorado. There were 246 total responses; 221 complete surveys.

See supporting materials for visitor panel/focus group summaries and the survey response report.

➢ EXHIBIT (Sub-Task)

After initially working with Legwork Studios to walk through backend discovery of content management systems and to outline avenues forward, the Gardens partnered with CacheFlow, a local digital design/development company, to develop a streamlined approach to digital systems, content, and exhibition interfaces.

A cross-disciplinary team ensured all exhibition components – emotional qualities, scientific data, object selection, and digital content – supported the primary themes of water in the West and biodiversity. Based on the early visitor feedback, designs and color palettes helped shape understanding in the exhibition space. Blue indicates water focus, and warm yellows and oranges add warmth and indicate more arid environments. Dotted floor graphics offer visual connections to reinforce interdependence of organisms in any environment. Through longer-term visitor studies, it is documented that visitors don't necessarily respond to data when considering

behavior, rather emotion. For that reason, the primary narrative arc places humans adjacent to other animals, plants, and water in an ecosystem. In the end, we're all neighbors, thus the exhibition title, *Welcome Home*. The Habitat Lounge – a low-tech visitor resource area allows for further contemplation of how animals adapt to environments and how humans should in our dry steppe region here in Colorado. From a beaver hide to butterfly to low-flow shower head, objects reinforce how visitors can lessen their footprint on the environment. A "waterfall wall" prompts visitors to highlight how they'll work to protect a lake, stream, or river – what new action they'll take to better support biodiversity, leaving behind their perspective for others to consider.

See supporting materials for an overview of the exhibition content, installation views, and interpretive arcs.

➢ K-12 CURRICULUM TIES / SCIENCE CHAT PROGRAMS

After planning sessions with the Gardens' children's and school program coordinators, educational consultant, Ms. Tiffany Kapler, was contracted for the following:

Discovery Day Learning Stations – Development of activities for three drop-in learning stations for Denver Botanic Gardens' Discovery Days for grades K-3, which can be adapted to additional grade levels as Science Inquiry Stations. Discovery Days offer a blend of guided and self-guided exploration of content. Deliverable includes list of materials/props, written instructions for volunteer facilitators that align with curriculum goals. The following Learning Stations have now been created, complete with references to 2020 Colorado Academic Standards for Science and Next Generation Science Standards Performance Expectations:

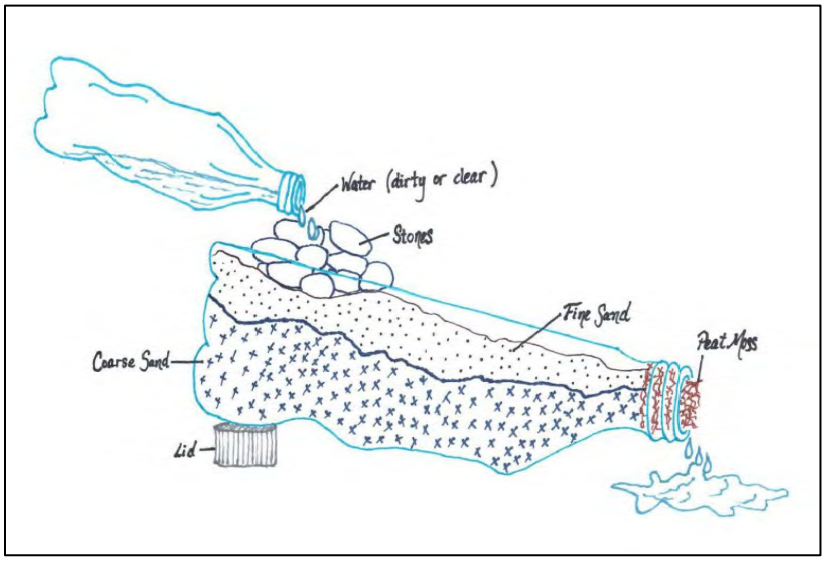
- **Microclimates and Urban Habitats**

  Students will make observations and collect data for a microclimate in the Denver Botanic Gardens. The data of various groups will be collected throughout the day so that students can compare their microclimate data to the data of others to draw conclusions. Students will also consider how people can create microhabitats within an urban environment.

- **Wetland Water Wonders**

  Students will use a model wetland in a bottle to observe water filtration. Then they will alter the model wetland as if it were covered over in concrete to observe any differences in water absorption and filtration. Finally, students will learn about several wetland plants that enhance the filtration capacity of wetlands by taking up heavy metals and other toxins.

  Wetland Model Setup:



➢ **So Happy Together: Perfect Pollination Pairings**
Students will use prior knowledge, a pollination syndrome chart, and additional clues to match flower cards to pollinator cards. Students are then encouraged to look for evidence of pollinator syndromes throughout the Gardens.

Online Resources for Families and Teachers – Text for one set of online resources for families and teachers to include: 1) pre-visit activities, 2) post-visit activities, 3) self-guided exploration, including talking points for the Science Pyramid that also connects the content from the Pyramid to the rest of the gardens.

➢ **Self-Guided School Group and Family Packet: Exploring the Gardens – Exploring Your Home**
Follow your curiosity, think and act like a scientist, and make discoveries that help you to better understand the world and your place in it.

As you explore the exhibit and the gardens, you may notice some of the following big ideas:
- Plants, animals, and people all live here on this earth we call home.
- Our home is so big that sometimes we can't easily see how many creatures we share it with. However, we still feel the effects of one another.
- We share limited resources, including water, with all other living organisms.
- All living creatures and ecosystems, no matter how different they seem, are interconnected.

Science Chat – Development of a drop-in, guided conversation on biodiversity and ecosystems to be led by trained volunteers or staff. Deliverables included: list of hands-on materials and props; training document for volunteers with background/context, clear learning outcomes, talking points/questions/hands-on activities, educational content, relevant images/graphics/visuals, tips for bringing the content to various knowledge and age levels, key vocabulary, recommended reading list of books, articles, etc. Big ideas here are: 1) Biodiversity is important at all levels of life and is valuable to all of earth's inhabitants – even us (human beings), and 2) Water is a critical natural resource that is impacted by and impacts ecosystem health and biodiversity.

Next steps include tracking and timing to document increased "dwell time" – the amount of time visitors spend exploring the exhibition and its content. Docents and staff have already seen visitors lingering for greater periods of time. In addition, visitor intercept surveys will help to evaluate visitor understanding.

Support from the Colorado Water Conservation Board made it possible for the Gardens to approach exhibition development from the point of best practices – doing research with visitors, prototyping, and evaluating. Denver Botanic Gardens looks forward to engaging audiences with the exhibition to foster understanding of the natural world, including understanding concepts of biodiversity and water in the West.

See supporting materials for curriculum guiding Science Chats and Discovery Days with resources for teachers, parents, volunteers, and staff.

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POGG1
Attachments

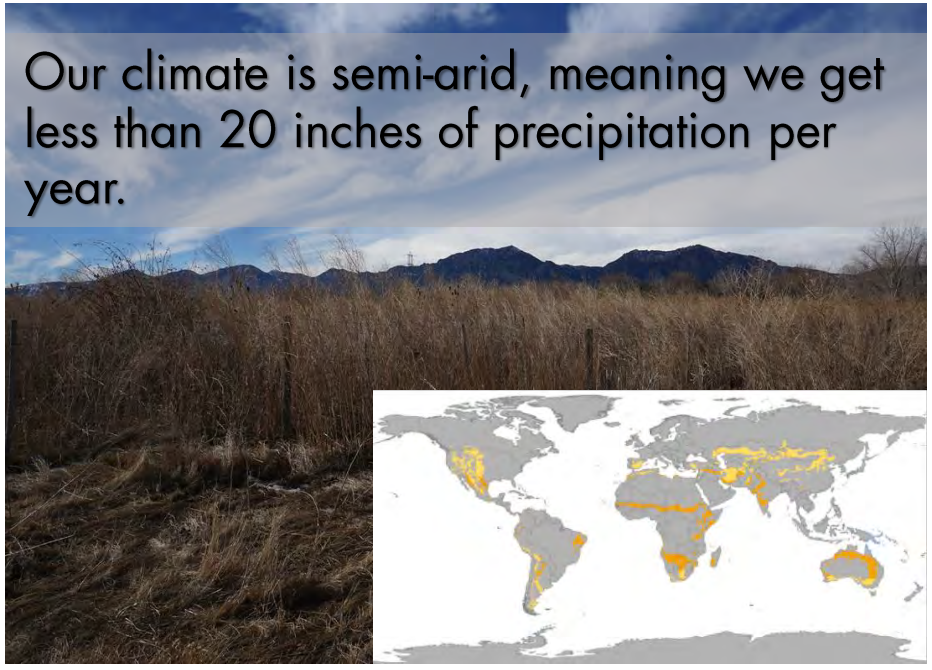
Explanatory and documentation materials included in this report are:

- Focus Group Materials
- Summary of Science Pyramid Visitor Panels
- Water Survey Report
- *Welcome Home* Exhibition Overview
- *Welcome Home* Color Palette
- *Welcome Home* Installation Views
- Ecosystem Wall Field Guide – English
- Habitat Lounge – Dry Adaptation Field Guide – English
- Habitat Lounge – Wet Adaptation Field Guide – English
- K12 Curriculum – Discovery Days – Teacher / Parent Resources – Science Chats
- Science Pyramid Web Page
- *Welcome Home* Press Release
- *Inside the Gardens* Member Magazine Excerpt

Plants and animals have adaptations to our dry climate.

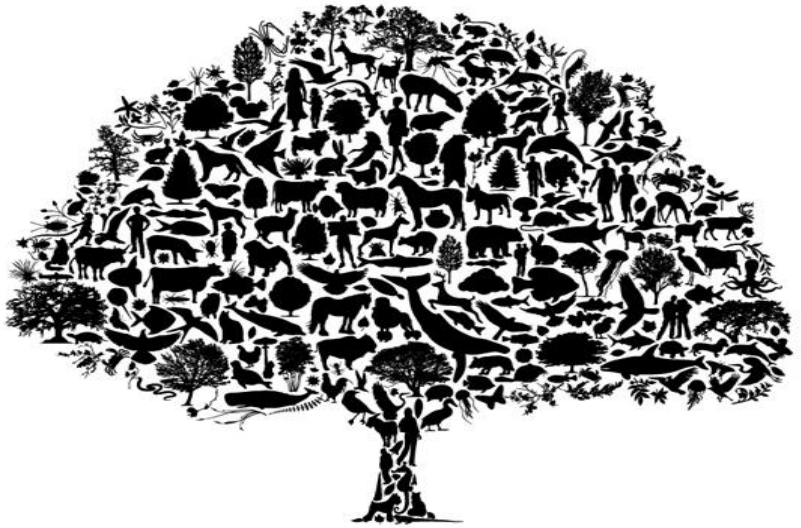
Drought is a natural occurrence in our climate.

Our climate is semi-arid, meaning we get less than 20 inches of precipitation per year.

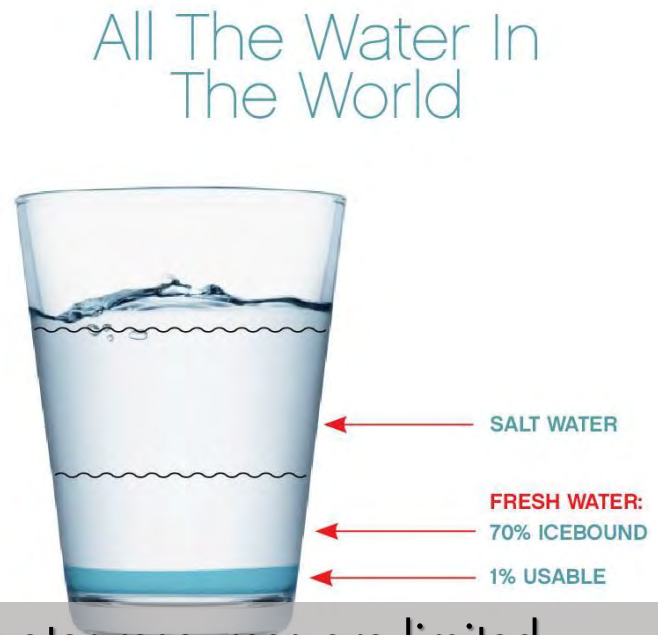


An ecosystem is a biological community of interacting organisms and their physical environment.

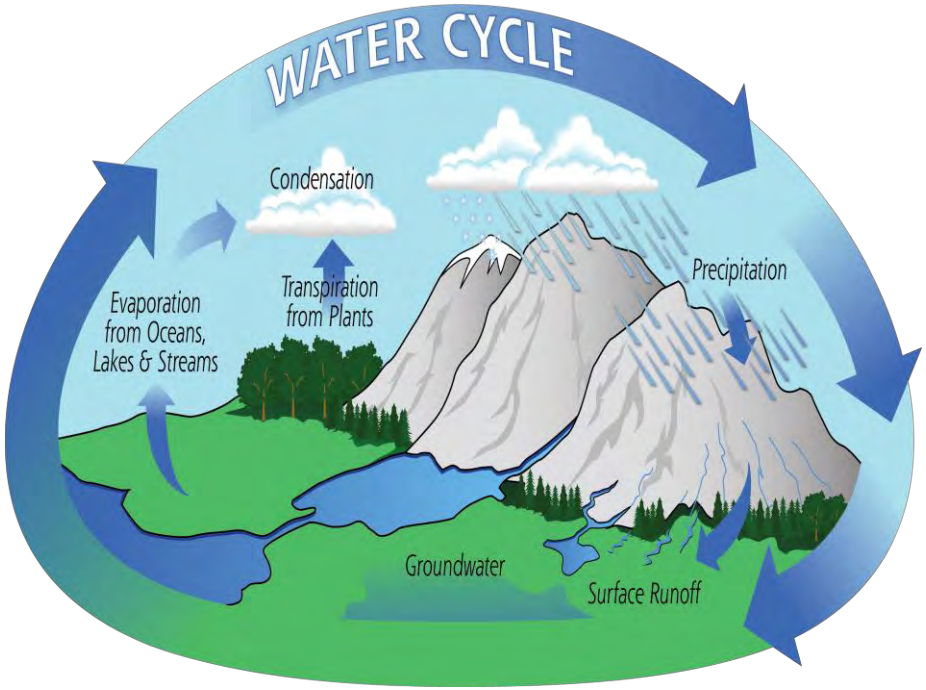
Biodiversity is the variety of life in the world or in a particular habitat or ecosystem.



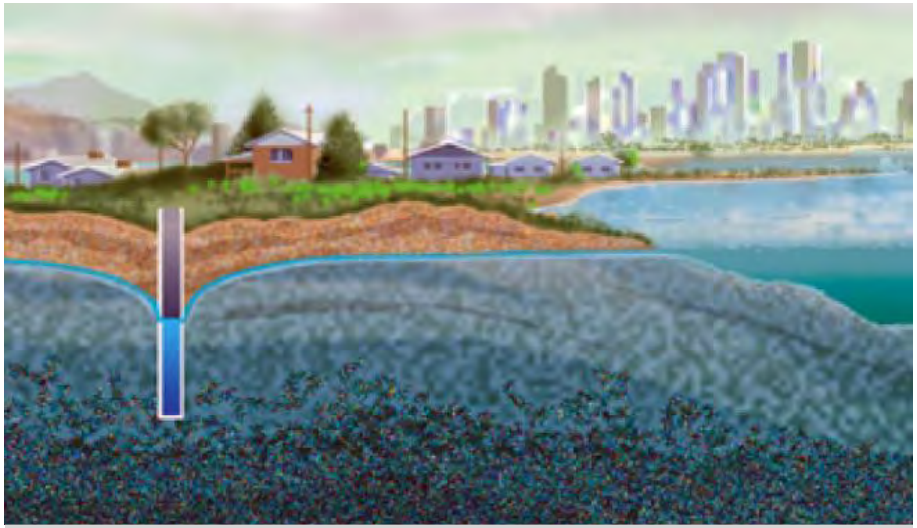
We share habitat with all living things– plants, animals, fungi, and bacteria.



Our water resources are limited.



Most of the water in our rivers comes from spring runoff of melted Rocky Mountain snow.

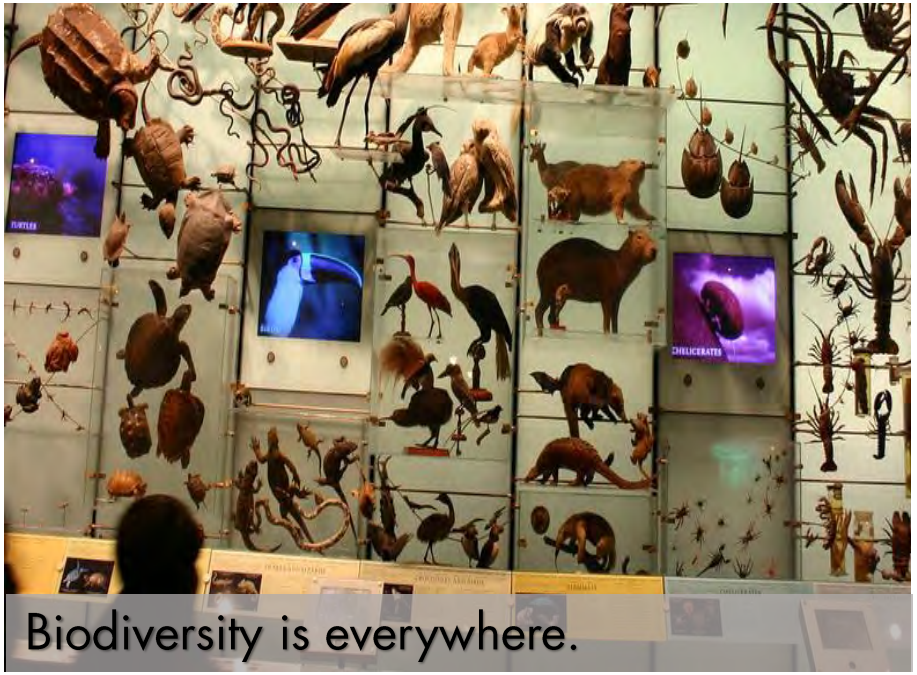


Groundwater is water held underground in the soil or rocks.

The amount of mountain snow affects rivers and underground aquifers.

Earth is a home for humans and many other creatures.

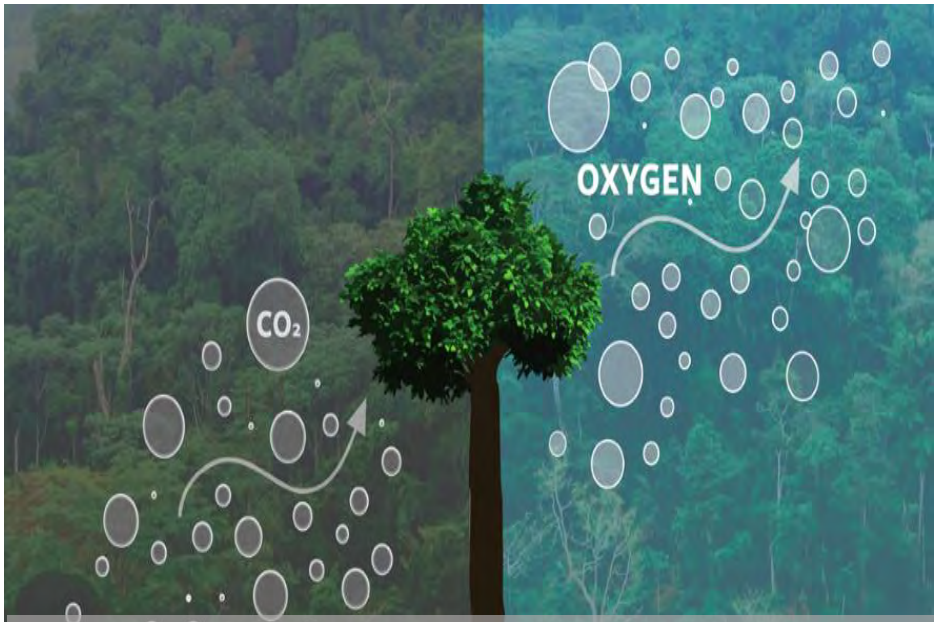
Even deserts can be home to a rich diversity of plants and animals.



Biodiversity is everywhere.

Some plants and animals thrive in the midst of our cities.

Wetlands near streams, lakes, or rivers support a lot of plant and animal species.



Biodiversity invisibly affects everything.

All plants and animals are interconnected with the places they live.

Wetlands help to purify our water supply.

Forests and wetlands help to control floods.

Climate change is altering our environment.

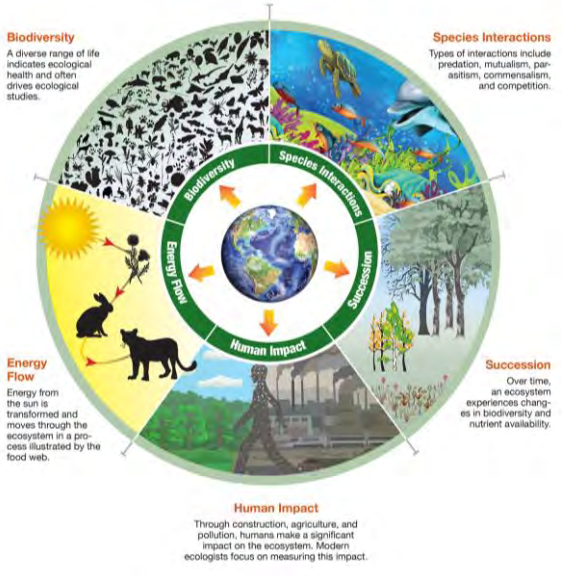
Our environment is changing due to population growth.

We need to adapt our way of life to meet future demands on the water supply.

We have a limited supply of water and population growth can impact water demand.

Earth is our home, and it is changing.

Urban areas are shared by humans and many other organisms.



Ecosystems are shared habitats between humans and all the other organisms that live there.

A healthy ecosystem is better able to cope with external stress and is more likely to support greater biodiversity.

A healthy ecosystem affects the health of its neighbors.

Science Pyramid Visitor Panels

2 visitor panels

English speaking | 10 participants, 8 of them members | All have been to the Gardens previously, many have been coming for years

Spanish speaking | 5 participants, all non-members | Almost all participants were first-time visitors

What's important to participants in relation to water?

Conservation (water scarcity, how we use water locally, how we can conserve water)

The connection of water to life (plants, animals and humans)

Colorado and local specific issues (for example, the Colorado River)

What they know, but want to hear more about…

Limited water in the West

Climate change and how it affects our planet

These were the most highly ranked images and statements by both groups in the **high knowledge / high interest category**

We have a limited supply of water and population growth can impact water demand

Our environment is changing due to population growth

trainer EVALUATION

What they don't know, but want to hear more about…

How they can **adapt to demands** on water

This was the most highly ranked image and statement by both groups in the **low knowledge / high interest category**

We need to adapt our way of life to meet future demands on the water supply

Issues of climate change and water that are **specific to Colorado**: droughts, floods and our semi-arid climate

These were also highly ranked images and statements by both groups in the **low knowledge / high interest category**

Drought is a natural occurrence in our climate

Forests and wetlands help to control floods

Our climate is semi-arid, meaning we get less than 20 inches of precipitation per year

What they don't think is important, but really is…

Biodiversity & Shared ecosystems with humans

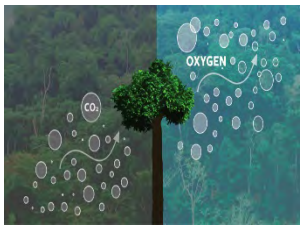
This was one of the stories ranked **lowest** by both groups

Leaves from a forest that fall into a stream feed microbes and insects. Insect larvae become food for fish and frogs, and adult flying insects become food for forest birds.

These statements were ranked as **low knowledge / low interest** by both groups

Biodiversity is the variety of life in the world or in a particular habitat or ecosystem

Ecosystems are shared habitats between humans and all the other organisms that live there



Biodiversity invisibly affects everything

What they don't appear to understand at this point…

The **connection** between water conservation, ecosystems and biodiversity

What type of overall aesthetic appeals to participants?

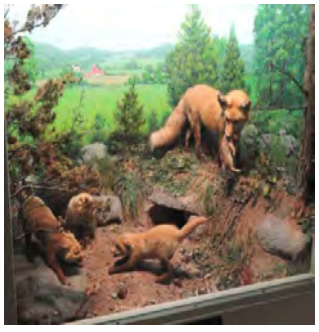
Naturalistic representations

Living collections, **"real" specimens**

Connections to local efforts/locations/issues

Art does not equal science, stylized was not appealing

These are the most popular images to depict the "feel" participants most liked for an exhibition



General thoughts about the Science Pyramid

English-speaking, members

***Note**: This group was able to spend about 30 minutes reacting to and talking about the Science Pyramid, including the building design, the entrance, the exhibition, and the interactives. This was something that the Spanish-speaking group did not have a chance to engage in at length. Therefore, there are more comments from this group of participants for this section.*

Did not see science in the Science Pyramid

They described it as **tired**, **disappointing**, **confusing**, **underwhelming** and **disconnected**.

As one participant put it, the Pyramid did not pass his "so-what" test: "In other words, if this weren't here, what would I be missing in my journey here? And if this were here, what is it adding to my visit here? Right now, it **doesn't satisfy my "so-what" test."**

Comments on the exhibits in the Science Pyramid

English-speaking, members

Were attracted to certain areas, but then disappointed by the exhibits

They did not understand the connection between the globe and the control station, which means they were frustrated by not understanding how to interact with the globe.

They like the topographic map made of glass but wanted it to do more; they wanted it to be less like an art piece.

They liked the concept of the light projection, but it did not react to them in the way they anticipated, which led to disappointment.

They thought the listening stations were all form over function; they didn't understand how to use them and then couldn't hear well once they did.

General thoughts about the Science Pyramid

Spanish speakers

***Note**: The exhibit had changed between the two visitor panels. As a complement to the annual outdoor exhibition, brightly colored panels with playful graphics were installed throughout the space, many featuring text that promoted the content of the respective interactives. An interactive video game and playful environmental elements were also installed in the back of the Science Pyramid.*

Additionally, due to time constraints, the Spanish speaking group had less time in the exhibit to discuss their thoughts.

Were much more forgiving of the space; overall, they found it interesting

There was a lot of new information for participants.

They liked the wall of butterflies; it caught their eye.

Comments on bilingual text in the Science Pyramid from both groups

***Note**: Participants were not asked specifically about the inclusion of bilingual text in the Science Pyramid; however, a few participants made note of the dual text.*

1 participant in the English-speaking group commented that the signs "did have some interesting information and it was simple and I thought it was great that they had things in Spanish." But, she wanted more, more things you can "listen to, tactile things, more things than just reading the signs on the wall."

1 participant in the Spanish-speaking group also commented on the bilingual text, "I just wanted to say I really like that everything's in English and Spanish. That's something people will appreciate, and they will want to come back because they'll feel welcomed. I'm very glad everything's in Spanish."

How could the Science Pyramid be improved?

More **signage about how to interact with elements** in the Science Pyramid – where you can interact and how to interact.

More **signage to invite people inside**; many participants, particularly in the Spanish-speaking group, thought this was a special event space where they were not welcome to enter.

Naming – **is Science Pyramid the right name?** Does it accurately reflect what is inside?

Things to think about for the new exhibit…

Stories/specimens need to **tie into the larger picture**; participants were consistently drawn to bigger stories over individual animals or plants.

Weave topics such as biodiversity and ecosystems into stories of conservation and local and Colorado-based examples. Participants did not show any interest in biodiversity and shared ecosystems, but these topics are crucial. How can they be included in a manner that is compelling and shows the important relationships between humans, plants, animals and where we live?

Participants found stories about **local systems and locations compelling**. For example, how drought and floods affect Colorado, the Colorado River, how water shortages in the West affect Colorado, and what they can do to adapt to our changing climate.

Be **overt in messaging**. Participants want to know how the exhibit relates to larger themes and what they can expect to find in the exhibit.

Be sure to **welcome visitors into the space**. Start to orient visitors before they enter the Science Pyramid and continue to orient them when they walk inside.

Participants enjoy **interaction** and want it in the exhibit. However, it needs to be **intuitive and explicit**, not hidden or subtle. When information/case studies are included in touch screens, include messaging that guides people to understand what they will find if they choose to explore.

Include messaging around "**what you can do to help**" as participants want to feel empowered to make a positive change in their local environment.

Science is viewed in a narrow framework; many people did not "see science" in the Science Pyramid exhibit. Consider explicitly stating that the study of ecosystems and biodiversity is science to relieve cognitive tension.

Naturalistic representations of plants, animals and locations appealed to participants; they were skeptical of anything that appeared too much like art. Additionally, include live specimens whenever possible.

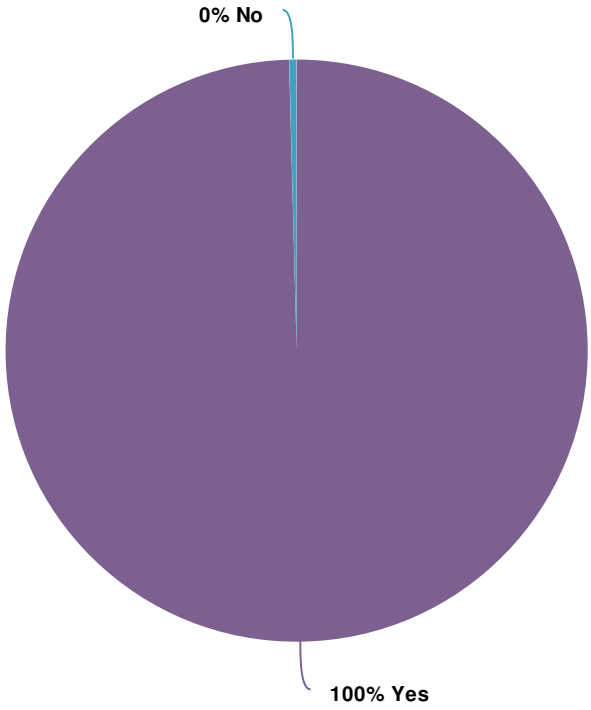
Report for Survey: Water Issues in Colorado

Response Counts

Completion Rate:	**89.8%**	
Complete		221
Partial		25

Totals: 246

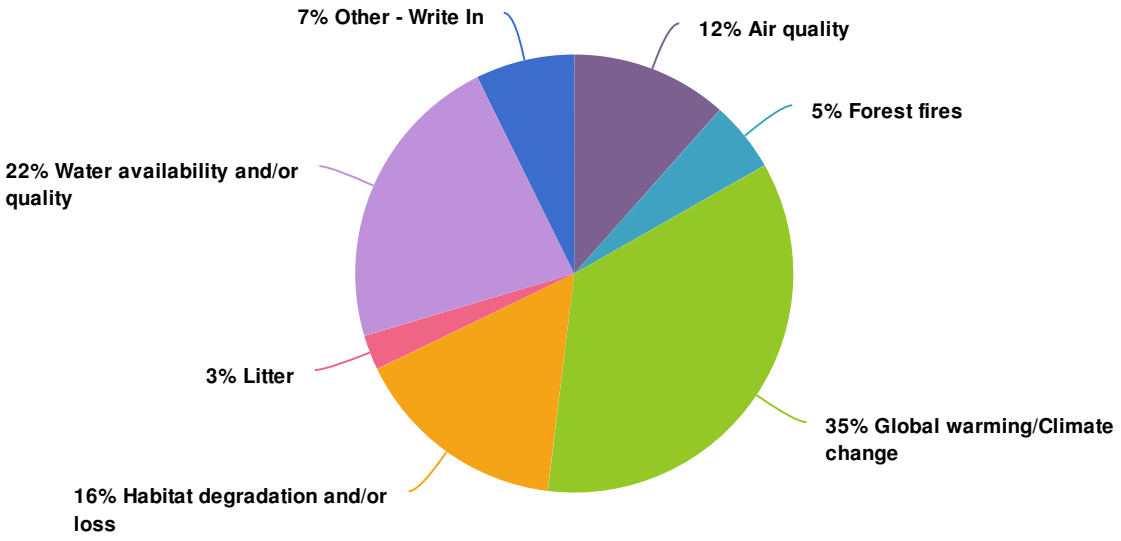
1. Do you currently live in Colorado?



Value	Percent	Responses
Yes	99.6%	244
No	0.4%	1

Totals: 245

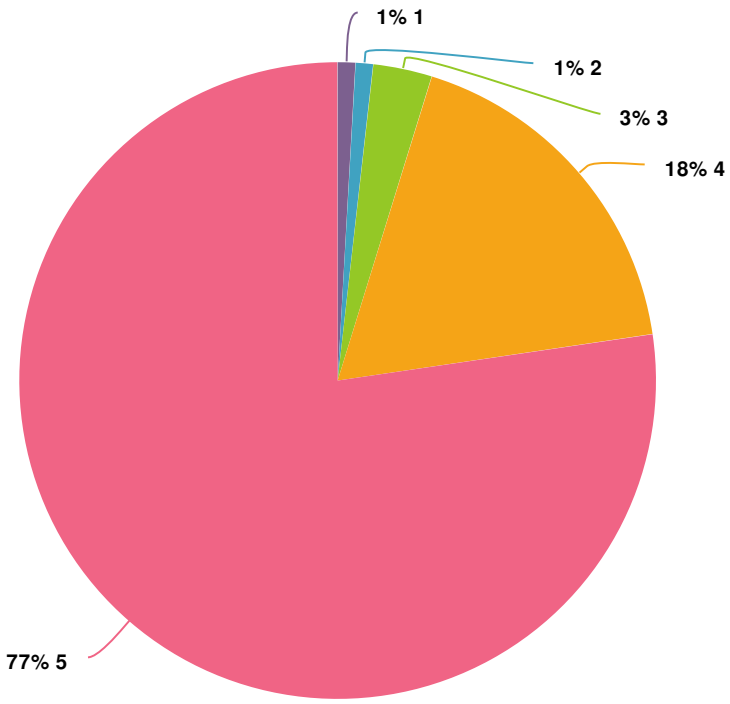
2. What do you think is the biggest environmental problem in Colorado?



Value	Percent	Responses
Air quality	11.6%	27
Forest fires	5.2%	12
Global warming/Climate change	35.2%	82
Habitat degradation and/or loss	15.9%	37
Litter	2.6%	6
Water availability and/or quality	22.3%	52
Other - Write In	7.3%	17

Totals: 233

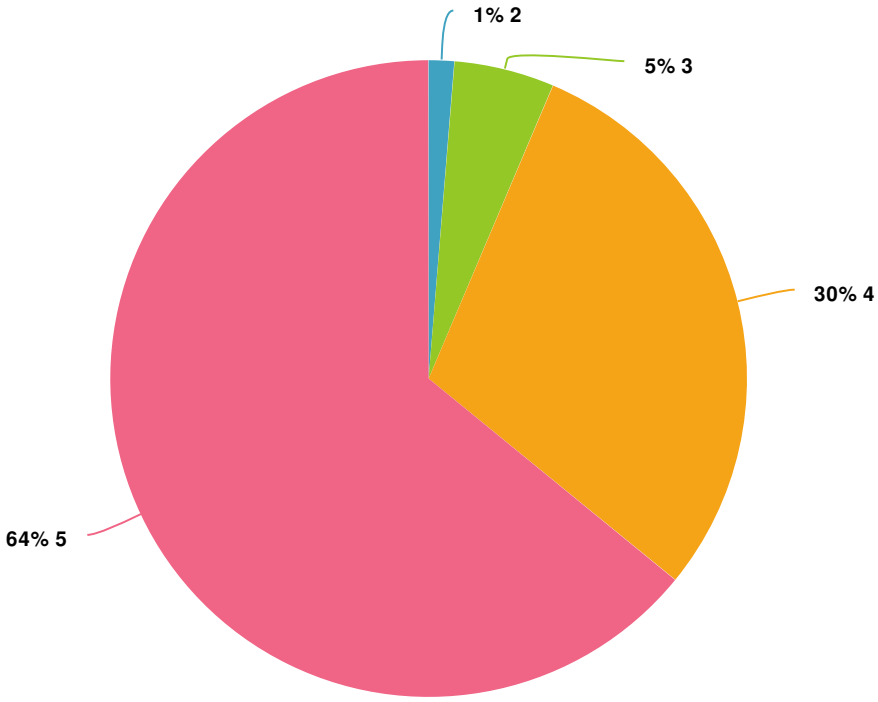
3. On a scale of 1 to 5, how important do you believe water resource issues are in Colorado?



Value		Percent	Responses
1		0.9%	2
2		0.9%	2
3		3.0%	7
4		17.9%	42
5		77.4%	181

Totals: 234

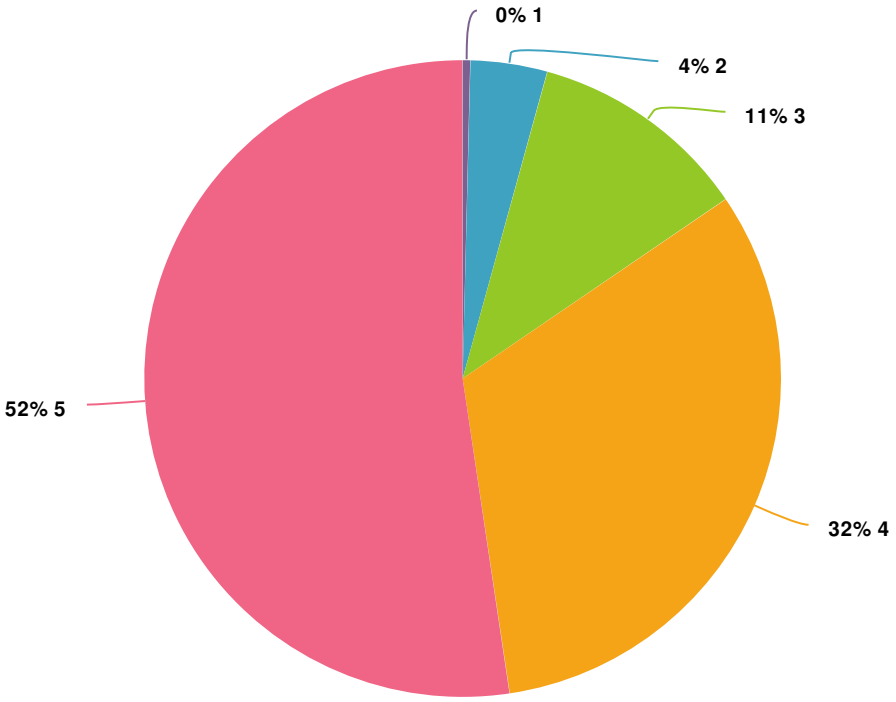
4. On a scale of 1 to 5, how important is water conservation to you?



Value	Percent	Responses
2	1.3%	3
3	5.1%	12
4	29.5%	69
5	64.1%	150

Totals: 234

5. On a scale of 1 to 5, how much responsibility do you believe households have in saving water?



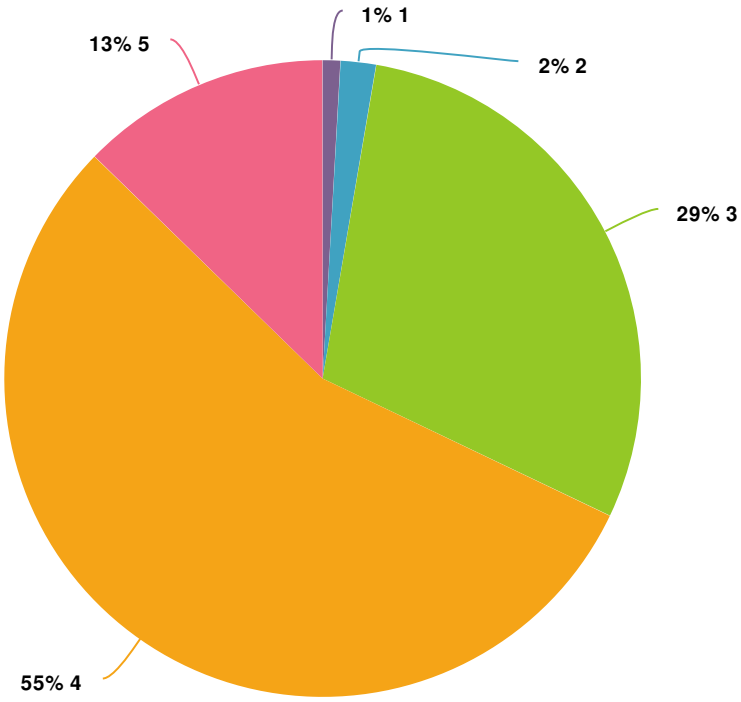
Value		Percent	Responses
1		0.4%	1
2		3.9%	9
3		11.2%	26
4		32.2%	75
5		52.4%	122

Totals: 233

6. What do you consider to be the greatest threats to the water supply in your area? Please rank your top three, with 1 being the greatest threat.

Item	Overall Rank	Rank Distribution	Score	No. of Rankings
Increase in local population	1		330	145
Increase in diversion of water to urban population growth	2		249	120
Decrease in precipitation/snowpack	3		228	114
Pollution from mining, oil/gas, or other industry	4		202	96
Increase in mining or oil and gas industrial water use	5		104	59
Pollution from agriculture	6		75	42
Forest fires	7		66	39
Increase in agricultural water use	8		61	32

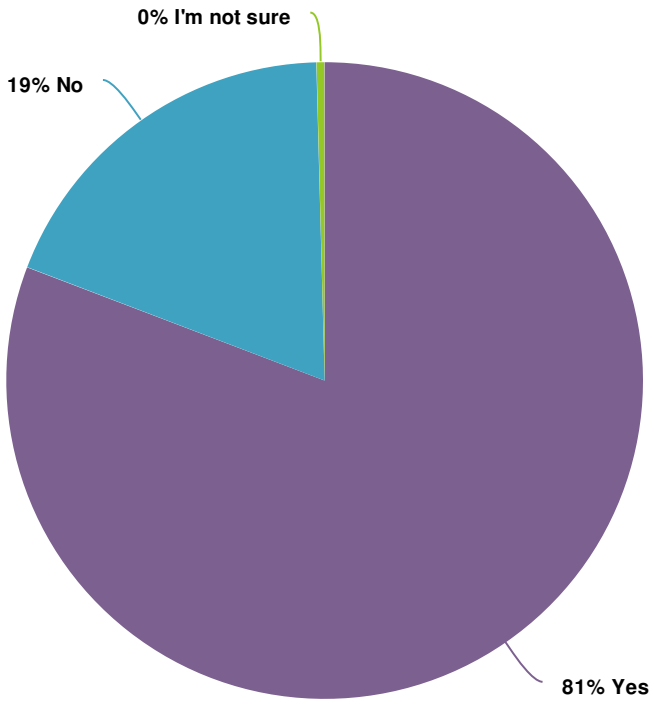
7. On a scale of 1 to 5, to what degree do you generally practice water conservation at home?



Value	Percent	Responses
1	0.9%	2
2	1.8%	4
3	29.4%	65
4	55.2%	122
5	12.7%	28

Totals: 221

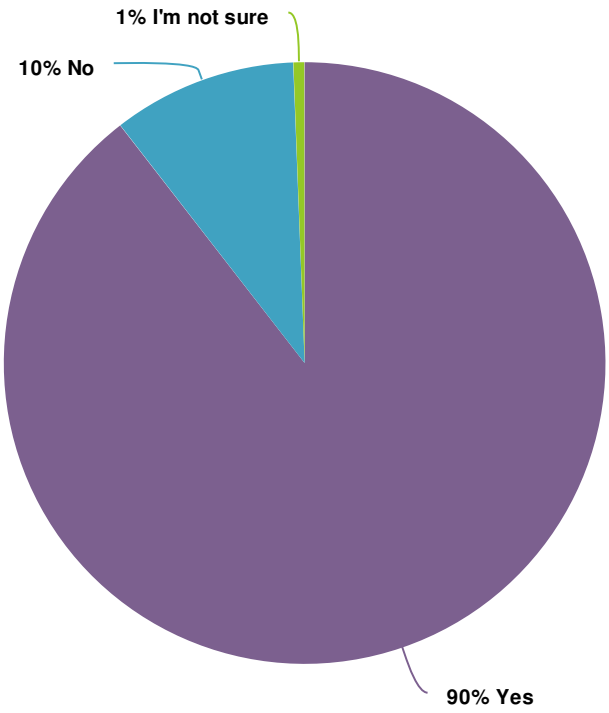
8. Are you or your family responsible for the care of a yard or garden?



Value	Percent	Responses
Yes	80.8%	181
No	18.8%	42
I'm not sure	0.4%	1

Totals: 224

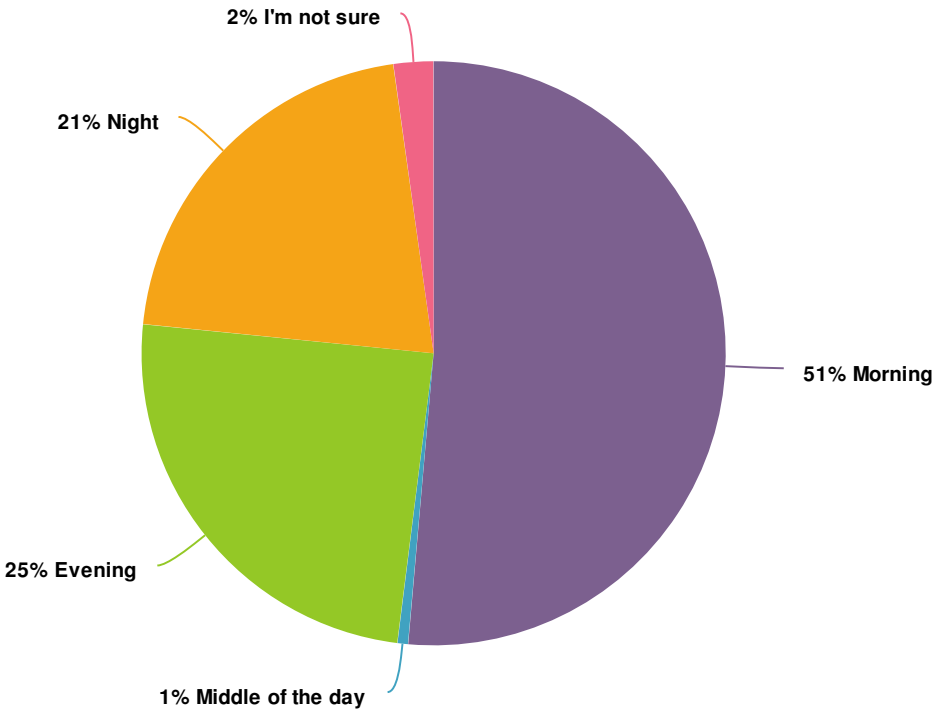
9. Do you use water for landscaping?



Value	Percent	Responses
Yes	89.5%	162
No	9.9%	18
I'm not sure	0.6%	1

Totals: 181

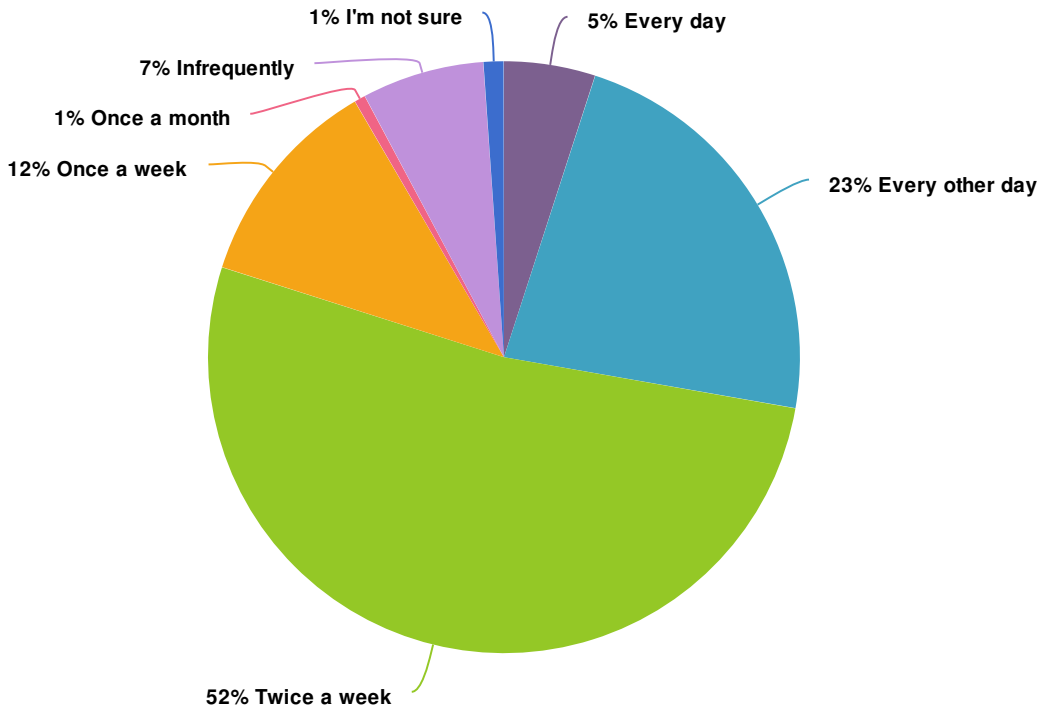
10. When do you water?



Value	Percent	Responses
Morning	51.4%	92
Middle of the day	0.6%	1
Evening	24.6%	44
Night	21.2%	38
I'm not sure	2.2%	4

Totals: 179

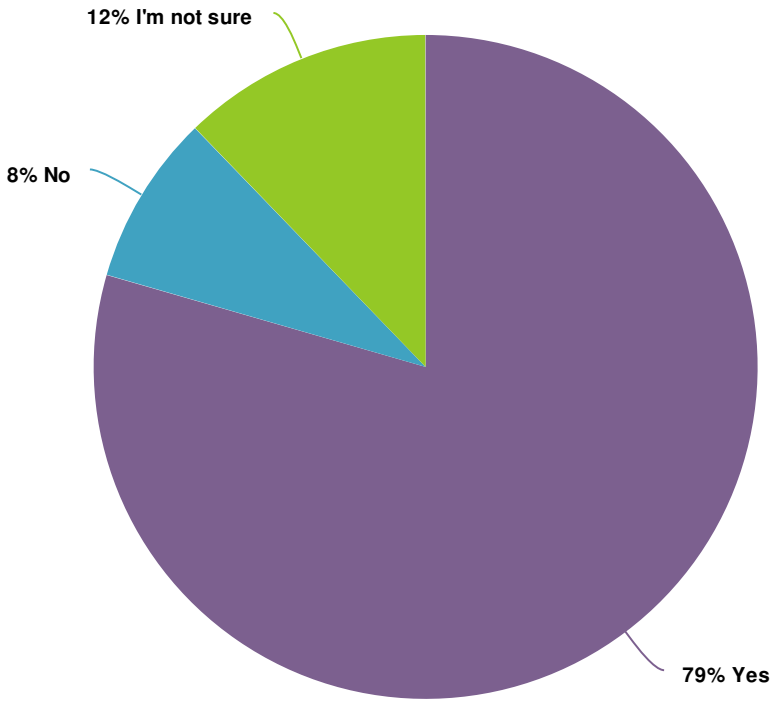
11. In general, how often do you water during the growing season?



Value	Percent	Responses
Every day	5.0%	9
Every other day	22.8%	41
Twice a week	52.2%	94
Once a week	11.7%	21
Once a month	0.6%	1
Infrequently	6.7%	12
I'm not sure	1.1%	2

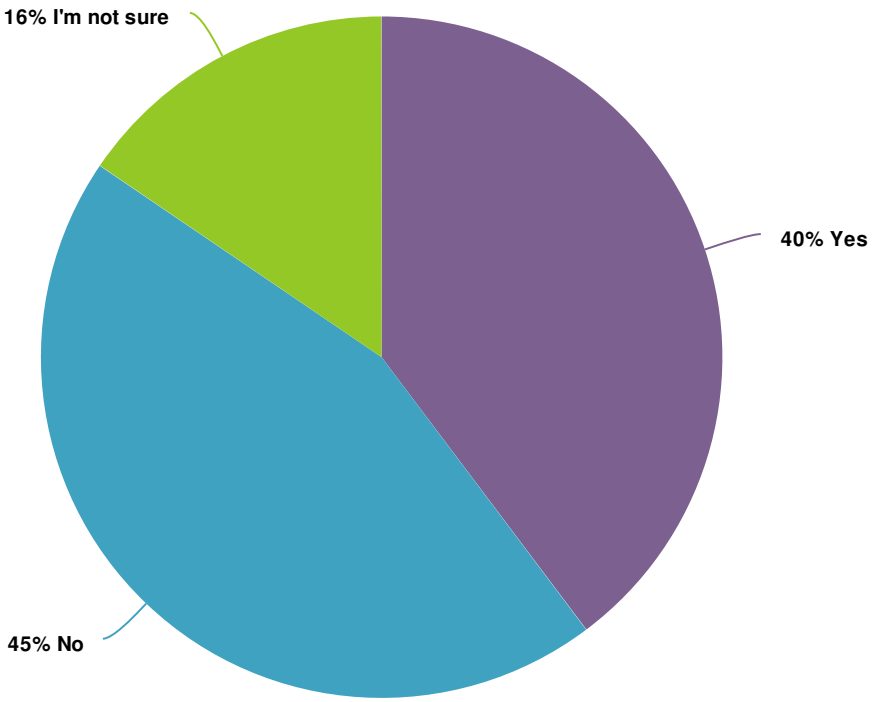
Totals: 180

12. Do you have any Colorado native plants in your garden?



Value	Percent	Responses
Yes	79.4%	143
No	8.3%	15
I'm not sure	12.2%	22
	Totals: 180	

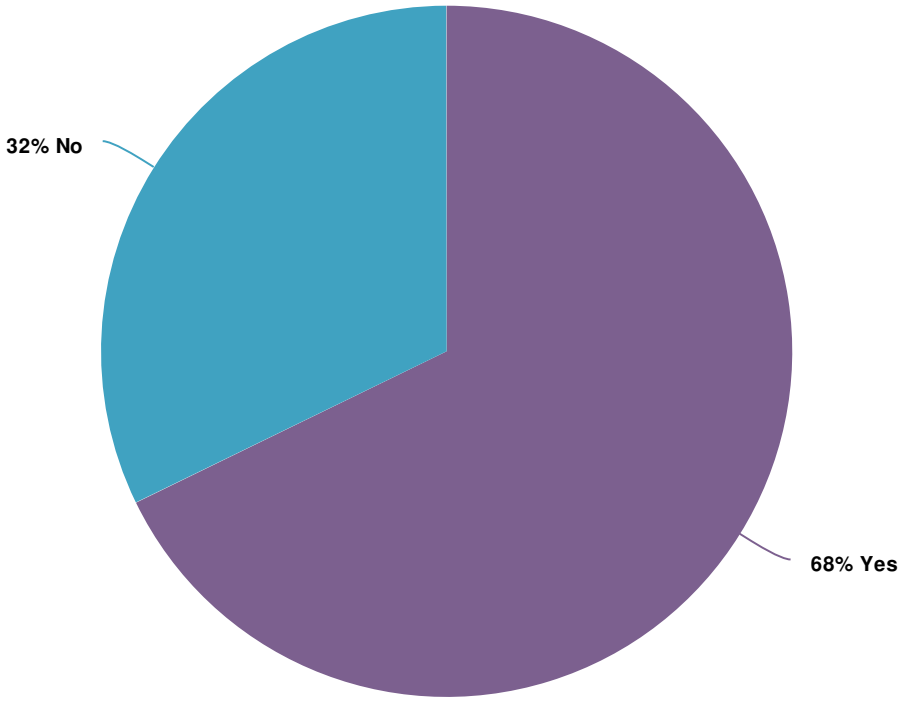
13. Do you have a bluegrass lawn?



Value	Percent	Responses
Yes	39.8%	72
No	44.8%	81
I'm not sure	15.5%	28

Totals: 181

14. Do you grow any fruits and/or vegetables in your garden?



Value	Percent	Responses
Yes	67.8%	122
No	32.2%	58

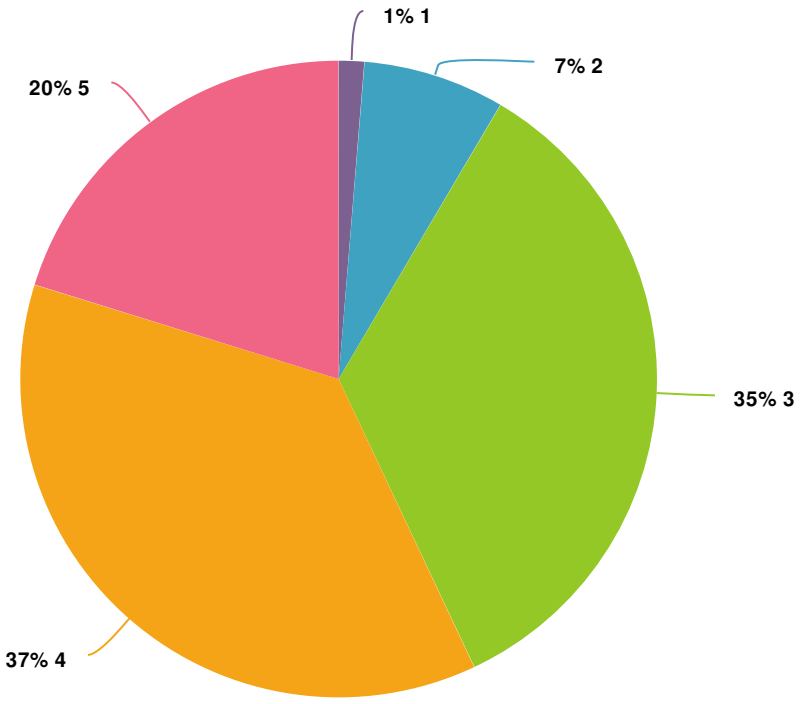
Totals: 180

15. Please rank the following factors in order of their importance to you when making decisions about your home landscape. Rank the most important #1, least important #6.

Item	Overall Rank	Rank Distribution	Score	No. of Rankings
Low maintenance	1		734	169
Water conservation	2		706	164
Appearance	3		685	167
Fruit and/or vegetable production	4		547	164
Cost of water	5		498	154
Outdoor activities	6		348	158

Lowest Rank — Highest Rank

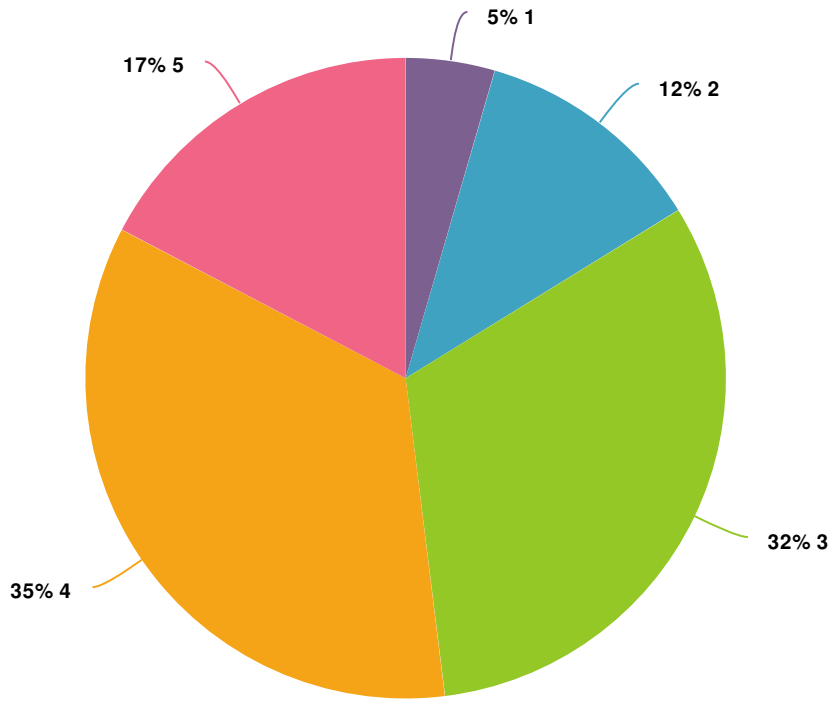
16. How would you rate your level of knowledge about water conservation?



Value	Percent	Responses
1	1.3%	3
2	7.2%	16
3	34.5%	77
4	36.8%	82
5	20.2%	45

Totals: 223

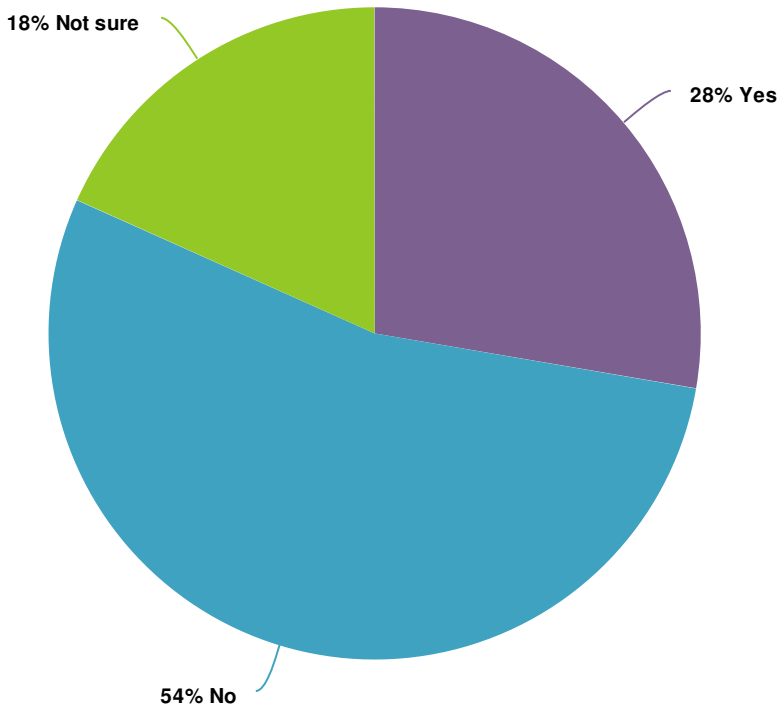
17. How would you rate your level of knowledge about water-saving alternatives for landscape care?



Value	Percent	Responses
1	4.5%	8
2	11.7%	21
3	31.8%	57
4	34.6%	62
5	17.3%	31

Totals: 179

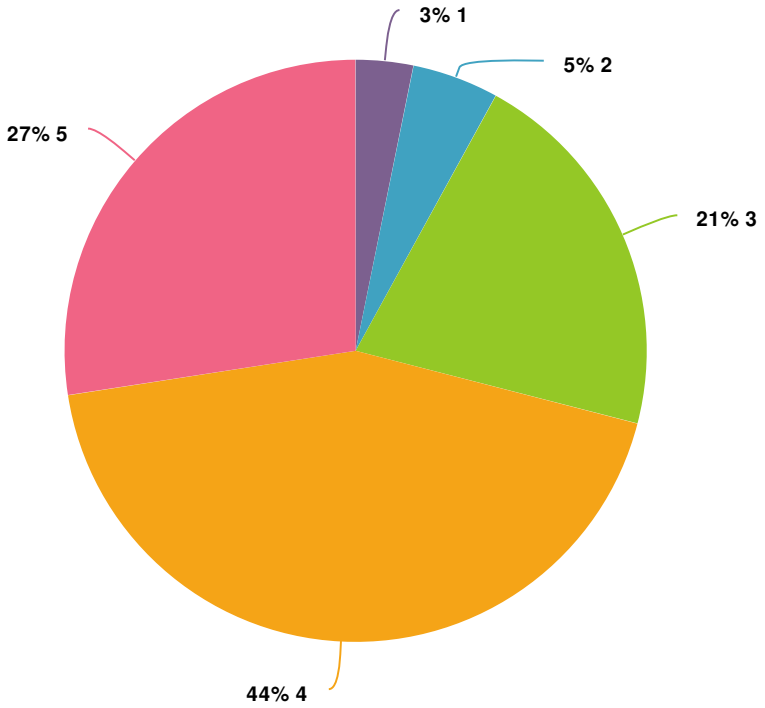
18. Have you seen, read or heard anything about what the state of Colorado plans to do to meet future water needs?



Value	Percent	Responses
Yes	27.7%	62
No	54.0%	121
Not sure	18.3%	41

Totals: 224

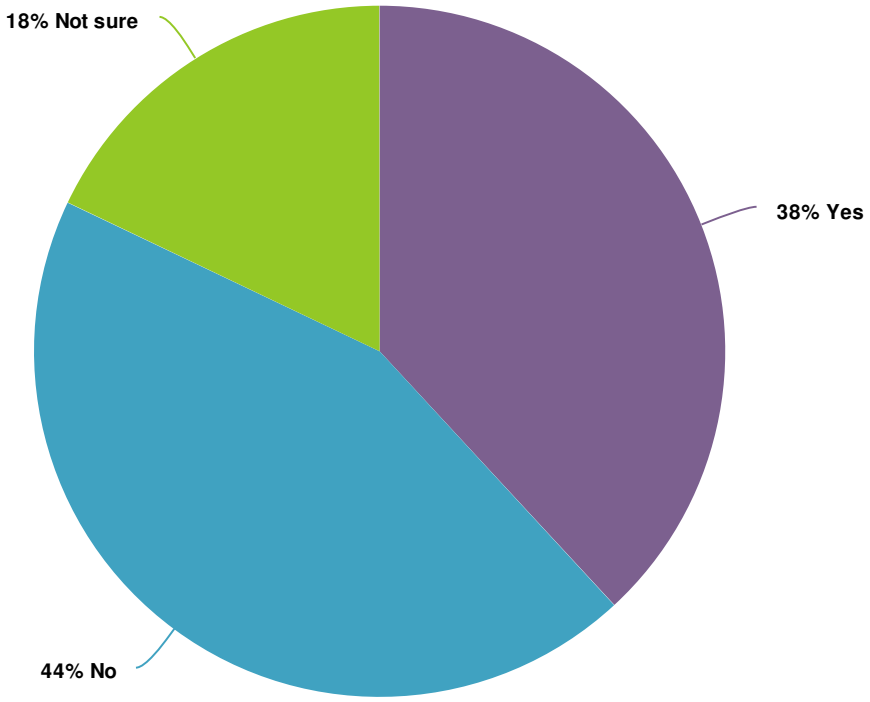
19. How supportive are you of what you have heard about those plans?



Value	Percent	Responses
1	3.2%	2
2	4.8%	3
3	21.0%	13
4	43.5%	27
5	27.4%	17

Totals: 62

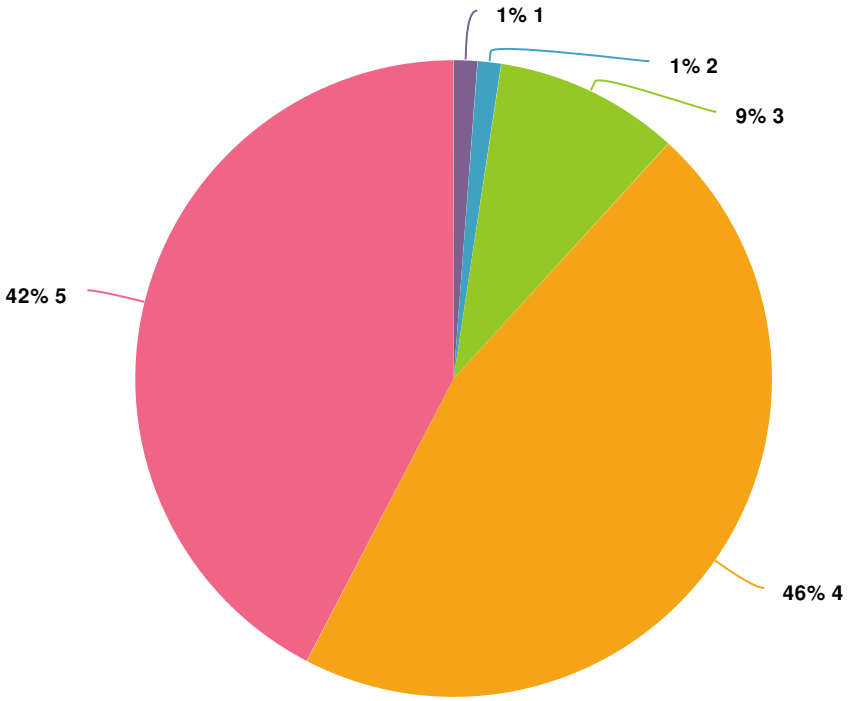
20. Are you aware of any local efforts to conserve water in your part of Colorado?



Value	Percent	Responses
Yes	38.1%	85
No	43.9%	98
Not sure	17.9%	40

Totals: 223

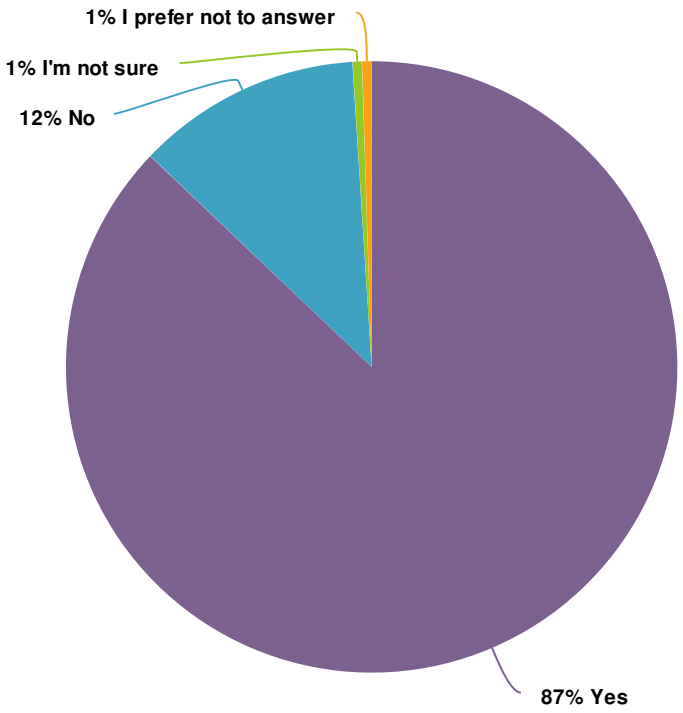
21. How supportive are you of what you have heard about those plans?



Value		Percent	Responses
1		1.2%	1
2		1.2%	1
3		9.4%	8
4		45.9%	39
5		42.4%	36

Totals: 85

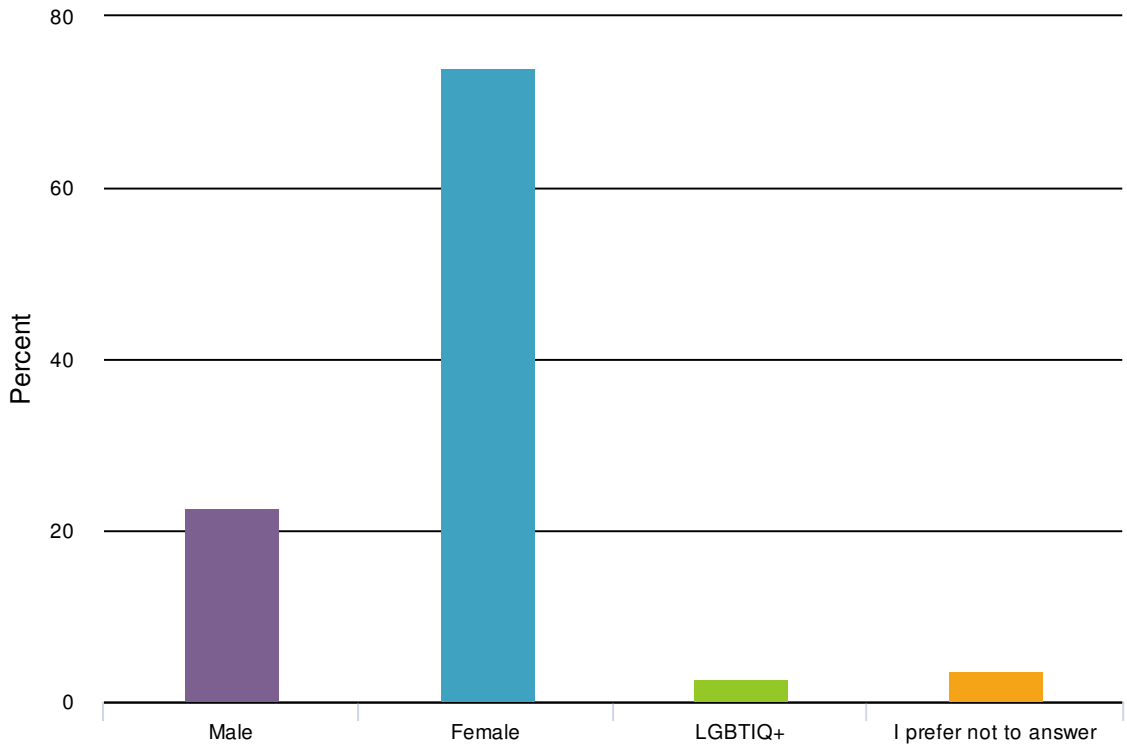
22. Have you ever visited Denver Botanic Gardens at York Street or Denver Botanic Gardens Chatfield Farms?



Value	Percent	Responses
Yes	87.2%	191
No	11.9%	26
I'm not sure	0.5%	1
I prefer not to answer	0.5%	1

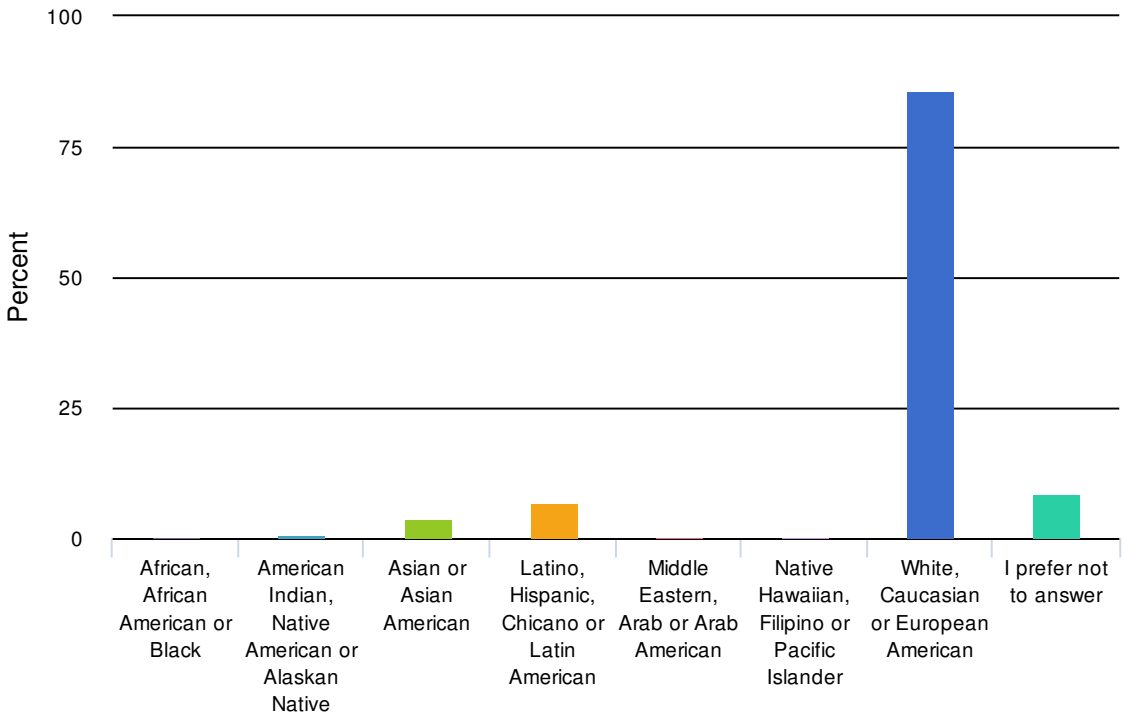
Totals: 219

23. Are you...?



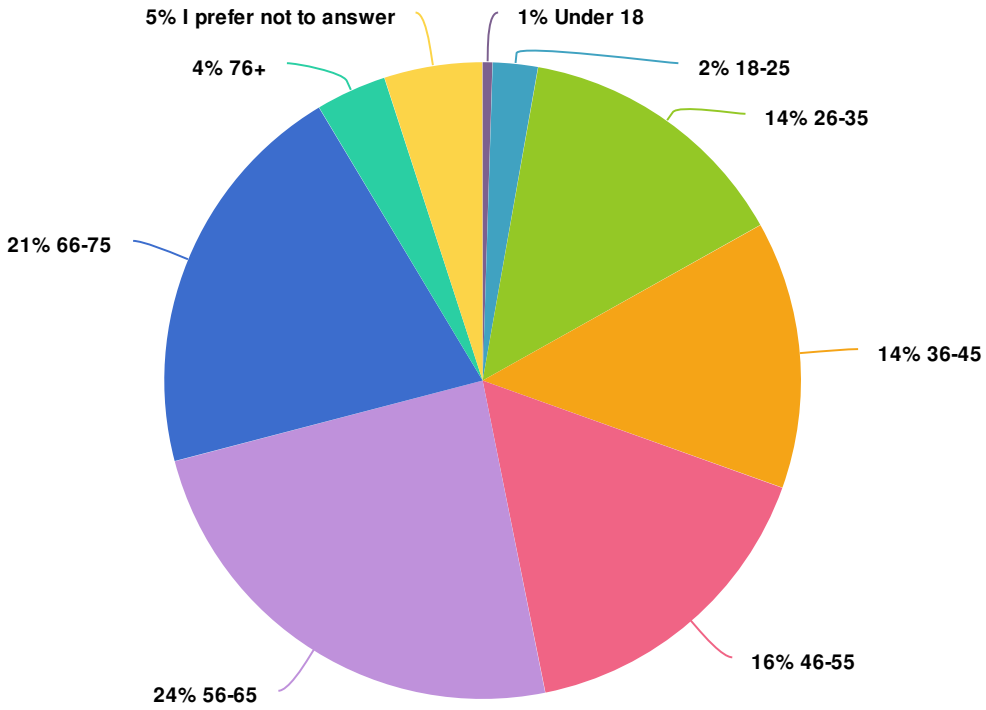
Value	Percent	Responses
Male	22.7%	50
Female	74.1%	163
LGBTIQ+	2.7%	6
I prefer not to answer	3.6%	8

24. What is your ethnic background or heritage? (Check all that apply.)



Value	Percent	Responses
African, African American or Black	0.5%	1
American Indian, Native American or Alaskan Native	0.9%	2
Asian or Asian American	3.6%	8
Latino, Hispanic, Chicano or Latin American	6.8%	15
Middle Eastern, Arab or Arab American	0.5%	1
Native Hawaiian, Filipino or Pacific Islander	0.5%	1
White, Caucasian or European American	85.9%	189
I prefer not to answer	8.6%	19

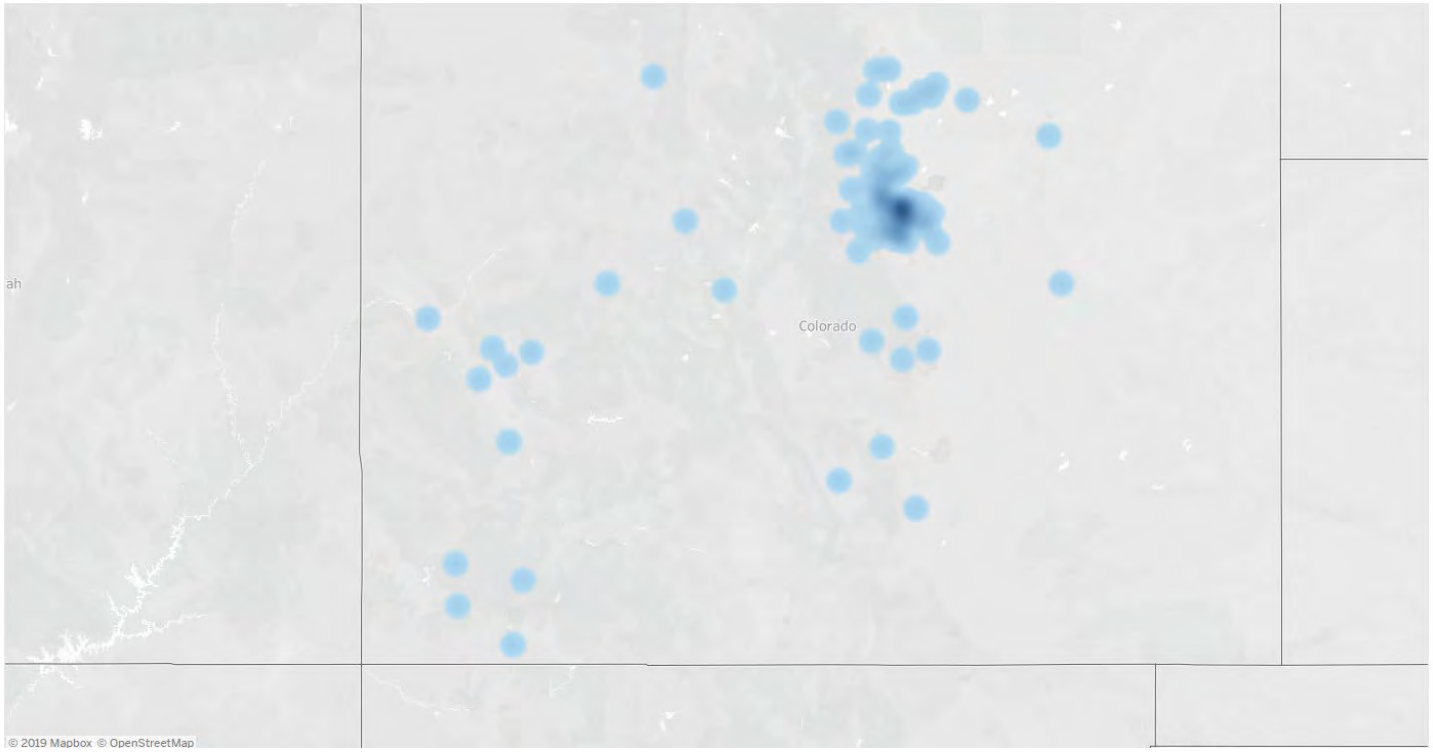
25. What is your age?



Value	Percent	Responses
Under 18	0.5%	1
18-25	2.3%	5
26-35	14.1%	31
36-45	13.6%	30
46-55	16.4%	36
56-65	24.1%	53
66-75	20.5%	45
76+	3.6%	8
I prefer not to answer	5.0%	11

Totals: 220

WATER SURVEY RESPONDENT ZIP CODE HEAT MAP



Welcome Home Exhibition Overview

"When one tugs at a single thing in nature, he finds it attached to the rest of the world."

Welcome Home: Meet your Habitat opened in November 2019 and explores the ways in which the lives of Colorado's living things are deeply intertwined through landscapes and the finite resources we share. The exhibit celebrates the surprising and often invisible ways organisms (including humans) are connected, with an emphasis on the ways in which human stewardship of water and other natural resources is key to supporting the shared habitats we call "home" and the plants and animals that are our neighbors.

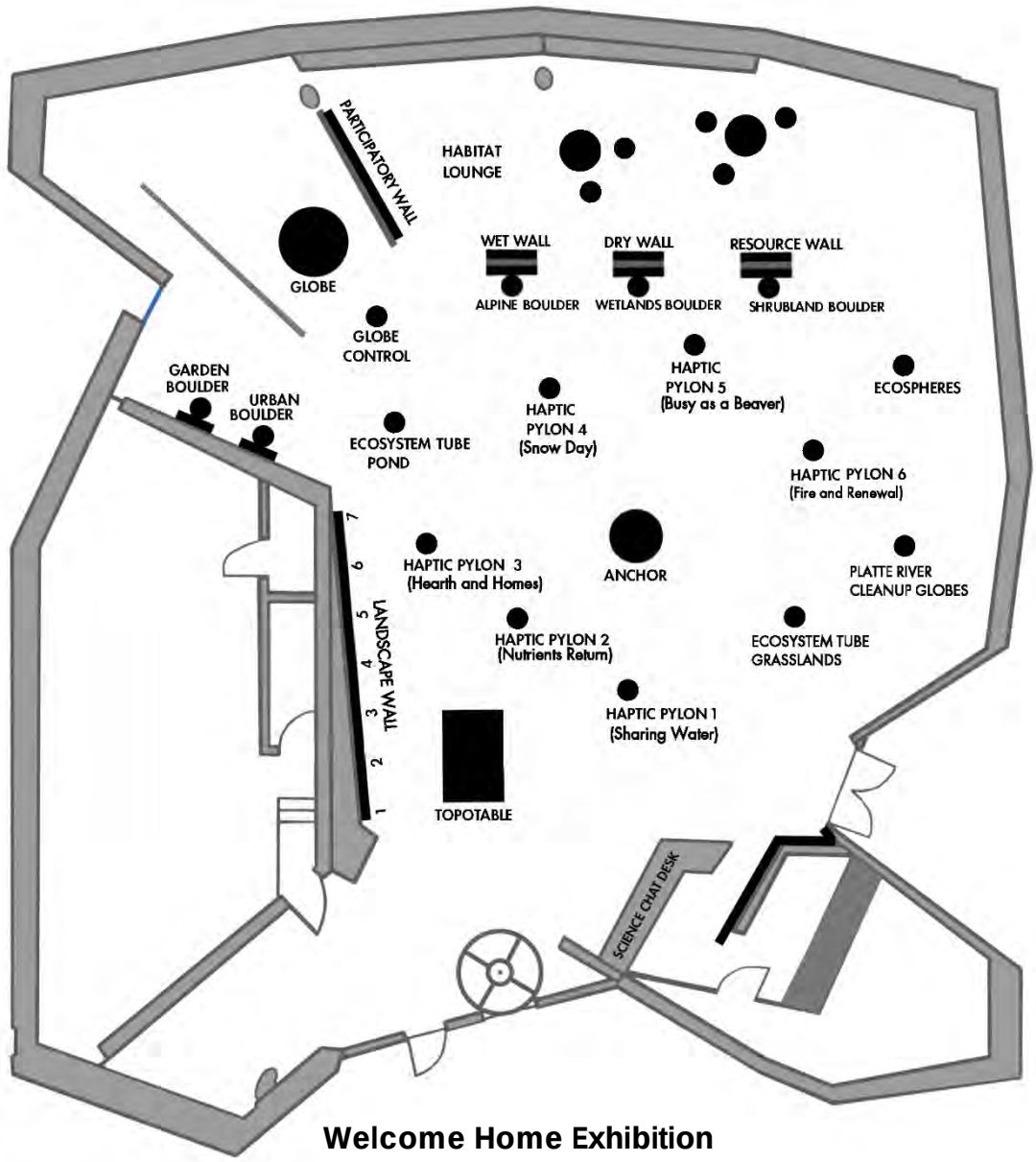
Combining natural objects and human artifacts with interactive digital stories throughout the gallery, visitors can explore various Colorado environments and some of the ways that organisms in those areas are connected. In the Habitat Lounge at the back of the Science Pyramid, visitors can discover the adaptations of plants, animals and fungi to wet and dry habitats, and learn how humans can adapt their behaviors to support biodiversity and the health of our shared home. The exhibition takes advantage of the Science Pyramid's non-linear space to create a narrative that is likewise non-linear. Rather, each element of the exhibition is a unique facet of the story of interconnectedness, each offering a different look at the depths of our bond with nature.

Visitors can:

- Connect with some of the organisms found in Colorado ecosystems.
- Witness how the lives of different plants, animals, and fungi are intertwined with those of humans.
- Learn simple, accessible ways to conserve water and help support the lives of other living things that we share it with, whether through gardening practices or using eco-friendly cleaning products.
- Learn about the changing climate and how they can mitigate their impact on the planet.
- Appreciate the beauty of Colorado landscapes, including urban ecosystems, which are shared habitats.

The exhibition is funded in part by a Water Plan grant from the Colorado Water Conservation Board. The importance of water across all ecosystems is conspicuous throughout the exhibition. With content featuring the changing climate and the myriad human uses of water, the exhibition invites visitors to rethink their water consumption and conserve it for future generations of organisms.

Field guides and books in the Habitat Lounge are intended to remain in the Science Pyramid. Visitors are welcome to take available pamphlets with them.



Welcome Home Exhibition Layout

Main Gallery Exhibition Elements:

The exhibition is interwoven with numerous interactive technologies that offer different opportunities for visitors to learn about the featured ecosystems, landscapes and organisms. Exhibition elements highlight topics that range from the impact of plastics on ecosystems to the hidden complexities of urban habitats.

The different components in the main gallery of *Welcome Home* are:

- **Landscape Wall**
- **Boulders**
- **Pylons**
- **Ecospheres**
- **Platte River Cleanup Globes**
- **Ecosystem Tubes**
- **Omniglobe**
- **Science Chat Desk**

Landscape Wall

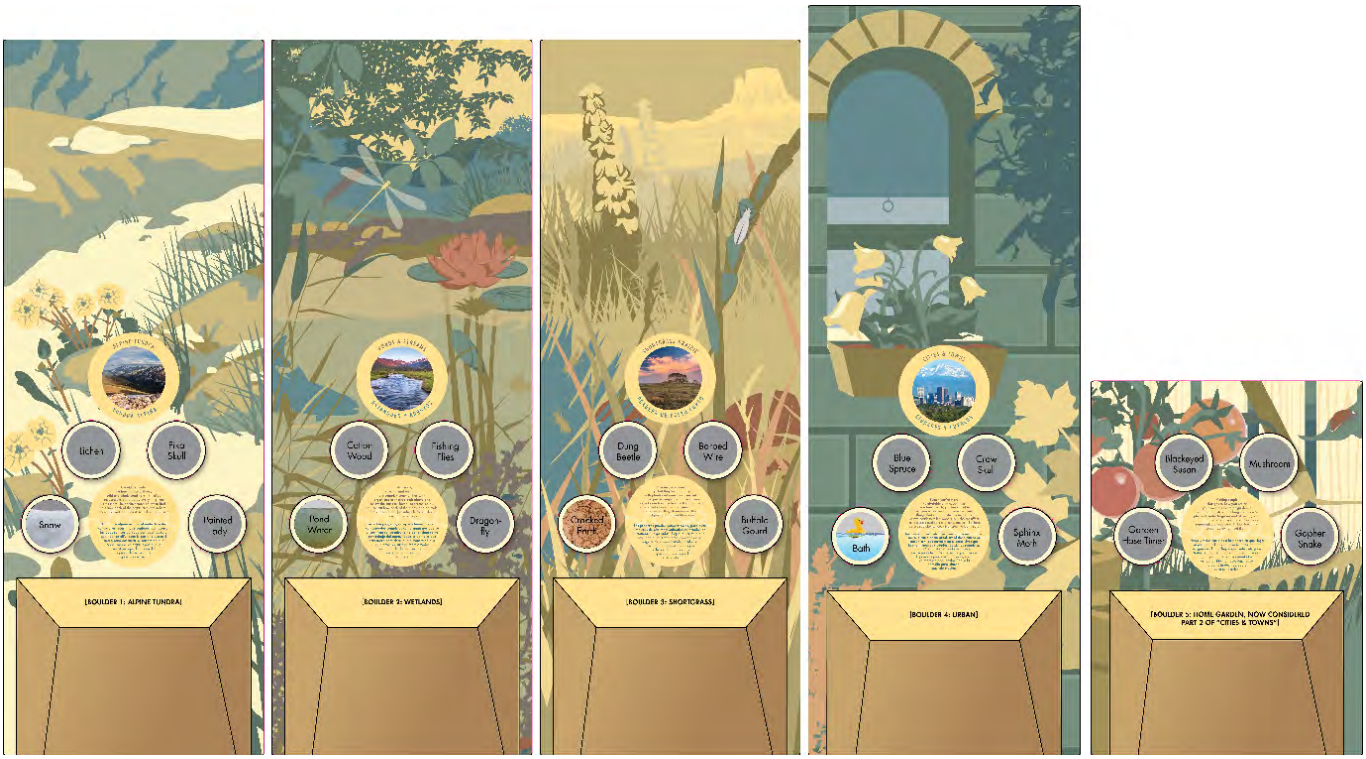
Landscape Wall

A series of panels to the left of the entryway orients visitors to key Colorado landscapes and includes natural and human objects. There are seven panels, each one representing a landscape found in Colorado: alpine tundra, urban spaces, foothills, shortgrass prairie, wetland, montane forest, and pinyon-juniper shrubland.

Each panel contains two images: a landscape illustration and a close-up photo of the landscape, as well as three objects and/orspecimens: one human and two from other organisms. These specimens represent organisms that live in the landscape, including human artifacts that reference the specific ways that people interact with it. The entire wall is meant to visually portray that all the organisms are interconnected accross even seemingly disparate landscapes. This is where the story of *Welcome Home* begins; all other components of the exhibition allow a deeper dive into biodiversity, interconnectivity, and adaptation.

For visitors who want to know more, Field Guides in both English and Spanish are located on the wall to the left of the Landscape Wall. These offer a short description of each ecosystem, as well as information about the specimens and ways in which the organisms depicted are connected. (See Appendix A for object list).

Boulders



Boulders: From left to right, they are alpine tundra, lakes and ponds, shortgrass prairie, urban and home garden.

Some landscapes are additionally highlighted in the digital touch-screen interactives called “boulders.” There are five boulders, each one focusing on one specific type of habitat: alpine tundra, ponds and streams, shortgrass prairie, cities and towns and home gardens.

Behind each boulder is a panel with an illustration of the habitat and a photo of the landscape. Each panel features four objects that highlight water and the organisms (including humans) that share the landscape.

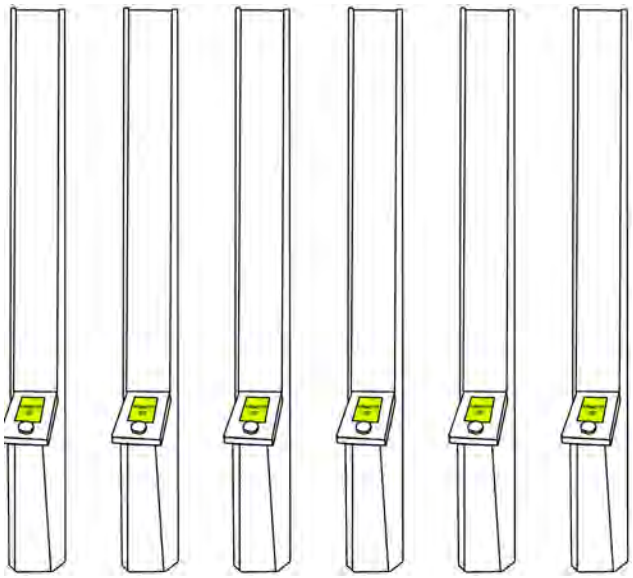
Each boulder tells a short, cyclical narrative about interconnections between the featured organisms, as well as their connections to water in that habitat. They also include one fact about each organism’s relationship to water, as well as suggestions for how humans can help sustain our shared home. The boulders give visitors an opportunity to explore a few of the organisms found in each ecosystem and how they relate to each other. Each boulder tells a short story about water in that habitat and some fun water facts are also included.

The table on the next page lists the boulder themes and the objects that accompany each one.

Boulder	Introduction	Object 1	Object 2	Object 3	Object 4
Alpine Tundra	The alpine tundra is a harsh place with dry, cold and windy conditions. Its limited resources are shared by everything that lives there. Each of the organisms shown here depends on water and on its neighbors for survival.	Snow	Lichen (*Xanthoparmelia* sp.)	American Pika (*Ochotona princeps*)	Painted Lady (*Vanessa cardui*)
Ponds & Streams	Ponds, rivers, streams and wetlands are complex communities with organisms connected both above and below the surface. Each of the plants and animals represented above (including humans) shares this watery landscape.	Pond Water	Plains Cottonwood (*Populus deltoides*)	Fishing Flies	Twelve-spotted Skimmer (*Libellula pulchella)*
Shortgrass Prairie	Prairies may seem dry, but they're brimming with plants and animals connected in unexpected ways. The lives of the organisms represented above are intertwined through the resources they share across their shortgrass steppe neighborhood.	Cracked Earth	Dung Beetle (Family Scarabaeidae)	Barbed Wire	Buffalo Gourd (*Cucurbita foetidissima*)
Cities & Towns	Even if you're more comfortable on a couch than on a tree branch, you have a lot in common with crows and the other living things that call our cities home. From showerheads to toilet flappers, our choices affect the resources available to others.	Bath	Colorado Blue Spruce (*Picea pungens*)	American Crow (*Corvus brachyrhync-hos*)	Sphinx Moth (*Hyles lineata*)
Home Garden	Making simple changes to how you water your own backyard or garden is an important step in making sure there's plenty of water to go around. After all, your plant, animal and fungi friends like those	Hose Timer	Black-Eyed Susan *(Rudbeckia 'Denver Daisy')*	Salt-loving Mushroom (*Agaricus bernardii*)	Gopher Snake (*Pituophis catenifer*)

	represented above need it, too.				

Haptic Pylons



There are six "pylons" in the main gallery—tall tree-like elements with screens. Each of these have a spinning dial mounted on the front—visitors spin the dial to control the speed at which the content goes by on the screen and may progress through content either forwards or backwards. The top of each pylon features the interconnection motif seen throughout the exhibition backed by glowing colors. The differently colored pylons indicate that each one houses a unique story. Each pylon has a unique narrative told through a series of video clips and accompanying text. The six pylons and their respective stories are:

Pylon 1: *Sharing Water*

- Key message: Plants, fungi and animals all need water -- it connects us to all other living things not only in Colorado, but across the planet.
- This set of videos shows how different organisms, from lichens to humans, use water resources in different ways.

Pylon 2: *Nutrients Return*

- Key Message: Worms and fungi help enrich the soil with nutrients by breaking down decaying plants and other organisms.
- This set of videos shows the natural cycle of decomposition and encourages visitors to compost their kitchen waste, helping reduce greenhouse gas emissions from landfills.

Pylon 3: *Hearth and Home*

- Key Message: Like humans, many birds, insects and other animals use plants to build their homes.
- These videos illustrate different ways that birds, bees, spiders and humans all use plants to construct our homes and remind visitors to help their non-human neighbors by caring for plants.

Pylon 4: *Snow Day!*

- Key Message: Snow is important for plants and animals not only as habitat, but as water from melting snow that runs downhill.
- The sequence of videos shows how water starts as snow high in the mountains, and is a resource shared by all living things.

Pylon 5: *Busy as a Beaver*

- Key Message: A winding stream that sometimes floods is a healthy stream. Beaver activity helps keep it that way as they build dams that create ponds and create new ecosystems.
- These videos show a beaver at work creating a dam and suggests that visitors can also provide homes for other organisms such as pollinators in their gardens.

Pylon 6: *Fire and Renewal*

- Key Message: Wildfires are a normal (and needed) part of life for Colorado's natural world. After a fire, a healthy forest or prairie will regenerate and, over time, it will be difficult to see that a fire even happened.
- These videos show the cycle of burning and regrowth in forests and prairies, and features footage of a controlled burn in the Gardens' Laura Smith Porter Plains Garden.

Ecospheres

There are three ecospheres displayed in the Science Pyramid – glass spheres each holding a self-contained ecosystem supporting living organisms. Each one can be considered a simplified model of our own planet, a world of interdependent organisms sharing water and nutrients. These tiny ecosystems are not only a metaphor for the interconnection of organisms, but a visible reminder of the importance of water in sustaining life.

Contained in each ecosphere are algae, shrimp and bacteria. The algae produce oxygen, which the tiny shrimp breathe. The shrimp produce carbon dioxide that the algae use to make food and grow. The shrimp, in turn, feed on the algae, while bacteria break down the shrimp waste into nutrients that feed the algae. As long as the algae, shrimp and bacteria are alive and healthy, this cycle of life continues.

The shrimp in the ecospheres can live for up to four years – they depend on the LED lights underneath the spheres that run on timers, helping the algae to thrive.

Platte River Cleanup Globes

Near the ecospheres are "Platte River Cleanup Globes" – glass spheres that contain trash collected from the South Platte River. These spheres offer a highly visible reminder of the plastic trash affecting waterways throughout the globe. The Ecospheres and the Platte River Cleanup Globes offer contrasting views of our planet, allowing visitors to reflect on the consequences of water pollution on our shared habitats.

All organisms, including humans, rely on their habitats to provide them with food, water and shelter. Usually, these exist in natural cycles of growth and decay that support the lives of plants and animals. That's what makes plastic such a problem – it plastic never really goes away; instead, it just breaks down into smaller and smaller pieces.

Ecosystem Tubes

Welcome Home features two Ecosystem Tubes – vertical dioramas in the style of traditional natural history museums that offer cutaway views of two different Colorado ecosystems. One tube depicts a Colorado grassland ecosystem and the other an urban Colorado pond ecosystem. Each tube features soil, plants, insects, small vertebrates, and human elements.

- **Colorado Grasslands Tube:**

The shortgrass prairie community represented in this tube is one you might find on the eastern plains of Colorado. The eastern plains of Colorado—all the way up to the Front Range—are part of the North American steppe. These grasslands are in the cold semiarid rain shadow of the Rockies. The harsh conditions of the shortgrass prairie include incessant wind, harsh winters, and periodic drought.

This Ecosystem Tube reveals a hidden slice of a grasslands ecosystem, including plants such as prickly pear (*Opuntia polyacantha*), locoweed (*Oxytropis sericea*) and native grasses as well as fungi, insects, and small vertebrates including a horned lizard (*Phrynosoma hernandesi*) and a hognose snake (*Heterodon nascicus*). This tube represents the interconnection of organisms both above and below the soil, including human interaction represented as a boot print. Quick facts:

- Precipitation: The shortgrass steppe extends from the Rocky Mountains east until the level of precipitation reaches about 30 inches a year.
- Much of the shortgrass steppe is used for dryland farming, but it is not capable of the productivity of farms farther east, where there is more precipitation.

- Shortgrass steppes in North America are adapted to the once-great herds of bison, but cattle now fill that role.

- **Colorado Pond Ecosystem**

The pond community represented in this tube is one you might find at lower elevations throughout the state, including Denver. Ponds are one of many different types of aquatic systems that support many forms of life, both resident species and species that are only moving through such as migrant birds or butterflies. Below are some pond characteristics that contribute towards a thriving ecosystem:

- Aquatic plants help maintain water quality, temperature, and oxygen levels; reduce bank erosion; and provide food, spawning grounds, and escape cover for wildlife.
- Logs and sticks can provide basking and sunning opportunities for amphibians and turtles; egg-laying sites for fish, frogs, and salamanders; shelter for fish; and perches for birds.
- Deeper pond areas provide habitat for fish. Amphibians prefer shallow, fishless waters for breeding and rearing.
- Vegetated areas surrounding ponds provide essential nesting, winter, and escape cover for wildlife. They also increase the amount of water infiltration of the soil. [i]

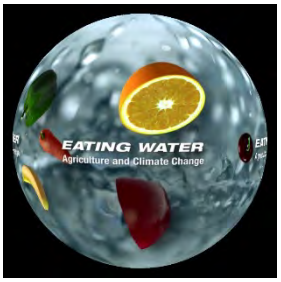
This Ecosystem Tube illustrates the community of organisms that one might find in a Denver pond or lake, including plants above and below the surface, including duckweed (*Lemna minor*) and spikerush (*Eleocharis palustris*), insects like the variegated meadowhawk dragonfly (*Sympetrum corruptum*), sever species of fish and other small vertebrates.

Omniglobe

The Omniglobe features three new videos in both English and Spanish, highlighting climate change and the importance of water – *Blue Planet*, *Eating Water,* and *Instrumented Earth*.

- Blue Planet is an overview of how water shapes our planet and nearly every aspect of human life. It emphasizes the limited amount of fresh water that exists on the planet.

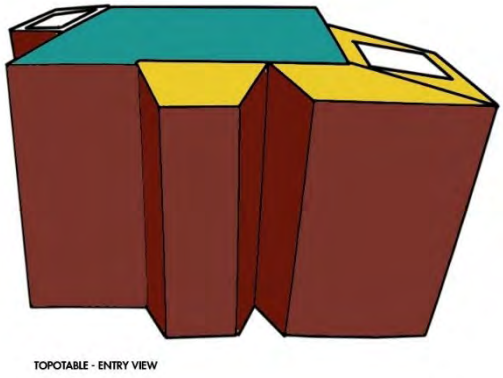
- "Eating Water" highlights the challenges of feeding a growing population with the uncertainty in rainfall patterns that comes with climate change. Importantly, this video notes that the water required to produce food is greater than the water we use to drink and for other purposes.



- "Instrumented Earth" focuses on technological advances that help us better understand Earth's systems as well protect human lives and the planet as a whole.

Topotable

The TopoTable features a light-up topographic map of landscape and ecosystems, allowing visitors to explore elevation and geography of Colorado. Areas selected areas on integrated touch screens illuminate corresponding areas on the topotable's acrylic table map.


TOPOTABLE - ENTRY VIEW

Science Chat Desk

The Science Chat desk area provides a space for drop-in Science Chats on a range of topics. With a large screen for presentation, the desk offers visitors a personal interaction with volunteers, learning engagement staff and Gardens scientists. Coinciding with the opening of *Welcome Home*, a new Science Chat called "Biodiversity Basics" is now offered. Science Chat topics are listed below:

Led by both staff and volunteers:

- Biodiversity Basics
- Beetles
- Pollination & Pollinators
- Strawberry DNA Extraction
- Fruit & Seed Dispersal
- Nature's Calendar
- Trichomes
- Colorado Is Thirsty
- Women in Science
- Orchid-gami

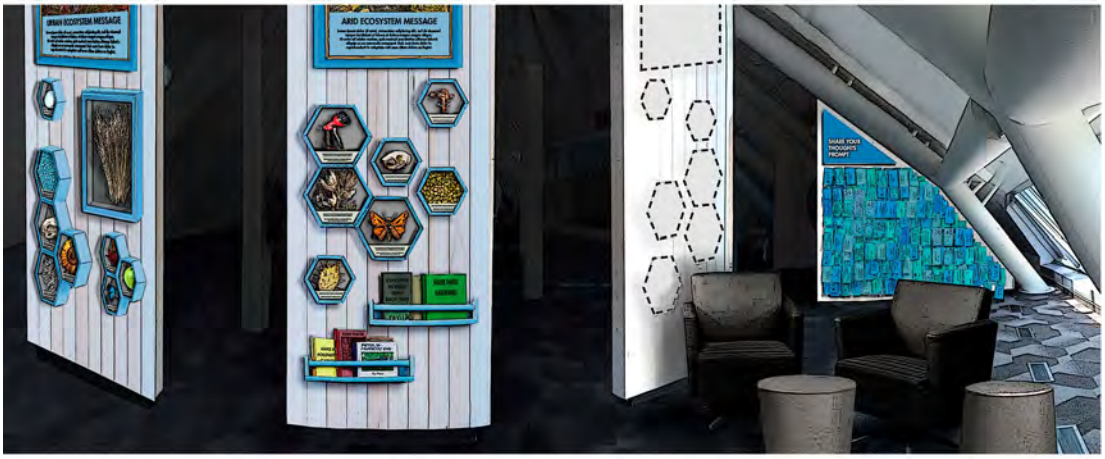
- Flowers Made of Flowers (Volunteers)

Led by only staff:

- Colorado Insects (Research Staff)
- Stomata: How Plants Breathe (Research Staff)
- Conservation in Action (Research Staff)
- Fabulous World of Fungi (Research Staff)
- Botanical Illustration (Botanical Illustration Staff)
- Collections Up Close (Research Staff)
- A Marriage of Art and Science (Staff: Panayoti Kelaidis)

When Science Chats are not happening, the screen loops a time-lapse created by the Platte Basin Timelapse project (PBT). Founded in 2011, PBT combines art and research to create multimedia content telling the stories of the Platte River. Currently, the project has more than 60 time-lapse cameras placed throughout the river basin, from its headwaters in the Colorado Rockies to the river's confluence with the Missouri River at Nebraska's eastern border. Each camera tells one part of the story as water makes a journey of roughly 900 miles through the heart of North America.

Habitat Lounge



The Habitat Lounge is located in the western part of the Science Pyramid and highlights adaptation, both biological and behavioral. The Habitat Lounge consists of four sections, from left (south) to right (north): the participatory wall; two walls that highlight animal, plant and human adaptations to wet and dry habitats, and a wall offering books and pamphlets relating to human behavioral adaptations.

This area invites contemplation of how organisms are adapted to environments with different water conditions, and how humans can change their behaviors to conserve water and reduce their environmental footprint. Human behavioral adaptations to dry areas like the Colorado steppe environments focus on using

water responsibly and efficiently, while human adaptations to wet environments focus on practices that protect the health of waterways and the organisms that call them home.

Visitors are encouraged to relax in the Habitat Lounge and take their time reading books, exploring specimens and enjoying the pond landscape outside. Running water sounds are integrated into the space to encourage a leisurely pace and relaxing experience, and to highlight the water-focused content.

Participatory Waterfall Wall

The Participatory Wall is also known as the "waterfall wall" for its cascade of water-colored tags. This space offers paper tags and pencils accompanied by a prompt for visitors to write about their favorite place to relax by the water and the action they'll take to protect it. Visitors are encouraged to share their thoughts by adding their tag to the wall, making a commitment to care for their environment and encouraging others to do the same. Different colors of tags correspond with different types of bodies of water – river, ocean, lake, and stream.

Adaptation Wall: Dry Habitats

Visitors can investigate the ways in which organisms are adapted to habitats with very little water and learn about sustainable practices to support the organisms that live there. Life in dry landscapes can be challenging, but plants and animals that live there have special adaptations to survive, from bristlecone pine needles that reflect sunlight to prairie dogs' ability to meet their water needs through their plant diet.

This wall features plant, animal and human specimens that demonstrate different kinds of adaptations to dry environments. For humans, these behavioral adaptations highlight ways in which people can change their behavior to responsibly use and reduce their water use. Field Guides in both English and Spanish explain and explore the various objects presented.

Note: See Appendix B for a full list of the objects on this wall.

Adaptation Wall: Wet Habitats

Visitors can learn how plants and animals are adapted to water-rich habitats and learn about human behaviors that are beneficial to waterways and the organisms who call aquatic habitats home.

Plants and animals have all sorts of adaptations for living in habitats with lots of water – some have built-in flotation devices while others have bills that can be used to spear fish. This wall features plant, animal and human specimens and objects that demonstrate different kinds of adaptations to wet habitats. Where humans are concerned, these behavioral adaptations focus on practices that

support waterway health, including topics like alternatives to common household and garden chemicals that affect water quality. Field Guides in both English and Spanish explain and explore the various objects presented.

Note: See Appendix B for a full list of the objects on this wall.

Resource Wall

This wall contains books and pamphlets in both Spanish and English that allow visitors to explore ways that they can change their behaviors to conserve water and support the other organisms that share our habitat. Resources will rotate throughout the run of the exhibition, but will broadly offer information on:

- Conserving water
- Citizen science projects that visitors can get involved with
- Supporting pollinators
- Creating backyard and garden habitats
- Reducing carbon and household chemical footprints
- Climate change
- The value of biodiversity
- The beauty of Colorado's natural landscapes

Visitors are encouraged to take pamphlets home with them, but books are intended to remain in the Science Pyramid. The books will be available to be checked out in the library when it reopens in 2020.

Appendix A: Landscape Wall Objects

Alpine Tundra

Marmot Skull (*Marmota flaviventris*) 	Even though winters in the tundra can be unforgiving, alpine plants share their home with a variety of animals year-round. These plants and animals don't only live together but rely on one another. By eating plants to build its fat reserves, marmots can hibernate to make it through the harsh winter.
Moss Campion (*Silene acaulis*) 	Like human visitors to the alpine tundra, alpine plants need strategies to shield them from the difficult conditions. This plant grows low to the ground, which helps it moderate its temperature and hold water in the drying winds. It also provides protected spaces for other plants to grow. Moss campions are long-lived and slow-growing (some are over 300 years old), so they rely on humans to be good neighbors and stay on designated trails—stepping on one can damage hundreds of years of growth.
Snow Hat 	The alpine tundra is a cold and windy environment. Since humans are not physically adapted to these conditions, people visiting these high-mountain places need warm clothing to protect them. Humans have other strategies to survive tundra conditions, too, like carrying water to stay hydrated. Just like all the other living things from the alpine peaks to the valleys below, water and shelter are essential to our survival.

Urban Spaces

Colorado Native Bees (Families Apidae, Halictidae, and Megachilidae) 	Did you know that Colorado has more than 900 native bee species? If you live in a city, you probably know your human neighbors, but you may not be aware that you also share your urban home with native bee species and the plants they rely on for food. Humans depend on these bees—as they gather flower pollen and nectar to eat, they pollinate native plants. Once pollinated, the plants produce seeds, ensuring future plant generations. Because most native bees don't live in colonies like European honeybees, in cities they rely on their human neighbors to leave bare soil and dead vegetation for nesting.

Sunflower (*Helianthus annuus*) 	Often symbolic of summer, this North American annual plant is common in gardens and along roadsides. Cultivated by humans for thousands of years, we still grow it for its seeds and oil as well as for its beauty. We aren't the only ones who like it, though—look carefully and you might see caterpillars feasting on its leaves or birds gathering its seeds for lunch.
Fashion Sneaker 	Take a walk along the pavement among a city's buildings and it may seem like a place that's only for humans, but many other organisms call it home, too. Urban humans live among millions of plants, from trees on medians to flowers in parks. These plants rely on humans to provide places for them to thrive, and in return they reduce summer temperatures and purify the air. They're good neighbors to other urban-dwellers, too, providing habitat for the non-human animals that share our cities.

Foothills

Hops (*Humulus lupulus*) 	Though rare, hops growing wild along Colorado's Front Range are hard to miss. Springing from the cracks in rocky hillsides, green waterfalls of hops grow up to 25 feet tall. You might know them from the flavor they add to your favorite beer, but we also share this plant with other animals. It is a favorite food of butterflies, including the rare hops blue butterfly (*Celastrina humulus*).
Dog Collar 	A dog has no need for accessories, but a collar and leash are one way we keep our promise to care for our fellow animals and plants when we visit their communities. When you take your furry friend into the hills, keeping your naturally delinquent pup firmly attached prevents plants from being trampled, prevents erosion and keeps wildlife free of harassment.
Swallowtail Butterfly (*Papilio multicaudata*) 	Cool streams in the foothills surrounded by greenery create a promenade for these giant butterflies, which float along in a parade. When it's time to settle down and start a family, the female butterflies lay their eggs on chokecherry and green ash trees so the hatched caterpillars will have breakfast, lunch and dinner.

Shortgrass Prairie

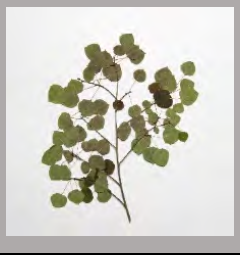
Western Meadowlark Eggs (*Sturnella neglecta*) 	Meadowlarks are right at home on the range, sharing habitat with both their human and native plant neighbors— you may notice them during the breeding season, with bright yellow chests decorated with a bold, black "V." They thrive in native grasslands, but they also use human-cultivated fields for breeding and foraging in winter.
Blazing Star (*Mentzelia nuda*) 	As evening falls, you may notice the large, white blooms of this night-blooming prairie flower. It may appear serene but look closer and you may see a tiny neighborhood battle unfolding. The blazing star blooms for six evenings, producing sweet nectar to attract pollinators, but it continues to create nectar after pollination is done. Like cake at a picnic, this attracts a small army of ants. The well-fed ants fiercely defend their supply against other marauders, offering the plant protection and allowing its seeds to develop.
Horseshoe 	Fueled by the rich grasses of the plains, horses helped both Native Americans and arriving Europeans to explore, use, and forever change the Western landscape and its inhabitants. Today, rural and tribal people still connect to the land via their horses, and well-managed horse pastures can also provide habitat for wildlife.

Wetlands

Fishing Lures 	All kinds of plants, animals and fungi share rivers and streams, including the humans that use them for activities like fishing and boating. The native plants that grow along the shore aren't just beautiful scenery; they also support the lives of the organisms around them—for example, vegetation purifies and adds oxygen to the water and provides places to hide and to lay eggs.
Rocky Mountain Pond Lily (*Nuphar polysepala*) 	This lily is more than just a pretty face—it also provides a home for small aquatic creatures and dinner for larger animals like turtles. These lilies even help their neighbors breathe easier, releasing oxygen into the water for fish and crayfish. That's not all, though. Without the pollination provided by beetles and flies to ensure the lily's continued existence, turtles (and others) might miss out on a tasty snack.

Beaver Skull (*Castor canadensis*) 	Like humans, beavers can change entire landscapes where they build their homes. North America's largest rodent builds dams that create ponds and alter how water moves through a landscape. These dams increase wetland area to the benefit of organisms living around them and can also change the kinds of plants found there, supporting greater species diversity. It's not just a one-way street—plants offer beavers food and materials to construct shelter.

Montane Forest

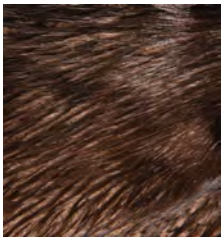
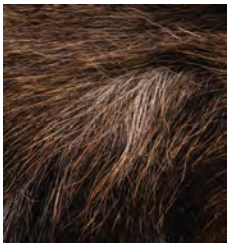
Hummingbird (*Selasphorus platycercus*) 	Hummingbirds are always on the move. Their chirps and metallic trills announce summer in the high country where they go to breed. Tiny but ferocious, they rely on finding space in their neighborhood evergreen and aspen trees for mating and nesting. They also depend on wildflowers, dining on their nectar until the blooms fade in fall and they move south and to lower altitudes. Wildflowers need them, too—they pollinate the plants as they sip their nectar.
Camo Glove 	Humans like to play in the mountains, hiking and biking, off-roading, fishing, hunting and skiing. While different recreational activities have different impacts on the organisms with whom we share our habitat, nearly all these activities depend on the lush forests and meadows and the clear, cold streams and rivers that connect them. Forests prevent erosion alongside our roads, support fish and game, and rejuvenate our busy modern minds.
Quaking Aspen (*Populus tremuloides*) 	Aspens can be much older than they look—even though individual trees may be young, the entire grove is a single organism that can continue to regenerate for thousands of years. And they are full of life, playing host to more diversity than any other western forest type. Plants thrive in the moist soil and bright light of an aspen forest floor, and the edges of the stand are a nursery for young fir trees. Young aspen saplings are also a favorite food of elk, sheep, cattle and other four-legged plant eaters. Beavers like them, too, cutting the trees for food and construction.

Pinyon Juniper Shrubland

Juniper (*Juniperus osteosperma*) 	If you've encountered this evergreen, you might have noticed its fresh, aromatic scent. But its enticing smell is just a bonus; it also helps the plants and animals that share its home. It provides a tasty meal for birds, jackrabbits and mule deer and offers protection from the wind and sun, too.
Sunglasses 	In this habitat, human visitors use sunglasses to protect themselves from the sun's strong rays. This might seem unique to people, but other animals need sun protection, too. Plants often provide the cover that mice and birds seek during a hot summer day. We can be good neighbors to our animal counterparts by taking care not to damage the plants they use for shelter.
Earth Star Fungus (*Geastrum smardae*) 	Uncommon but very noticeable, these fascinating star-shaped fungi peek from arid soil and leafy debris. Along with thousands of other fungi, they make a huge impact on their community by serving the essential function of breaking down dead grass and leaves to make their nutrients available to plants.

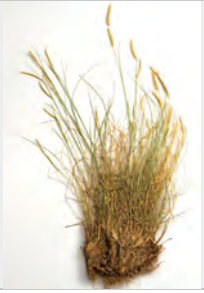
Appendix B: Habitat Lounge Objects

Adaptation Wall: Wet		
Alfalfa Fertilizer	Most commonly used fertilizers on lawns threaten wetland ecosystems because the nitrogen and phosphorous washes into creeks, rivers, and eventually, the ocean. To prevent the pollution of water in our shared habitats, humans can use slow-release organic fertilizers to build soil fertility instead of the more common inorganic fertilizers. These fertilizer alternatives save water, too—lawns with applied alfalfa-based fertilizer generally require less water to stay green and healthy.	
Soap Nuts from Chinese Soapberry (*Sapindus mukorossi*)	You can make small changes to your own behavior to protect your wetland neighbors. Using non-toxic cleaning products, like soap nuts instead of detergent, is one way we can help protect the water we all need. In fact, most household cleaning can be accomplished with just baking soda and white vinegar—they're non-toxic and cheaper to boot.	
Rocky Mountain Iris (*Iris missouriensis*)	This survivor's secret to success is one of extremes, an extremely wet period prior to its spring flowers followed by very dry conditions for the rest of the growing season. Colonies spread through underground rhizomes, and new ones form from its copious seeds. Showy flowers provide a runway, guiding in flying pollinators.	
Great Blue Heron (*Ardea herodias*)	Herons have a unique adaptation to their watery homes–their powerful, dagger-like bills can snap up or spear fish, frogs, reptiles and other animals that share their wetland habitat.	
Western Painted Turtle (*Chrysemys picta bellii*)	When cold weather rolls around, these turtles are adapted to spend a long, chilly winter in the water under the ice. It's a very low oxygen environment, and to survive, their metabolism slows to a crawl. But like a runner's exhausted muscles starved of oxygen, lactic acid builds up in the turtle's body. The turtle's shell counteracts this by releasing carbonate to neutralize the acid.	

Cutthroat Trout (*Oncorhynchus clarkii*)	Most trout in Colorado's waters were recently introduced by humans, but three cutthroat trout subspecies—the greenback, the Rio Grande and the Colorado—have been living in Colorado's streams and lakes for centuries. These fish are adapted to cooler waters and can't survive when it's too hot. They're at risk of losing their watery homes as the climate warms and stream temperatures increase.	
Boxelder (*Acer negundo*)	If you have a garden or backyard, you might think of this tree as weedy—hard to kill, fast-growing, and attractive to insects. But in nature, its weediness is a virtue. Boxelder's shallow, spreading roots help stabilize the tree and help it stay oxygenated in river bottoms and canyonlands, even during floods. These root networks benefit their human neighbors, too, reducing erosion by holding in the soil.	
Beaver (*Castor canadensis*)	A beaver's coat is adapted to aquatic conditions– its hair is water repellent, making it appear silvery with bubbles as it swims. Because this special fur is important for survival, beavers spend time on personal grooming – distributing oil from their glands while detangling.	
Coyote Willow (*Salix exigua*)	Growing along streams across western North America, willows have uniquely flexible stems that are resilient to the constant movement of water. Their dense, spreading roots prevent erosion in severe floods. A broken branch stuck in some mud easily grows into a new willow plant.	
Moose (*Alces alces*)	If you spent as much of your life in the water as moose do, built-in floaties would come in handy. Moose hair is like that—it's buoyant, acting as a flotation device in the deep water where moose feed. They have built-in nose clips, too—moose's bulbous noses can seal shut underwater.	

Adaptation Wall: Dry

Toilet Flapper	Humans have ways to thrive in dry environments, too. Installing a low-flow flapper in your toilet is one of many ways that you can reduce the amount of water that you use—every drop you save is more water available for your plant and animal neighbors.	
Colorado Hairstreak (*Hypaurotis crysalus*)	Butterflies often have close relationships with specific plants. This hairstreak, Colorado's state butterfly, is no exception. It relies on Gambel oak (*Quercus gambelii*), an oak species that grows well in areas that receive very little precipitation, for food and as a place to lay its eggs.	
Rocky Mountain Bristlecone Pine (*Pinus aristata*)	Living high in the mountains in drying winds and strong solar radiation, this drought-tolerant tree grows very slowly and is a champion at needing minimal water; its waxy needles help retain water and reflect sunlight. Even in some of the driest areas, it can live for more than 2,000 years.	
Cooked Black Beans (*Phaseolus vulgaris*)	It might not seem like everyday food choices have much impact on water conservation, but it's actually a great way to reduce water use. Because beef takes more than three times as much water to produce than beans, swapping out that beef taco for a veggie burrito is an impactful (and tasty) way to conserve water.	

Big Sagebrush (*Artemisia tridentata*)	Adapted to living in places where the sun is intense and drought is common, sagebrush conserves water in many ways. Its silvery leaves are covered in tiny hairs that provide shade, and its extensive root system can absorb water quickly when it's available. Its roots can even move water around in the soil to use it more efficiently.	
Black-Tailed Prairie Dog (*Cynomys ludovicianus*)	Adapted to its dry grassland home, the prairie dog gets all the water it needs from the food it eats. And we're not talking watermelon and popsicles–prairie dogs survive on the water from the grasses and other semi-arid plants that make up their diet.	
Blue Grama Grass (*Bouteloua gracilis)*	To survive in a dry environment like the shortgrass steppe of eastern Colorado, native grasses like blue grama have dense and extensive root systems that can quickly absorb water to take advantage of even small amounts of rain.	
Mountain Lion (*Puma concolor*)	The solitary mountain lion drinks water whenever it is available, but when it lives in a hot, dry habitat, that's not very often. As a result, the mountain lion has adapted to survive for long, dry periods by relying on just the water obtained from prey, which can be anything from a deer to a rabbit.	
Wolf Spider (*Hogna* sp.)	You're not the only one who likes to lounge at home during the dog days of summer. These spiders avoid being active when temperatures are high and instead hunt for insects and other spiders at night, helping them conserve water for survival.	

Cottontail (*Sylvilagus sp.*)	Cottontails are mostly active at dawn or at dusk, which makes it harder for predators to see them. Another benefit to this behavior is that the temperatures are cooler at these times. If you are an animal that lives in an environment with limited water, you can prevent water loss by being less active when temperatures are hottest.	

[i] The information presented above has been selected from "Farm Pond Ecosystems" by Natural Resources Conservation Service. For more information, please refer to: https://efotg.sc.egov.usda.gov/references/public/SC/Farm_Pond_Ecosystems.pdf

SCIENCE PYRAMID & WELCOME HOME

Spatial Color Blocking - palette

Zone A: WH Main Exhibit

entry wall
ecosystem wall
anchor element
interconnected hub/spoke floor graphics
accent for tie-in elements: globe, topo table, boulders, etc.

Zone B: WH Resource Lounge / Water Narrative

waterfall wall (visitor feedback area)
3 walls: wet, dry, books/resources
floor graphics

Zone C:

Science Chat area
SciPy employee workspace

Welcome Home: Meet Your Habitat

An Exhibition
in Denver Botanic Gardens' Science Pyramid

Funded in part by the Colorado Water Conservation Board.

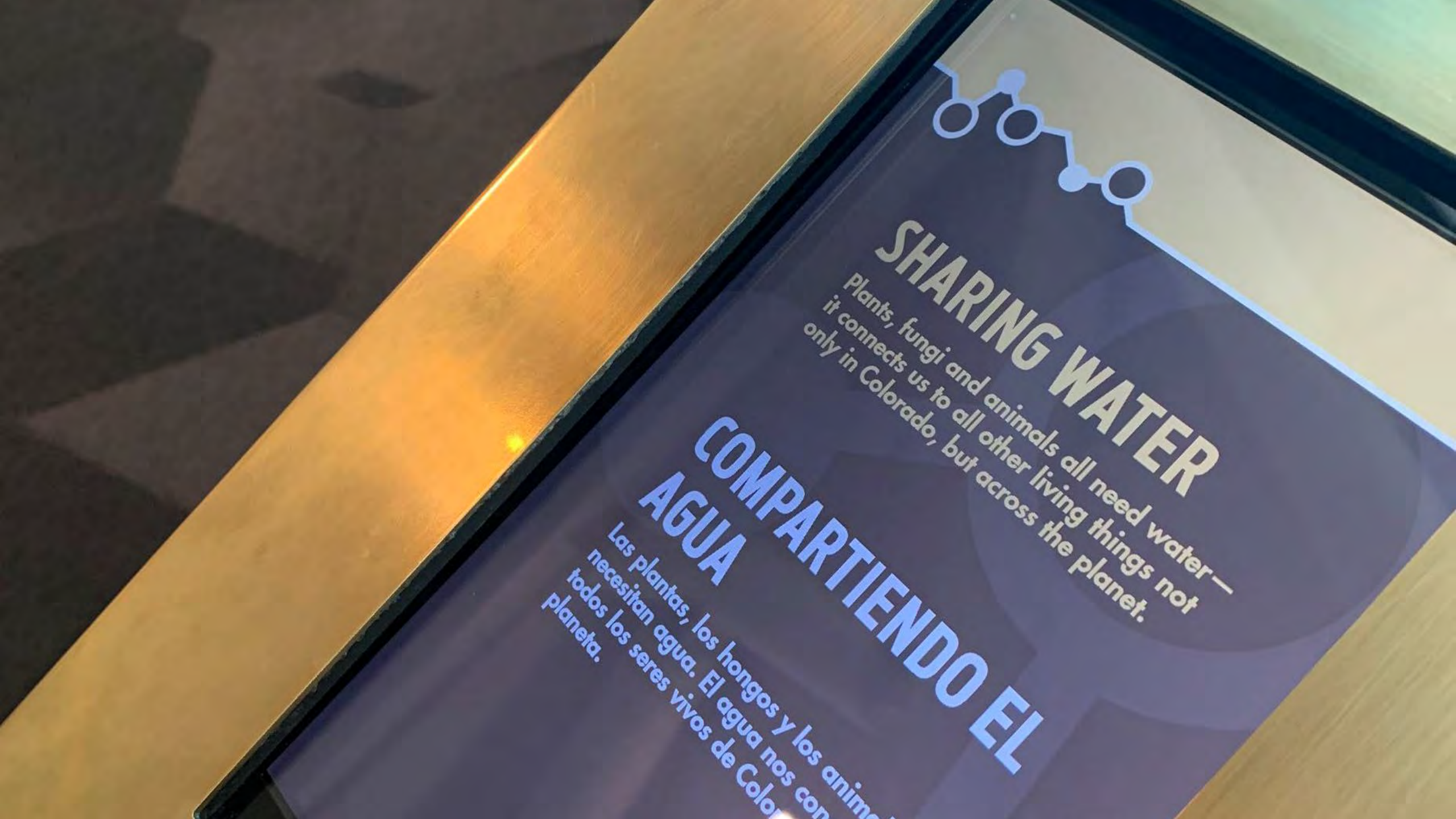

WELCOME HOME
Meet Your Habitat
BIENVENIDO A CASA
conozca su hábitat
YOU'RE PART OF NATURE
Explore How We're All Connected
USTED ES PARTE DE LA NATURALEZA
Explore cómo estamos todos conectados
EXPLORE YOUR CONNECTIONS WITH NATURE
EXPLORE SUS CONEXIONES CON LA NATURALEZA

LANDSCAPE WALL

LANDSCAPE WALL – detail, with Field Guide for visitors

BOULDERS: OBJECTS & RELATED TOUCH SCREENS (Cities & Towns; Ponds & Streams)

HAPTIC PYLONS


SHARING WATER
Plants, fungi and animals all need water—
it connects us to all other living things not
only in Colorado, but across the planet.
COMPARTIENDO EL
AGUA
Las plantas, los hongos y los anima
necesitan agua. El agua nos con
todos los seres vivos de Colo
planeta.

A Miniature World with Limited Resources

Think of these spheres as a simplified model of our own planet, a world of interdependent organisms sharing water and nutrients. Here, algae produce oxygen, which tiny shrimp breathe. The shrimp produce carbon dioxide that the algae use to make food and grow. The shrimp, in turn, feed on the algae, while bacteria break down the shrimp waste into nutrients that feed the algae.

As long as the algae, shrimp and bacteria are alive and healthy, this cycle of life continues. Since they need each other to survive, the loss or decline of one might spell disaster for all.

Un mundo en miniatura con recu

Piense en estas esferas como un modelo sim
propio planeta: un mundo formado por org
que comparten agua y nutrientes. Aquí, l
oxígeno que los pequeños camarones re
producen dióxido de carbono, que las a
alimento y crecer. Los camarones, en c
las algas, mientras que las bacterias d
de los camarones en nutrientes que al

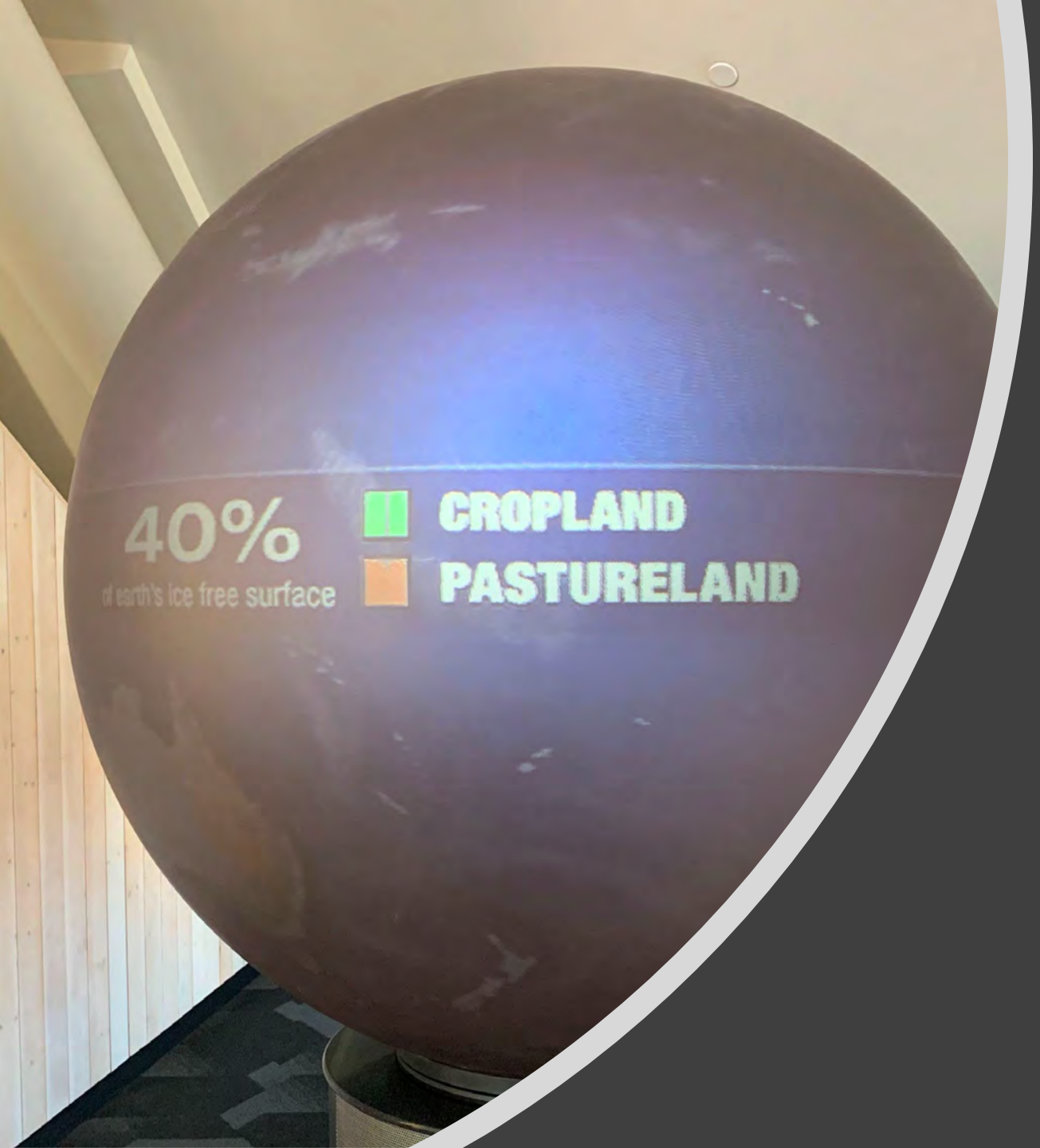
Mientras que las algas, los camarone
y sanos, este ciclo de vida continúa
de los otros para sobrevivir, la pérd
ellos puede tener efectos desastros

ECOSPHERES

PLATTE RIVER CLEANUP GLOBES

ECOSYSTEM TUBE: GRASSLANDS

ECOSYSTEM TUBE: URBAN POND



OMNIGLOBE

HABITAT LOUNGE

HABITAT LOUNGE with bilingual children's books, visitor resources and Field Guides

HABITAT LOUNGE: Waterfall Wall

HABITAT LOUNGE: WATERFALL WALL with visitor comments

WELCOME HOME

Meet Your Habitat

FIELD GUIDE

ALPINE TUNDRA

You may not know it, but if you've been hiking or skiing in the mountains and above the trees, you've visited your plant and animal neighbors living in the alpine tundra.

Yellow-bellied Marmot

(*Marmota flaviventris*)

Even though winters in the tundra can be unforgiving, alpine plants share their home with a variety of animals year-round. These plants and animals don't only live together, but rely on one another. By eating plants to build its fat reserves, marmots can hibernate to make it through the harsh winter.

Moss Campion

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Human (*Homo sapiens*) Snow Hat

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URBAN SPACES

Cities are best known as human habitats, but they are also increasingly important homes for other organisms as human populations spread into areas that used to be open space or rangeland.

Colorado Native Bees

(Families Apidae, Halictidae, and Megachilidae)

Did you know that Colorado has more than 900 native bee species? If you live in a city, you probably know your human neighbors, but you may not be aware that you also share your urban home with native bee species and the plants they rely on for food. Humans depend on these bees—as they gather flower pollen and nectar to eat, they pollinate native plants. Once pollinated, the plants produce seeds, ensuring future plant generations. Because most native bees don't live in colonies like European honeybees, in cities they rely on their human neighbors to leave bare soil and dead vegetation for nesting.

Common Sunflower

(*Helianthus annuus*)

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Human (*Homo sapiens*) Shoe

Take a walk along the pavement among a city's buildings and it may seem like a place that's only for humans, but many other organisms call it home, too. Urban humans live among millions of plants, from trees on medians to flowers in parks. These plants rely on humans to provide places for them to thrive, and in return they reduce summer temperatures and purify the air. They're good neighbors to other urban-dwellers, too, providing habitat for the non-human animals that share our cities.

FOOTHILLS

Looking for a walk in the woods near Denver? You'll probably end up in the foothills, a place where the city often meets the wilderness: Golf courses, hiking trails and mountain parks meet ponderosa pines and red sandstone.

Hops

(Humulus lupulus)

Though rare, hops growing wild along Colorado's Front Range are hard to miss. Springing from the cracks in rocky hillsides, green waterfalls of hops grow up to 25 feet tall. You might know them from the flavor they add to your favorite beer, but we also share this plant with other animals. It is a favorite food of butterflies, including the rare hops blue butterfly (*Celastrina humulus*).

Human (*Homo sapiens*) Object: Dog Collar

A dog has no need for accessories, but a collar and leash are one way we keep our promise to care for our fellow animals and plants when we visit their communities. When you take your furry friend into the hills, keeping your naturally delinquent pup firmly attached prevents plants from being trampled, prevents erosion and keeps wildlife free of harassment.

Two-tailed Swallowtail Butterfly

(Papilio multicaudata)

Cool streams in the foothills surrounded by greenery create a promenade for these giant butterflies, which float along in a parade. When it's time to settle down and start a family, the female butterflies lay their eggs on chokecherry and green ash trees so the hatched caterpillars will have breakfast, lunch and dinner.

SHORTGRASS PRAIRIE

A drive through the prairie may feel empty with its vast, flat views, but it's bursting with plants and animals. These grassland dwellers share their habitat not only with one another but with human activities like oil extraction and cattle operations.

Western Meadowlark

(*Sturnella neglecta*)

Meadowlarks are right at home on the range, sharing habitat with both their human and native plant neighbors—you may notice them during the breeding season, with bright yellow chests decorated with a bold, black "V." They thrive in native grasslands, but they also use human-cultivated fields for breeding and foraging in winter.

Bractless Blazingstar

(*Mentzelia nuda*)

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Human (*Homo sapiens*)
Object: Horseshoe

Fueled by the rich grasses of the plains, horses helped both Native Americans and arriving Europeans to explore, use, and forever change the Western landscape and its inhabitants. Today, rural and tribal people still connect to the land via their horses, and well-managed horse pastures can also provide habitat for wildlife.

WETLAND

Whether you walk alongside a pond or tube down the South Platte River, you share wetland spaces with all kinds of plants and animals in a community extending both above and below the water.

Human (*Homo sapiens*)
Object: Fishing Lures

All kinds of plants, animals and fungi share rivers and streams, including the humans that use them for activities like fishing and boating. The native plants that grow along the shore aren't just beautiful scenery; they also support the lives of the organisms around them—for example, vegetation purifies and adds oxygen to the water and provides places to hide and to lay eggs.

Rocky Mountain Pond Lily

(*Nuphar polysepala*)

This lily is more than just a pretty face—it also provides a home for small aquatic creatures and dinner for larger animals like turtles. These lilies even help their neighbors breathe easier, releasing oxygen into the water for fish and crayfish. That's not all, though. Without the pollination provided by beetles and flies to ensure the lily's continued existence, turtles (and others) might miss out on a tasty snack.

American Beaver

(*Castor canadensis*)

Like humans, beavers can change entire landscapes where they build their homes. North America's largest rodent builds dams that create ponds and alter how water moves through a landscape. These dams increase wetland area to the benefit of organisms living around them and can also change the kinds of plants found there, supporting greater species diversity. It's not just a one-way street—plants offer beavers food and materials to construct shelter.

MONTANE FOREST

Recreation destinations like Rocky Mountain National Park or Winter Park are best known for hiking trails and skiing, but they're home to much more than that. Their lower elevations include montane forests, a habitat that we share with plants, animals and fungi and whose presence makes it such a gorgeous place to visit.

Broad-tailed Hummingbird

(Selasphorus platycercus)

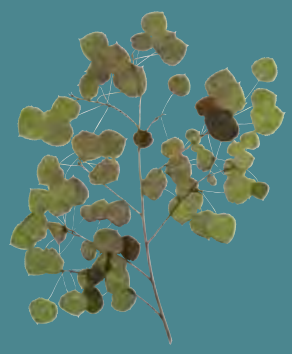
Hummingbirds are always on the move. Their chirps and metallic trills announce summer in the high country where they go to breed. Tiny but ferocious, they rely on finding space in their neighborhood evergreen and aspen trees for mating and nesting. They also depend on wildflowers, dining on their nectar until the blooms fade in fall and they move south and to lower altitudes. Wildflowers need them, too—they pollinate the plants as they sip their nectar.

Human *(Homo sapiens)* Camouflage Glove

Humans like to play in the mountains, hiking and biking, off-roading, fishing, hunting and skiing. While different recreational activities have different impacts on the organisms with whom we share our habitat, nearly all these activities depend on the lush forests and meadows and the clear, cold streams and rivers that connect them. Forests prevent erosion alongside our roads, support fish and game, and rejuvenate our busy modern minds.

Quaking Aspen

(Populus tremuloides)



Aspens can be much older than they look—even though individual trees may be young, the entire grove is a single organism that can continue to regenerate for thousands of years. And they are full of life, playing host to more diversity than any other western forest type. Plants thrive in the moist soil and bright light of an aspen forest floor, and the edges of the stand are a nursery for young fir trees. Young aspen saplings are also a favorite food of elk, sheep, cattle and other four-legged plant eaters. Beavers like them, too, cutting the trees for food and construction.

PINYON-JUNIPER SHRUBLAND

You might enjoy eating pine nuts, but you might not know that the plants that produce them are your neighbors. In Colorado, you are most likely to see these shrublands dominated by pinyon pine and juniper on the western slope, below the pine forests.

Utah Juniper

(*Juniperus osteosperma*)

If you've encountered this evergreen, you might have noticed its fresh, aromatic scent. But its enticing smell is just a bonus; it also helps the plants and animals that share its home. It provides a tasty meal for birds, jackrabbits and mule deer and offers protection from the wind and sun, too.

Human (*Homo sapiens*) Sunglasses

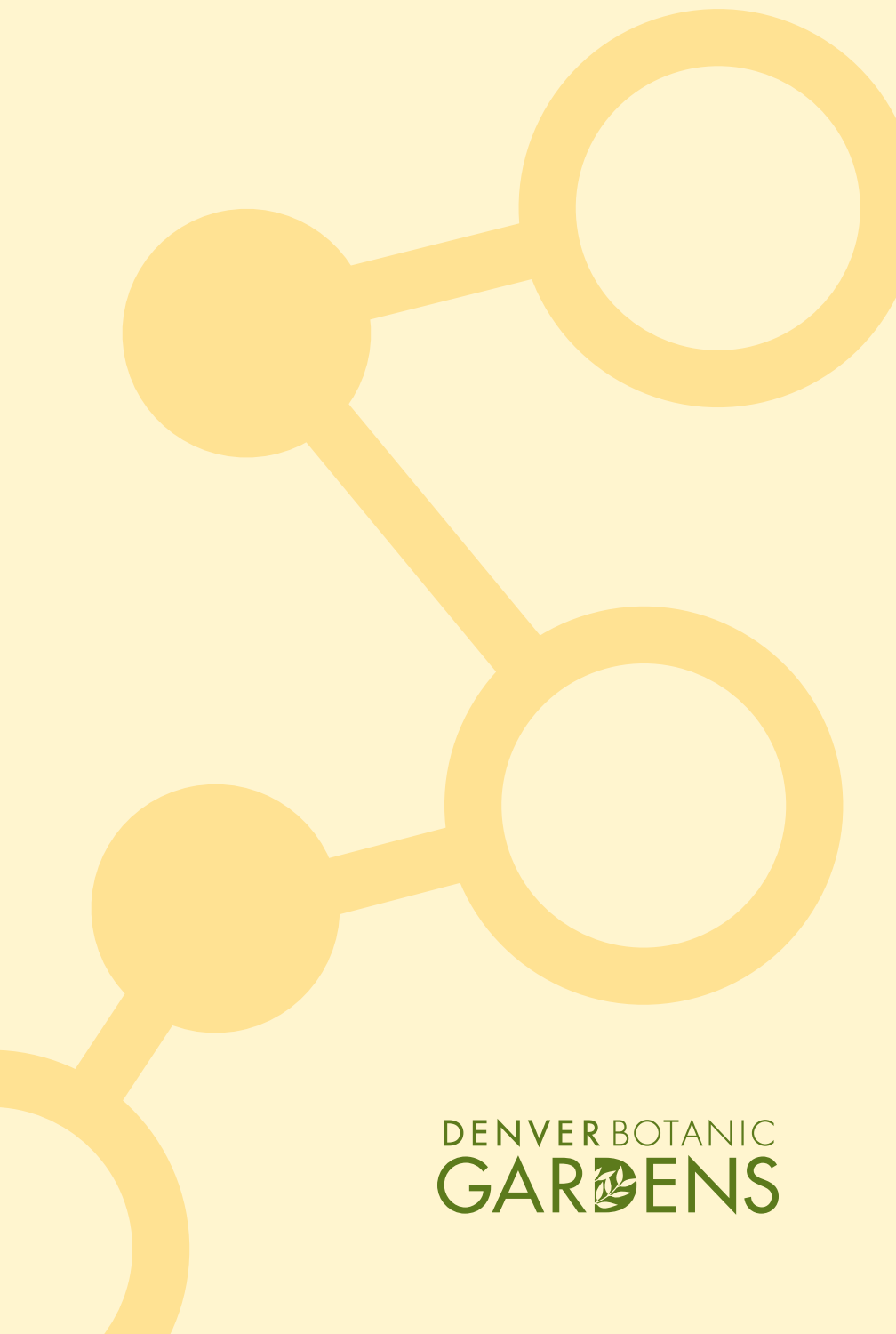
In this habitat, human visitors use sunglasses to protect themselves from the sun's strong rays. This might seem unique to people, but other animals need sun protection, too. Plants often provide the cover that mice and birds seek during a hot summer day. We can be good neighbors to our animal counterparts by taking care not to damage the plants they use for shelter.

Earth Star

(*Geastrum smardae*)

Uncommon but very noticeable, these fascinating star-shaped fungi peek from arid soil and leafy debris. Along with thousands of other fungi, they make a huge impact on their community by serving the essential function of breaking down dead grass and leaves to make their nutrients available to plants.

Please return this Field Guide.



DENVER BOTANIC GARDENS

WELCOME

Meet Your Habitat

FIELD GUIDE

DRY HABITAT

HABITAT LOUNGE

Human (*Homo sapiens*)
Object: Toilet Flapper

Humans have ways to thrive in dry environments, too. Installing a low-flow flapper in your toilet is one of many ways that you can reduce the amount of water that you use—every drop you save is more water available for your plant and animal neighbors.

Colorado Hairstreak

(*Hypaurotis crysalus*)

Butterflies often have close relationships with specific plants. This hairstreak, Colorado's state butterfly, is no exception. It relies on Gambel oak (*Quercus gambelii*), an oak species that grows well in areas that receive very little precipitation, for food and as a place to lay its eggs.

Rocky Mountain Bristlecone Pine

(*Pinus aristata*)

Living high in the mountains in drying winds and strong solar radiation, this drought-tolerant tree grows very slowly and is a champion at needing minimal water; its waxy needles help retain water and reflect sunlight. Even in some of the driest areas, it can live for more than 2,000 years.

Cooked Black Beans

(*Phaseolus vulgaris*)

Feeling hungry? It might not seem like everyday food choices have much impact on water conservation, but it's actually a great way to reduce water use. Because beef takes more than three times as much water to produce than beans, swapping out beef for protein-rich beans is an impactful (and tasty) way to conserve water.

Big Sagebrush

(*Artemisia tridentata*)

Adapted to living in places where the sun is intense and drought is common, sagebrush conserves water in many ways. Its silvery leaves are covered in tiny hairs that provide shade, and its extensive root system can absorb water quickly when it's available. Its roots can even move water around in the soil to use it more efficiently.

Black-Tailed Prairie Dog

(*Cynomys ludovicianus*)

Can you imagine never drinking water? Adapted to its dry grassland home, the prairie dog gets all the water it needs from the food it eats. And we're not talking watermelon and popsicles—prairie dogs survive on the water from the grasses and other semi-arid plants that make up their diet.

Blue Grama Grass

(*Bouteloua gracilis*)

To survive in a dry environment like the shortgrass steppe of eastern Colorado, native grasses like blue grama have dense and extensive root systems that can quickly absorb water to take advantage of even small amounts of rain.

Mountain Lion

(*Puma concolor*)

The solitary mountain lion drinks water whenever it is available, but when it lives in a hot, dry habitat, that's not very often. As a result, the mountain lion has adapted to survive for long, dry periods by relying on just the water obtained from prey, which can be anything from a deer to a rabbit.

Wolf Spider

(*Hogna* sp.)

You're not the only one who likes to lounge at home during the dog days of summer. These spiders avoid being active when temperatures are high and instead hunt for insects and other spiders at night, helping them conserve water for survival.

Cottontail rabbit

(*Sylvilagus* sp.)

Cottontails are mostly active at dawn or at dusk, which makes it harder for predators to see them. Another benefit to this behavior is that the temperatures are cooler at these times.
If you are an animal that lives in an environment with limited water, you can prevent water loss by being less active when temperatures are hottest.

WELCOME HOME

Meet Your Habitat

FIELD GUIDE

WET HABITAT

HABITAT LOUNGE

Alfalfa Fertilizer

Most commonly used fertilizers on lawns threaten wetland ecosystems because the nitrogen and phosphorous washes into creeks, rivers, and eventually, the ocean. To prevent the pollution of water in our shared habitats, humans can use slow-release organic fertilizers to build soil fertility instead of the more common inorganic fertilizers. These fertilizer alternatives save water, too—lawns with applied alfalfa-based fertilizer generally require less water to stay green and healthy.

Soap Nuts from Chinese Soapberry

(***Sapindus mukorossi***)

You can make small changes to your own behavior to protect your wetland neighbors. Using non-toxic cleaning products, like soap nuts instead of detergent, is one way we can help protect the water we all need. In fact, most household cleaning can be accomplished with just baking soda and white vinegar—they're non-toxic and cheaper to boot.

Rocky Mountain Iris

(***Iris missouriensis***)

This survivor's secret to success is one of extremes, an extremely wet period prior to its spring flowers followed by very dry conditions for the rest of the growing season. Colonies spread through underground rhizomes, and new ones form from its copious seeds. Showy flowers provide a runway, guiding in flying pollinators.

Great Blue Heron

(***Ardea herodias***)

Herons have a unique adaptation to their watery homes—their powerful, dagger-like bills can snap up or spear fish, frogs, reptiles and other animals that share their wetland habitat.

Western Painted Turtle

(*Chrysemys picta bellii*)

When cold weather rolls around, these turtles are adapted to spend a long, chilly winter in the water under the ice. It's a very low oxygen environment, and to survive, their metabolism slows to a crawl. But like a runner's exhausted muscles starved of oxygen, lactic acid builds up in the turtle's body. The turtle's shell counteracts this by releasing carbonate to neutralize the acid.

Cutthroat Trout

(*Oncorhynchus clarkii*)

Most trout in Colorado's waters were recently introduced by humans, but three cutthroat trout subspecies—the greenback, the Rio Grande and the Colorado—have been living in Colorado's streams and lakes for centuries. These fish are adapted to cooler waters and can't survive when it's too hot. They're at risk of losing their watery homes as the climate warms and stream temperatures increase.

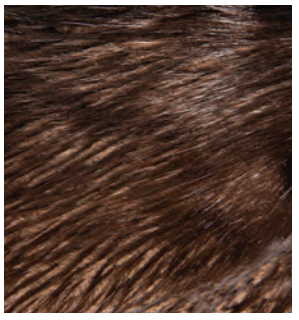
Boxelder

(*Acer negundo*)

If you have a garden or backyard, you might think of this tree as weedy—hard to kill, fast-growing, and attractive to insects. But in nature, its weediness is a virtue. Boxelder's shallow, spreading roots help stabilize the tree and help it stay oxygenated in river bottoms and canyonlands, even during floods. These root networks benefit their human neighbors, too, reducing erosion by holding in the soil.

Beaver

(*Castor canadensis*)



A beaver's coat is adapted to aquatic conditions—its hair is water repellent, making it appear silvery with bubbles as it swims. Because this special fur is important for survival, beavers spend time on personal grooming, but not quite like you do. They distribute oil from their oil glands as they detangle their hair with a special combing claw.

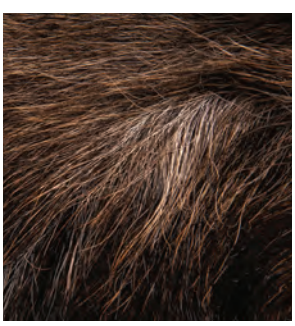
Coyote Willow

(*Salix exigua*)

Growing along streams across western North America, willows have uniquely flexible stems that are resilient to the constant movement of water. Their dense, spreading roots prevent erosion in severe floods. A broken branch stuck in some mud easily grows into a new willow plant, making it a favorite of our staff's habitat restoration teams.

Moose

(*Alces alces*)



If you spent as much of your life in the water as moose do, built-in floaties would come in handy. Moose hair is like that—it's buoyant, acting as a flotation device in the deep water where moose feed. They have built-in nose clips, too—moose's bulbous noses can seal shut underwater.

Microclimates and Urban Habitats
Discovery Days Learning Station

Activity Description
Students will make observations and collect data for a microclimate in the Denver Botanic Gardens. The data of various groups will be collected throughout the day so that students can compare their microclimate data to the data of others to draw conclusions. Students will also consider how people can create microhabitats within an urban environment.

Objectives
Cognitive: Students will understand that within an urban environment humans can create many different microclimates, providing habitats for a wide variety of plants and animals.

Experiential: Students will use thermometers and their senses to make observations, gather data, and compare the microclimates of the Denver Botanic Gardens.

Affective: Students will reflect on how their own behavior and choices create microclimates.

2020 Colorado Academic Standards for Science
MS.2.5b Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. (*NGSS Performance Expectation MS-LS2-2*)

MS.2.7a Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. (*NGSS Performance Expectation MS-LS2-4*)

MS.3.10a Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. (*NGSS Performance Expectation MS-ESS3-3*)

Materials/Props
- Thermometers (with different colored tape at top of each)
- Beaker of ice water
- Signage
- Whiteboard or laminated poster with chart
- Laminated map of area where table is set up
- Dry erase markers

Set up
- Set all thermometers in beaker of ice water. After 5 minutes, check to make sure that all thermometers read between 0°C and 0.5°C. Choose the thermometer that reads closest to 0°C as the primary thermometer. Make a note of how each of the other thermometers vary from

the primary thermometer. You may need to help students add or subtract from their temperature measurements in order to standardize the results.
- Keep the thermometers in ice water when not in use for the duration of the program.
- Familiarize yourself with the map so that you can clearly indicate the boundaries of the activity to students.

Signage Text

Sign #1

[Title] Microclimates = Tiny Habitats

Across a larger environment or ecosystem, small areas can vary in their temperature, moisture, and sunlight. These small areas are known as **microclimates**. Consider the microclimate at the top of a tree as compared to the microclimate in the shade under the very same tree. These microclimates can provide habitats for plants and animals with very different niches.

As people develop urban living spaces, they also contribute to the urban ecosystem. ***What aspects of a city might create different microclimates?***

Sign #2

[Title] Explore the Microclimates of the Denver Botanic Gardens

Cont

Choose a nearby spot to investigate as a microclimate. *Make sure that the spot you choose is within the boundaries of the map.* Gather the following data for your microclimate:

- Description (sunny/shady/other, nearby features and how they relate to the microclimate, etc.)
- Air temperature (let the thermometer sit for 5 minutes)
- Animals or plants found (or signs of animals)
- Any other interesting observations
- BONUS: Download a light meter to your smartphone and measure the illuminance of your microclimate in lux or foot-candles.

Record your data and observations on the chart. Mark your data collection spot on the map using the corresponding letter from the chart. Compare your results with the results of others.

Sign #3

[Title] Think and Discuss

- What do you notice about the collection of results?
- Do you think your results would be different at different times of day? Why or why not?
- How do different features of the landscape impact microhabitat?
- How do humans create or impact your microhabitat?
- How do microhabitats contribute to biodiversity?
- How can understanding microclimates help homeowners or city planners?
- What other microclimates can you find around the Gardens?

Sign #4

[*Title*] *Do* Try This at Home!

Explore the microhabitats of your own yard or neighborhood. Use your investigations to participate in one or more of the following activities:

- **Practice small-scale habitat management.** Use your observations and learning to make helpful changes to your yard or community garden.
- **Contribute.** Upload your observations to the citizen science project The Habitat Network at www.yardmap.org. You can be part of real science!
- **Develop a science fair project that matters!** Design an investigation to answer one or more of your microhabitat questions.

Data Chart
[Laminated or copied onto whiteboard]

Students use this chart to record their observations and data. Facilitators do not need to erase data between groups, as new groups can compare their data to past groups that are no longer present.

[Title] Data Chart

Data Label	Description	Temperature (°C)	Animals/Plants Found	Other Observations	Light Illumination (lux)
A					
B					
C					
D					
E					

F					
G					
…					

Map of Area

The station should include a map of the area where the activity is to take place. Facilitators should refer to the map when indicating the boundaries for the activity.

Wetland Water Wonders
Discovery Days Learning Station

Activity Description
Students will use a model wetland in a bottle to observe water filtration. Then they will alter the model wetland as if it were covered over in concrete to observe any differences in water absorption and filtration. Finally students will learn about several wetland plants that enhance the filtration capacity of wetlands by taking up heavy metals and other toxins.

Objectives
Cognitive: Students will understand the value of wetlands for filtering water and maintaining a healthy water cycle for people, as well as other plants and animals.

Experiential: Students will use a model wetland to make observations and draw connections to real world water issues.

Affective: Students will reflect on the value of wetlands in their own lives.

2020 Colorado Academic Standards for Science
MS.2.6a Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. (*NGSS Performance Expectation MS-LS2-3*)

MS.3.4a Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. (*NGSS Performance Expectation MS-ESS2-1)*

MS.3.6b Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. (*NGSS Performance Expectation MS-ESS2-4*)

MS.3.10a Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. (*NGSS Performance Expectation MS-ESS3-3*)

Materials/Props

- Clear 2 liter bottle (with cap), cut in half without damaging the neck of the bottle
- Coarse sand
- Fine sand
- Stones
- 2 2-liter bottles of water
- 1.5 cups dirt
- Peat moss

- Small bowl
- Small plastic or acrylic tiles
- Signs

Set Up

Prepare wetland model in the plastic bottle. [See Fig. 1]

- Pack the neck of the bottle with a bit of peat moss.
- With the bottle lying down, fill the bottom with a layer of coarse sand.
- Add a layer of fine sand on top. There should be enough sand (coarse and fine) to cover the neck of the bottle. The moss will prevent the sand from spilling out.
- Add a handful of stones near the wide end of the bottle (opposite the neck)
- Prop up the wide end of the bottle with the bottle cap. The bottle should be at an angle so that water poured on top of the stones will run down towards the neck of the bottle.
- Place a shallow bowl under the neck of the bottle to catch liquid.

Prepare dirty water

- Add ½ cup of dirt to one of the bottles of water. Shake.

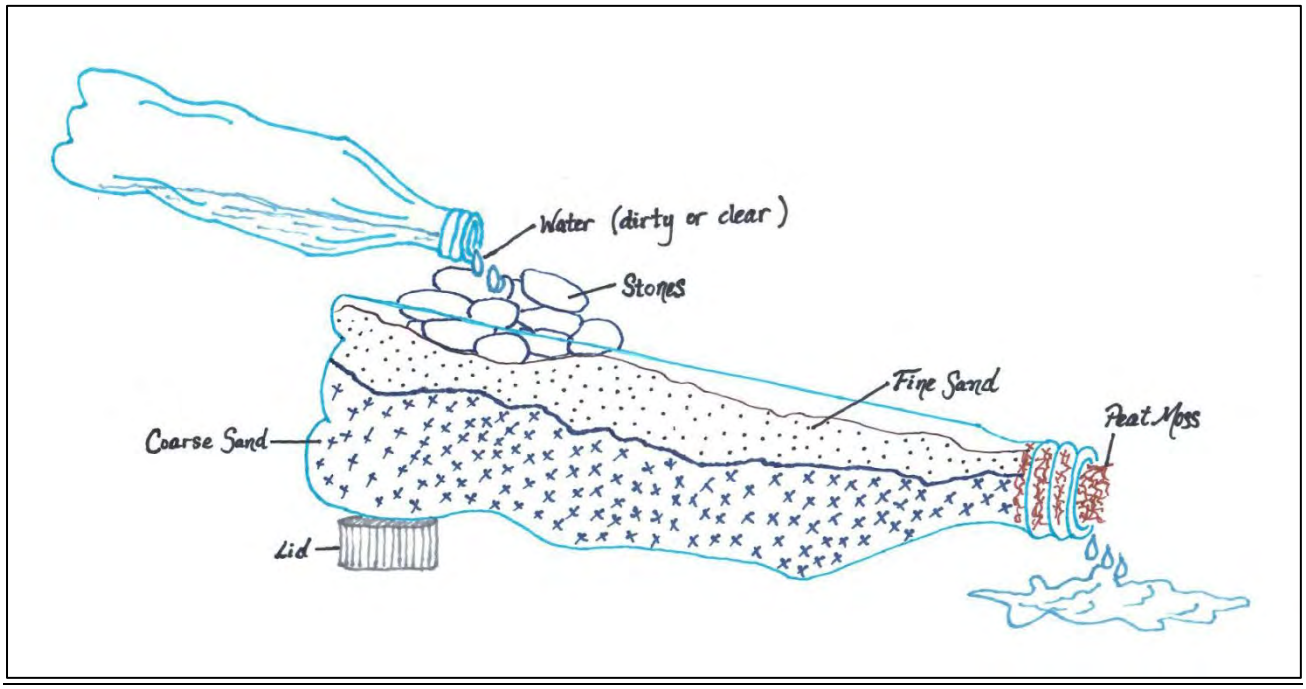


Figure 1: Wetland model set up

Signage Text

Sign #1

[Title] Wetlands: What are they?

Wetlands, such as marshes and swamps are areas of land covered in water. Some wetlands are covered year round, while others are saturated intermittently. Wetlands are often found on the edges of larger bodies of water, such as lakes and oceans.

[include pictures of wetland ecosystems on DBG sites and DBG research sites]

Sign #2

[Title] Wetlands: What's the big deal?

Use the wetland in a bottle model to discover a few benefits of wetland ecosystems.

The Wetland as Water Storage

Pour a little bit of water onto the rocks near the top of the wetland model. Pour enough water to see water pour out of the end with the moss. What do you notice? Does all of the water flow out of the bottle? If not, where does it go?

The Wetland as Water Filter

Pour some of the dirty water onto the rocks. What do you notice? What does the water look like as it flows out of the wetland bottle?

What happens when wetlands are paved over with concrete and buildings?

- Cover the top of the sand with the plastic tiles. These are like concrete and asphalt on roads and buildings. Remove the moss from the neck of the bottle, as this has been "paved over," too.
- Pour some of the dirty water onto the rocks and tiles near the top of the bottle. What do you notice?

Sign #3

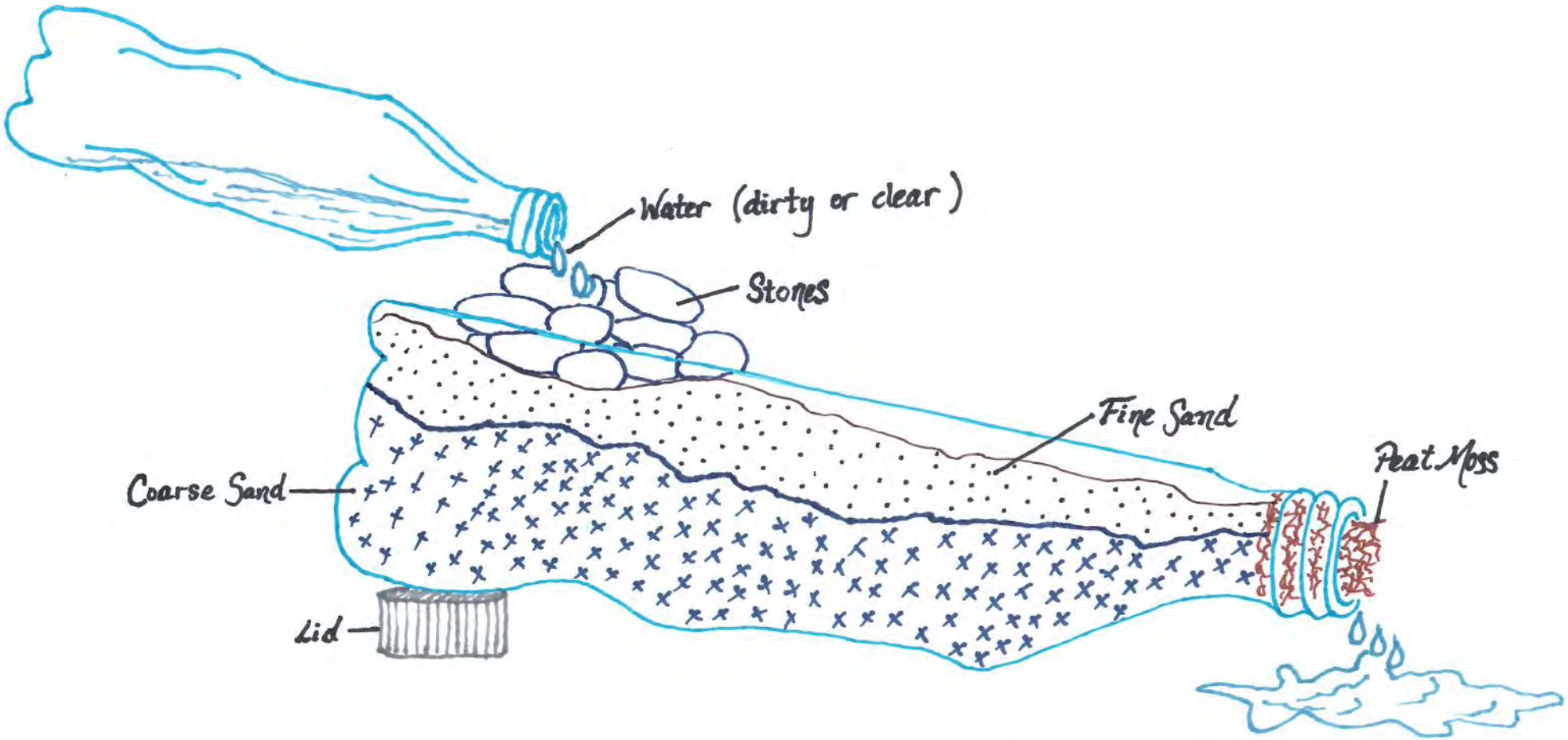
[Title] Think and Discuss

- Describe the role(s) of wetlands in the water cycle.
- Some have used a sponge to model a wetland. Do you think this model is accurate? Why or why not?
- What value do wetlands have for humans?
- What other benefits might wetlands hold for plants, animals, and humans?
- Why might people create man-made wetlands?

Background Information for Facilitators

EPA Wetlands Factsheet Series

- Wetlands Overview
- Types of Wetlands
- Functions and Values of Wetlands
- Economic Benefits of Wetlands


Water (dirty or clear)
Stones
Fine Sand
Peat Moss
Coarse Sand
Lid

So Happy Together: Perfect Pollination Pairings
Discovery Days Learning Station

Activity Description
Students will use prior knowledge, a pollination syndrome chart, and additional clues to match flower cards to pollinator cards. Students are then encouraged to look for evidence of pollinator syndromes throughout the Gardens.

Objectives
Cognitive: Students will understand that many flowers and pollinators are successful in their ecosystems thanks to unique adaptations that allow them to be mutually dependent upon each other. They will also gain an appreciation for the scope and value of biodiversity of pollinators and plants, especially as they relate to human dependence on pollinators for a multitude of crops.

Experiential: Students will use prior knowledge and newly presented information to predict which pollinators and which flowers might share mutualistic relationships in their ecosystem.

Affective: Students will feel excited to make connections between pollinators and flowers as they notice these interactions in the Denver Botanic Gardens and beyond.

2020 Colorado Academic Standards for Science
MS.2.2a Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. (*NGSS Performance Expectation MS-LS1-4*)

MS.2.5b Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. (*NGSS Performance Expectation MS-LS2-2*)

Materials/Props
- Pollinator Cards
- Flower Cards
- Pollinator Syndrome Traits Chart
- Signage

Signage Text
Sign #1

[Title] So Happy Together: Perfect Pollination Pairings

Plants have special adaptations that help them attract the best pollinators. Animal pollinators also have special adaptations that help them to get what they need from the flowers. In these ***mutualistic*** relationships, both plants and animals are dependent on the adaptations of the other for survival within their ecosystem.

Use what you already know and the Pollinator Syndromes chart to match flower cards to their most likely pollinator card. Defend your pairings to a partner, and then check your work on the back of the cards.

Sign #2

[Title] Pollinator Syndromes Chart

Botanists (plant scientists) have noticed patterns in the flower characteristics that tend to attract different kinds of pollinators. These sets of flower characteristics are called **syndromes**. Use this syndrome chart to help you match the most likely pollinators to flowers. *Some flowers may have more than one kind of pollinator.*

[insert syndrome chart here… if you have one already, you could use that, or here are some that could be used: https://www.fs.fed.us/wildflowers/pollinators/What_is_Pollination/syndromes.shtml http://pollinator.org/assets/generalFiles/Pollinator_Syndromes.pdf

Sign #3

[Title] Consider During Your Visit

- Do you notice any pollinators in the Gardens? Do they follow the patterns in the Pollinator Syndromes Chart? How so?
- Why do you suppose that pollinator syndromes have evolved?
- Why would it be helpful to have healthy populations of lots of different kinds of pollinators?
- How could you attract different kinds of pollinators to your area?

Pollinator Card Matching Key
[for use by facilitator]

Flower	**Pollinators**	**Additional Info**
Tomato flower	Bumblebee	Bumblebees (and other non-honeybees) use buzz pollination (sonication) to vibrate pollen loose from the tomato flower. Buzz pollination is necessary for several species of plants, including potatoes, peppers,

		blueberries and cranberries.
Rafflesia or Corpse Flower	Fly	Ants are also common pollinators of flowers that use stinky odors as an attraction.
Red or Purple penstemon	Bumblebee, butterfly, hummingbird	
Saguaro Flower	Bat	Saguaro flowers are only pollinated by lesser long-nosed bats and Mexican long-tongued bats
Scarlet Gilia	Bumblebee, butterfly, hummingbird, hawkmoth	Scarlet gilia blooms for a long time during the summer. Some of its pollinators, such as hummingbirds, migrate and are not available for the entire season.
Magnolia Flower	Beetle	
Sunflower [find one with a hint of red]	Bumblebee, butterfly	
Papaya Flower	Hawk moth	Recent studies have shown that hawk moths (aka sphinx moths) are the primary pollinator of the papaya fruit tree – at least in Australia, and perhaps worldwide.
Cacao Flower	Midge	The Forcipomyia genus of midges/flies is the only pollinator for cacao trees.
Wild banana flower	Bat	While cultivated bananas self-pollinate, wild bananas rely almost exclusively on bats for pollination. If a disease were to devastate the banana industry, banana farmers might have to figure out how to grow wild ones… which would mean depending on bats!

Pollinator and Flower Cards

[Make each of these cards using images from DBG or elsewhere. It may be helpful to make pollinator cards one color or size and make the flower cards a different color or size.]

Pollinators	Clue on back of Pollinator Card
Bumblebee	Bees have special light receptors in their eyes that allow them to see ultraviolet light! Bumblebees and other bees (but not honeybees!) can vibrate their abdomen making a buzzing sound (different from the buzzing they create while flying).
Fly	
Butterfly (Western Tiger Swallowtail)	Look closely at the butterfly. Can you see it's *long*, straw-like tongue knowns as a proboscis? Butterflies prefer a large flower surface where they can stand while they suck up nectar with their long proboscis.
Yucca Moth	The yucca moth lays her eggs in the ovaries of only one kind of flower. When the eggs hatch, the larvae eat some of the seeds to grow.
Bat (lesser long-nosed bat or Mexican long-tongued bat)	
Broad-tail Hummingbird	The long tongue, or proboscis, of the butterfly allows it to reach the nectar deep within these trumpet-shaped flowers. The broad tailed hummingbird reaches the nectar with its long, thin beak
Beetle	
Hawkmoth/Sphinxmoth	A hawkmoth has a long tongue, known as proboscis, for sucking nectar out of flowers. It can also hover, much like a hummingbird, and does not need to land in order to feed from a flower.
Midge (small fly)	This small fly lives in the tropics.

Flower	Clue on back of card
Tomato Flowers	This flower releases its pollen when it is vibrated, or "buzzed" in an action called buzz pollination or sonication.
Rafflesia or corpse flower	This flower is known for its strong, unpleasant odor… but some pollinators find the smell delightful!
Red or Purple Penstemon	In addition to the red that your eyes detect, penstemon blooms also reflect ultraviolet light. The pattern formed by the ultraviolet color forms lines that direct some pollinators to the nectar. These kinds of ultraviolet color patterns are known as nectar guides.
Cacao flower (Chocolate!)	The small, nearly odorless flowers of the cacao flower grow in the tropics and appear to be attractive to only one kind of pollinator.
Saguaro flower	The saguaro flower opens for just one night in the spring.
Scarlet gilia	In some areas, scarlet gilia has been observed with red flowers early in the season, turning pink later in the season, and finally finishing out the season with white blooms.
Magnolia flower	Magnolias are a very ancient plant that evolved before bees and butterflies even existed!
Sunflower	The sunflower is a composite flower. Look closely. Each petal is part of a tiny individual "ray flower", and there are many tiny "disk flowers" packed together in the center of the flower. Pollinators

	must be able to reach down into these tiny tube-like flowers in order to reach the nectar. Sunflower petals also have nectar guide patterns that are visible to animals that can see ultraviolet light.
Papaya flower	Once pollinated, the papaya flower develops a delicious fruit native to the tropics, but eaten worldwide.
Wild banana flower	The blossoms of wild banana flowers contain lots of nectar and open at night.

Self-Guided School Group and Family Packet

Exploring the Gardens – Exploring Your Home

Welcome to the York Street site of Denver Botanic Gardens. Thank you for bringing your class or family to enjoy everything that the Gardens has to offer. We encourage you to follow your curiosity, to think and act like scientist, and to make discoveries that help you to better understand the world and your place in it.

Beginning in 2019, we proudly invite you to visit the new *Welcome Home* exhibit in the Science Pyramid. In this exhibit you can explore the semi-arid landscapes of Colorado and how they, and the water that runs through them, connect the plants, animals, and people who call this state home. As you and your children explore the exhibit you may notice some of the following big ideas:

- Plants, animals, and people all live here on this earth we call home.
- Our home is so big that sometimes we can't easily see how many creatures we share it with. However, we still feel the effects of one another.
- We share limited resources, including water, with all other living organisms.
- All living creatures and ecosystems, no matter how different they seem, are interconnected.

Examples of these themes can also be seen and investigated throughout Denver Botanic Gardens. Use the activities and discussions in this packet to guide your learning in the Gardens and to extend your exploration beyond our gates.

Before and After Your Visit

Your visit can be made even more meaningful if you prepare yourself and your students for the concepts and themes they will experience here. You can also add meaning to your field trip by reflecting on your visit and extending the experience in your classroom. Consider incorporating some of these activities into your curriculum before or after your field trip.

- Introduce or review relevant vocabulary.
- Read books about Colorado ecosystems ranging from semi-arid grasslands to marshy wetlands. (Check your school library for specific ecosystems/habitats or see the Recommended Resources section of this packet).
- Play the water cycle dice game to learn more about how water moves through earth's systems. The National Weather Service/NOAA explains one version of the game on their website.
- Think about how you use water and other limited resources that you share with other organisms. Calculate the amount of water an average student or household uses in a day/month/year. Use the Water Footprint Calculator, or another method of your choice.
- Carry out related lesson plans about water, biodiversity, ecosystems, and the interactions between humans and their environments. See the recommended resources in this packet, or use your own.
- Create or work in a school garden. Focus on the resources plants need to grow and how a garden provides habitat for other organisms.

Vocabulary

Adaptation – physical or behavioral aspects of an organism that allow it to survive in its environment.

Climate – the typical weather patterns of a place. Climate stays the same over many years, while weather can change from day to day.

Ecosystem – all of the living and non-living things in a given area and the interactions between them.

Habitat – the home of an animal, plant, or other living organism where it can get everything that it needs for survival such as food, water, shelter, etc.

Semi-arid – a climate description that means partially dry with only light rainfall (between 10-20 inches per year)

Water Cycle – the movement of water through different forms and locations

Activity	Location	Description	Think and Discuss	Extension Ideas	CAS Science GLEs
Science Pyramid Scavenger Hunt (*handout*)	Science Pyramid	Use the Science Pyramid handout to explore the Welcome Home exhibit. The search highlights the key themes of the exhibit and helps students to see our planet and its ecosystems as a shared home for all living organisms, including us!	1. What do animals and plants need to survive? 2. What happens when different living organisms need the same things/resources, such as water? 3. How are humans a part of different ecosystems?	Draw or create a model of the water cycle. Include your home in your drawing or model. Visit different ecosystems, such as an urban ecosystem in your neighborhood, the riparian ecosystem around Deer Creek at the DBG Chatfield Farms site, the short grass prairie at the Plains Conservation Center, or the alpine at the DBG Mount Goliath site.	K.2.1 5.2.2 5.3.5 MS.2.3 MS.2.5 MS.2.6 MS.3.6 MS.3.8
I Notice I Wonder (*handout*)	Anywhere outside in the Gardens	Assign each student a 1x1 meter area on the ground. They should be able to observe this area without leaving the paths and trails, but the square can include any type of terrain (sidewalk, garden, rocks, etc.). Give students 5 minutes to observe and draw everything in their square. Students should also think about and/or write what they notice and what they wonder about the living organisms and non-living things (e.g., rocks, water, etc.) in their area. After the exercise, have students talk with a partner about their drawings, observations, and questions.	1. How do the living things in your square interact with each other? Does one help or hurt another? Explain. 2. How do the living things in your square interact with non-living things, such as rocks or water? 3. How do people affect your square? Is their affect good? Bad? Something else? Explain. 4. How could you figure out explanations or answers for the questions you wonder about?	Pick a spot at home or school and repeat the activity. Compare and contrast the two spots. Revisit the school/home square throughout the year to make additional observations. Have students choose one of the questions they wonder about and design an investigation to figure out an explanation.	1.2.1 2.2.2 MS.2.5 MS.2.12

Activity	Location	Description	Think and Discuss	Extension Ideas	CAS Science GLEs
Plant Adaptations (*Focus: dry climate adaptations*)	Roads Water-Smart Garden and/or Cactus and Succulent House Boettcher Memorial Tropical Conservatory	Explain to students that, while all plants need water, some have adaptations that help them to survive in ecosystems where water is a limited resource. Have students work in pairs to study these plants and the signage. Ask them to identify possible adaptations that allow these plants to live in dry climates. They should give explanations for their ideas and their partner should discuss why they agree or disagree. Continue on to the Boettcher Memorial Tropical Conservatory and ask students to compare their observations of dry-climate plants to plants that have adaptations for surviving in humid and wet environments. Ask them to continue their discussion with their partner and make any changes to their ideas based on their new observations	1. What dry climate plant adaptations did you and your partner agree upon discuss? What did you agree upon? What did you disagree about? 2. How did your observations of wet-climate plants affect your ideas about dry-climate adaptations? 3. What are some adaptations that animals might have for living in low water environments? 4. Colorado has a semi-arid, or partly dry, climate. What can we learn from plant or animal adaptations that might help us to conserve water?	Research and design a garden for your school or home using plants that are well-adapted to arid or semi-arid ecosystems. Consider container gardening if space or time are limited. Research additional plant adaptations for surviving in dry climates. Look especially at adaptations at the cellular level. Challenge students to design and carry out an experiment using live plants to test the effects of climate on plant growth. Areas for experimentation might include amounts of sunlight, rainfall, and temperature. Repeating the experiment(s) on different kinds of plants can help students to draw connections between their DBG visit and the results.	3.3.1 4.2.1 MS.3.8

Activity	Location	Description	Think and Discuss	Extension Ideas	CAS Science GLEs
				Using plant adaptations as inspiration, design a tool or method that helps humans to conserve water in dry climates.	
Ecosystems as Shared Habitats (*Focus: urban ecosystems*)	Anywhere outside in the Gardens	Start by asking students if the city is an ecosystem. Have them defend their answers and then assign them quiet areas, or "sit spots", to sit and observe over a 10-20 minute period. As they sit, they should sketch the animals that they observe (vertebrates and invertebrates) and think about how each uses the space to meet their needs. Are they using the Gardens for food? Water? Shelter? Space? After their observations, have them use the discussion questions in pairs or small groups.	1. What animals use Denver Botanic Gardens as part (or all) of their habitat? (Remember that humans are animals too!) 2. How is the city an ecosystem? 3. What are some of the challenges that non-human animals in urban habitats face? What resources must humans and other organisms share? 4. Urban ecosystems include different microclimates, or smaller areas that are environmentally distinct from one another. What microclimates do you notice near your sit spot?	Repeat this activity at home or at school. Set aside time each day or each week to return to this space and to become fully familiar with the plants and animals that share this portion of the urban ecosystem with you. Pay attention to patterns and changes in your observations over time. Turn your observations into real science. Participate in a citizen science project such as Nature's Notebook or one of many projects coordinated by The Cornell Lab of Ornithology.	2.2.2 5.3.5 MS.2.5 MS.2.12

Science Pyramid Scavenger Hunt

Explore the *Welcome Home* exhibit inside the Science Pyramid to complete the scavenger hunt.

Find examples of the following:

A plant adapted to a semi-arid climate (like Colorado)…

Plant _____

Adaptation _____

An animal adapted to a semi-arid climate…

Animal _____

Adaptation_____

A way that humans adapt to a semi-arid climate

Adaptation: _____

Three Colorado ecosystems and examples of water found in the ecosystem…

Colorado Ecosystem	Water in the Ecosystem
Example: ***Riparian Ecosystem***	*Example:* ***Creek water and run-off from rain.***

A reason why flooding can be good for some ecosystems…

_____

_____

Two ways that people use water…

1. _____

2. _____

Two ways in which humans and other organisms interact with each other…

1. _____

2. _____

Two ways people can help keep our home (our ecosystems) healthy…

1. _____

2. _____

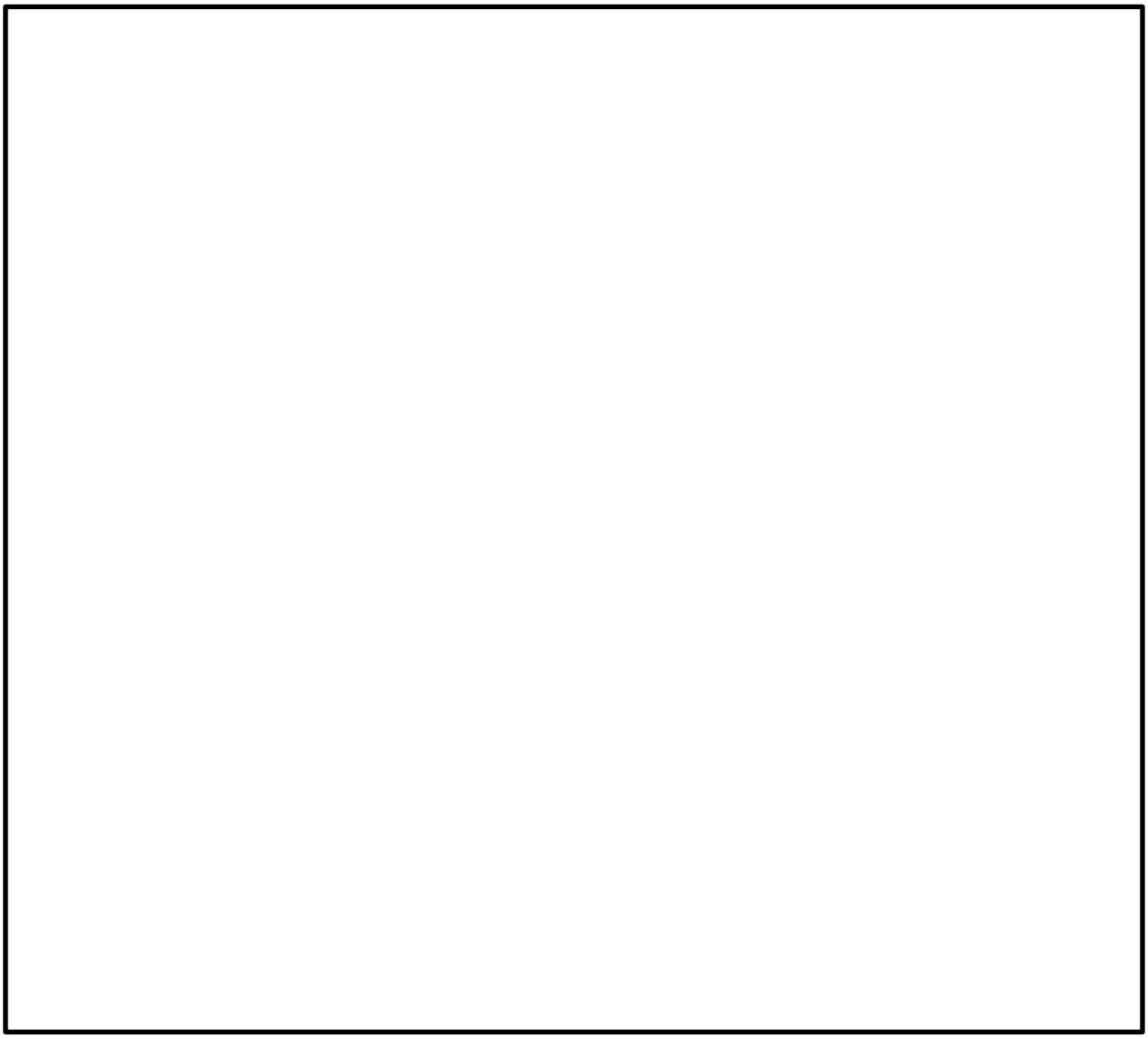
One thing you learned from the Science Chat (if a Science Chat is happening in the Pyramid)…

_____

_____

I Notice… I Wonder…

Sit and observe a square space of ground that is about 1 meter by 1 meter. The measurement doesn't have to be perfect. Draw what you see in the box below. Write down other things that you notice and things that you wonder about on the other side of the page.



Things that I notice:

Things that I wonder:

Recommended Resources

Books

C is for Centennial: A Colorado Alphabet by Louise Doak Whitney. Explore the Colorado landscape through the alphabet. This beautifully illustrated book gives lots of information about the ecosystems and history of the state we call home.

From Grassland to Glacier: The Natural History of Colorado and the Surrounding Region by Cornelia Fleischer Mutel and John C. Emerick. This concise edition introduces readers to a multitude of ecosystems in Colorado.

How to Raise a Wild Child by Dr. Scott Sampson. This book can be useful for parents and teachers, alike, in helping children of all ages to see themselves as part of nature and to understand their own interconnectedness to all other living things. His explanations and guidance for developing "sit spots" may help you to extend the "Ecosystems and Shared Habitats" activity for years to come.

Sierra Club Naturalist's Guide: the Southern Rockies by Audrey Benedict. A comprehensive guide to local ecosystems.

Websites

20 Lesson Plans for Urban Environmental Education – This collection of lesson plans includes options that span from kindergarten through high school. Most of the lessons connect directly to the key concepts of Science Pyramid and the themes that are explored in this packet, especially Use these lessons prior to your visit to create context for your DBG exploration or implement one or more lessons after your visit to extend student learning.

Landscope Colorado – part of the Colorado Natural Heritage Program, this website provides a wide range of resources about the plants, animals, and ecosystems of Colorado.

Learning Lesson: What a Cycle! – This lesson from the National Weather Service/NOAA details a game students can play to gain a deeper understanding of the water cycle.

Science Chat: Biodiversity & Ecosystems

Take visitors on a deep dive into the value and importance of biodiversity in their own lives. Explore the riparian ecosystem of Deer Creek as it flows through Denver Botanic Gardens at Chatfield Farms. Use the creek, its inhabitants, and its surroundings as a lens to make connections between water quality and ecosystem biodiversity and health. Discover the role of genetic biodiversity in terms of food security and a few of our favorite foods and beverages. Share a few examples of how Denver Botanic Gardens researchers and volunteers are working to better understand and protect biodiversity at the ecosystem and genetics levels.

Table of Contents

Big Ideas

- Biodiversity is important at all levels of life and is valuable to all of earth's inhabitants – even us (human beings).

- Water is a critical natural resource that is impacted by and impacts ecosystem health and biodiversity.

Objectives

Cognitive: Visitors will learn about ecosystem biodiversity through the lens the riparian ecosystem along Deer Creek at Denver Botanic Gardens Chatfield Farms. They will learn about genetic diversity with a focus on crops such as coffee, bananas, and wine grapes. Participants will gain awareness of the value of biodiversity, how biodiversity can be supported, and DBG efforts to protect biodiversity.

Experiential: Visitors will interact directly with DBG scientists and/or volunteers and will have the opportunity to ask questions, share their own understanding and connections to the topic of biodiversity, and will generally participate in a science-based conversation that increases their understanding and appreciation of the topic.

Affective: Visitors will feel motivated and empowered to choose actions that support a healthy ecosystem and encourage biodiversity locally and globally.

Key Vocabulary

Biodiversity – the variety of all life in a given area – within a population, species, in a **habitat** or **ecosystem**, or even across the entire planet

Ecosystem – all of the living organisms in a physical environment and the interactions between the individuals and populations with one-another as well as with the non-living elements.

Ecosystem Services – the direct and indirect contributions of ecosystems to the well-being of humans Monoculture – the cultivation of a single plant type in a given area. Examples: Kentucky bluegrass lawns, large-scale farming of corn or soybeans the American Midwest

Genetic Diversity – the variation in genetic information within and among individuals of a population, species, or community. Genetic diversity is one aspect of biodiversity.

Invasive Species – an organism that is not native to an ecosystem and that can cause harm. Invasive species often cause the greatest damage where they can out-compete or over-hunt native species.

Monoculture – the agricultural practice of cultivating a single crop in a large area

Population – all of the organisms of the same species (or subspecies) living in a specified geographical area.

Riparian – referring to an area where terrestrial and aquatic ecosystems intersect. Generally indicating the zones around and including creeks, streams, and rivers.

Species – a group of organisms (animals, plants, etc.) that share common characteristics and are capable of interbreeding. "Capable" typically refers to the likelihood of breeding. For example, lions and tigers are physically capable of producing viable offspring in captivity, but are geographically and behaviorally separated in nature, so would not breed. They are, therefore, considered separate species. The species concept is more complicated in botany, as interbreeding between species is more common. For example, various species of cottonwood trees interbreed in areas where their range overlaps.

Materials/Props

- Map of Denver Botanic Gardens Chatfield Farms
- Map of Deer Creek from beginning of both north and south forks to Chatfield Reservoir
- Poster of riparian ecosystem
    - Poster that matches page 51 from here: https://cpw.state.co.us/Documents/Education/TeacherResources/CrossroadsBioiversity.pdf (poster is free at CPW regional offices)
- Printed or bound copy of WILD Colorado: Crossroads of Biodiversity (bound copy is available for free at CPW regional offices) with a
- Laminated copy of page 55 WILD Colorado: Crossroads of Biodiversity for reference.
- Beaver skeleton
- Riparian Erosion/Filtration Models (see Appendix A)
- Example of tamarisk branch
- Riparian erosion/filtration model (see Appendix A)
- Videos of Deer Creek at DBGCF with meandering flows and beaver dams
- Riparian benefits metaphor objects
    - Sponge
    - Pillow/doll bed
    - Mixer/egg beater
    - Cradle/doll crib
    - Sieve/strainer
    - Filter
    - Antacid
    - Cereal box (with fortified qualities clearly advertised on the box)
- Sample tamarisk branch
- Sample smooth brome
- Sample Russian Olive branch
- Saltcedar Fact Sheet (laminated)
- Russian Olive Fact Sheet (laminated)
- Smooth Brome Fact Sheet (laminated)
- Noxious Weed List
- Arabica coffee beans in a labeled jar
- Robusta coffee beans in a labeled jar
- Package of coffee with “Rainforest Alliance Certified” Seal
- Images of coffee plantations (shade-grown and traditional), coffee trees, wild coffee trees, coffee leaf rust
- Coffee plant or parts if possible
- Fake bananas
- Empty bottle of Colorado wine
- Chromosome image
- Pictures listed on the next page

- Pictures (laminated or on a screen)
    - Deer Creek from here
    - Image of Deer Creek as it flows through a recognizable part of DBG Chatfield Farms
    - Beaver dams and beavers
    - Freshwater plankton
    - Boreal Toads
    - Deer Creek at DBGCF meandering flows, channelized flow, beaver dams
    - Siberian Elms, Russian olives, smooth brome at DBGCF
    - Tamarisk in riparian areas
    - Coffee plantations, coffee trees, wild coffee trees, coffee leaf rust

Set Up

See individual activities.

Primary Messages for Facilitators

Biodiversity is…

Biodiversity refers to the variety of all life in a given area – within a population, species, in a **habitat** or **ecosystem**, or even across the entire planet. The term biodiversity was coined in 1985 by the tropical and conservation biologist, Thomas Lovejoy and is represents the merging of the words *biological* and *diversity.*

Among biologists and ecologists, biodiversity is universally understood to be a measure of biological health. More genetic diversity in a population or species makes the population or species more adaptable to environmental pressures such as disease. Greater species diversity makes for a more robust ecosystem that is resilient to environmental changes such as climate change. A wider variety of life and ecosystems in a region or around the globe protects life on earth from complete collapse.

Biodiversity is important to all of us.

Human beings have a tendency to see ourselves outside of nature or peripheral to ecosystems. This framing rarely serves us well. A broader perspective makes it clear that we live as one of many inhabitants in a variety of ecosystems (urban ecosystems, agrarian ecosystems, etc.). What is more, we depend upon ecosystems that border our own, as well as others around the globe.

Our connection to other organisms in our ecosystems is far more predictable and concrete than the proverbial butterfly flapping her wings on the other side of the world. Biodiversity within these ecosystems can be both hugely impacted by human actions and can also greatly affect human health and society.

Deer Creek, as it runs through Denver Botanic Gardens Chatfield Farms, can be looked to as an example to understand the importance of biodiversity. (See exploration and discussion below for additional details)

Biodiversity in terms of agriculture is important to our enjoyment of food as well as critical to our food security. (See exploration and discussion below for additional details)

Denver Botanic Gardens is actively working to protect and improve biodiversity at Denver Botanic Gardens Chatfield Farms, as well as in other projects right here at DBG York Street. (See exploration and discussion below for additional details)

Exploration and Discussion Themes

Theme: Where (and what) is Deer Creek?

Visuals:

- Map of Denver Botanic Gardens Chatfield Farms
- Map of Deer Creek from beginning of both north and south forks to Chatfield Reservoir
- Image of Deer Creek as it flows through a recognizable part of DBG Chatfield Farms

Information:

- Both the north fork and south fork of Deer Creek start in the mountains west of Littleton near Conifer, CO.

- Deer Creek feeds into Chatfield Reservoir along the South Platte River. In addition to being an ecosystem for animals, plants, and human recreation, the reservoir serves as water storage for Denver Water. This water does not supply Denver's drinking water. Rather it is released downstream for agricultural water rights that Denver Water owes instead of releasing its water from upstream reservoirs such as Cheesman or 11 Mile Canyon.

- Deer Creek flows over public and private land, including a series of Jefferson County parks and open spaces and Denver Botanic Gardens Chatfield Farms.

- The area around a creek or a river is called a **riparian ecosystem**. Riparian ecosystems lie at the interface between terrestrial and aquatic zones. These ecosystems make up a relatively small percentage of the land, but provide food, cover, and water for a proportionally large number of animals. They can also serve as migration routes and can act as wildlife corridors between habitats.

Discussion Points/Questions:

Are you familiar with Deer Creek or Chatfield Botanic Gardens at Chatfield Farms? What are your experiences and impressions of the creek, the location, or the ecosystem?

What creeks or rivers are you familiar with?

What do you know about the animals and plants that live in and around creeks?

Theme: Biodiversity in Riparian Ecosystems and Deer Creek

Visuals:

- Poster of riparian ecosystem
    - Poster that matches page 51 from here: https://cpw.state.co.us/Documents/Education/TeacherResources/CrossroadsBioiversity.pdf (poster is free at CPW regional offices)
    - 2nd choice: print top and bottom images here: http://eekwi.org/teacher/Climateguide/PDF/ecosystemposter.pdf
- Printed or bound copy of WILD Colorado: Crossroads of Biodiversity (bound copy is available for free at CPW regional offices) with a laminated copy of page 55 for reference.
- Beaver skeleton
- Images
    - Beaver dams and beavers
    - Freshwater plankton
    - Freshwater insects

Information:

Facilitators are strongly encouraged to read/review pages 51-62 of the Colorado Parks & Wildlife (previously Colorado Division of Wildlife) WILD Colorado: Crossroads of Biodiversity.

- While freshwater ecosystems (including riparian ecosystems) make up between 1% and 3% of Colorado land, these areas support most of the state's species – both animal and plant!
- Species diversity can be 2-3 times higher in riparian areas than in surrounding ecosystems.
    - Phytoplankton (microscopic plants) and zooplankton (microscopic animals) form the base of the aquatic food chain as they provide food for macroinvertebrates such as water boatman, diving beetles, backswimmers, and a large variety of insects in their immature (larval) forms. The macroinvertebrates, in turn, provide food for vertebrates such as fish, amphibians, reptiles, birds and mammals.
    - Wetlands and riparian areas have the greatest diversity of bird species of any Colorado ecosystem.
    - Nearly all species of mammals live in or visit riparian areas.
- Cottonwood trees play a central role in Colorado riparian ecosystems. Cottonwood reproduction is adapted to (and even requires) regular flooding events. The seeds require bare, wet soil in order to germinate. These trees provide a wide variety of microhabitats for a diverse spread of animals and plants.
    - Fallen trees (older trees that are washed out by flooding) provide food for decomposers and can act as dams that hold back sand from flowing through with the water. The sandbars that are created provide prime habitat for willows and new cottonwoods.

- Regular flooding events lead to changes in the path of the riparian area as the river or creek reshapes itself. These changes can leave some cottonwoods stranded where they are unlikely to reproduce. However this creates a wide variety of cottonwood stands. Some are older, some middle-aged, others young. This variety of ages also provides different microhabitats for different animals and plants.

- Beavers also play a central role in riparian ecosystems. As natural engineers, this species can alter its environment by building dams, lodges, burrows, and canals. In doing so, they control water levels and flow. The resulting ponds provide prime habitat for fish and other species that prefer the slower moving water. Beavers eat willow, cottonwood, and aspen (in the cottonwood genus) for building, as well as for food. As the area is depleted of these trees, beavers move on, allowing the area to regrow and eventually become ideal habitat for another family of beavers to move in some day. The cycle of growth and change creates biodiversity over time and space.

Discussion Points/Questions:

Referring to the poster: How are each of the animals and plants connected in this ecosystem?

Microhabitats are small areas within an ecosystem that provide slight variations in the environment (examples: cooler microhabitats can be created by close proximity to water or the shade of a tree or shrub).

- How many microhabitats can you identify in the poster?
- How might a variety of microhabitats lead to greater biodiversity?

What waterways and riparian ecosystems are near your home? Are they healthy or not? How do you know? Do you see a lot of biodiversity there or not?

Not sure about the nearest water to you? Google your address and look for blue on the map! Go check it out. Learn more about the ecosystems around you.

Theme: What are the benefits, or ecosystem services, of a healthy and diverse riparian ecosystem?

Materials:

- Riparian erosion/filtration model (see Appendix A)
- Photos/Videos of Deer Creek at DBGCF with meandering flows and beaver dams
- Riparian benefits metaphor objects
    - Sponge
    - Pillow/doll bed
    - Mixer/egg beater
    - Cradle/doll crib
    - Sieve/strainer
    - Filter
    - Antacid
    - Cereal box (with fortified qualities clearly advertised on the box)

Information:

Ecosystem services is a term that refers to all of the services or benefits that we receive from the natural environment, not the least of which include food and water.

According to recent estimates by the International Union for Conservation of Nature, **ecosystems services around the globe can be valued at $125 trillion per** year! Of course, this economic value is in addition to the non-material benefits such as general enjoyment and peace of mind.

In the case of ecosystem services in **riparian ecosystems**, biodiversity strengthens the overall health of the ecosystem. In turn the ecosystem offers the following services:

1. *Streambank erosion prevention* – Vegetation helps to hold soil and dirt in place, preventing erosion, but this is just the beginning of the story. A wide variety of plants (biodiversity) with differing sizes and root structures also shape the land over which the river flows. Minor variations can lead to a meandering path for the creek or river as it follows the path of least resistance. The bends and the curves slow the speed of the current, which also helps to prevent additional erosion. While a certain amount of erosion is expected and natural for a riparian ecosystem, acceleration of the process can lead to increased sediment carried downstream and damage to the ecosystem leading to even less biodiversity.

2. *Pollutant removal from the water* – The slow meandering quality of streams with high biodiversity also offers time for water to seep into the ground below and for *contaminants to be filtered out.* Biodiversity in terms of animals can also play a role. Beaver ponds slow down the flow of water even more, allowing for even greater filtration. Nutrients (including fertilizers), pesticides, heavy metals, and animal waste can all end up in water, but healthy

riparian ecosystems provide a way for these pollutants to be filtered out of the water. Many of these items are then broken down and put back into the ecosystem and/or neutralized. Maintaining riparian ecosystem biodiversity can be more effective and less costly than maintaining and building water treatment plants!

3. *Flood Risk Reduction* – Slow, meandering creeks and rivers minimize the risk of fast-moving flood events. While flooding is natural and even beneficial in healthy riparian ecosystems, it tends to be minor and cause minimal damage. A variety of plants also help to slow the floodwater. Low-growing plants such as grasses and other herbaceous plants can grow in dense stands and are quite effective at slowing water flow. If the water level rises higher than these low-growing plants, a variety of trees (while not as dense) can provide some additional slowing during severe flood events. Without a variety of plants to slow the flow, fast-moving water in one area can lead to even more intense and destructive flooding downstream.

4. More resilient and healthy ecosystem – Healthy ecosystems with greater biodiversity tend to beget healthy ecosystems with high biodiversity. While this is not directly considered an ecosystem service, the maintenance of healthy ecosystems ensures that these services are available. See the "Riparian Ecosystem Services Metaphor Activity" for a list of examples.

Activities:

- Riparian Ecosystem Services Metaphor Objects: Have visitors guess, discuss, or explain how each of the objects represents a function or service provided by riparian ecosystems. This activity is adapted from WILD Colorado: Crossroads of Biodiversity.

  - Sponge – absorbs excess water caused by runoff; retains moisture for a time even if standing water dries up (e.g., sponge placed in a small puddle of water absorbs water until saturated, then stays wet after standing water has evaporated)
  - Pillow/doll bed – resting place for migratory birds
  - Mixer/egg beater – mixes nutrients and oxygen into the water
  - Cradle/doll crib – provides a nursery for young wildlife
  - Sieve/strainer – strains silt, debris, etc., from water
  - Filter – filters smaller impurities from the water
  - Antacid – neutralizes some toxic substances
  - Cereal – provides nutrient-rich food (a wide diversity of plankton, plants and animals (both vertebrate and invertebrate) provides a broad selection of foods with a wide diversity of nutrients.)

- **Erosion Prevention**: Demonstrate how the healthy riparian ecosystem (with plants) prevents erosion.
    1. Pour clean water into each of the three models until they are saturated and water begins to pour out of the bottle opening.
    2. Compare the quality of the water coming out of each of the trays.
        - Which ecosystem experienced the most erosion? The least?
        - How does this model demonstrate one of the benefits of a heathy riparian ecosystem?
        - How might erosion be a problem for Deer Creek? (destruction of the soil/ecosystem, debris carried downstream into Chatfield Reservoir)
        - Show pictures of meandering creek from Deer Creek at DBGCF . Discuss how a slower flow of water reduces erosion. Connect biodiversity of plant life to a more meandering water way.

Discussion Points/Questions:

Which ecosystem experienced the most erosion? The least?

How does this model demonstrate one of the benefits of a heathy riparian ecosystem?

How might erosion be a problem for Deer Creek? (*destruction of the soil/ecosystem, debris carried downstream into Chatfield Reservoir*)

Show pictures of meandering creek from Deer Creek at DBGCF . Discuss how a slower flow of water reduces erosion. Connect biodiversity of plant life to a more meandering water way.

- **Pollutant Removal/Filtration**: Demonstrate how the healthy riparian ecosystem (the tray with plants) helps remove pollutants from the water.
    1. Pour the muddy/dirty water into the model with grass/plants until water begins to pour out of the bottle opening.
    2. Compare the quality of the water coming out of the riparian model to the water being poured in.

Discussion Points/Questions:

Why is the water coming out of the riparian ecosystem clearer than the water going in?

What happens to pollutants we can't see such as chemicals from fertilizer?

What pollutants might be found in Deer Creek and how might they be problematic? (*animal feces, fertilizer, road salt – all can be detrimental to animals – large and small – that use or live in the creek as well as bodies of water further downstream*)

Show pictures of meandering creek and beaver dam from Deer Creek at DBGCF. Discuss how a slower flow of water with regular flooding events allows time for water to seep into the soil for better filtration of pollutants. Connect to biodiversity (*beavers, variety of plant/root structures, etc.*)

Theme: Human Impacts on Biodiversity and How DBG is Helping

Materials:

- Sample tamarisk branch
- Sample Russian olive
- Sample smooth brome
- Pictures of Siberian Elms, Russian olives, smooth brome, and tamarisk in riparian areas
- Pictures of Deer Creek from here
- Pictures of Boreal Toads
- Saltcedar Fact Sheet (laminated)
- Russian Olive Fact Sheet (laminated)
- Smooth Brome Fact Sheet (laminated)
- Noxious Weed List

Information:

There are no hands-on activities for this section. Use the images, fact sheets, and examples – along with visitor curiosity – to prompt discussion.

It is no secret that human actions can lead to negative consequences for organisms around the globe and in a variety of ecosystems. Due to the importance of water as a resource for all living things, including humans, riparian ecosystems can feel the impacts of humans in particularly strong ways. This Science Chat focuses on just a few human impacts on biodiversity with a focus on riparian systems and Deer Creek.

Invasive Species – Invasive species are organisms that are not native to an ecosystem and that can cause harm. Invasive species often cause the greatest damage where they can out-compete or over-hunt native species. In the case of Colorado riparian ecosystems, Russian olives and tamarisk are some of the greatest offenders. Some of the invasive or problematic species around Deer Creek include:

- Russian olives were introduced to the US in the 1800's as an ornamental plant. Even until recently, these woody shrubs/trees were recommended by the U.S. Soil Conservation Service as a wind break and wildlife planting. While native birds are known to eat the fruit of the tree (and aid in seed dispersal in this way), bird species diversity has been shown to be higher in riparian areas with native vegetation. Unfortunately, Russian olives easily out competes native trees such as cottonwoods by disrupting their natural nutrient cycles and taking up more than its fair share of water in the environment.

- Siberian Elms, native to northern Asia, were first introduced to North America in the 1860s and has been planted widely for windbreaks and lumber. These trees are drought-tolerant and spread rapidly by their abundant, wind-dispersed seeds, forming dense thickets, out-competing native vegetation and reducing forage plants for wild animals (and livestock!).

- Smooth Brome, is often grown on pasture land and is not identified as a noxious weed in Colorado. That said, this grass can become invasive, or weedy, in some areas where it is not well managed. In the Deer Creek riparian area this grass has displaced more desirable vegetation and is limiting biodiversity.

While not a problem at Deer Creek, it is worth mentioning tamarisk, also known as saltcedar. This invasive species was introduced for ornamental purposes and is now widespread in the U.S. Officially considered a noxious weed in many states, including Colorado, tamarisk out competes and crowds out native vegetation. It also increases the salinity of the soil, preventing native plants from growing. While it populates stream banks and prevents erosion, its excessive water use contributes to the problem of drought. The dense growth of saltcedar also can lead to narrowing and channelizing of streams and rivers – preventing regular, minor flood events and increasing the speed of the water. While tamarisk provides habitat for some bird species (including the endangered southwester willow flycatcher), these are species that would also live well in native willows and cottonwoods. Furthermore, biodiversity is higher in the native tree stands than in tamarisk. Tamarisk is not a problem along Deer Creek, but is a destructive and costly problem across the Southwest, including along the Colorado River.

Physical Changes to the Land – Channelization – Meandering flows are important for riparian areas, as they maintain the ecosystem services and contribute to a healthy and biologically diverse ecosystem. Channelization of riparian areas by humans (or by tamarisk) can prevent regular minor bank overflows and cause faster water flow. At some point in its history, Deer Creek, as it flows through DBGCF, was channelized.

Endangered Species – Biodiversity is obviously impacted as species become endangered and even risk extinction. The list of human causes for endangered species is long and includes both direct and indirect connections. To name a few: habitat destruction, over-hunting, climate change, environmental pollutants. In riparian ecosystems some of the most sensitive species are amphibians such as frogs and salamanders. Due to their permeable skin (through which they breathe) and their nearly constant need for moisture, amphibians are especially prone to human impacts. In fact, 39% of amphibians worldwide are

threatened with extinction. In comparison, 10% of birds and 16% of mammals find themselves in the same predicament.

The **Boreal Toad** is a prime example of a Colorado wetland animal that was once widespread and is now scarce. Researchers have found evidence that the precipitous decline of the population over the past few decades can be attributed to chytrid fungus Bd. A recent study suggests that global climate change may be to blame for the increased prevalence of the fungus While boreal toads are typically found higher in elevation (in fact, they are the only alpine toad species), they represent a problem that is worldwide and that can also affect amphibians in Deer Creek.

So how is Denver Botanic Gardens helping? Chatfield Farms Deer Creek Restoration Project: As a result of intensive land management (human change) since the 1800's, the Deer Creek riparian area – and in particular the stretch of the creek that runs through Chatfield Farms – had become much degraded ecologically. People had channelized the creek, preventing regular spilling over of the water during high water flows and minimizing the ecosystem services and limiting biodiversity. Additionally, Siberian elms and Russian olives had been planted and/or spread from nearby plantings, limiting biodiversity. In the part of the creek below Chatfield Farms, beavers have moved in and restored the riparian habitat on their own.

Rebecca Hufft, Associate Director of Applied Conservation at Denver Botanic Gardens, is leading a team of staff and volunteers in a project to restore the Chatfield Farms portion of Deer Creek. In the few short years that the project has been implemented, beavers have already moved back into the area and are helping with the restoration in their own way.

The long-term aspirations of the project are:

- Improve creek hydrology
- Improve habitat quality
- Increase biodiversity
- Educate visitors on the importance of riparian corridors

This project includes:

- Protect desirable trees from beaver damage
- Remove Siberian elms, Russian olives and other noxious weeds
- Burn, treat and till areas overrun with smooth brome
- Restore native deciduous shrubs and trees
- Install temporary in-stream diversions to mitigate the creek's previous channelization
- Plant and seed native understory and riparian species
- Provide hands-on restoration opportunities for volunteers
- Provide public education
- Collect and monitor baseline and ongoing biodiversity, plant cover, and water quality data for assessment of project impacts
- For more details and updates, see the Ecological Stewardship: Restoration at Chatfield Farms report.

Discussion Points/Questions:

How do we know what biodiversity looked like in the past or how "should" it look if we aim to restore it? (*Natural history collections such as the plant and fungal specimens housed in the DBG herbarium can help*)

How do beavers help restore an ecosystem? (*see beaver information above*)
Why do we care about restoring riparian ecosystems or other ecosystems? (*see ecosystem services information above*)

What riparian or wetland ecosystems are near your home? How biodiverse are they? What could you do to make improvements or enjoy the area more fully?

Volunteer opportunities for visitors who seem very interested or who demonstrate interest.

Theme: Challenges to Biodiversity: Agriculture & Genetic Diversity

Materials:

- Arabica coffee beans in a labeled jar
- Robusta coffee beans in a labeled jar
- Package of coffee with "Rainforest Alliance Certified" Seal
- Images of coffee plantations (shade-grown and traditional), coffee trees, wild coffee trees, coffee leaf rust
- Coffee plant or parts if possible
- Fake bananas
- Empty bottle of Colorado wine
- Chromosome image

Information:

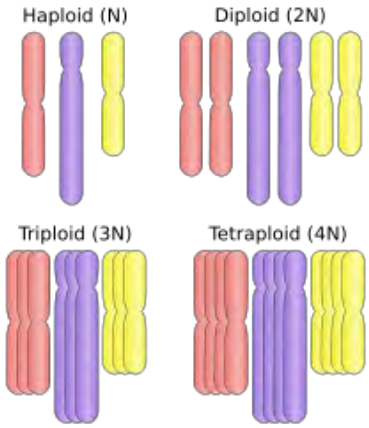
Agriculture, monocultures and genetic diversity – While not directly related to riparian ecosystems, monocultures are one of the larger challenges to ecological and genetic biodiversity. **Monoculture** is the agricultural practice of cultivating a single crop in a large area. In addition to growing just one species, it is common for monocultures to be just one variety and to have very little genetic diversity. Monocultures have arisen in agriculture for many reasons. From a practical standpoint, planting and harvesting can be more easily mechanized in a field where all plants are the same, allowing for higher yields and lower costs. Genetic diversity is can also be limited due to small number of individual original plants. One or two plants may give rise to an entire region's crop. Selection for specific desirable traits can also lead to lowered genetic variation as farmers and agricultural supply companies breed for bigger fruits, higher yields, greater heat or cold hardiness, desirable flavors and colors, etc.

The lack of genetic diversity in agriculture has a significant downside. Within a genetically diverse population, it is likely that at least a few, if not a reasonable percentage of the plants will be resistant to a given pathogen, parasite, or pest. However, in a crop of genetically similar or identical individuals, if one plant is susceptible to a disease, most – if not all – of the harvest will be affected. The results can be economically challenging, if not disastrous. In some cases farmers have little other choice than to use environmentally problematic pesticides (insecticides as well as herbicides), and in some cases the loss of the crop is nothing short of a humanitarian crisis.

Example with DBG Connection: Arabica Coffee

- There are two main species of coffee that are cultivated as cash crops: *Coffea arabica* (commonly known as Arabica) and *Coffea canephora* (commonly known as Robusta). Of these two, Arabica tends to be preferred for its flavor and makes up about 70% of the industry.

- Genetic diversity is limited in Arabica coffee for a couple of reasons
    - Arabica is a natural hybridization of two wild coffee species. When these species hybridized the resulting offspring had four sets of chromosomes rather than two (Most multicellular organisms have two sets of chromosomes). This genetic condition, known as tetraploidy, generally results in plants that are self-pollinated and offspring that is genetically similar, if not identical, to the parent plant. In other words, genetic diversity is generally minimal within crops of a particular region.



    - Wild Arabica coffee is native to Eastern Ethiopia, Yemen and South Sudan (and possibly Kenya), so most other coffee-growing regions have more limited genetic diversity (Central and South America, Asia)
- ***The problem:*** Lack of genetic diversity means that if one coffee plant is susceptible to a disease, the rest of the plants probably are susceptible, too. In fact, coffee leaf rust, a fungal disease, has caused major epidemics in coffee plantations around the world. Most recently from 2008 – 2013 this disease plagued coffee production in the western hemisphere from Mexico to South America. The economic impact was considerable given the already low economic situations of many of these countries and the large portion of their GDP that comes from coffee exportation. Similar epidemics in India and Sri Lanka in the 1960's were economically devastating and resulted in complete shifts to alternative crops (to Robusta coffee in India and to tea in Sri Lanka)

- ***Additional Challenges*** for maintaining genetic diversity and minimizing diseases such as coffee leaf rust
    - Coffee leaf rust epidemics appear to be enhanced by weather conditions consistent with climate change.
    - Coffee is very climate specific. If the home region of Arabica experiences enough change, the genetic diversity available from wild plants may diminish or disappear.
    - Coffee is not a good candidate for seed banking, as it can only be stored for 6 to 12 months and then loses viability. Instead genetic diversity is by growing coffee field gene banks. In addition to being subject to climate change and other environmental hazards, most of these gene banks were started in the 1960's and 1970's and the plants are aging and dying.
- ***The Good News (and the DBG connection):*** Dr. Sarada Krishnan, Director of Horticulture and Center for Global Initiatives at DBG and coffee scientist, studies the genetic diversity of Arabica coffee.
    - South Sudan Arabica coffee land race survey
        - Determined the current status of wild and cultivated Arabica coffee on the Boma Plateau

        - Assessed the genetic diversity of the wild populations found
        - Establish a field gene bank in South Sudan using specimens representing the greatest genetic diversity
        - For more information see this report (detailed citation in Appendix C)
    - Genetic study of Geisha Coffee from Panama and Ethiopia
        - The Geisha variety of Arabica coffee is relatively resistant to coffee leaf rust.
        - Genetic testing was conducted to understand the differences between Geisha coffee grown in Panama and coffee from the original forests in Ethiopia.

- Results may help produce more coffee varieties with coffee leaf rust resistance.
- For more information see this report (detailed citation in Appendix C)

Additional crops that are at risk due to low genetic diversity

- ***Cavendish banana*** (the one most people in the developed world eat) – all of the Cavendish banana plants are genetically identical and have been bred to be seedless, so they cannot cross pollinate with other varieties. Some scientists liken the severity of the situation to that of the potato in Ireland right before the famine. While bananas may not be as central of a staple in North America and Europe as the potato was in Ireland, bananas *are* central to many developing counties' economies. The collapse of the industry could be catastrophic and lead to a humanitarian crisis.

Banana plantation

- ***Wine grapes in western Colorado*** – Closer to home, the Phylloxera louse has been found in vineyards in western Colorado. This pest is extremely destructive to roots and eventually requires replanting the entire vineyard. European varieties of grapes are very susceptible to the louse. Many years ago, scientists realized that American varieties were more resistant. Horticulturalists found a solution by grafting European plants onto American roots. Unfortunately, the European varieties grown in the Grand Valley of Colorado are still growing on their own roots. Learn more here.

Vineyard, Palisade, CO
Photo credit: Don Graham

Discussion Points/Questions:

Compare the different species of coffee beans. Can you tell the difference with your senses?

What would your morning look like without your daily cup of Joe?

What foods do you enjoy? How would you feel if that food was suddenly unavailable? What would that mean for your food enjoyment? Your lifestyle?

What are some ways to improve genetic diversity as a consumer? – *see ideas in box above.*

Compare the shade-grown coffee plantation picture with the traditional monoculture plantation. Which do you think provides more habitat for other organisms and why?

How YOU can make a difference with your wallet.

- ✓ Choose the equivalent of "heirloom" variety coffee by buying coffee labeled "single origin". Single origin also increases sustainability, as farmers can focus on quality instead of mass-production for large companies. Single origin may come at a higher price, but the cost is passed along to the growers who use improved growing techniques with an eye towards environmental sustainability.
- ✓ Choose Fair Trade certified or direct trade coffees. Fair Trade certified farms must prove that they are meeting environmentally sustainable standards. Direct trade bypasses the middleman and puts more money in the hands of the farmer. Environmental options are not guaranteed with direct trade, but consumer demand for environmental sustainability can be passed along directly to the farmers.
- ✓ Choose shade-grown coffee. Shade-grown coffee addresses the ecosystem biodiversity concerns of a monoculture. By growing coffee in the shade of trees, farmers provide a more diverse habitat and attract a more diverse community of birds and other animals. This method also helps prevent soil erosion and help with natural pest control and improved pollination. While coffee yield may be lower in shade-grown coffee, farmers can make up for the difference with other opportunities such as eco-tourism (plantation tours), firewood, fruits, and building materials.
- ✓ Choose Rainforest Alliance Certified coffee (and other products, too!). Their sustainable farming standards focus on biodiversity conservation and natural resource conservation, along with improved livelihoods and human well-being for farmers as individuals and businesspeople.

Tips for Adjusting Content to Different Ages

- Stick to more hands-on activities with younger audiences. They will enjoy the models, but may need extra facilitation.

- Do not avoid the hands-on activities with mature audiences. You may be surprised how engaged they will become and the connections they will make.

- Ask visitor to make connections to their own lives. Ask what the information, visuals, or activities remind them of. This will help you to identify their level of understanding and also to add more information within a context that they can connect to.

- Follow the visitor's curiosity. Regardless of age, this technique – rather than sharing everything you know about a particular subject – will ensure that they are engaged and learning at their own level.

- When using vocabulary words with younger visitors, follow the word with a synonym, if possible. If necessary, pause to ask visitors if they know what a term means and check for understanding after you define new words. You may find that you need to drill down to simpler concepts even if they were smiling and nodding. Actually checking for understanding can ensure that they actually walk away with new knowledge. (This is true for adults, too!)

- Younger audiences may not connect as much with coffee or wine, so focus the storytelling on bananas. "Ask: How would you feel if all the bananas suddenly disappeared?" To pull them in. Use this tactic with adults and coffee, too.

Appendix A – Riparian Erosion/Filtration Models

Materials

- 3 2-liter soda bottles
- Soil
- Dry leaves (tamarisk if possible)
- Small ground cover plants or sod/grass
- Pitcher or bottle of clean water
- Bottle of muddy/dirty water
- 3 clear plastic cups
- String (optional)
- Hole punch (optional)
- Box or stand (if not using string)

Set Up

1. Cut the three soda bottles to create three "trays". [See Fig. 1 and Fig. 2]

2. Prepare 3 riparian models in the plastic bottle. [See Fig. 1 and Fig. 2]
    a. Just bare soil
    b. With dead leaves on top of the soil
    c. Plants growing in the soil (prepare this bottle a week or two ahead of time to allow for root growth in the bottle).

3. Prop up the end of the bottle away from the neck on the bottle lid or another small object so that the bottle is at a slight incline with the bottle neck on the downhill end.

4. Prepare the water overflow-catching cups.
    a. If setting up bottles on a box or stand (See Fig. 1] place clear plastic cups below to catch water during the activity.
    b. If setting up bottles on the table top, place them so that bottle necks hang out past the edge of the table. Use string and a hole punch to hang a plastic cup beneath the opening of the bottle to catch water. [See Fig. 2]

5. Prepare dirty water by adding ½ cup of dirt to a bottle and fill with water. Shake.
6. Activity instructions are found in the section on Ecosystem Services.

Figure 1: Riparian model set up on box/stand

Figure 2: Riparian Model with hanging water catchers

Appendix B: Images

Sample images from Deer Creek Restoration Project.
See *https://sway.office.com/R0Yc85grcxKJCxe8* for additional photographs

Channelized portion of Deer Creek running through Chatfield Farms

Healthy portion of Deer Creek at Chatfield Farms with slow, meandering flows.

Beaver dam with meandering flows.

Beaver dam causing flooding, resulting in more water seeping through the soil and filtering pollutants out.

Freshwater Zooplankton
(https://www.silverflaskfishing.com/news/https//www.silverflaskfishing.com/news-1)

Boreal Toad
Photo by Colorado Parks and Wildlife (public domain)
https://cpw.state.co.us/learn/Pages/ResearchBorealToad.aspx

Tamarisk or Saltcedar
Photo by NASA (public domain)
https://www.usgs.gov/media/images/tamarisk-or-saltcedar (can download high res image from this website)

Coffee fruit
Download here:
https://en.wikipedia.org/wiki/Coffee_in_world_cultures#/media/File:Coffee_Berries.jpg

Coffee Leaf Rust

Download image here: https://commons.wikimedia.org/wiki/File:Hemileia_vastatrix_-_coffee_leaf_rust.jpg

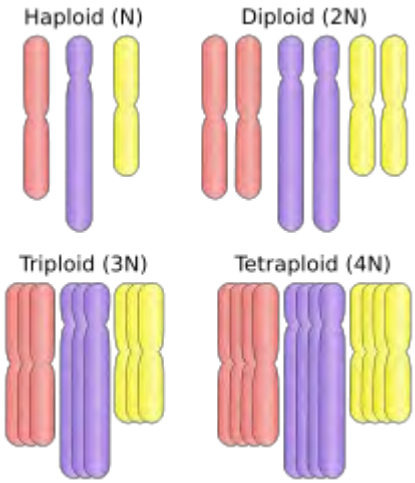
https://www.rainforest-alliance.org/faqs/what-does-rainforest-alliance-certified-mean

Shade-grown coffee plantation

Download here: https://commons.wikimedia.org/wiki/File:Coffee_plantation_in_Araku_Valley_09.jpg

Traditional coffee plantation

Download here: https://commons.wikimedia.org/wiki/File:Coffee_plantation,_Kaua%CA%BBi_59.jpg



Chromosomes: Most plants and animals have two sets of chromosomes (diploid). Some plants hybridize between two species and the offspring has more than two sets of chromosomes (triploid or tetraploid)

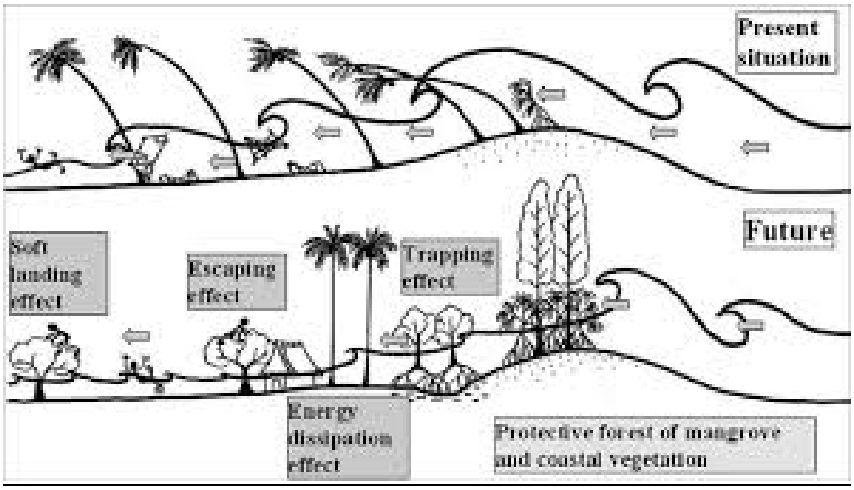
Coffee Research in South Sudan
https://www.botanicgardens.org/beyond/center-global-initiatives/coffee-research

Appendix C: Additional Information & Readings

Disaster Risk Reduction - Healthy ecosystems (those with relative high biodiversity) can act as buffers against natural disaster. Coastal ecosystems such as coral reefs and mangroves can provide protection from hurricanes, storm surges, and tsunamis, etc. Forest ecosystems can reduce erosion as well as the risks associated with landslides. Forest ecosystems can also mitigate droughts and floods.

A biodiverse ecosystem is more resilient and more likely to quickly recover from damages. Therefore, it will be able to protect from future natural disasters. Genetic diversity can contribute to the success of a population if certain genotypes/phenotypes exist that are more resistant to the environmental changes. At the same time a diversity of species makes an ecosystem more resilient when several species fulfill similar functions. Even if not all species survive the disaster episode, most or all ecological functions will still be filled.

Biodiversity, itself, can also play a key role in buffering one individual disaster event. For example, a variety of trees in mangroves has been shown to offer a wider variety of protections. Variation of tree heights can reduce the speed of tsunami currents. Trees with more complex aerial root structures can protect from shoreline damages. Larger trees can catch larger, man-made debris, while some trees provide softer landing or even escape routes for people. [see figure below from ICUN document]



Tanaka, et al., 2006

Further Reading

What is biodiversity and why does it matter to us? – Article from The Guardian, March 12, 2018
https://www.theguardian.com/news/2018/mar/12/what-is-biodiversity-and-why-does-it-matter-to-us

Ecological Stewardship – Restoration at Chatfield Farms - https://sway.office.com/R0Yc85grcxKJCxe8 - background and preliminary results of the restoration project of Deer Creek at Denver Botanic Gardens Chatfield Farms.

Riparian Areas: Reservoirs of Diversity, Working Paper No. 13 – an extensive overview of the importance of riparian areas and the impact of biodiversity on the water as well as the impact of the water on biodiversity.

Wild Colorado: Crossroads of Biodiversity – a visual and written overview of the biodiversity of the state, produced by the Colorado Division of Wildlife (now Colorado Parks and Wildlife)

United Nations Decade on Biodiversity – Living in Harmony with Nature Factsheets

- Agricultural Biodiversity
- Inland Waters Biodiversity
- Dry and Sub-Humid Lands
- Forest Biodiversity

EPA Wetlands Factsheet Series

- Wetlands Overview
- Types of Wetlands
- Functions and Values of Wetlands
- Economic Benefits of Wetlands

Genetic Characterization of Geisha Coffee – final report by Dr. Sarada Krishnan

South Sudan Arabica Coffee Land Race Survey in Boma Germplasm Assessment and Conservation – final report by Dr. Sarada Krishnan and Dr. Aaron P. Davis.

A Louse Has Moved Into Colorado's Vineyards – Colorado Matters audio report, Jan. 3, 2017 – Interview with a CSU viticulturist and CSU entomologist about the appearance of the Phylloxera insect, a devastating pest of wine grapes, in the Grand Valley region of Colorado.

Helping nature help us: Transforming disaster risk reduction through ecosystem management, Part 1, Chapter 3, IUCN report by Fabiola Monty, Radhika Murti, and Naoya Furuta, 2016.

The Ecological Benefits of Shade-Grown Coffee: The Case for Going Bird Friendly® - Published by the Smithsonian Migratory Bird Center

Appendix D: Discussion Prompts & Questions

Use this document as a quick reference guide to help get the chat started or keep it moving. These questions are also found in the full document with each of the themes and activities.

- Is the visitor familiar with Deer Creek? What are their experiences and impressions of the creek and its ecosystem?
- Referring to the poster: How are each of the animals and plants connected in this ecosystem?
- Microhabitats are small areas within an ecosystem that provide slight variations in the environment (examples: cooler microhabitats can be created by close proximity to water or the shade of a tree or shrub). How many microhabitats can you identify in the poster? How might a variety of microhabitats lead to greater biodiversity?
- What waterways and riparian ecosystems are near your home? Are they healthy or not? Do you see a lot of biodiversity there or not? Not sure about the nearest water to you? Google your address and look for blue on the map! Go check it out. Learn more.
- Which ecosystem experienced the most erosion? The least?
- How does this model demonstrate one of the benefits of a heathy riparian ecosystem?
- How might erosion be a problem for Deer Creek? (destruction of the soil/ecosystem, debris carried downstream into Chatfield Reservoir)
- Show pictures of meandering creek from Deer Creek at DBGCF . Discuss how a slower flow of water reduces erosion. Connect biodiversity of plant life to a more meandering water way.
- Why is the water coming out of the riparian ecosystem clearer than the water going in?
- What about pollutants we can't see such as chemicals from fertilizer?
- What pollutants might be found in Deer Creek and how might they be problematic? (animal feces, fertilizer, road salt – all can be detrimental to animals – large and small – that use or live in the creek as well as bodies of water further downstream)
- Show pictures of meandering creek and beaver dam from Deer Creek at DBGCF. Discuss how a slower flow of water with regular flooding events allows time for water to seep into the soil for better filtration of pollutants. Connect to biodiversity (beavers, variety of plant/root structures, etc.)
- How do we know what biodiversity looked like in the past or how "should" it look if we aim to restore it? (*Natural history collections such as the plant and fungal specimens housed in the DBG herbarium can help*)
- How do beavers help restore an ecosystem? (*see beaver information above*)
- Why do we care about restoring riparian ecosystems or other ecosystems? (*see ecosystem services information above*)

- What riparian or wetland ecosystems are near your home? How biodiverse are they? What could you do to make improvements or enjoy the area more fully?
- Volunteer opportunities for visitors who seem very interested or who ask.
- What would your morning look like without your daily cup of Joe?
- What foods does the visitor enjoy? How would they feel if that food was suddenly unavailable? What would that mean for their food enjoyment? Their lifestyle?
- What are some ways to improve genetic diversity as a consumer? – *see ideas above.*
- *Compare the shade-grown coffee plantation picture with the traditional monoculture plantation. Which do you think provides more habitat for other organisms and why?*

DENVER BOTANIC GARDENS WEB SITE
https://www.botanicgardens.org/our-collections/science-pyramid

Science Pyramid

Learn about plants, animals, people and how water connects us all.

1007 York Street
Denver, CO 80206 | Map
720-865-3500

Welcome Home: Meet Your Habitat explores the ways in which the lives of Colorado's living things are deeply intertwined through landscapes and the finite resources we share. Your home is not only part of a human neighborhood, it's part of your habitat, one you share with millions of plants, animals, fungi and other organisms. *Welcome Home* combines natural objects and human artifacts with interactive digital stories to reveal the surprising and often invisible depths of our bonds with nature.

Need a breather? Pull up a comfy chair in the Habitat Lounge to learn how organisms adapt to their habitats and explore easy ways to adapt your own behavior to support the health of our shared home.

This exhibition is funded in part by a grant from the Colorado Water Conservation Board.

Welcome Home Gallery

Lisa Eldred

From: Press Release from Denver Botanic Gardens <erin.bird@botanicgardens.org>
Sent: Thursday, September 26, 2019 10:14 AM
To: Lisa Eldred
Subject: New Exhibit in the Science Pyramid

DENVER BOTANIC GARDENS

Press Release

WELCOME HOME: MEET YOUR HABITAT

Welcome Home: Meet your Habitat is a science-based exhibit in the Science Pyramid that highlights the surprising connections between humans, plants and animals across diverse landscapes from the alpine tundra to urban backyards. Natural objects and human artifacts are combined with interactive digital stories to reveal the important yet often invisible depths of our bonds with water and nature. The multiyear-long exhibit opens November 16, 2019 and is included with general admission.

A lounge area features a variety of resources for visitors to explore sustainable living practices that encourage us to adapt to our environment rather than altering the environment to fulfill our needs at the expense of valuable ecosystems.

Weekly staff and volunteer-led drop-in conversations allow visitors to dig deeper into select topics that often feature research and conservation projects the Gardens' scientists are doing, such as restoration of the riparian ecosystems at Chatfield Farms.

The exhibit content is geared toward adults but has engaging interactive elements and children's books for younger visitors. The exhibit is funded in part by a grant from the Colorado Water Conservation Board.

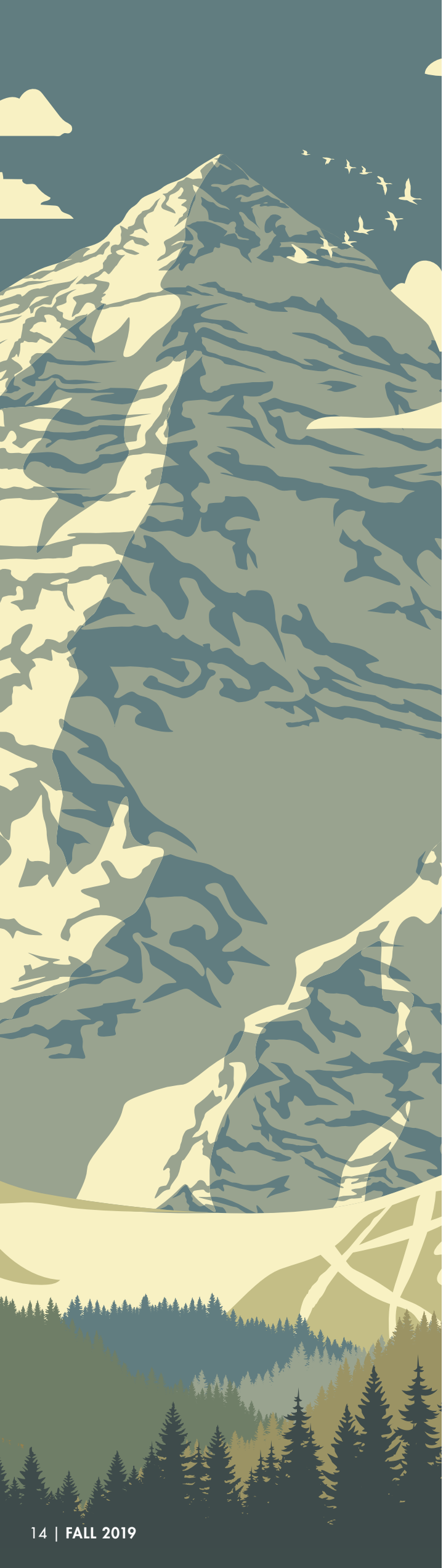
PRESS CONTACT: Erin Bird | erin.bird@botanicgardens.org | 720.865.3552

# # #

About Denver Botanic Gardens
Green inside and out, Denver Botanic Gardens began in 1951 and is considered one of the top botanical gardens in the United States and a pioneer in water conservation. Accredited by the American Alliance of Museums, the Gardens' living collections encompass specimens from the tropics to the tundra, showcasing a plant palette chosen to thrive in Colorado's semi-arid climate. The Gardens is a dynamic, 24-acre urban oasis in the heart of the city, offering unforgettable opportunities to flourish with unique garden experiences for the whole family – as well as world-class education and plant conservation research programs. Additional sites extend this experience throughout the Front Range: Denver Botanic Gardens Chatfield Farms is a 700-acre native plant refuge with an active farm in Jefferson County; Mount Goliath is a high-altitude trail and interpretive site on the Mount Evans Scenic Byway. The Gardens also manages programming at Plains Conservation Center in Aurora. For more information, visit us online at www.botanicgardens.org.

INSIDE THE GARDENS

FALL 2019 A QUARTERLY MAGAZINE FOR MEMBERS OF DENVER BOTANIC GARDENS



WELCOME HOME

Meet Your Habitat

Opens Mid-November | Science Pyramid

You've probably heard that home is where the heart is, but you might not know it's where lichens are, too. Actually, not just lichens, but also spruce trees, marmots, mushrooms, turtles, sagebrush, beavers, grasses, beetles, crows, sunflowers and trout (to name just a few). Your home is not only part of a human neighborhood, it's part of your habitat, one you share with millions of plants, animals, fungi and other organisms. Your non-human neighbors might not have brought you cookies when you moved in, but their lives are inextricably connected with your own and the places we all call home.

A new exhibition in the Science Pyramid highlights many of the ways in which the lives of Colorado's living things are deeply intertwined through landscapes and the finite resources we share. *Welcome Home: Meet Your Habitat* combines natural objects and human artifacts with interactive digital stories to reveal the surprising and often invisible depths of our bonds with nature.

Need a breather? Pull up a comfy chair in the Habitat Lounge and learn about the ways that organisms are adapted to their habitats and how you can adapt your behaviors to yours. Explore easy, practical things you can do to steward water and other natural resources to support the health of our shared home.