



**OUR HOME, OUR WORLD  
DISCOVERING EARTH AND SPACE  
SCIENCE IN KUMAMOTO AND MONTANA**

**EDUCATOR'S GUIDE | GRADES 5-6**



## INTRODUCTION

### OUR HOME, OUR WORLD

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POSSIBLE IN PART BY**



**The Japan Foundation  
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**INTRODUCTION**  
**OUR HOME, OUR WORLD**

<b>WELCOME LETTER</b> .....	<b>4</b>
<b>MONTANA KUMAMOTO SISTER-STATE RELATIONSHIP</b> .....	<b>5</b>
<b>KUMAMOTO MONTANA NATURAL SCIENCE MUSEUM ASSOCIATION</b> .....	<b>6</b>
<i>Museum of the Rockies, Montana State University</i> .....	<b>7</b>
<i>Carter County Museum</i> .....	<b>7</b>
<i>Mifune Dinosaur Museum</i> .....	<b>8</b>
<i>Goshoura Cretaceous Museum</i> .....	<b>8</b>
<i>Aso Volcano Museum</i> .....	<b>9</b>
<i>Kumamoto City Museum</i> .....	<b>9</b>
<b>BUILDING COMMUNITY PARTNERSHIPS</b> .....	<b>10</b>
<b>EDUCATOR'S GUIDE OVERVIEW</b> .....	<b>12</b>
<b>OPENING LESSON: OUR HOME</b> .....	<b>23</b>
<b>UNIT 1 - ASTRONOMY</b>	
<i>Lesson 1: One Sky, Many Stories</i> .....	<b>39</b>
<i>Lesson 2: Starscapes &amp; Star Charts</i> .....	<b>57</b>
<i>Lesson 3: Colorful Constellations, Classifying Stars</i> .....	<b>75</b>
<b>UNIT 2 - GEOLOGY</b>	
<i>Lesson 1: Volcanic Landscapes</i> .....	<b>91</b>
<i>Lesson 2: Natural Disasters - Our Changing Landscapes</i> .....	<b>105</b>
<i>Lesson 3: Sedimentology - Building Our Landscape</i> .....	<b>121</b>
<b>UNIT 3 - PALEONTOLOGY</b>	
<i>Lesson 1: Practices of Paleontology</i> .....	<b>133</b>
<i>Lesson 2: Different Times, Different Fossils</i> .....	<b>155</b>
<i>Lesson 3: Transforming Land and Life</i> .....	<b>179</b>
<b>CLOSING LESSON: OUR WORLD</b> .....	<b>197</b>
<b>REFERENCES &amp; APPENDICES</b> .....	<b>210</b>



## **INTRODUCTION**

### **OUR HOME, OUR WORLD**

## **WELCOME LETTER**

### **DEAR EDUCATORS,**

Welcome to the “Our Home, Our World” Educator’s Guide created through the “Building Community Partnerships: The Japan-U.S. Natural Science Museums Project.”

Funded by the Japan Foundation Center for Global Partnerships and the Museum of the Rockies, this curriculum promotes educational learning through the sciences of paleontology, geology, and astronomy.

In 2016, four museums in Kumamoto, Japan and two museums in Montana, USA began a collaboration built on the strong sister-state relationship between Montana and Kumamoto. What began as a sharing of ideas, scientific knowledge, and training methods evolved into this robust educator’s guide highlighting our increased appreciation of our sister-state relationship and shared understanding of earth and space science.

These lessons were designed thoughtfully to be effective in both Japanese and American classrooms and museums. All partners, including Montana State University, contributed to writing and developing these lessons and activities. The format of each lesson plan blends the very different ways our two cultures structure curriculum. While some portions of this curriculum are adapted for our different cultures (like curriculum standards), our goal is that educators in both our cultures will be able to teach these lessons the same way, further uniting our communities.

We welcome educators to use the entire curriculum or just one unit that applies most to their current studies. Additionally, we encourage each classroom to participate in the opening and closing lessons to better understand this project and our sister-state relationship. The three units (astronomy, geology, and paleontology) can be taught in any order. However, the lessons within each unit are strongest in sequential order.

Join us in exploring and celebrating our great sister-state relationship through the lens of earth and space science!

Sincerely,

Museum of the Rockies, Montana  
Carter County Museum, Montana  
Mifune Dinosaur Museum, Kumamoto  
Goshoura Cretaceous Museum, Kumamoto  
Aso Volcano Museum, Kumamoto  
Kumamoto City Museum, Kumamoto



## INTRODUCTION

### OUR HOME, OUR WORLD

## MONTANA KUMAMOTO SISTER-STATE RELATIONSHIP

In 1979, Mike Mansfield, U.S. Ambassador to Japan, recommended that the Governors of Kumamoto and Montana establish a sister-state relationship. After three years of discussion, Kumamoto Governor Issei Sawada and Montana Governor Ted Schwinden signed a sister relationship agreement at a ceremony in Helena, Montana's State Capitol on July 22, 1982.

Since then many cultural exchanges and friendships have been established between Kumamoto and Montana governments, universities, museums, businesses, cultural institutions, and communities.

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## DECLARATION

### SISTER-STATE PREFECTURE AFFILIATION BETWEEN MONTANA AND KUMAMOTO

The State of Montana, USA, and the Prefecture of Kumamoto, Japan hereby declare the establishment of a Sister-State Prefecture Affiliation to strengthen the existing bonds of friendly relations and establish everlasting friendship.

Both the State of Montana and the Prefecture of Kumamoto will widely promote interchange in the fields of industry, culture and education; encourage the growth

of goodwill and understanding between the people of both the State and the Prefecture, thus making a contribution to our mutual development.

We firmly believe that this affiliation to the friendship between the United States of America and Japan, and to world peace.

*Dated this 22nd day of July 1982.*

## INTRODUCTION

### OUR HOME, OUR WORLD

## KUMAMOTO MONTANA NATURAL SCIENCE MUSEUM ASSOCIATION

The Kumamoto Montana Natural Science Museum Association (KMNSMA) was founded October 2015. There are currently more than 30 professional individual members representing seven institutions from Kumamoto and Montana. Participating institutions in Kumamoto are the Mifune Dinosaur Museum, Goshoura Cretaceous Museum, Aso Volcano Museum, Kumamoto City Museum, and the Kumamoto Museum Network. Participating institutions in Montana are the Museum of the Rockies at Montana State University and the Carter County Museum.

The purpose of the KMNSMA is to establish and strengthen the natural science museum relationships between Kumamoto, Japan and Montana, USA, and to

inspire life-long learning within Kumamoto and Montana communities.

Typical KMNSMA activities strive to create an innovative network of natural science museums in Kumamoto, Japan and Montana, USA that will inspire professional dialogue for the advancement of museum activities and community engagement; advocate natural science research and education for the greater public benefit; promote science museum relationships and events in Kumamoto and Montana; provide technical assistance and training to all association members as needed; develop bilingual educational resources that can be disseminated to Japanese and American audiences; communicate useful information about the natural sciences through public lectures, workshops, and museum events.



## MISSION STATEMENT

KMNSMA inspires and connects people and institutions within the natural science museum field, engages in creative collaboration for the advancement of teaching and learning, and provides professional knowledge and training that will empower Kumamoto Montana museums to sustain themselves as vibrant and essential institutions within their communities.



## INTRODUCTION

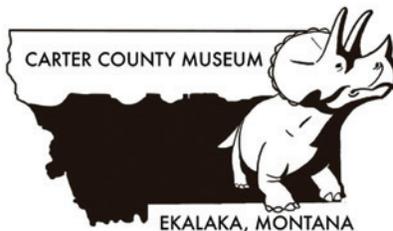
### OUR HOME, OUR WORLD



## MUSEUM OF THE ROCKIES, MONTANA STATE UNIVERSITY

The Museum of the Rockies (MOR) at Montana State University was established in 1957 in Bozeman, Montana. As a Smithsonian Affiliate institution, the MOR is world renowned for its dinosaur research and collections program, engaging exhibits in paleontology and history, the Taylor Planetarium, the outdoor Living History Farm, and innovative educational programming. Temporary exhibits change frequently throughout each year drawing more than 160,000 visitors annually.

Museum of the Rockies is both a college-level division of Montana State University and an independent nonprofit institution. Accredited by the American Alliance of Museums, MOR is one of just 775 museums to hold this distinction from the more than 17,500 museums in the United States. In 2012, the MOR and the Mifune Dinosaur Museum in Mifune Town, Kumamoto, Japan became sister museums. As an institution that is dedicated to its global partnerships, the Museum of the Rockies brings the world to Montana, and shares Montana with the world.



## CARTER COUNTY MUSEUM

Located in Ekalaka, Montana, the Carter County Museum (CCM) was the first county museum in the state and the first to display fossils. It was founded in 1936 by the Carter County Geological Society, a group of amateur archaeologists and paleontologists who wanted to preserve and share the world-class dinosaur fossils found in southeastern Montana. Exhibits cover a comprehensive 90 million year history of the region,

from fossil dinosaurs from the Western Interior Seaway through the extinction event in the K-Pg boundary of the Hell Creek Formation, Ice Age hunting techniques of paleoindian tribes, and homesteading in the West. Exhibits include fully mounted skeletons of *Anatotitan copei* and *T. rex*, a complete skull of *Triceratops*, mounts and casts of a pachycephalosaur, mosasaur, and pterosaur as well as displays on the enduring cultures of American Indian nations in the area, natural history, ranching, rodeo, and the story of life on the Plains.

The CCM is a repository for federal and state fossils, a sister museum to the Museum of the Rockies, and a member of the Kumamoto Montana Natural Science Museum Association and the Montana Dinosaur Trail.

## INTRODUCTION

### OUR HOME, OUR WORLD



## MIFUNE DINOSAUR MUSEUM

Mifune Dinosaur Museum (MDM) is a small natural history museum located in the center of Mifune Town in Kumamoto Prefecture, Japan. The first carnivorous dinosaur fossil discovered in Japan was found near here. A municipal museum, the MDM was established in 1998. It has developed a significant paleontological research and collections program, and engaging educational activities to promote lifelong learning.

The MDM conducts numerous field excavations at

fossil localities within geologic sediments from the early Late Cretaceous Mifune Group, and has been collecting remains of ancient animals, particularly focusing on dinosaurs and other vertebrate fossils.

The MDM houses unique fossils that cannot be found in other museums, and a large collection of Mesozoic bivalves from Japan that were collected by Dr. Minoru Tamura (Professor Emeritus of Kumamoto University). The most important role of the MDM is to collect remains of extinct life, preserve them for future generations, and inspire the public to learn about science and nature.

In 2014, the MDM constructed a new building and is now serving 150,000 visitors and school groups annually. In 2012, the MDM and the Museum of the Rockies established a sister museum relationship. Since then, there have been many shared scientific and educational projects. The Preparation Project demonstrates the technical aspects of research in the MDM's new viewing lab, which is credited for repeat visitation.



## GOSHOURA CRETACEOUS MUSEUM

The Goshoura Cretaceous Museum (GCM) was founded after the discovery of dinosaur fossils on Goshoura Island in 1997. Goshoura Island is one of the 120 Amakusa islands, a series of islands located in the Amakusa Geopark in southwestern Kumamoto Prefecture. This island is known as "Dinosaur Island" or "Fossil Island." There is an abundance of various vertebrate and invertebrate fossils found in stratigraphic sediments deposited during the Cretaceous and Paleogene Periods,

100–49 million years ago. These ancient fossils offer visitors a glimpse into Earth's prehistory.

The GCM is a scientific museum and a central research and collections facility with approximately 30,000 scientific specimens that have been collected both locally and abroad. The 1,000 exhibits include a rare carnivorous dinosaur tooth, dinosaur footprint, and the oldest large mammals in Japan.

The GCM offers fossil discovery experiences and sightseeing adventures near the museum. Visitors can also visit the 1997 dinosaur footprint discovery site on Bentejima Island, and "The Cretaceous Wall," a 200-meter high cliff where the largest carnivorous dinosaur tooth in Japan and other dinosaur fossils were discovered.



## INTRODUCTION

### OUR HOME, OUR WORLD

公益財団法人

# 阿蘇火山博物館

## ASO VOLCANO MUSEUM

Founded in 1983, Aso Volcano Museum is located at Kusasenri-ga-Hama, the top of the Aso central cones. The museum's exhibits focus on Aso Volcano and the unique geography, topography, animals and plants within the Mount Aso area. Museum exhibitions change regularly. Entry fees and donations from the local public utility foundation provide funding for its operation. The Aso Geopark Promotion Council's office is situated in the museum and functions as the Geopark's administrative

center. Led by full-time volcanologists, curators and skilled geological interpreters, the staff conducts museum and field tours for tourists and students. These engaging professionals also provide educational support to many schools around the park.

Because Aso is in close proximity to Korea and Hong Kong, the museum is an important educational facility and destination for the entire Asian region. Many of these visitors do not live near active volcanoes. In 2015, paid visitation increased to more than 200,000 which included 160,000 visitors from abroad. The 2016 Kumamoto Earthquake caused severe damage to the museum and it was closed for several months while the building and exhibits were being repaired.



## KUMAMOTO CITY MUSEUM

The Kumamoto City Museum (KCM) is a general museum founded in 1952. There have been numerous transitions in the facility over the years. The current main building was opened in 1978. The KCM features a planetarium and collections that contain approximately 130,000 artifacts and scientific specimens representing the fields of geology, paleontology, biology, archaeology, history, and ethnology. There are many artifacts and scientific

specimens on exhibit that depict the natural sciences and humanities within the Kumamoto area including elaborate and engaging dioramas.

The KCM planetarium has a 16-meter diameter dome where visitors can view the stars and constellations of our universe. An informative lecture by planetarium staff demonstrates how a starlit sky will appear on the day of their visit, which is a very popular program at the KCM. Images are projected with subtitles during special program performances.

The KCM mission is to encourage members of our community and the Kumamoto region to participate in our museum programs. We inspire active lifelong learning through independent thinking and educational activities that are beneficial to all age groups.

## INTRODUCTION

### OUR HOME, OUR WORLD

## BUILDING COMMUNITY PARTNERSHIPS: THE JAPAN-U.S. NATURAL SCIENCE MUSEUMS PROJECT

Building upon the successful sister relationships and associations established between Kumamoto and Montana, the project goal is to develop and expand a sustainable U.S./Japan museum network that will promote educational learning and community engagement through the sciences of paleontology, geology, and astronomy.

Funded by the Japan Foundation Center for Global Partnership and the Museum of the Rockies, the primary objectives of the project are to promote shared ideas, training methods and networking that will improve teaching and science learning, and develop educational curricula that can be used in Japanese and American museums and schools.



*Members of the Building Community Partnerships Project pose on Mount Aso at the edge of the volcano's crater in November 2017.*

# INTRODUCTION

## OUR HOME, OUR WORLD



*Members of the Kumamoto Montana Natural Science Museum Association and the Building Community Partnership Project with Kumamon, Kumamoto's mascot, in November 2016.*



*Members of the Kumamoto Montana Natural Science Museum Association and the Building Community Partnership Project with Kumamoto Governor, Ikuo Kabashima, in Kumamoto, Japan in November 2016.*

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### HOW TO USE THIS GUIDE

The “Our Home, Our World” Educator’s Guide is designed to be used in fifth and sixth grade classrooms, as well as informal learning environments like museums. This curriculum has eleven lessons including an opening lesson, three science units with three lessons each, and a closing lesson. All lessons are designed to be 45 minutes in length.

This curriculum was written and designed to be used in both Montana and Kumamoto, Japan; however, the contents and activities are suitable for anyone interested in learning about science and the similarities and differences of our two cultures. Our sister-state classrooms will be using the same lessons and doing the same activities to help Japanese students study astronomy, geology, and paleontology while learning about Montana. A Japanese version of this guide includes content standards for Kumamoto, Japan, but the lessons are the same.

To make the most of this Educator’s Guide, use the opening and closing lessons to frame the science content and provide the context for studying Montana’s sister state with your students. We encourage all classrooms and museums to use these opening and closing lessons regardless of the number of science lessons that will be used from this curriculum. The closing lesson includes three activities, one that ties to each of the three units.

All three science units are designed to be taught by including all three lessons from the unit. Classrooms are encouraged to use just one or all three science units. To transition between science units, consider the following curriculum connections:

TRANSITION FROM...	TO...	CURRICULUM CONNECTION
Astronomy	Geology	Our night sky is made of constellations we all see, connecting our world. The Earth’s surface is made of many moving plates, that affect all of us and create volcanoes.
Astronomy	Paleontology	Star stories help us describe our past, just as sedimentary rock layers can tell stories of the Earth’s history.
Paleontology	Astronomy	Sedimentary rock layers can tell stories of the Earth’s history, just as star stories help us describe our past.
Paleontology	Geology	Just as we can sort and classify fossils, we sort and classify volcanoes to better understand their characteristics.
Geology	Astronomy	Sedimentary rock layers tell us about the Earth’s geologic past, while star stories help us understand how past cultures interpreted their world.
Geology	Paleontology	Fossils are found in sedimentary rock layers.



# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### LESSON ORGANIZATION

Japanese and American curriculum is organized very differently. As a result, the lesson structure is a blend of our two approaches to lesson planning.

### UNIT ORGANIZATION

Each unit (Astronomy, Geology, and Paleontology) is color-coded with different headers to help educators quickly identify the unit. The opening and closing lessons share the same colors and headers. Within each unit, lessons are numbered (1, 2, and 3).

When identifying the content standards each lesson addresses, we have shortened these lesson names to "ASTRO1," "GEO1," "PALEO1," etc.

### LESSON ORGANIZATION

All lessons begin with the Lesson Instructions. In an American style, the first page of each lesson identifies goals, objectives, materials and preparation, and assessment.

The specific instructions of the lesson are based on the Japanese lesson format using a table. Along with a description of the learning activities within the lesson, Japanese lessons also include expected student reactions with teacher responses, and the goals and evaluation for each segment of the lesson.

Some lessons may include additional activities or extensions after this table.

Background information follows the lesson instructions. Japanese lessons do not typically include background information because of standard textbooks through the entire prefecture. This content was included in this curriculum because of the specific information on astronomy, geology, paleontology, and culture of each of our states not available elsewhere.

The final portion of each lesson are student pages. These are designed to be printed as a double-sided booklet for each student to support the lesson activities.

Because the educational standards of our two countries are so different, content standards are available at the beginning of the entire unit and are not identified on each individual lesson. This is the only portion of the curriculum guide that is different between the Japanese and American versions. Montana standards closely follow the Next Generation Science Standards and Common Core State Standards. Classrooms and museums outside of Montana will be able to align their state standards using these two national sets of standards.

### SUPPORTING HANDS-ON MATERIALS

These lessons are designed to be able to be taught without any supplemental materials. However, in Montana, teachers are encouraged to contact Museum of the Rockies to inquire about borrowing outreach kits containing real fossils to support the paleontology lessons.

*Museum of the Rockies Outreach Kits –  
moroutreach@montana.edu – 406-994-6591*

Montana's Office of Public Instruction has numerous online resources to support the astronomy lessons that include star stories from the Crow and Blackfeet tribes.

<https://opi.mt.gov/Educators/Teaching-Learning/Indian-Education/Science>

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### MONTANA SCIENCE CONTENT STANDARDS

#### 5TH GRADE EARTH AND SPACE SCIENCE

This curriculum guide addresses Montana Content Standards for Science, English Language Arts and Literacy, and Social Studies for students in grades 5 & 6. This curriculum also supports the Essential Understandings for Indian Education for All.

Montana Standard <i>Students must know and be able to:</i>	Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts	Related Lesson
develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, or atmosphere interact	ESS2.A	Developing and Using Models	System and System Models	GEO2, GEO3, PALEO2, PALEO3
obtain and combine information from various sources about ways individual communities use science ideas to protect the Earth's resources, environment, and systems and describe examples of how American Indians use scientific knowledge and practices to maintain relationships with the natural world	ESS3.C	Obtaining, Evaluating, & Communicating Information	System and System Models	GEO2, PALEO1
use evidence or models to support the claim that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth	ESS1.A	Engaging in argument from evidence	Scale Proportion & Quantity	ASTRO3
graph the daily changes in the length, shape, and direction of shadows; lengths of day and night; and the seasonal appearance of select stars to communicate the patterns of the Earth's movement and describe how astronomical knowledge is used by American Indians	ESS1.B	Analyze & Interpret Data	Patterns	ASTRO1, ASTRO2, ASTRO3

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### MONTANA SCIENCE CONTENT STANDARDS

#### 5TH GRADE LIFE SCIENCE

Montana Standard <i>Students must know and be able to:</i>	Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts	Related Lesson
develop and critique a model to describe the movement of matter among plants, animals, decomposers, and the environment	LS2.A	Developing and Using Models	System and System Models	PALEO2

### MONTANA SCIENCE CONTENT STANDARDS

#### 5TH GRADE PHYSICAL SCIENCE

Montana Standard <i>Students must know and be able to:</i>	Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts	Related Lesson
observe and record qualitative and quantitative evidence to support identification of materials based on their properties	PS1.A	Planning and Carrying Out Investigations	Scale Proportion and Quantity	GEO2, GEO3

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### MONTANA SCIENCE CONTENT STANDARDS 6TH – 8TH GRADE EARTH AND SPACE SCIENCE

Montana Standard <i>Students must know and be able to:</i>	Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts	Related Lesson
analyze and interpret data to determine scale properties of objects in the solar system	ESS1.B	Analyze and Interpret Data	Scale Proportion and Quantity	ASTRO3
construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6 billion-year-old history	ESS1.C	Construct explanations and design solutions	Scale Proportion and Quantity	GEO3, PALEO2, PALEO3
construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time scales and spatial scales	ESS2.A, ESS2.C	Construct explanations and design solutions	Scale Proportion and Quantity	GEO1, GEO2, GEO3
analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions	ESS1.A, ESS1.B	Analyze and Interpret Data	Patterns	GEO1, GEO2, GEO3, PALEO2, PALEO3
develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process	ESS2.A	Developing and Using Models	Stability and change	GEO1, GEO2, GEO3, PALEO2, PALEO3
develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity	ESS2.C	Developing and Using Models	Energy and Matter: Flows, Cycles, & Conservation	GEO1, GEO3, PALEO2
construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes	ESS3.A	Construct explanations and design solutions	Cause and effect	GEO1, GEO2, GEO3, PALEO2, PALEO3
analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects	ESS3.B	Analyze and Interpret Data	Patterns	GEO2

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### MONTANA SCIENCE CONTENT STANDARDS

#### 6TH – 8TH GRADE LIFE SCIENCE

Montana Standard <i>Students must know and be able to:</i>	Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts	Related Lesson
analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem and analyze scientific concepts used by American Indians to maintain healthy relationships with environmental sources	LS2.A	Analyze and Interpret Data	Cause and Effect	PALEO3
construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems	LS2.A	Construct Explanations and Design Solutions	Patterns	PALEO2
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	LS1.B	Engaging in Argument from Evidence	Cause and Effect	PALEO3
construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth and development of organisms	LS1.B	Construct Explanations and Design Solutions	Cause and Effect	PALEO3
analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past	LS4.A	Analyze and Interpret Data	Patterns	PALEO2, PALEO3
apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships	LS4.A	Construct Explanations and Design Solutions	Patterns	PALEO1, PALEO2, PALEO3



## EDUCATOR'S GUIDE OVERVIEW

### OUR HOME, OUR WORLD

## MONTANA SCIENCE CONTENT STANDARDS

### 6TH – 8TH GRADE PHYSICAL SCIENCE

Montana Standard <i>Students must know and be able to:</i>	Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts	Related Lesson
develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed	PS1.A, PS3.A	Developing and Using Models	Cause and Effect	ASTRO3

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### MONTANA ENGLISH LANGUAGE ARTS AND LITERACY CONTENT STANDARDS 5TH AND 6TH GRADE

This curriculum guide addresses Montana Content Standards for Science, English Language Arts and Literacy, and Social Studies for students in grades 5 & 6. This curriculum also supports the Essential Understandings for Indian Education for All.

Reading Standards (ALL)	Astronomy Lessons	Geology Lessons	Paleontology Lessons	Opening/ Closing
Key Ideas and Details	1, 2, 3	1, 2, 3	1, 2, 3	Open
Craft and Structure	1, 2, 3	1, 2, 3	1, 2, 3	Open
Integration of Knowledge and Ideas	1, 2, 3	1, 2, 3	1, 2, 3	Open
Range of Reading and Level of Text Complexity	1, 2, 3	1, 2, 3	1, 2, 3	Open
Reading Standards: Foundational Skills	Astronomy Lessons	Geology Lessons	Paleontology Lessons	Opening/ Closing
Phonics and Word Recognition	1, 2, 3	1, 2, 3	1, 2, 3	Open
Fluency	1, 2, 3	1, 2, 3	1, 2, 3	Open
Writing Standards	Astronomy Lessons	Geology Lessons	Paleontology Lessons	Opening/ Closing
Text types and purposes	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Production and Distribution of Writing	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Research to Build and Present Knowledge	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Range of Writing	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Speaking and Listening Standards	Astronomy Lessons	Geology Lessons	Paleontology Lessons	Opening/ Closing
Comprehension and Collaboration	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Presentation of Knowledge and Skills	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Language Standards	Astronomy Lessons	Geology Lessons	Paleontology Lessons	Opening/ Closing
Conventions of Standard English	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Knowledge of Language	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Vocabulary Acquisition and Use	1, 2, 3	1, 2, 3	1, 2, 3	Open Close

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### MONTANA SOCIAL STUDIES CONTENT STANDARDS 8TH GRADE BENCHMARKS

This curriculum guide addresses Montana Content Standards for Science, English Language Arts and Literacy, and Social Studies for students in grades 5 & 6. This curriculum also supports the Essential Understandings for Indian Education for All.

Montana Social Studies Standard	Astronomy Lessons	Geology Lessons	Paleontology Lessons	Opening/ Closing
Social Studies Content Standard 1 <i>Students access, synthesize, and evaluate information to communicate and apply social studies knowledge to real world situations</i>		2		Open
Social Studies Content Standard 2 <i>Students analyze how people create and change structures of power, authority, and governance to understand the operation of government and to demonstrate civic responsibility.</i>	1, 2, 3			Open Close
Social Studies Content Standard 3 <i>Students apply geographic knowledge and skills (e.g., location, place, human/environment interactions, movement, and regions).</i>	1, 2, 3	1, 2, 3	1, 2, 3	Open Close
Social Studies Content Standard 4 <i>Students demonstrate an understanding of the effects of time, continuity, and change on historical and future perspectives and relationships.</i>	1, 2, 3	1, 2		Open Close
Social Studies Content Standard 5 <i>Students make informed decisions based on an understanding of the economic principles of production, distribution, exchange, and consumption.</i>				Open Close
Social Studies Content Standard 6 <i>Students demonstrate an understanding of the impact of human interaction and cultural diversity on societies.</i>	1, 2, 3	1, 2	1	Open Close

# EDUCATOR'S GUIDE OVERVIEW

## OUR HOME, OUR WORLD

### MONTANA'S INDIAN EDUCATION FOR ALL ESSENTIAL UNDERSTANDINGS

This curriculum guide addresses Montana Content Standards for Science, English Language Arts and Literacy, and Social Studies for students in grades 5 & 6. This curriculum also supports the Essential Understandings for Indian Education for All.

Essential Understanding	Description	Astronomy Lessons	Opening/ Closing
1	There is great diversity among the twelve tribal nations of Montana in their languages, cultures, histories and governments. Each Nation has a distinct and unique cultural heritage that contributes to modern Montana.	1, 2, 3	Open Close
2	There is great diversity among individual American Indians as identity is developed, defined and redefined by entities, organizations and people. A continuum of Indian identity, unique to each individual, ranges from assimilated to traditional. There is no generic American Indian.	1	Open Close
3	The ideologies of Native traditional beliefs and spirituality persist into modern day life as tribal cultures, traditions, and languages are still practiced by many American Indian peoples and are incorporated into how tribes govern and manage their affairs. Additionally, each tribe has its own oral histories, which are as valid as written histories. These histories pre-date the "discovery" of North America.	1, 2, 3	Open Close
4	Reservations are lands that have been reserved by the tribes for their own use through treaties and was not "given" to them. The principle that land should be acquired from the Indians only through their consent with treaties involved three assumptions: I. That both parties to treaties were sovereign powers. II. That Indian tribes had some form of transferable title to the land. III. That acquisition of Indian lands was solely a government matter not to be left to individual colonists.	1	Close
5	History is a story most often related through the subjective experience of the teller. With the inclusion of more and varied voices, histories are being discovered and revised. History told from an Indian perspective frequently conflicts with the stories mainstream historians tell.	1	Close



# OPENING

**OPENING LESSON**  
Our Home



## LESSON INSTRUCTIONS

### Opening Lesson: Our Home

## GOAL

By studying the sister-state relationship between Montana and Kumamoto, students will gain a global perspective and an understanding of the world around them.

## OBJECTIVES

Students will be able to:

1. Identify the sister-state to their state or prefecture.
2. Describe how their school day is similar and different to the school day in their sister-state.
3. Explain one benefit to a sister-state relationship.

## ASSESSMENT

1. Assess student's understanding of their sister-state through discussion and evaluation of students' coloring of maps.
2. Use the Venn Diagram student pages to measure if students are able to identify similarities and differences between Kumamoto and Montana.
3. Through the closing discussion, evaluate if students can identify one benefit to the sister-state relationship.

## MATERIALS

- o PowerPoint presentation loaded onto a projection system
- o Video clips of sister-state school day and city loaded onto a projection system
- o World map
- o Copies of "Student Pages," one per student (pages 30-37)

## PREPARATION

- o Make copies of the student pages, one per student

### Preview and load these videos for later use in class:

- o Kumamoto prefecture video (10 min): <https://youtu.be/T4-Qg9wpWcy>
- o Montana videos (3:35 and 3:58 min): <https://youtu.be/c7XYzOd8R01>, <https://youtu.be/R4-ZbVlzMVM>
- o Japan Elementary School (4:11 min): <https://youtu.be/KCvy3Pcp7ul>
- o US Elementary School (4:32 min): <https://youtu.be/MINNGeusB7M>

# LESSON INSTRUCTIONS

## Opening Lesson: Our Home



LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Using a world map, ask students to identify where their country and state are located. Introduce the Montana Kumamoto sister-state relationship using the presentation provided.</p>	<p>Expect students to want to know why they are learning about the sister-state relationship. Explain the importance of this relationship and describe the upcoming lessons you will be using.</p>	<p>This provides the opportunity to introduce the curriculum, explain the sister-state relationship, and share the partner museums involved in the project.</p>
<p>Activity 1: Using the student worksheets, help students review what they know about their home state and learn about their sister-state. Have students color in the provided maps to identify the locations of partner museums.</p>	<p>Expect students to ask questions about their sister-state and need help identifying the location of cities in their home state and sister-state.</p>	<p>This provides the opportunity to better understand the geographical location of their home and world, including the sister-state and partner museums.</p>
<p>Activity 2: Prompt students to draw a picture of their home. Have students share their drawing with a partner or group.</p>	<p>Encourage students to draw specific landmarks and think about things that are important to them.</p>	<p>This provides the opportunity to make connections between Montana and Kumamoto. Students in both areas have objects or landmarks that make their home special to them.</p>
<p>Activity 3: Ask students to watch the appropriate videos for your sister-state including the prefecture or state video and the school video. After the videos, ask students to use the Venn Diagram to compare their home to their sister-state.</p>	<p>Expect to provide one example to the students to start the activity. Students may need to start with what is different that they saw in the videos before being able to find similarities.</p>	<p>This provides an opportunity to begin comparing Montana and Kumamoto.</p>
<p>Lead a group discussion of how Montana and Kumamoto are similar and different. Discuss with the students why Montana and Kumamoto are sister-states because of similarities.</p>	<p>Encourage students to think about the videos they watched. Expect students to ask questions about the sister-state relationship.</p>	<p>This provides an opportunity to share the value of the sister-state relationship.</p>
<p>Give a short preview of the next lessons your group will complete.</p>	<p>Expect students to ask questions.</p>	<p>This provides an opportunity to tell students that classrooms in Montana and Kumamoto are using the same lessons.</p>

## BACKGROUND INFORMATION

### Opening Lesson: Our Home



## MONTANA AND KUMAMOTO PREFECTURE: SISTER-STATES

In 1979, Mike Mansfield, U.S. Ambassador to Japan, recommended that the Governors of Kumamoto and Montana establish a sister-state relationship. After three years of discussion, Kumamoto Governor Issei Sawada and Montana Governor Ted Schwinden signed a sister relationship agreement at a ceremony in Helena, Montana's State Capitol on July 22, 1982. In signing this agreement, Montana and Kumamoto Prefecture agreed to promote interchange in the fields of industry, culture and education; encourage the growth of goodwill and understanding between the people of both the State and the Prefecture.

In October of 2015, 25 individuals representing seven institutions from Montana and Kumamoto formed the Kumamoto Montana Natural Science Museum Association. The *Our Home, Our World* curriculum is a joint project between those institutions and is designed to foster understanding and cultural connections through science education.

Participating institutions in Kumamoto are the Mifune Dinosaur Museum, Goshoura Cretaceous Museum, Aso Volcano Museum, and the Kumamoto City Museum. Participating institutions in Montana are the Museum of the Rockies at Montana State University, and the Carter County Museum. Professional staff from each institution contributed in crafting this curriculum, offering their expertise in the fields of astronomy, geology, paleontology, and education.



## BACKGROUND INFORMATION

### Opening Lesson: Our Home

## KUMAMOTO: FIRE COUNTRY

Video link (5:00): Start at 1:30

<https://www.youtube.com/watch?v=cHjqJKbjAHA&sns=em>

**POPULATION:** 1.822 million

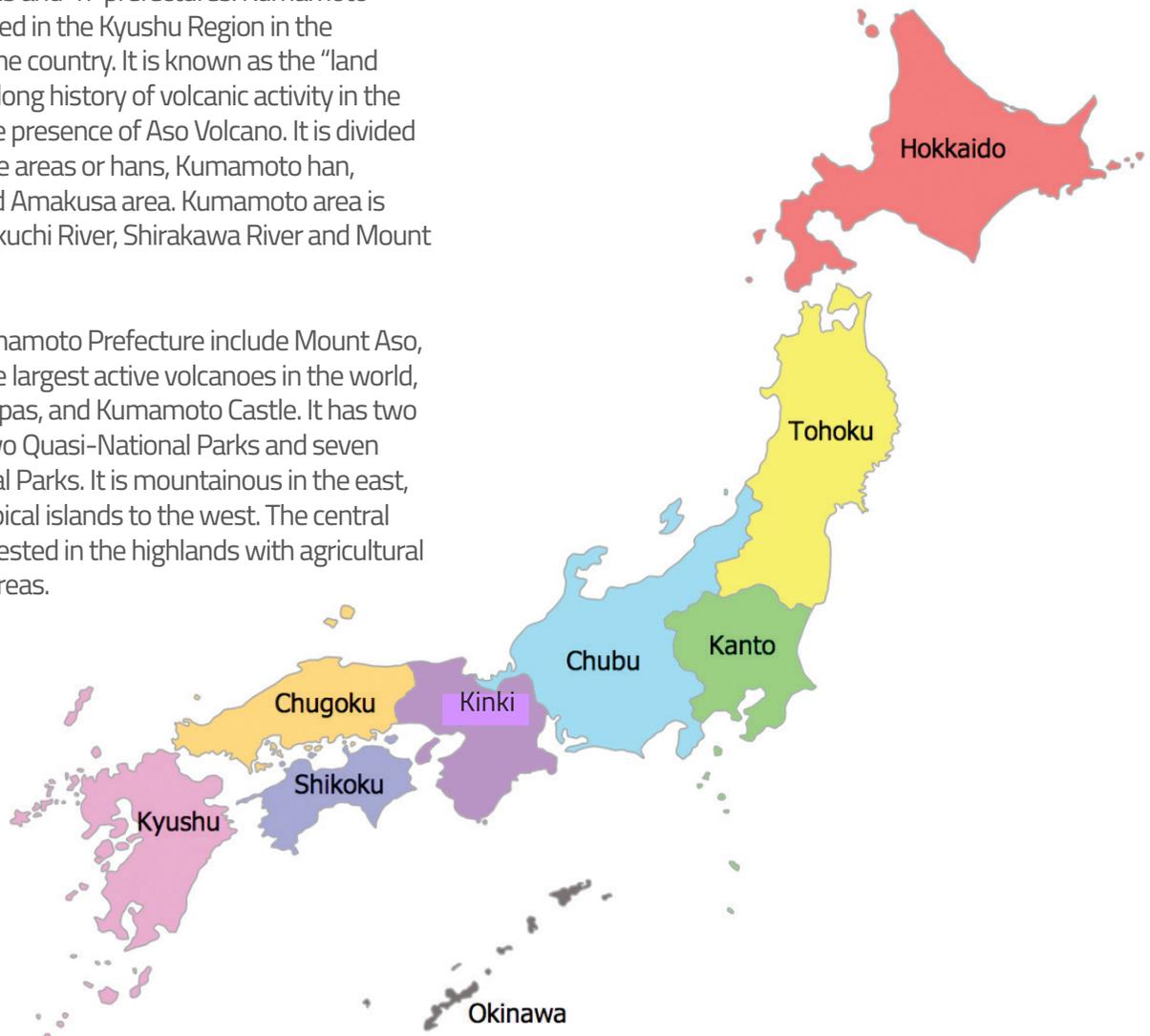
**SIZE:** 2,859 square miles, or 7,405 square kilometers, (roughly equal to the size of Carter County, Montana, which covers 3,348 square miles, or 8,671 square kilometers).

Japan has 8 regions and 47 prefectures. Kumamoto Prefecture is located in the Kyushu Region in the southern part of the country. It is known as the “land of fire” due to the long history of volcanic activity in the region through the presence of Aso Volcano. It is divided primarily into three areas or hans, Kumamoto han, Hitoyoshi han, and Amakusa area. Kumamoto area is made up of the Kikuchi River, Shirakawa River and Mount Aso area.

Attractions of Kumamoto Prefecture include Mount Aso, which is one of the largest active volcanoes in the world, many hot spring spas, and Kumamoto Castle. It has two National Parks, two Quasi-National Parks and seven Prefectural Natural Parks. It is mountainous in the east, with lush sub-tropical islands to the west. The central part is densely forested in the highlands with agricultural plains in the low areas.

The main industries are agriculture, forestry, fishing, electronics, and automobile manufacturing.

Museums like the Mifune Dinosaur Museum and Goshoura Cretaceous Museum are uncovering the prefecture’s paleontological history. The first carnivorous dinosaur fossil in Japan was discovered near Mifune and Goshoura Island is known as “Fossil Island”, where an abundance of vertebrate and invertebrate fossils dating back to the Cretaceous and Paleogene Periods (100–49 million years ago) can be found.



Maps courtesy Wikipedia

OUR HOME

# BACKGROUND INFORMATION

## Opening Lesson: Our Home



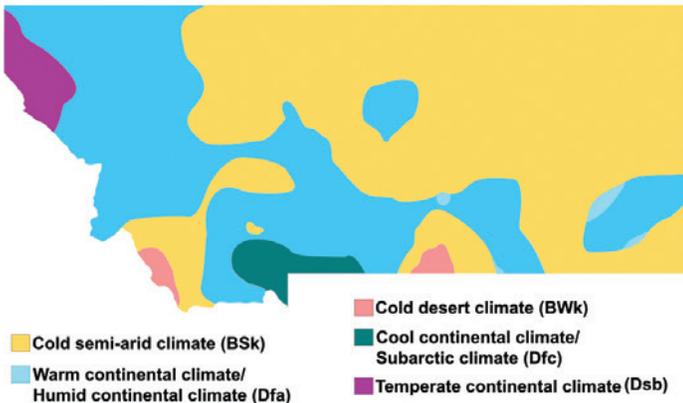
# STUDENT PAGE

## Opening Lesson: Our Home

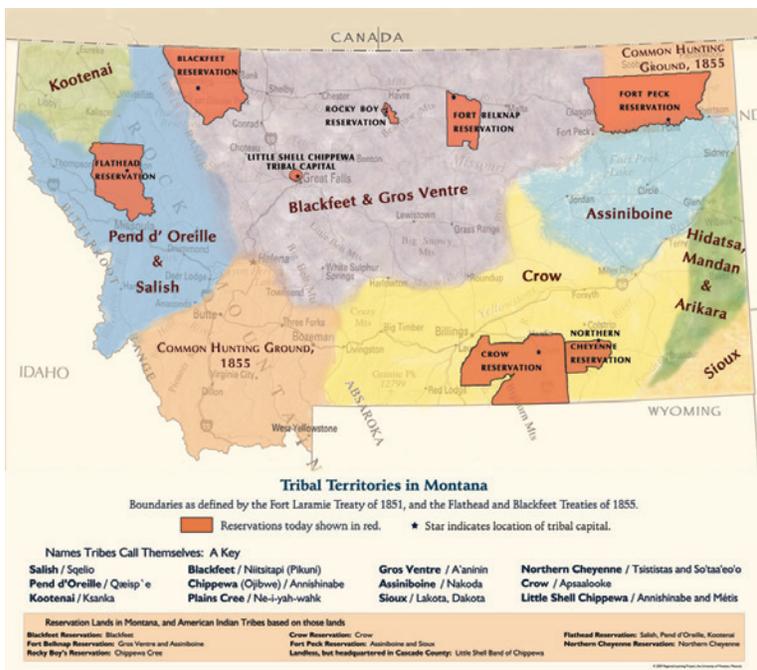
### MONTANA

About 9,251 km ( 5,748 miles ) away from Japan is the country of the United States of America. The United States is divided into 6 regions and 50 states. Montana, in the Western region, is Kumamoto Prefecture's sister-state. This means that our two states work together to promote the exchange of culture, education and trade between one another. Over the next few class periods, you will explore the landscapes and starscapes of Kumamoto and Montana through science and learn to understand your home and your world.

Montana map of Köppen climate classification



**POPULATION:** 1.04 million  
**SIZE:** 147,040 square miles or 380,832 square kilometers



Ponderosa



Western Meadowlark



Bitterroot

Map courtesy montanatribes.org

All images courtesy Wikipedia except where noted.

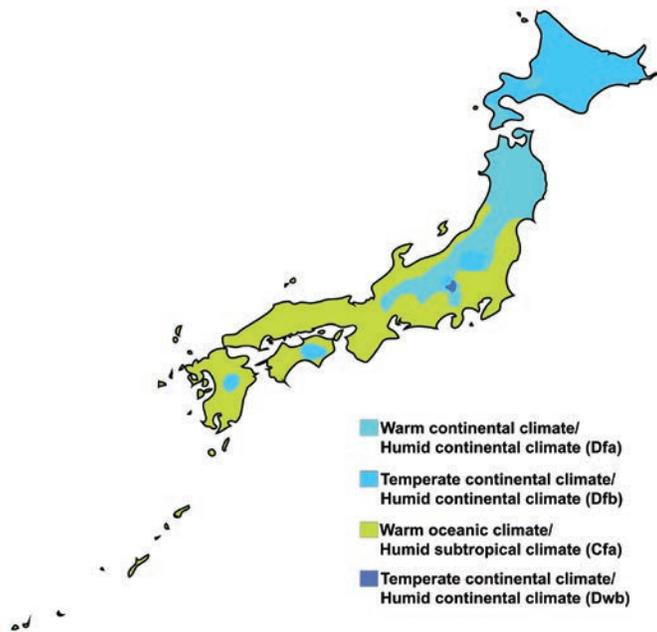
# STUDENT PAGE

## Opening Lesson: Our Home

### KUMAMOTO PREFECTURE

About 5,748 miles (9,251 km) away from the USA is the country of Japan. Japan is divided into 8 regions and 47 prefectures, or states. Kumamoto Prefecture, in the region of Kyushu, is Montana's sister-state. This means that our two states work together to promote the exchange of culture, education and trade between one another. Over the next few class periods, you will explore the landscapes and starscapes of Kumamoto and Montana through science and learn to understand your home and your world.

Japan map of Köppen climate classification



Outline of Kumamoto and flag



**POPULATION:** 1.822 million  
**SIZE:** 2,859 square miles, or 7,405 square kilometers

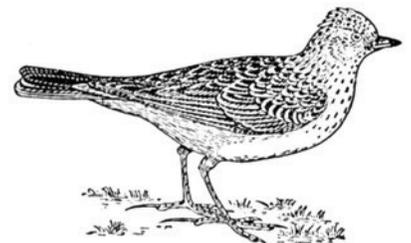
#### STATE SYMBOLS



*Camphor tree*



*Japanese Gentian*



*Eurasian Skylark*

All images courtesy Wikipedia

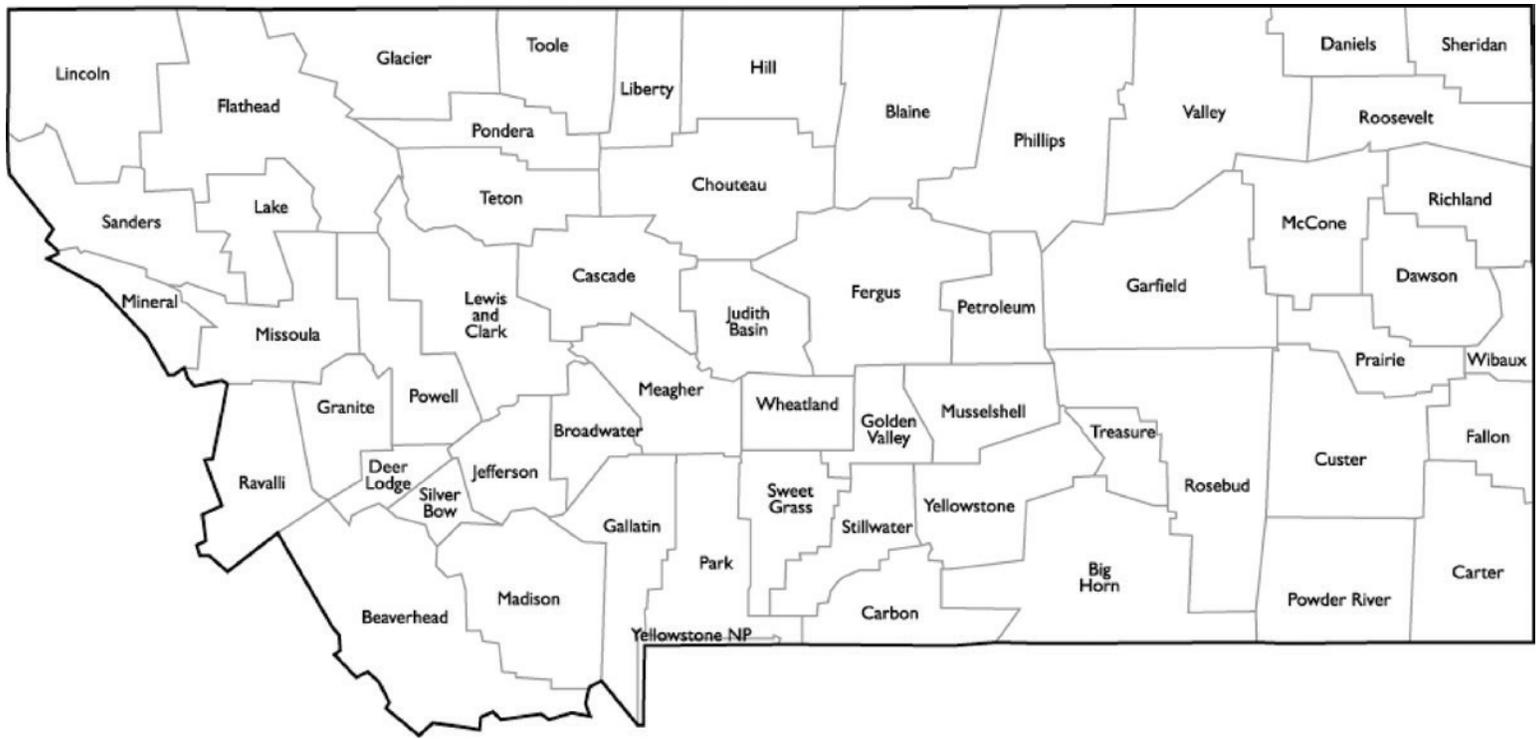
# STUDENT PAGE

## Opening Lesson: Our Home

### ACTIVITY 1

1. Bozeman is in Gallatin County. Color Gallatin County blue.
2. Ekalaka is in Carter County. Color Carter County red.
3. If you live in Montana, draw a star on your home county.

## MONTANA



Images courtesy Wikipedia

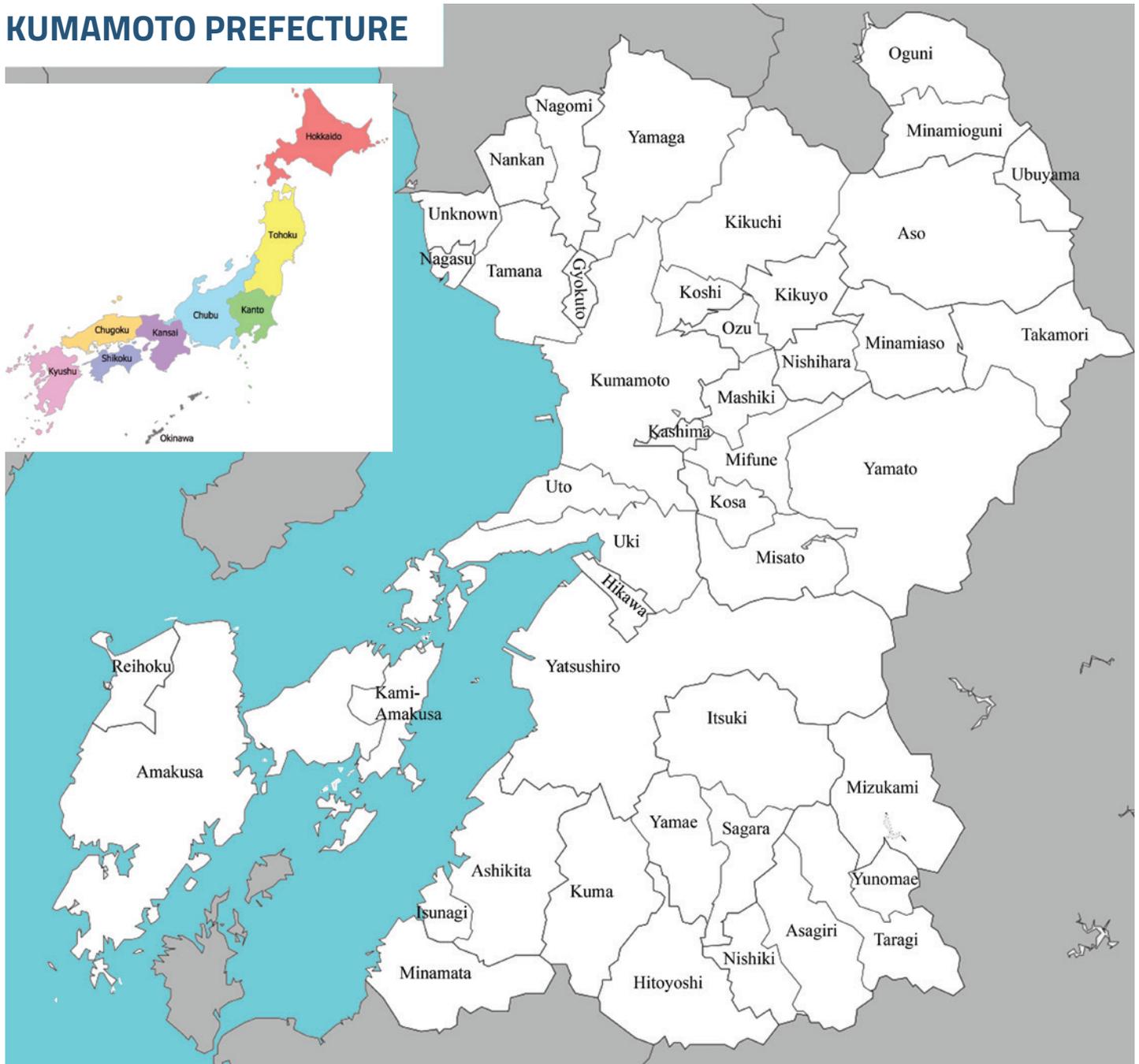
# STUDENT PAGE

## Opening Lesson: Our Home

### ACTIVITY 1

1. Kumamoto City is in the Kumamoto municipality, or area. Color the Kumamoto municipality blue.
2. Goshoura is in the Amakusa municipality or area. Color the Amakusa municipality red.
3. If you live in Kumamoto Prefecture, draw a star on your county.

### KUMAMOTO PREFECTURE



Images courtesy Wikipedia



## STUDENT PAGE

### Opening Lesson: Our Home

#### ACTIVITY 2

Draw a picture of your home or your town. Include places that are special to you, your house, or other important parts of your home.

# STUDENT PAGE

## Opening Lesson: Our Home

### ACTIVITY 3

After watching the video of an elementary school in your sister-state, think about your own school day. Write details that explain how Japan and Montana are different in the outer circles. Write details that tell how our schools are the same where the circles overlap.

*Kumamoto*

*Montana*

*Similarities*

A Venn diagram consisting of two overlapping circles. The left circle is labeled 'Kumamoto', the right circle is labeled 'Montana', and the overlapping area in the center is labeled 'Similarities'. Each of the three sections contains five horizontal lines for writing.

## STUDENT PAGE

### Opening Lesson: Our Home

## COLOR PAGE

Montana is known for the dinosaur fossils found throughout the state. Color *Maiasaura*, Montana's state fossil.

### FUN FACTS ABOUT *MAIASAURA*:

- *Maiasaura* was a large herbivore, or plant eater, that lived 65-80 million years ago.
- *Maiasaura* could grow up to a height of 8.2 feet, or 2.5 meters and weighed as much as a modern hippo.
- The name *Maiasaura* means "caring mother lizard."
- *Maiasaura* was first discovered in Montana in 1979.

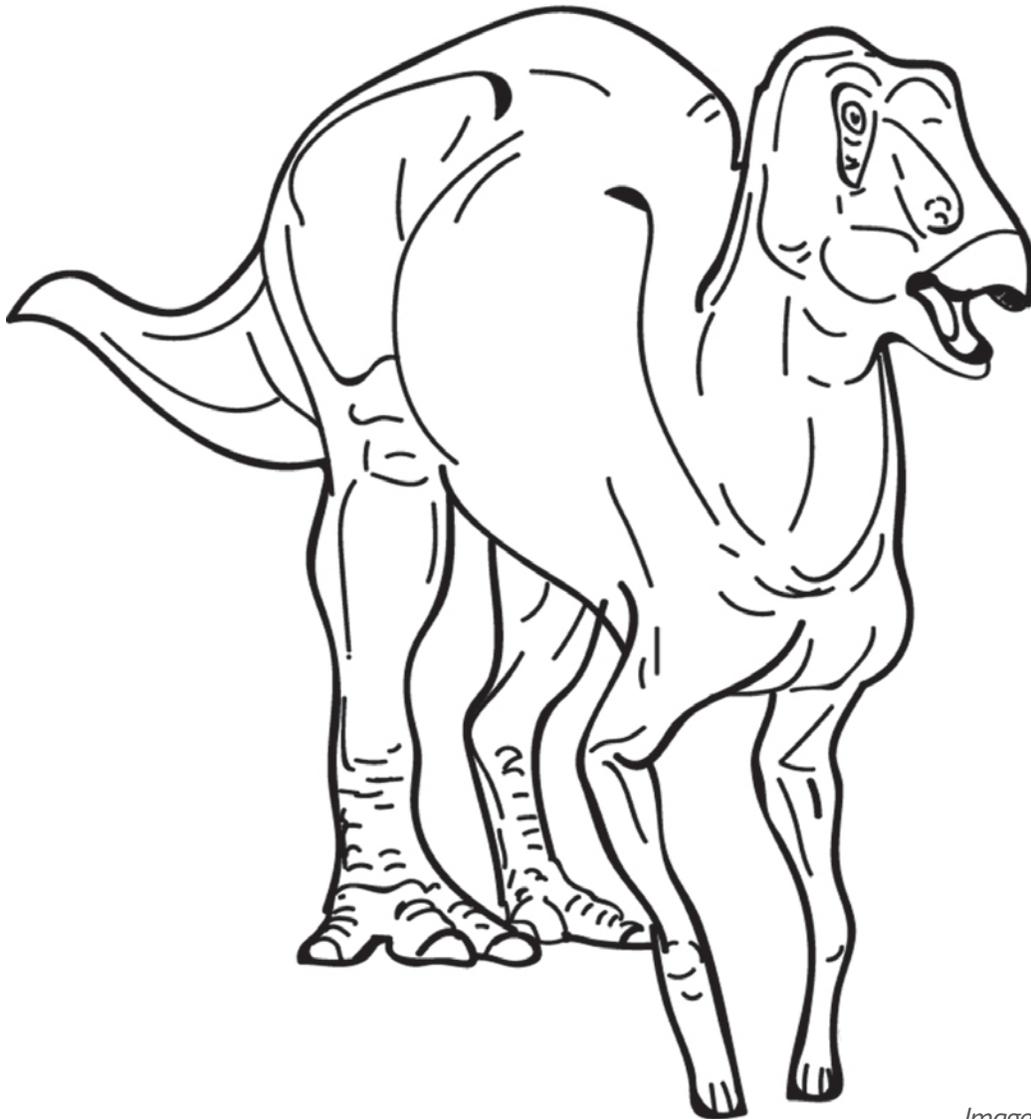


Image by Doyle Trankina

## STUDENT PAGE

### Opening Lesson: Our Home

## COLOR PAGE

Japan is well known throughout the world for its castles. Color the Kumamoto Castle, one of the most famous castles in Japan.

### FUN FACTS ABOUT KUMAMOTO CASTLE:

- *It is also called "Ginkgo Castle" for the large number of ginkgo trees around it*
- *Kumamoto Castle was originally built in 1467 then completed by Kato Kiyomasa in 1607. He was the first lord of the castle.*
- *The castle was in use from 1467-1874.*



*Image courtesy Micah Rauch*



# 1

## **ASTRONOMY LESSON 1** One Sky, Many Stories



## LESSON INSTRUCTIONS

### Astronomy Lesson 1: One Sky, Many Stories

## GOAL

By listening to the story of the Big Dipper through three different cultural lenses, students will explore how cultures around the world created star stories to teach life lessons and how the landscapes of these cultures impact their stories.

## OBJECTIVES

Students will be able to:

1. Describe that there is great diversity among the tribal nations of Montana in their cultures and histories as shown through star stories.
2. Explain how constellation stories are different for different cultures.

## ASSESSMENT

1. Use the Venn Diagram student pages to measure if students are able to identify similarities and differences between the various star stories.
2. Through discussion and student responses to reflective questions, assess student understanding of how different cultures can interpret the night sky differently.

## MATERIALS

- o Optional: Video clips of Montana's tribal nations from Montana's Office of Tourism loaded onto a projection system
- o World map
- o "Tribal Territories in Montana" map from montanatribes.org loaded onto a projection system or printed for each student
- o Video clip of "The Seven Bulls" star story from Montana's Office of Public Instruction loaded onto a projection system
- o Copies of "Student Pages," one per student (pages 46-55)

## PREPARATION

- o The Crow and Blackfeet people do not tell stories in the summer and so it is, only in the deepest, coldest time of winter may their stories be told. Please plan to use these lessons in the winter months.
- o Make copies of the student pages, one per student.
- o Preview and load the video for later use in class.

# LESSON INSTRUCTIONS

## Astronomy Lesson 1: One Sky, Many Stories

LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Introduce students to Montana’s tribes by using the background information and showing the suggested videos. Tell students that you will be reading stories from the Blackfeet, Crow and Japanese.</p>	<p>Expect students to need a physical map to guide their understanding of tribal history. Show the “Tribal Territories in Montana” Map.</p>	<p>This gives teachers the opportunity to discuss how Montana tribes, despite being located in the same state, are unique nations and endure today. For Montana teachers, this links back to IEFA Essential Understandings 1-3 and 6.</p>
<p>Introduce star history in Japan by showing the Kitora star chart. Ask students if they can find any familiar constellations on this chart.</p>	<p>Expect students to need some examples of constellations to get started. Teachers should be ready to identify popular constellations (the Big Dipper for example) on the chart.</p>	<p>This gives teachers the opportunity to introduce the constellations.</p>
<p>Tell the students that they will be listening to stories about the same constellation, the Big Dipper, from Japanese, Crow, and Blackfeet cultures. Have students follow along on the student pages as you read the Japanese story. Use the OPI video for the Crow story or read the Blackfeet story as students follow along. After the stories, have students complete a Venn Diagram to compare and contrast the stories.</p>	<p>Invite students to share the differences and guide the discussion by beginning with the differences in the Japanese and Crow stories, then the Crow and Blackfeet stories.</p>	<p>This gives teachers the opportunity to discuss the relationships between people and the landscape and how that can vary from culture to culture.</p>
<p>On the star maps, help students identify Polaris and the Big Dipper and have students mark them on the map. Explain why the star maps are different for Montana and Kumamoto.</p>	<p>Expect students to begin connecting other stars with familiar constellations. Teachers can point out others, such as Orion. The different sky maps will be covered in Astronomy Lesson 2.</p>	<p>This gives teachers the opportunity to provide background for future lessons (the two other lessons for this activity incorporate Orion and Pleiades).</p>
<p>Have students draw their own constellation on the map and write an accompanying story.</p>	<p>Expect students to need some help with constructing their stories. Teachers should walk through the class and give aid as needed.</p>	<p>This gives teachers the opportunity to assess students’ comprehension of the material as they use key ideas and details to create a story.</p>
<p>If the class is big enough, ask students to break into groups and share their stories. For small classes, ask for volunteers to share.</p>	<p>Expect students to need a little encouragement to begin sharing stories. If this is the case, the teacher can come up with a short story of their own and present it to get things started.</p>	<p>This gives teachers the opportunity to have students present their knowledge in a creative writing assignment and demonstrate their knowledge of spoken and written language.</p>

# BACKGROUND INFORMATION

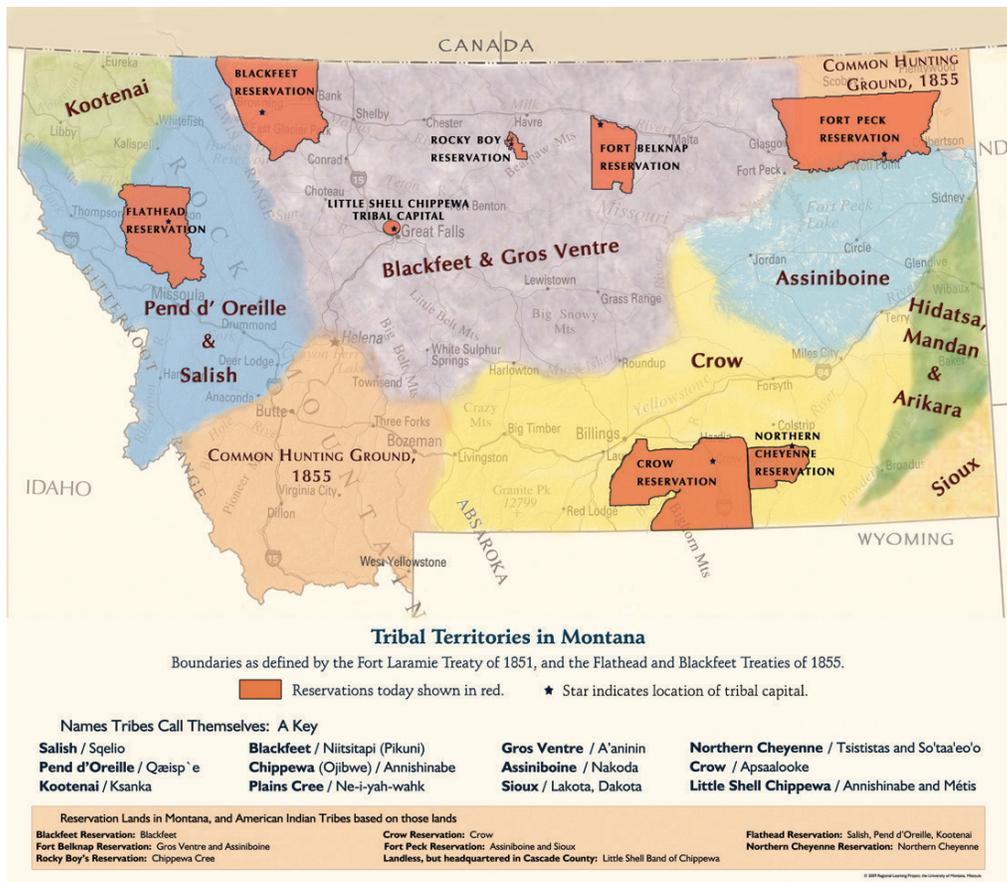
## Astronomy Lesson 1: One Sky, Many Stories

### AMERICAN INDIAN NATIONS IN MONTANA, USA

The United State of America recognizes eleven of the twelve American Indian tribes in Montana. These include the Assiniboine, Blackfeet, Chippewa, Cree, Crow, Gros Ventre, Kootenai, Northern Cheyenne, Pend d'Oreille, Salish and Sioux Nations. These tribes are located on seven reservations throughout Montana. The Little Shell Chippewa Tribe is additionally recognized by the state and is working toward federal recognition.

“One Sky, Many Stories” presents oral histories from two of the tribal nations in Montana, the Blackfeet and Crow. Both stories were used in these cultures to teach younger generations the life ways of the tribe. The differences in the stories account for different practices. While both are Plains tribal nations, it is important to remember that all American Indian tribes are diverse in their languages, cultures, histories and governments. Each Nation has a distinct and unique cultural heritage and there is no generic American Indian. Many of these stories continue to be told today and are a distinct facet of cultural traditions.

Introduce your students to the enduring indigenous nations of Montana by showing this video from the Montana Office of Tourism: <https://vimeo.com/49771618>



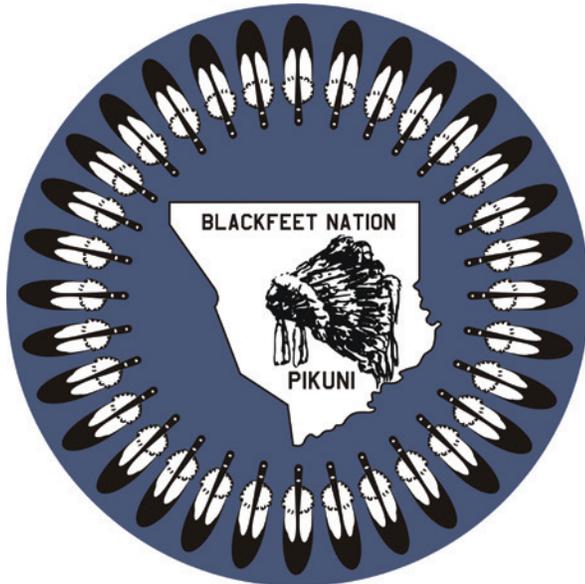
### Tribal Territories of Montana

- Salish / Sqelio
- Pend d'Oreille / Qæisp`e
- Kootenai / Ksanka
- Blackfeet / Niitsitapi (Pikuni)
- Chippewa (Ojibwe) / Annishinabe
- Plains Cree / Ne-i-yah-wahk
- Gros Ventre / A'aninin
- Assiniboine / Nakoda
- Sioux / Lakota, Dakota
- Northern Cheyenne / Tsististas & So'taa'eo'o
- Crow / Apsaalooke
- Little Shell Chippewa / Annishinabe and Metis

Image courtesy montanatribes.org

## BACKGROUND INFORMATION

### Astronomy Lesson 1: One Sky, Many Stories



#### THE BLACKFEET TRIBE

The Blackfeet Reservation is located in northwestern Montana near the Rocky Mountains and borders Glacier National Park. The town of Browning serves as the headquarters for the Blackfeet Indian Agency since the establishment of the reservation in 1894. Present day Blackfeet peoples are descended from the Siksika, Kainah (Bloods), and Piegians, and speak a language that belongs to the Algonquin linguistic family. The name "Blackfeet" is thought to refer to the characteristic black color of their moccasins ("Montana Indians, Their History and Location"). The location of their territory was relatively isolated and they encountered the white man later than most tribes (during the latter half of the 19th century).

Today, 9,000 of the 17,250 enrolled members of the tribe live on or near the reservation. They call themselves Niitsitapi, meaning "the real people".

Introduce the Blackfeet tribe to the students by showing this short video from the Montana Office of Tourism:

<https://vimeo.com/74325278>

*Tribal seals courtesy montanatribes.org*



#### THE CROW TRIBE

The Crow Reservation is located mostly in Big Horn County in south central Montana. It is bordered to the South by the state of Wyoming and the Northern Cheyenne Reservation to the East. Members of the Crow nation are historically divided between three subgroups: Mountain Crow, River Crow, and Kicked in the Bellies. Crow peoples are originally from the headwaters of the Mississippi and the Winnipeg Lake region, known as "land of many lakes" in their oral histories. The Crow Tribe in Montana is descended from the Apsaalooke, who migrated westward from the Missouri River, having split from the Hidatsa tribe 400 years ago.

Today, 75 percent of the tribes' 12,527 members live on or near the reservation and 85 percent speak Crow as their first language. Their name, Apsaalooke, means "children of the large beaked bird."

Introduce the Crow tribe to the students by showing this short video from the Montana Office of Public Instruction:

<https://youtu.be/N7fLb29bWM8> (begin at 25:40, end at 26: 50)

## BACKGROUND INFORMATION

### Astronomy Lesson 1: One Sky, Many Stories

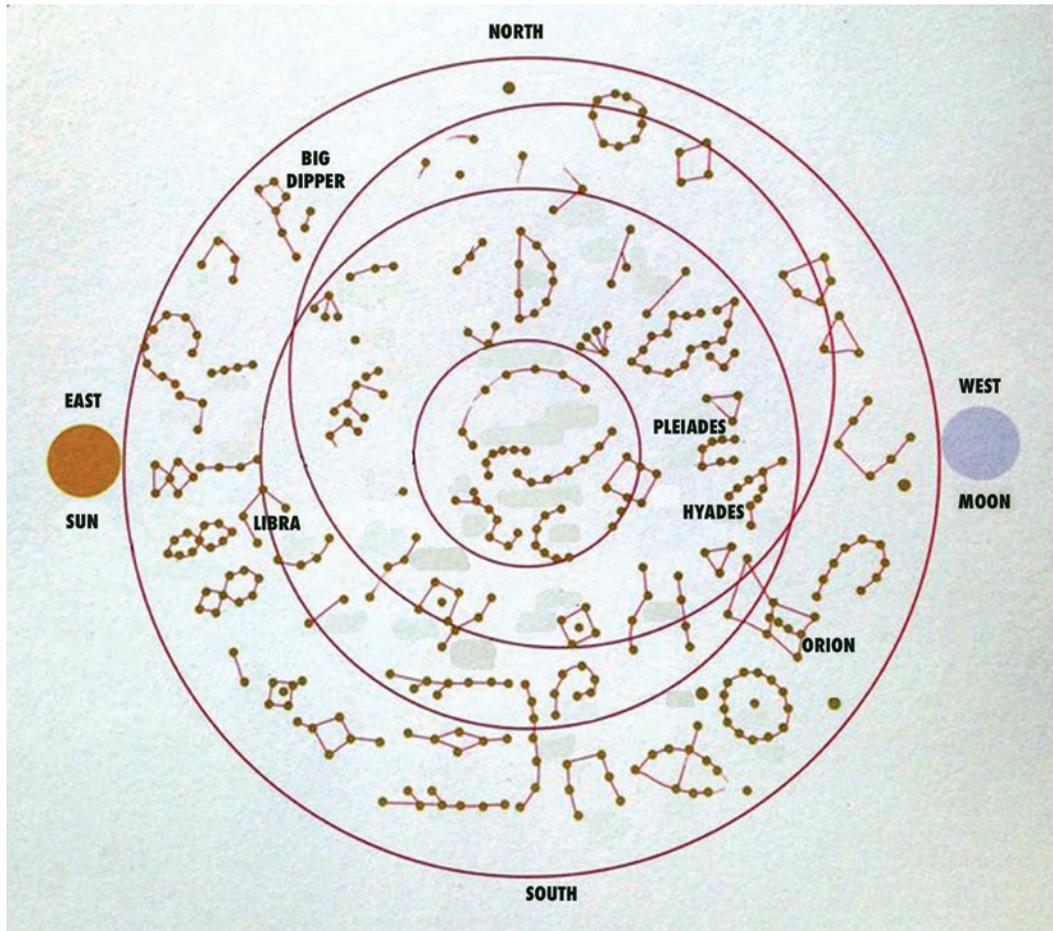


Image courtesy Wikipedia

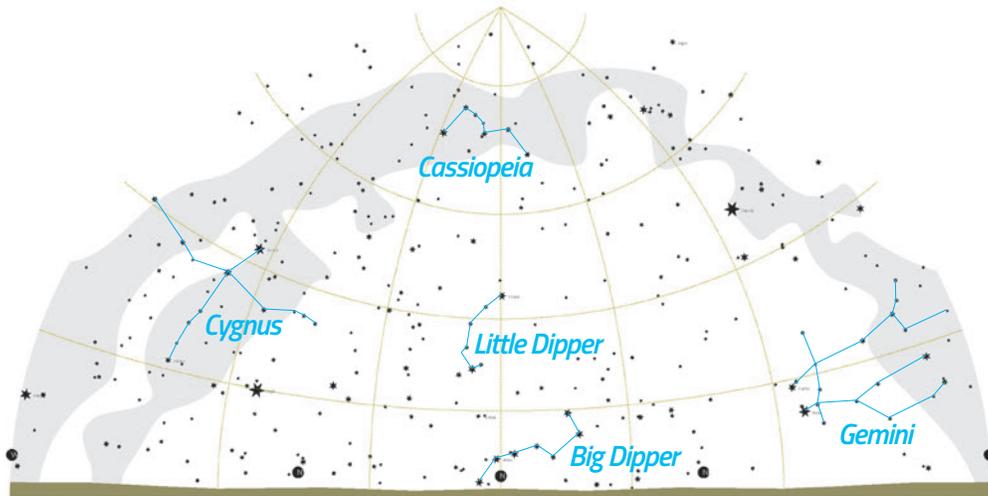
*Star chart, Kitora Tomb, Asuka, Japan (7th century)*

In 1998, a star map was discovered in the Kitora Tomb in the Asuka village in Japan. Dating back to the late seventh, early eighth century, this star chart is the oldest existing map of its kind in the world. It features 68 constellations and the movement of celestial objects is represented by the three concentric circles in the chart. The polar star is featured in the center.

Cultures all over the world have created star stories based on constellations to pass traditions and knowledge on to the next generation. Each culture had different names and stories for the Sun and Moon, visible planets, stars, and star groups. These stories are told at night and during the time of year when the featured constellation is in the night sky. In American Indian cultures, stories are told during the winter-time, when the nights are long and cold. Many of the stories endure today as they are passed down to new generations.

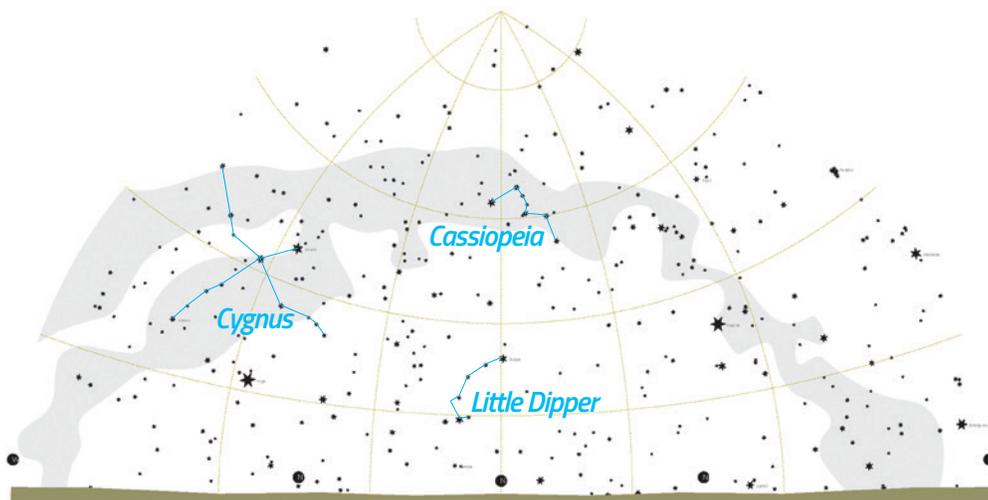
# BACKGROUND INFORMATION

## Astronomy Lesson 1: One Sky, Many Stories



### Bozeman, Montana, USA

[Date] 2017 - 12 - 01 20:00:00 [Moon Age] 12/7



### Kumamoto City, Kumamoto Prefecture, Japan

[Date] 2017 - 12 - 01 20:00:00 [Moon Age] 13

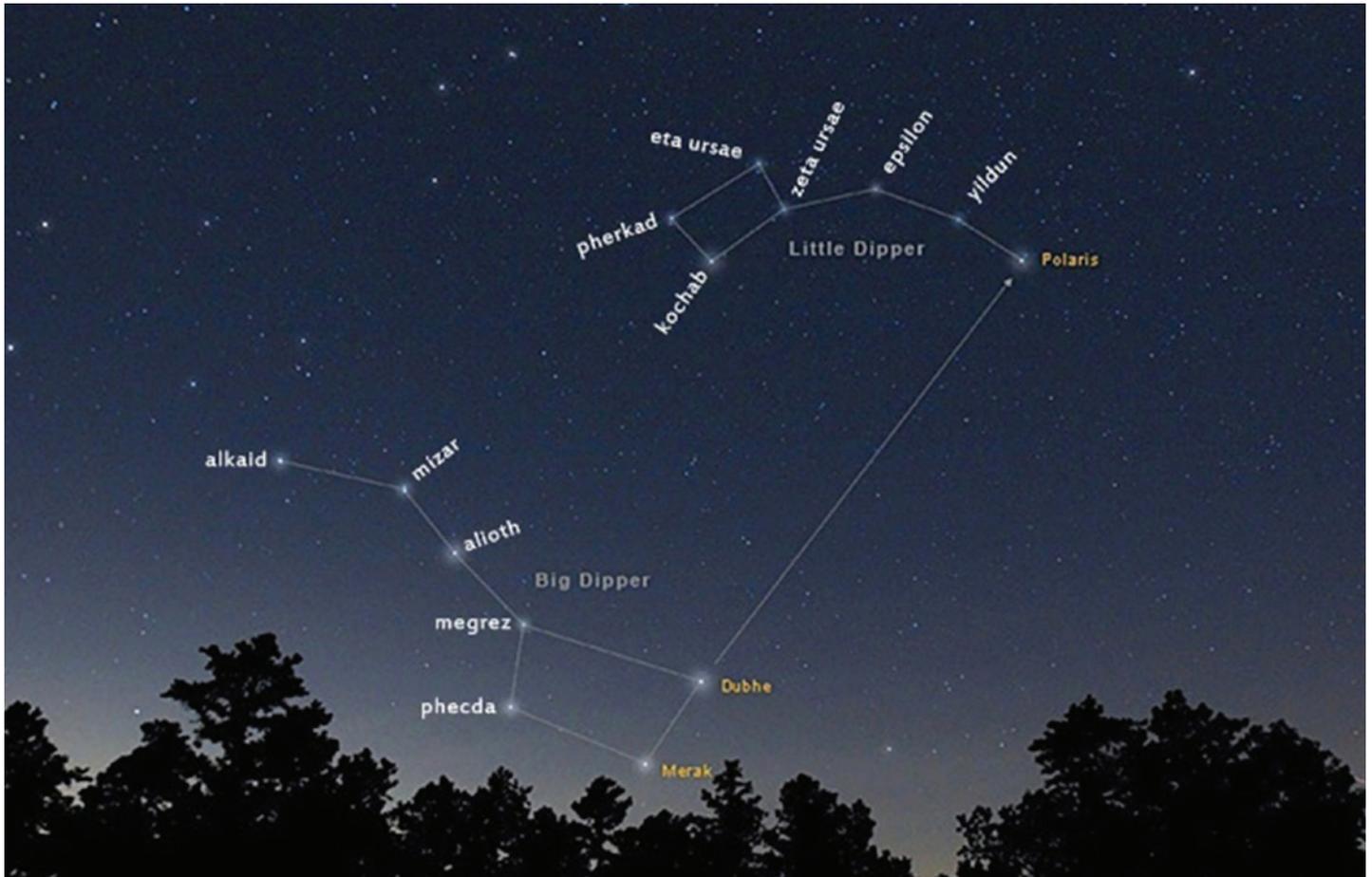
The difference between the two is because Kumamoto and Montana are located at different latitudes on the Earth. Montana is about  $45^\circ$  north of the equator, and Kumamoto is about  $32^\circ$  north of the equator. In the Kumamoto skies Polaris (the North Star) will be slightly lower on the Northern horizon, and some stars will rise on the Southern horizon that cannot be seen in Montana.

Let's focus on the Big Dipper, for example. You can see the Big Dipper in Montana throughout the year, but in Kumamoto you will not be able to see it on winter nights. The starry sky of Montana and the starry sky of Kumamoto may look similar, however, there are many differences including constellations that can only be seen in one country and not the other. This affects the stories told about stars as well.

Images by 星降る hoshifuru ([hoshifuru.jp](http://hoshifuru.jp))

# STUDENT PAGE

## Astronomy Lesson 1: One Sky, Many Stories



CONSTELLATION/STAR	JAPANESE	GREEK	BLACKFEET	CROW
Big Dipper/Polaris	The One Star & Big Dipper	Ursa Minor	Fixed Star	The Seven Bulls

### CONSTELLATIONS

The history of the constellations is ancient; many were likely created by the Babylonian, Egyptian and Assyrian peoples. These constellations would have moved through the regions via trade, and eventually they made their way into Greece, where they were assimilated into the culture and mythology. In the second century, Ptolemy organized

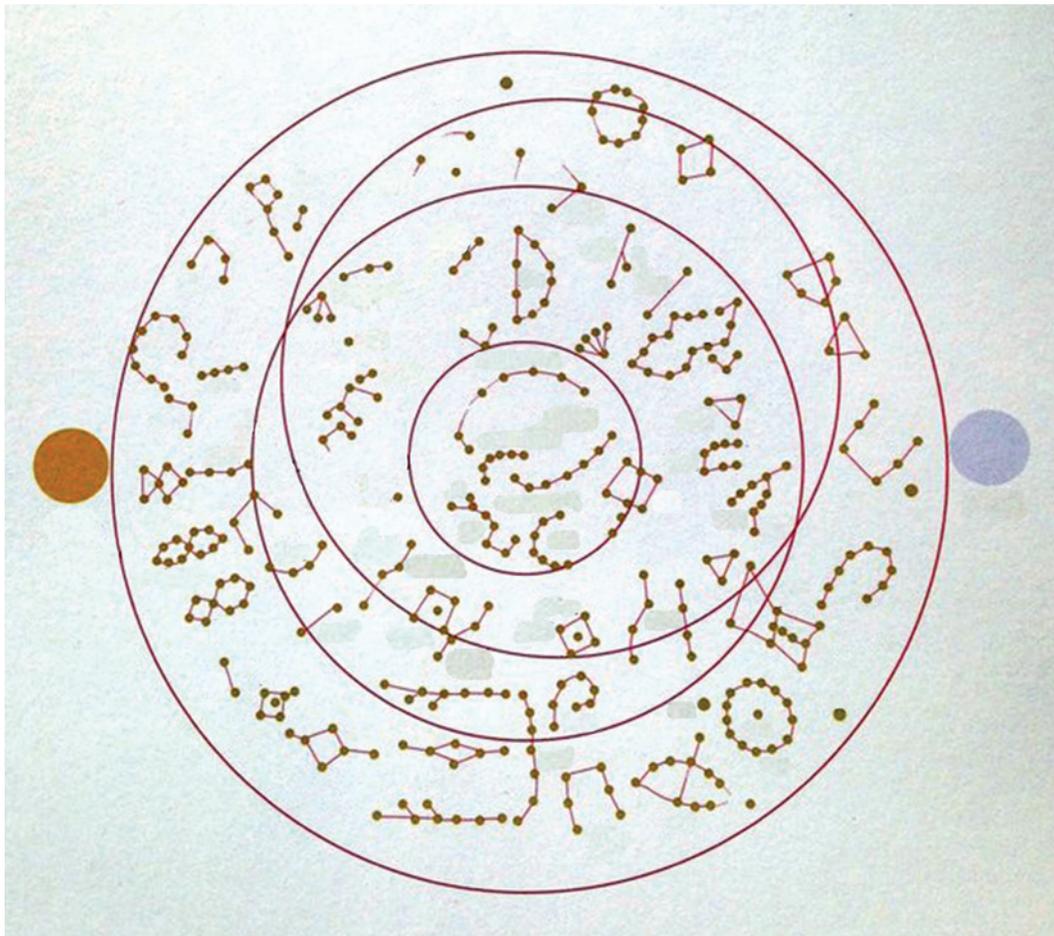
48 constellations in his famous book "Almagest". These are called the "Ptolemaic constellations," and most of them survive to this day.

There are 88 official constellations recognized by the International Astronomical Union. Only the official boundaries of these constellations are determined; there is no official line drawing that makes up the shape of any constellation.

*Image courtesy wikihow*

## STUDENT PAGE

### Astronomy Lesson 1: One Sky, Many Stories



*Image courtesy Wikipedia*

*Star chart, Kitora Tomb, Asuka, Japan (7th century)*

In 1998, a star map was discovered in the Kitora Tomb in the Asuka village in Japan. Dating back to the late seventh, early eighth century, this star chart is the oldest existing map of its kind in the world. It features 68 constellations and the movement of celestial objects is represented by the three concentric circles in the chart. The polar star is featured in the center.

Cultures all over the world have created star stories based on constellations to pass traditions and knowledge on to the next generation. Each culture had different names and stories for the Sun and Moon, visible planets, stars, and star groups. These stories are told at night and during the time of year when the featured constellation is in the night sky. In American Indian cultures, stories are told during the winter-time, when the nights are long and cold. Many of the stories endure today as they are passed down to new generations.

## STUDENT PAGE

### Astronomy Lesson 1: One Sky, Many Stories

#### THE ONE STAR AND BIG DIPPER (SIZUOKA, JAPAN)

Big Dipper always boasted about being rich and important, but One Star (Polaris), the child of a poor family, bragged about being the center of the northern sky. This made Big Dipper very angry because he wanted to be more important than One Star.

Big Dipper tried to conquer One Star so he could again boast about being more important. However, he was unable to reach One Star because the pair of stars in the constellation Ursa Minor (Kochab and Pherkad) always stayed between One Star and Big Dipper as they turned in the sky. This prevented Big Dipper from ever getting close to One Star. For this reason, Kochab and Pherkad are known as the “Guardians of the Pole,” because they will always protect One Star (Polaris).

**KEYWORDS:** *Polar star, Big Dipper, Ursa Major, Little Dipper, Ursa Minor*

#### THE SEVEN BULLS (CROW NATION)

*NOTE: Story courtesy “Montana Skies: Crow Astronomy” by Lynn Moroney, OPI (2011)*

The Crow people do not tell stories in the summer and so it is, only in the deepest, coldest time of winter is the following story told.

*It is best to show students a 15 minute video in place of this telling: <https://youtu.be/nzMljr1XP38>*

Once, there lived a young woman who was with child. When the baby was born, the young woman didn't want him. She took her son far out into the prairie, placed him on the prairie grass and left him there. Just left him there! A newborn.

They say that not long after that some buffalo bulls came along. There were seven of them. They saw the child lying there. They went close to the baby and surrounded him. They sniffed him and nudged him. The leader of these seven buffaloes was called “Crazy Bull”. Crazy Bull gently scooped up the boy and held him for a moment. He tossed him in the air, but the baby was not hurt, for when he landed on the ground, he began to crawl about. Another bull came forth and like the first, used his horns to toss the boy into the air. This time, when the boy landed, he could stand up and he could talk. There was yet a third buffalo who did the same thing and when the boy landed, he had turned into a young man. And they say they named him “Buffalo Boy”.

The bulls came to love the boy, really love the boy. Those seven buffaloes took the boy with them, they cared for him, they watched over him and taught him many things. They warned him, saying, “There is a bull that is very mean. His name is “Connected Bones” and he has several pretty wives. They will offer you water, and when they do,

## STUDENT PAGE

### Astronomy Lesson 1: One Sky, Many Stories

you must refuse to take even one drop.”

One day, Connected Bones’ youngest wife came to Buffalo Boy and as he had been told, she offered him water. Buffalo Boy refused to drink any water. He turned away and said no. She took her finger to the water and then placed a small drop on Buffalo Boy’s lips and said, “Well, you drank my water anyway. Now, I will tell my husband.”

She ran to her husband, told him what happened and Connected Bones was filled with anger. Maybe because it was his prettiest wife. At once, he went to the lodge of Buffalo Boy, called to him, “Buffalo Boy, get up! Come outside!” And they say the seven bulls came to the aid of Buffalo Boy, telling him, “Stay inside the lodge! We’ll take care of him.” But they could not protect the boy, and one by one, Connected Bones broke their bones and left them dead. All seven of them. Dead. Their bodies lying here and there on the prairie.

Again, Connected Bones called to Buffalo Boy, “Come out!” Buffalo Boy appeared at the door of his lodge. He had an eagle feather tucked to the back of his head and he had his arrows. They say that Connected Bones started pawing and snorting, and then charged the boy. But when the huge buffalo passed under him, Buffalo Boy twisted his body, aimed his arrow, and shot the bull in the rump. That was one of the weakest parts of the buffalo.

They say that the bull started wallowing and snorting, and charged the boy a second time. But Buffalo Boy did the same as before. He jumped into the air just as the bull charged him. He spun around and shot his arrow into the bull’s collarbone. That is another weak spot. When the arrow struck, the bull fell. Dead.

They say that the boy took all seven buffaloes into the sweat lodge and there, all seven bulls were healed. When

they came outside the lodge, they knew that Buffalo Boy had great powers, and that he was strong. They knew it was time for him to go back to his people. And they said, “But we want to continue to watch over him. We need to become something that will watch over the boy and all the Crow people.” The seven buffaloes agreed that they needed to become something that would last forever. They talked among themselves.

One of them said, “Why don’t we become trees?” One of them said, “No. The Crow chop the trees and make fire. They use the trees for firewood.”

One of them said, “Why don’t we become a river?” And one of them said, “No, the river can die. Especially in hot weather. The river can dry up.”

One of them said, “Why don’t we become a mountain? Mountains last forever.” And one of them said, “No. The rain wears away a mountain. In time, even the mountains disappear.”

There was one who had been looking at the sky and he said, “For as long as I can remember, there have been stars. Why don’t we become stars and watch over the Crow?”

The seven bulls went to the sky and became the seven stars in the Big Dipper. And they say Buffalo Boy went back to his mother. His mother didn’t want him and he left. And they say he went to be with his buffalo family and he became the constant star. The star some call the North Star.

When you look at the Big Dipper and the North Star, remember this story of a family, held together by their story and their love for one another. And that is the end of the story of the Seven Bulls and the Buffalo Boy.

**KEYWORDS:** *North Star, Big Dipper, Buffalo, Sweat lodge*

## STUDENT PAGE

### Astronomy Lesson 1: One Sky, Many Stories

#### THE FIXED STAR (BLACKFEET NATION)

*NOTE: Story citation: "They Dance in the Sky: Native American Star Myths" by Jean Guard Monroe and Ray A. Williamson (1987)*

One summer night in Montana, two sisters decided to sleep outside their lodge. The sky was clear and there was a warm breeze; the young women went to sleep quickly. Before dawn, both of them awoke and gazed at the beautiful night sky and early morning stars. Looking toward the East, one girl pointed out Morning Star to her sister. "That star is so beautiful. He is winking at me. How happy I would be to have him for a husband."

As the sun came up and the day broadened, the tasks of the day soon grew upon them, and both young women forgot the night's talk.

Several days later, the sisters walked out to gather firewood. They picked up sticks, made up their packs, and tied them on their backs with strong leather straps. They were cheerful and chatted happily as they went. Soon the strap on one of the bundles broke. It was that of the girl who wished for Morning Star. Each time she re-tied her bundle, the strap broke again. Her sister said, "I'll go on ahead. After I unload my firewood, I'll come back and help you."

The first girl kept trying to fix her bundle of firewood. Finally she decided to wait for her sister. When she looked up from her task, she found a handsome young man watching her. He was dressed all in fine beaver skins and wore a tall eagle feather in his hair. The young woman started to hurry away but he stopped her. "What do you want of me?" she asked him.

"You said you wanted me for your husband, and here I am," he replied.

"You are a stranger to me. Why would I want you for a husband?" She asked, startled. "I don't even know you."

The young man laughed and replied, "One night you looked at me in the sky and said you wished to have me as your husband. I am Morning Star. I have come to take you as my wife." The next moment, the handsome youth gently took her hand. They smiled at each other as he removed the feather from his hair. "Shut your eyes," he told her and placed the feather in her hair. They rose up into the sky.

When the young maiden opened her eyes, she was in the house of Sun and Moon, the youth's mother and father. She was not afraid, but she did feel a little confused because she had seen no place like this before. "Come and meet my wife," Morning Star called to his parents. "Make her feel at home in Sky Country."

Moon fed the girl four berries and a little water in a shell. The four berries, one for each direction, symbolized all the food in the world, and the water in the shell represented all the water in the oceans. She could not finish her meal.

After she had eaten, Moon took her aside and said, "I have something special for you." She gave her a root-digger and showed her how to gather roots, warning her not to touch a certain turnip. "This turnip is special to the Gods. It is a sacred turnip," Moon explained. "Evil will come to us all if it is touched."

Now, this turnip was very large, and the young woman often looked at it when she was out digging for roots. She wondered, "What would happen to me if I dug that turnip up? Why is it so special?"

Many happy days came and went for the young woman and Morning Star. After a while, she gave birth to a baby. Each day she went out to gather vegetables for the evening meal. Each day her curiosity and desire to dig up the turnip increased. One day she sat the baby outside to play and decided to go out alone and dig up the turnip. The turnip was big and the earth was hard. Her root-digger got stuck in the ground. She grew afraid and tried to pull it out, but it would not budge. She sat down and started to cry.

Crane Man and Crane Woman were flying overhead and

## STUDENT PAGE

### Astronomy Lesson 1: One Sky, Many Stories

heard her crying. When she saw them, she prayed to them, "Please help me."

Crane Woman said, "I have been a good and faithful wife, so I have much power to help you. Your mother-in-law gave you the root digger. I will teach you the songs that go with it. They are special and will help you." Crane Woman burned incense and sang. Soon she pulled out the root-digger and, dancing around the turnip, made three thrusts with the digger. With the fourth try, she pulled out the turnip. "Take your root-digger and your turnip home," Crane Woman said.

As she was leaving, Morning Star's wife looked at the hole Crane Woman had left when she pulled out the big turnip. She thought she could see something moving and looked a little closer. "I can see my people and my old camp," she thought. She felt sad to see everyone down there working so hard while she was happy and living at ease in Sky Country. It was the first time the young woman had been sad during her stay in Sky Country, the first time she had missed her people.

Morning Star and Sun and Moon were extremely unhappy when they saw what she had done. They asked her if she had seen anything when she pulled out the turnip. "I saw the camp and hunting grounds of my people," she replied.

Morning Star shook his head and told her that she would have to take the baby and go back to the Blackfeet people. "It was wrong to dig up the sacred turnip. Sorrow has come to Sky Country. I cannot keep you now," he said. "When you return to your people, do not let our baby touch the ground for fourteen days. If he does, he will turn into a puffball and return to me. Then he will become a star."

The woman did not want to leave her husband, but she longed for her own people more. Sun called an old man to help return the woman to her people. The man brought a strong spider web. "I will tie you and your son to one end and let you down through the hole in the sky," he told her. So the old man let her down the turnip hole and right into her own camp.

"Here is the woman who went to the sky," some boys called when they saw her. "She has come back." Soon the whole camp came out to greet her and look at her baby.

Before the woman left Sky Country, Morning Star had told her to paint a morning star symbol on the back of her lodge so she would remember her mistake in digging up the turnip and not make another mistake and let the baby touch the ground. She did this and watched the baby very carefully for thirteen days.

On the fourteenth day, the woman's mother said, "I am tired. Will you go get water for our lodge? I will watch the baby." The young woman agreed but warned her mother against letting the baby touch the ground -- although she did not tell her why. The grandmother left the baby on the pallet a few feet away and was humming and doing beadwork in the sunlight. Now, the baby had just learned to crawl and wanted to play in the sunlight. He very quietly crawled off the pallet. Just as he touched the earth, he turned into a puffball and got tangled in a robe. The grandmother turned around and saw the bundle squirming. "He is asleep," she thought happily.

Soon the mother came back. "Where is my baby?" she asked.

"I just checked him. He is asleep in the robe," the grandmother answered.

The mother turned to pick up her son. In his place she found only a puffball.

That night a bright new star shone in the sky. The puffball had risen and stuck in the hole in the sky where the woman dug up the turnip. This is why that one star never moves. The Blackfoot call it Fixed Star.

The grief-stricken woman went home and painted circles all along the bottom of her lodge to represent the puffball her son had become.

**KEYWORDS:** *Moon, Sun, Root-Digger, Incense, Star, Beadwork, Fixed Star (North Star/Polaris)*

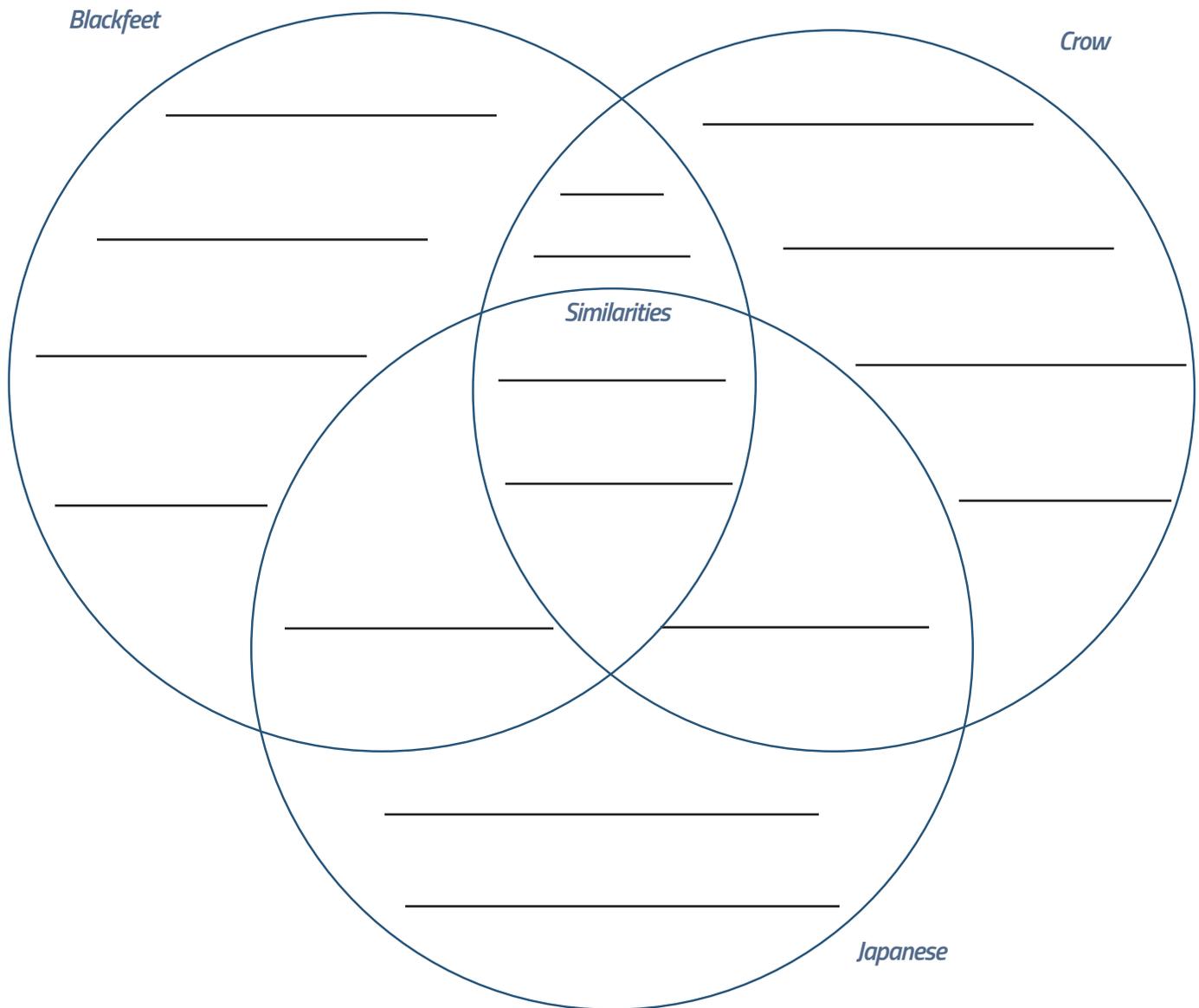
# STUDENT PAGE

## Astronomy Lesson 1: One Sky, Many Stories

### COMPARE AND CONTRAST

The Big Dipper is a constellation. Listen to the stories about this group of stars from Japanese, Crow and Blackfeet cultures. Using the Venn Diagram below, describe the similarities and differences in these stories.

### ANSWER





## STUDENT PAGE

### Astronomy Lesson 1: One Sky, Many Stories

How does our culture and where we live shape our understanding of the stars and stories we tell?

#### ANSWER

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Why do you think these stories are different from one another?

#### ANSWER

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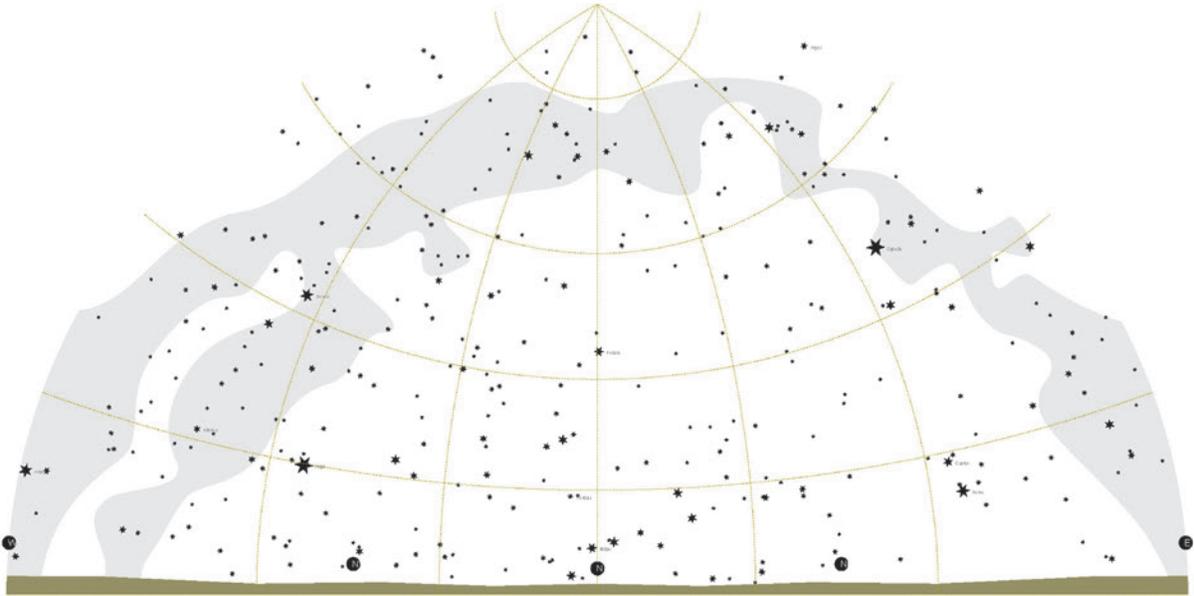
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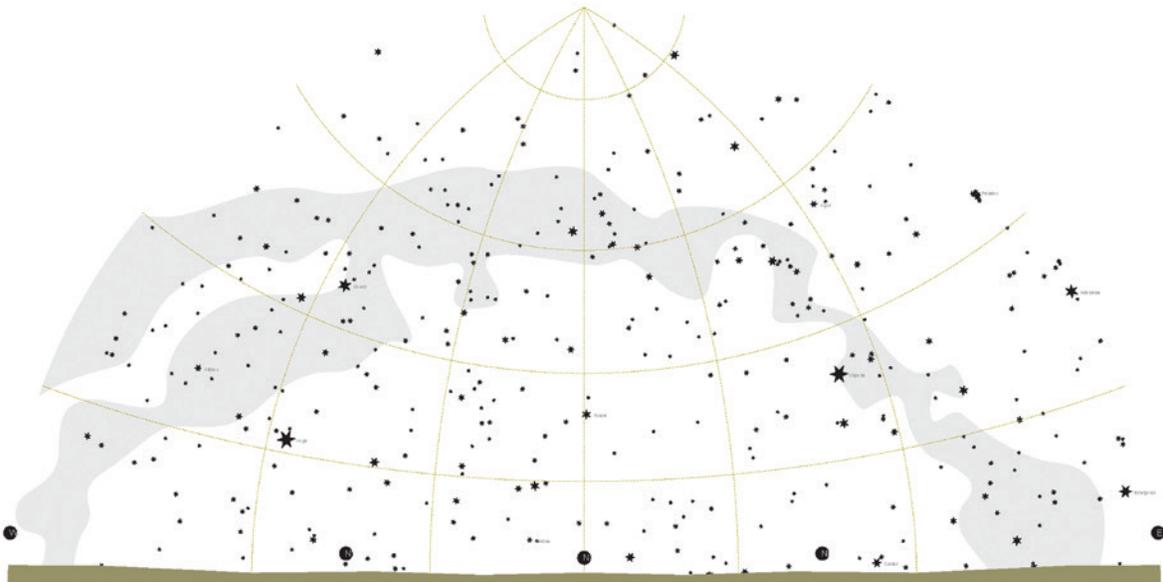
## Astronomy Lesson 1: One Sky, Many Stories

Choose one of the star maps below and draw a picture in the sky by connecting the dots.



Bozeman, Montana, USA

[Date] 2017 - 12 - 01 20:00:00 [Moon Age] 12/7



Kumamoto City, Kumamoto Prefecture, Japan

[Date] 2017 - 12 - 01 20:00:00 [Moon Age] 13

NOTICE THE DIFFERENCE BETWEEN THE TWO

This is because the night sky looks different depending on where you are on Earth.

Images by 星降る hoshifuru (hoshifuru.jp)





# 2

## **ASTRONOMY LESSON 2** Starscapes and Star Charts



## LESSON INSTRUCTIONS

### Astronomy Lesson 2: Starscapes & Star Charts

## GOAL

Using star maps, star charts, and star stories, students will explore how latitude and longitude can be used to determine one's place on Earth in relation to others and to the sky as a whole.

## OBJECTIVES

Students will be able to:

1. Explain how latitude affects the night sky seen in Kumamoto and Montana.
2. Describe how constellation stories are different for different cultures.
3. Proficiently use a star chart to identify constellations in their own night sky.

## ASSESSMENT

1. During class discussion, assess student comprehension of latitude through questions and answers.
2. Use the Venn Diagram student pages to measure if students are able to identify similarities and differences between the various star stories.
3. After students have created star charts, assess the students' ability to use the chart correctly by asking them to set the chart for different dates and times.

## MATERIALS

- o Power Point slides of the night sky in Kumamoto and Montana loaded onto a projection system
- o Prepared star chart copies, two charts per student (one for Kumamoto and one for Montana)
- o Copies of "Student Pages," one per student (pages 64-73)

## PREPARATION

- o Star stories from the Blackfeet people are told at night and often in the winter. Please plan to use these lessons in the winter months.
- o Make copies of the student pages, one per student.
- o Preview and load the video for later use in class.
- o The star charts for this lesson require extensive preparation. Each student should receive two star charts: one from Montana and one from Kumamoto. Prior to the lesson:
  1. Copy both pages of each chart (single-sided) on to cardstock paper. (Light weight paper makes the use of these charts difficult.)
  2. Cut out the main chart piece (colored pink). You will need to use a craft knife to remove the white interior sections of the chart.
  3. Depending on the amount of class time available and your students' abilities, students may cut out the black circle portion of the star map.

# LESSON INSTRUCTIONS

## Astronomy Lesson 2: Starscapes & Star Charts

LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
Begin the lesson by handing out the student pages. On the star maps for Kumamoto and Montana identify three popular constellations. Ask students how these maps are different and why.	Expect students to need help identifying constellations. Ask students direct questions to help them focus their efforts and find differences in the two maps.	This gives the teacher the opportunity to introduce the concept of latitude. Using the student worksheet with the world map, identify Montana's latitude (45 degrees) and Kumamoto's latitude (32 degrees).
Using the presentation slides, show students the images of the night sky as seen in Kumamoto, Goshoura, Ekalaka, and Yellowstone Park.	Expect students to need some help knowing what they should look for. Ask them to focus on what stars they see.	This gives teachers the opportunity to talk to students about how you can see more stars in rural areas.
Using the presentation slides, show an image of the Pleiades star cluster and have students find it on their maps.	Expect students to have some trouble recognizing the constellation.	This gives teachers the opportunity to reinforce the differences in the maps and to show that the constellation is in both skies, but in different places.
Tell students that they will be listening to stories about the Pleiades constellation from Japanese and Blackfeet cultures. Have students follow along on the student pages as you read the Japanese story. Use the OPI video for the Blackfeet story. After the stories, have students complete a Venn Diagram to compare and contrast the stories.	Invite students to share the differences and guide the discussion.	This gives teachers the opportunity to discuss how constellation stories can vary from one culture to another.
Hand out the prepared pieces of the two star charts. Have students cut and assemble the chart and teach them how to use them.	Expect students to need help assembling. Build a prototype. Use the instruction page for more details.	This gives teachers the opportunity to have students apply what they've learned through the readings and background information in a hands on activity.
Ask students to use their charts at home the following evening to find stars.	Finish the lesson in class the next day by having students volunteer to share what they discovered with their star charts.	This gives teachers the opportunity to tie lesson two into the final lesson of the unit, which incorporates constellations and star colors/brightness -- factors that are included on the star chart design.

# BACKGROUND INFORMATION

## Astronomy Lesson 2: Starscapes & Star Charts

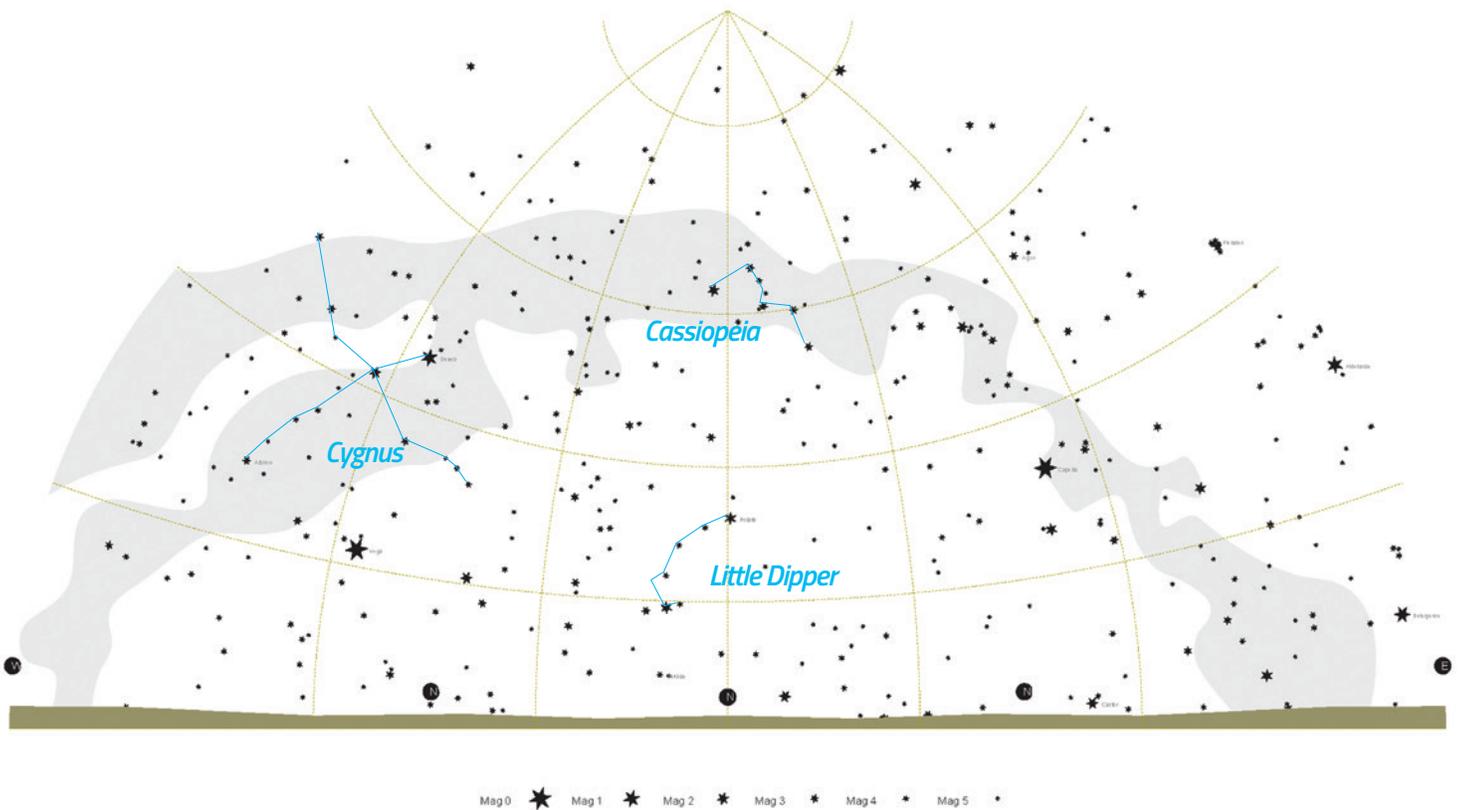


Image by 星降る hoshifuru (hoshifuru.jp)

Kumamoto City, Kumamoto Prefecture, Japan

[Date] 2017-12-01 20:00:00 [Moon Age] 13

Above is a horizon view of the night sky as seen from Kumamoto.

The difference between the two is because Kumamoto and Montana are located at different latitudes on the Earth. Montana is about  $45^\circ$  north of the equator, and Kumamoto is about  $32^\circ$  north of the equator. In the Kumamoto skies Polaris (the North Star) will be slightly lower on the Northern horizon, and some stars will rise on the Southern horizon that cannot be seen in Montana.

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## Astronomy Lesson 2: Starscapes & Star Charts

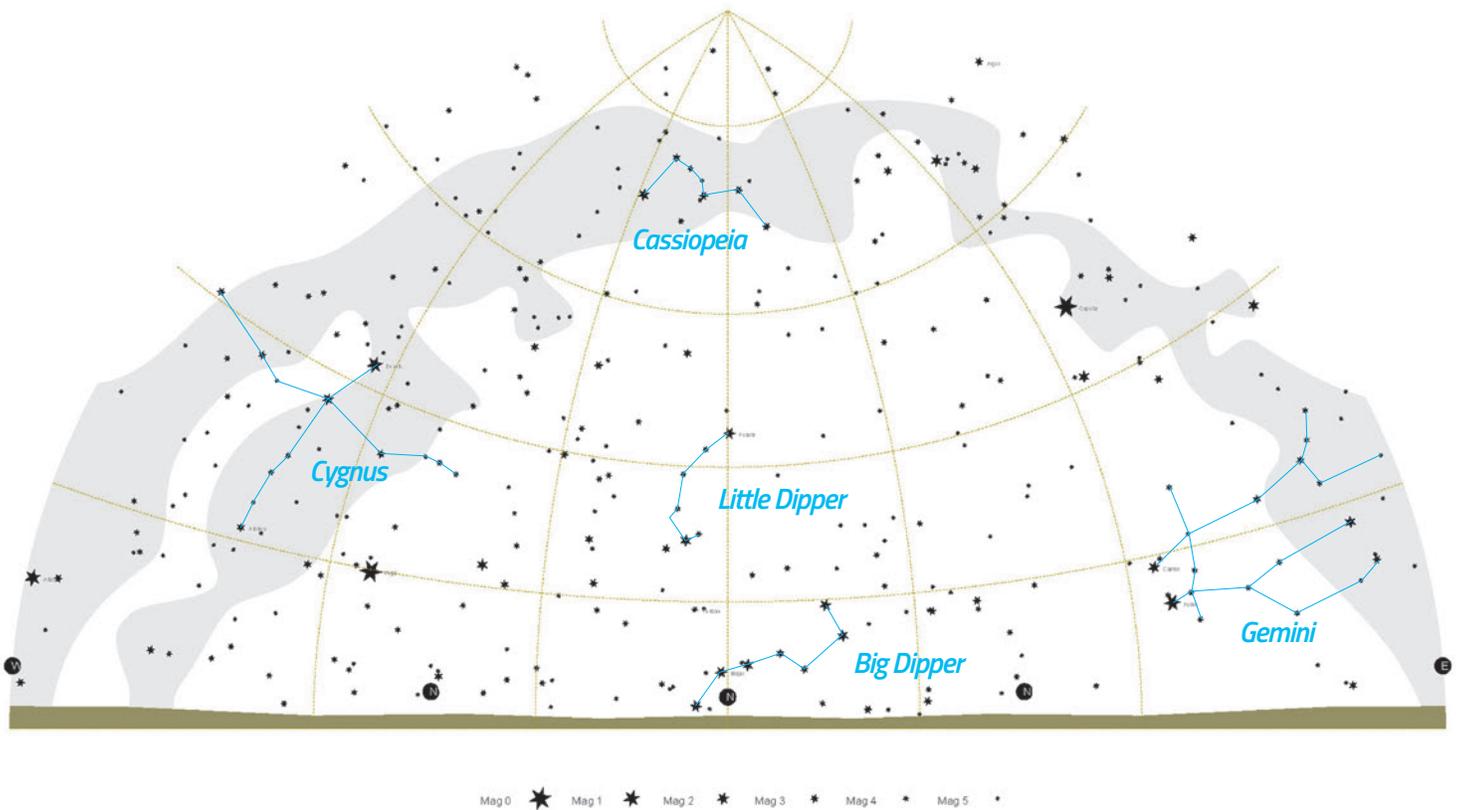


Image by 星降る hoshifuru (hoshifuru.jp)

Bozeman, Montana, USA

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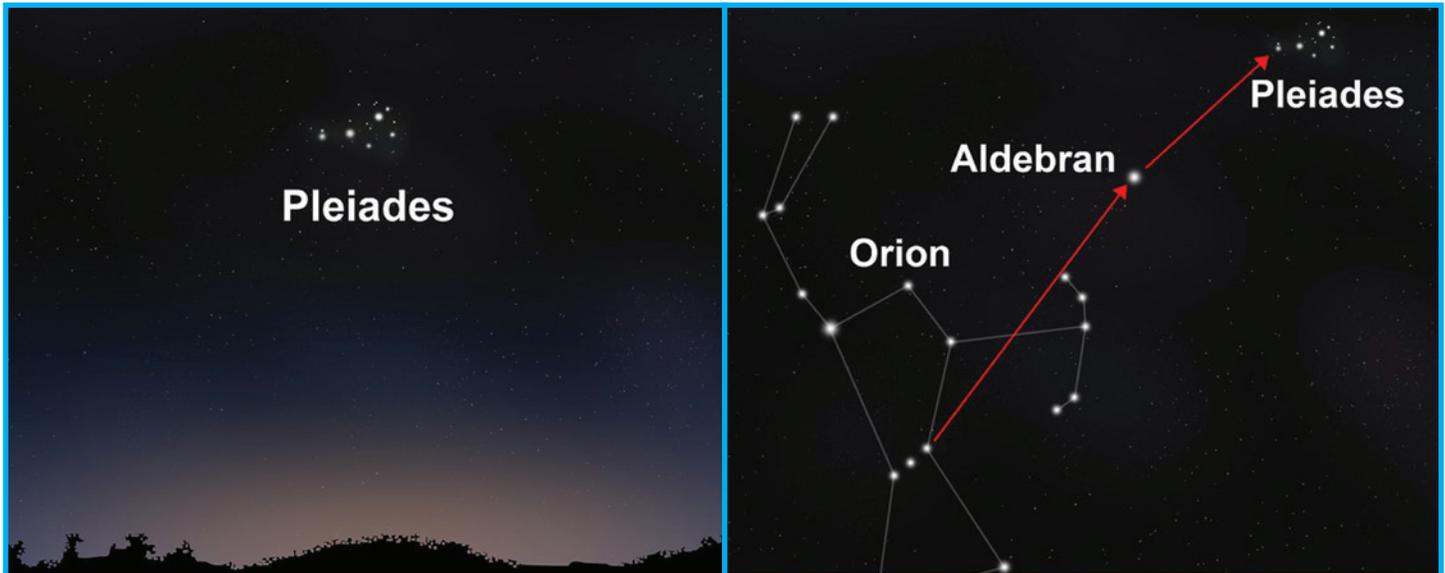
Above is a horizon view of the night sky as seen from Montana.

Let's focus on the Big Dipper, for example. You can see the Big Dipper in Montana throughout the year, but in Kumamoto you will not be able to see it on winter nights. The starry sky of Montana and the starry sky of Kumamoto may look similar, however, there are many differences including constellations that can only be seen in one country and not the other. This affects the stories told about stars as well.

# BACKGROUND INFORMATION

## Astronomy Lesson 2: Starscapes & Star Charts

### PLEIADES: STAR STORIES FOR THIS LESSON



CONSTELLATION	JAPANESE	GREEK	BLACKFEET
Pleiades	Murikabushi	The Seven Sisters	Bunched Stars

These legends focus on the constellation Pleiades, which are a group of seven stars, sometimes referred to as the “Seven Sisters”. The Pleiades cluster is about 410 light years from Earth, and contains roughly 400 stars.

The constellation of Pleiades is used in popular culture for the car company Subaru, which is the Japanese name for the star cluster.



Images courtesy Wikipedia

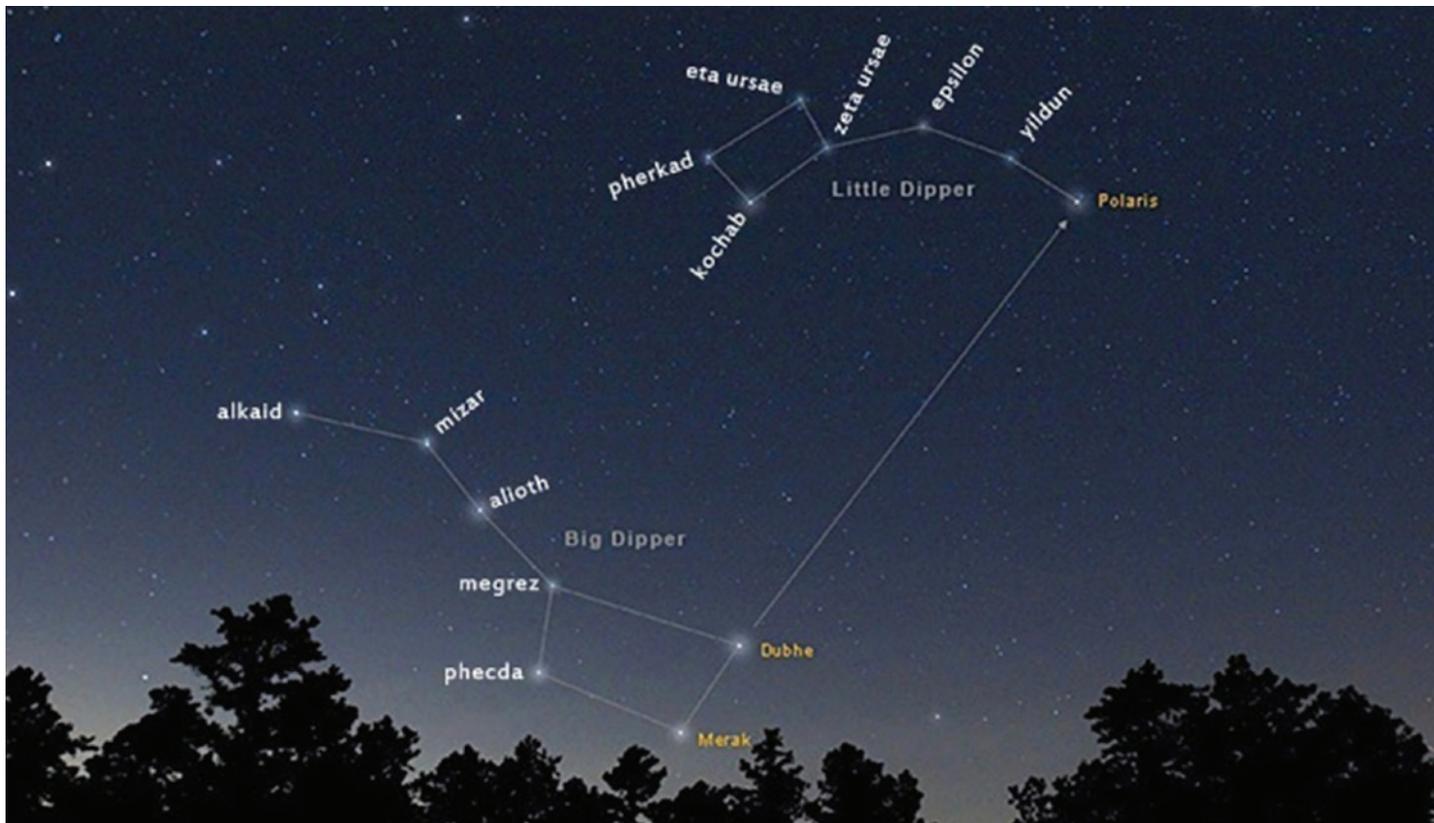
Some American Indian tribes used the constellation as an eye test for young adults and children. People who could see more than seven stars had exceptional vision, whereas seeing 6 stars meant the person had average vision. Less might be an indication of near-sightedness.

This test gave elders who told the stories indications of the skills their listeners may have as they grew up. Hunters who could see long distances were particularly useful to the tribes.

# BACKGROUND INFORMATION

## Astronomy Lesson 2: Starscapes & Star Charts

### STAR CHART INSTRUCTIONS



The star charts for this lesson require extensive preparation. Each student should receive two star charts: one from Montana and one from Kumamoto. Prior to the lesson:

1. Copy both pages of each chart (single-sided) on to cardstock paper. (Light weight paper makes the use of these charts difficult so use cardstock if possible.)
2. Cut out the main chart piece (colored pink). You will need to use a craft knife to remove the white interior sections of the chart.
3. Depending on the amount of class time available and your students' abilities, students may cut out the black circle portion of the star map.

To use the star chart, pick the date and hour you want to observe and set the chart so this date (located on the rim of the cut out sphere) matches the time indicated on the sleeve (the pink chart). The sphere shows the whole sky, and the curved edge of the oval on the chart represents the horizon you're facing.

Once outside, hold the chart in front of you and line up the chart so that it faces North. Remember that the sun sets in the west and look for Polaris, the North Star. The stars within the oval should map the stars in front of you.

*Note: If students have trouble turning the star chart, or if the sphere doesn't fit, they can cut slits up from the top cutouts.*

*Image courtesy Wikipedia*

# STUDENT PAGE

## Astronomy Lesson 2: Starscapes & Star Charts

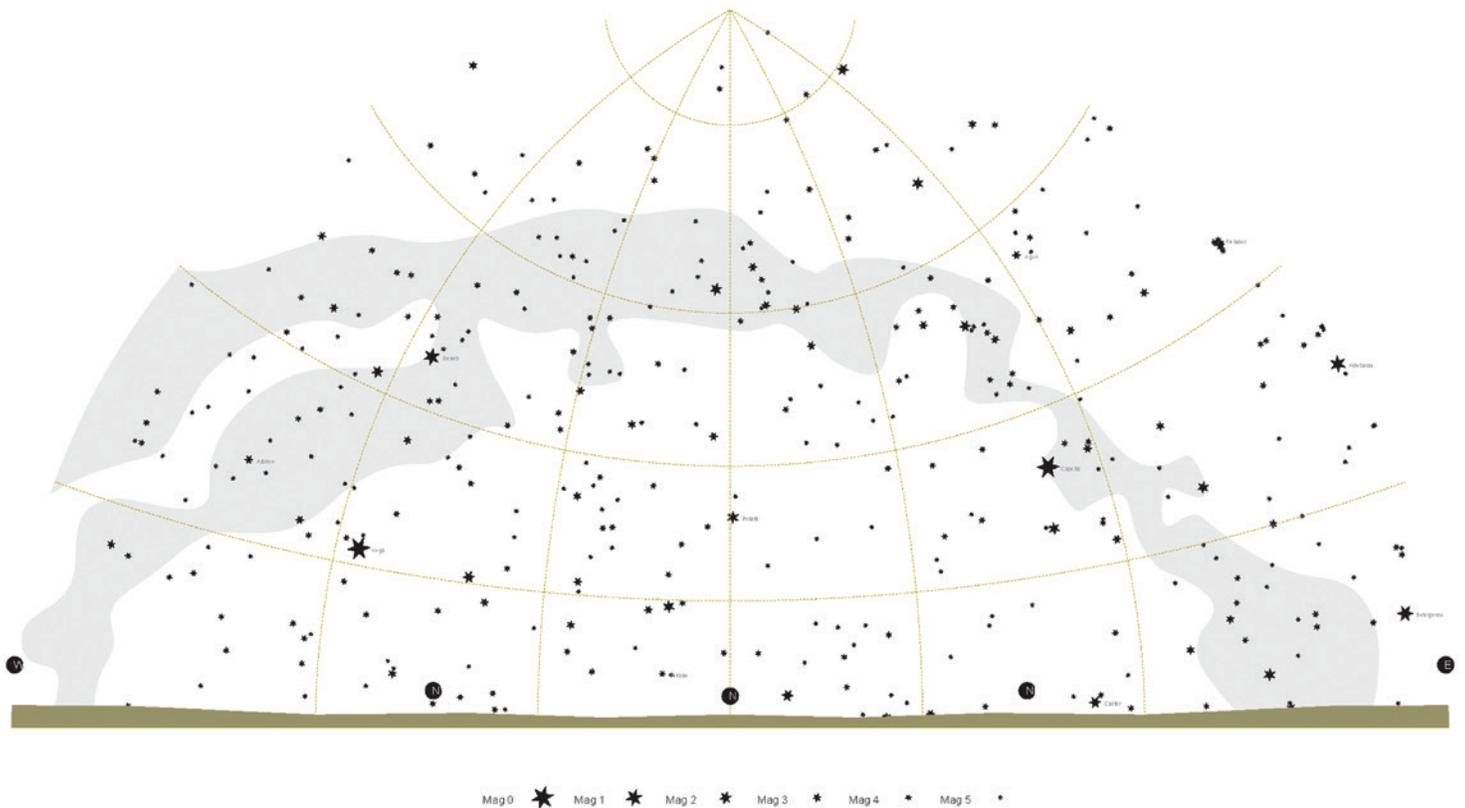


Image by 星降る hoshifuru (hoshifuru.jp)

Kumamoto City, Kumamoto Prefecture, Japan

[Date] 2017-12-01 20:00:00 [Moon Age] 13

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## Astronomy Lesson 2: Starscapes & Star Charts

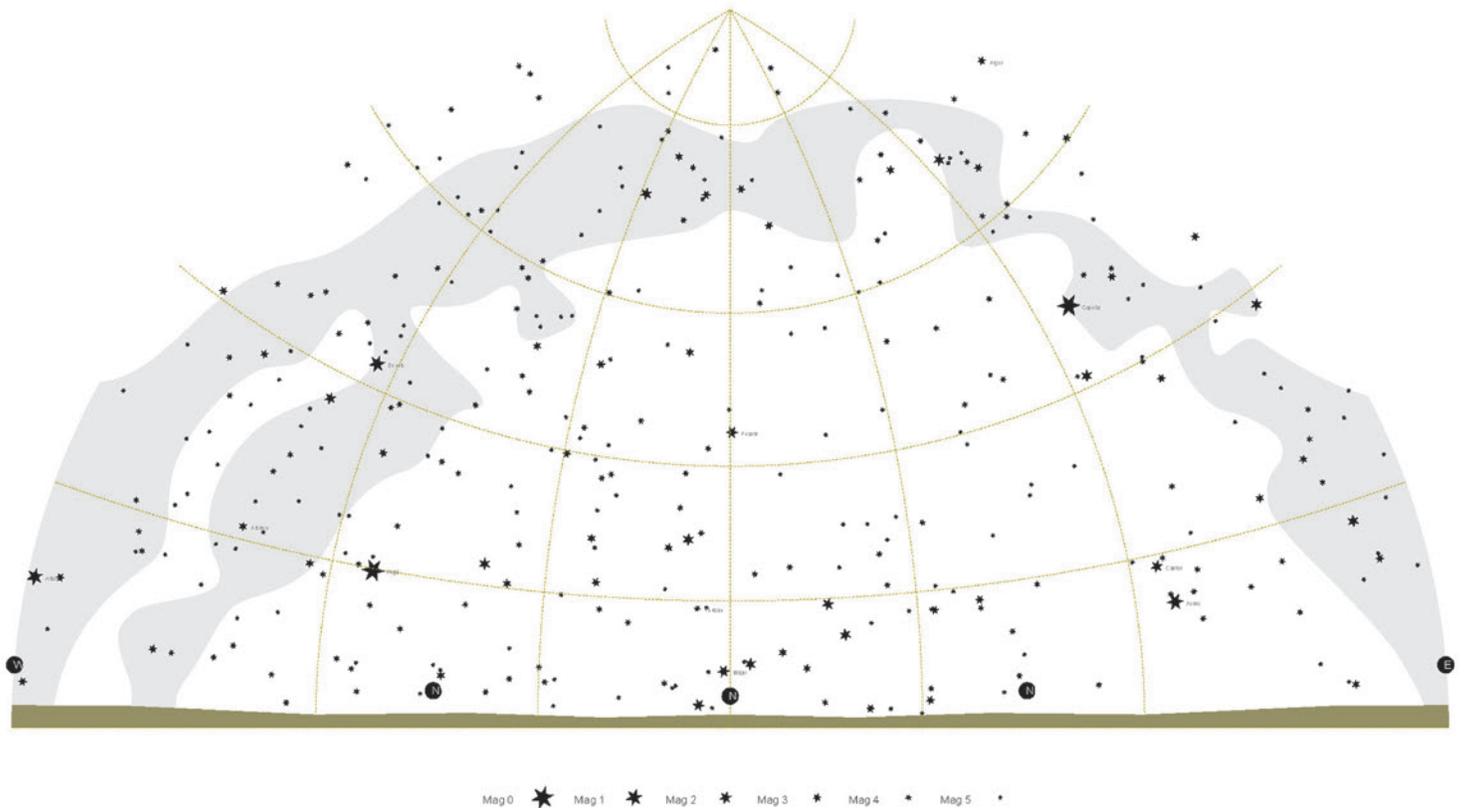


Image by 星降る hoshifuru (hoshifuru.jp)

Bozeman, Montana, USA

[Date] 2017-12-01 20:00:00n [Moon Age] 12:7

Above is a horizon view of the night sky as seen from Montana.

Let's focus on the Big Dipper, for example. You can see the Big Dipper in Montana throughout the year, but in Kumamoto you will not be able to see it on winter nights. The starry sky of Montana and the starry sky of Kumamoto may look similar, however, there are many differences including constellations that can only be seen in one country and not the other. This affects the stories told about stars as well.

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## Astronomy Lesson 2: Starscapes & Star Charts

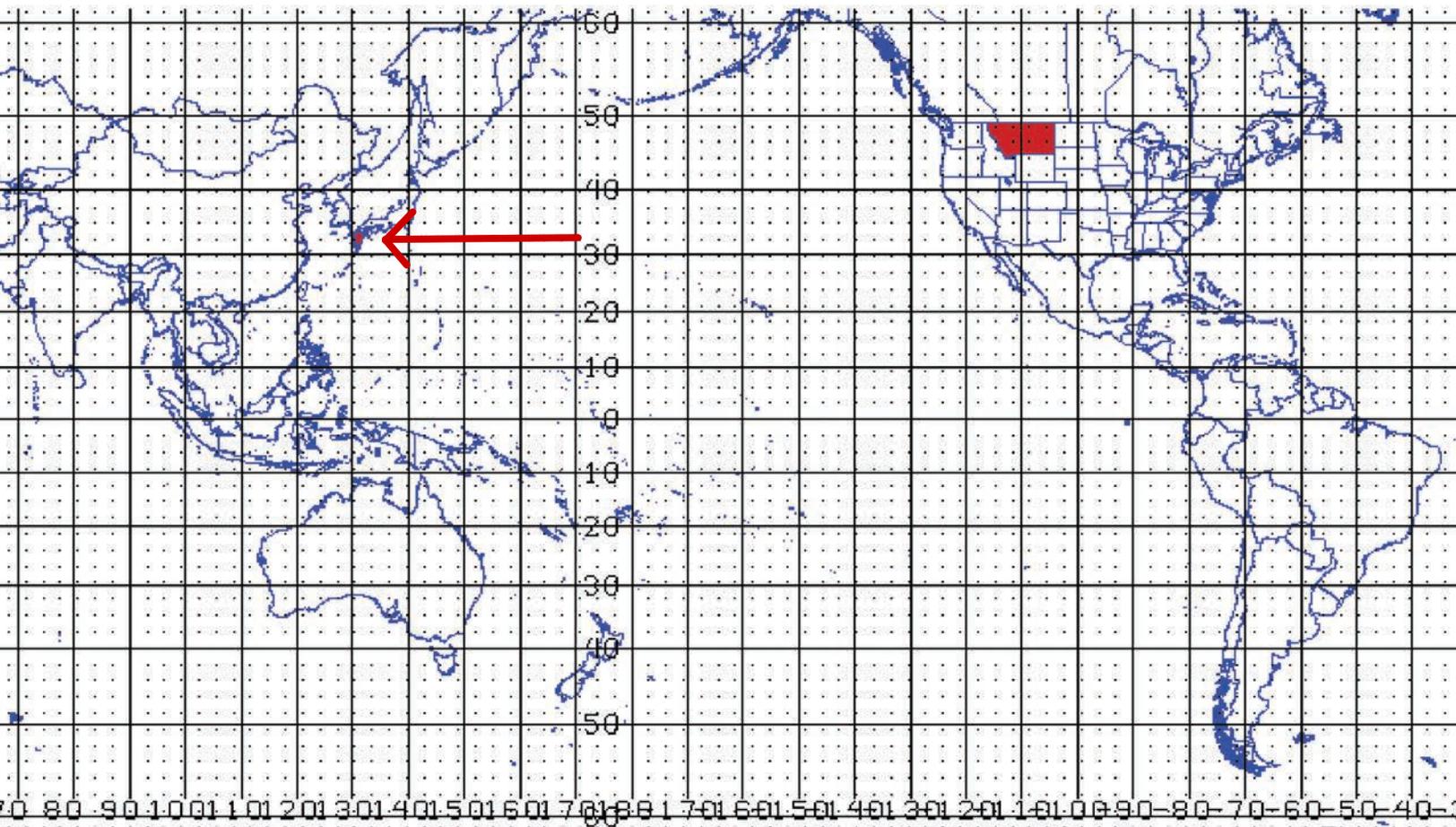


Image courtesy National Oceanic and Atmospheric Administration

### LATITUDE AND LONGITUDE

BOZEMAN, MT:  $45.6770^{\circ}$  N,  $111.0429^{\circ}$  W  
EKALAKA, MT:  $45.8889^{\circ}$  N,  $104.5527^{\circ}$  W

KUMAMOTO CITY, JAPAN:  $32.8031^{\circ}$  N,  $130.7079^{\circ}$  E  
GOSHOURA ISLAND, JAPAN:  $32.4667^{\circ}$  N,  $130.2000^{\circ}$  E

*The Pleiades is a star cluster located in the constellation Taurus (the bull). It is commonly addressed as the "Seven Sisters" in Greek mythology, but has different names in other cultures. The Blackfeet, a tribe in Montana, refers to the constellation as "Bunched Stars" and the Japanese have a story about it called "Murikabushi"*

## STUDENT PAGE

### Astronomy Lesson 2: Starscapes & Star Charts

#### JAPANESE

##### “Murikabushi” (Okinawa, Japan)

Long ago, the people who lived on the island of Okinawa were unable to find enough food, and many were starving. For this reason, the King of heaven summoned Nishinanachibushii and Hainanachiibushii and ordered them to help the people on the island.

But they refused the King’s order and he angrily banished Nishinanachibushii and Hainanachiibushii to the corner of the sky. From that day on, Nishinanachibushii became known as the Big Dipper, and Hainanachiibushii the Milk Dipper.

Then the little star Murikabushi spoke and said, “I will try to help them!” So Murikabushi passed through the zenith every day to keep watch on the island. The people on the island began to use Murikabushi’s position in the sky to help them determine when they should plant and grow their crops.

Thanks to Murikabushi, the people on the island of Okinawa would enjoy large harvests that would feed everyone.

Today Murikabushi is called Pleiades.

**KEYWORDS:** *Pleiades, Latitude, Zenith*

#### BLACKFEET

##### Bunched Stars (Blackfeet Nation)

*NOTE: Story courtesy “Montana Skies” by Lynn Moroney, Office of Public Instruction (2011)*

**The Blackfeet people do not tell stories in the summer and so it is, only in the deepest, coldest time of winter is the following story told.**

*It is best to show students a 15 minute video for the story:*  
<https://youtu.be/DUkZdEocUzY>

It is a clear winter night. Tonight, the stars seem to sparkle more brightly than usual. High above we can see a small group of stars known to the Blackfeet people as the bunched stars.

When the Blackfeet people see these six stars, they are reminded of a story of six brothers. Sit quietly and let your imagination see the story as you listen to its words, which teach parents and elders to treat young people properly and tells us about family love and how the six brothers came to live in the sky.

There once lived a certain family, a father, a mother, and their six boys. The father was not a very good hunter and the mother was able to gather only a few roots and berries to feed them. They were very poor. The six brothers spent their time close together because they had no friends.

In those days, it was the custom that when the buffalo were calving, buffalo robes made from calf hides were made for all the young people. The calf robes were yellow, whereas the buffalo robes of the older buffalo were dark brown. The children placed the robes around themselves and played “buffalo”.

Each spring, every child got a new yellow buffalo robe. That is every child except the six boys. Year after year, it was the same. The boys hoped for yellow robes but none came. The other children in the camp made fun of the boys, telling the six that they looked foolish in their brown robes. The boys

## STUDENT PAGE

### Astronomy Lesson 2: Starscapes & Star Charts

were embarrassed. They lived each day in anger because of the many hateful words and deeds they had to endure.

One day, the brothers agreed that after the next spring, if they received no yellow robes, they would go far away from their people. Someplace so far away that they would never have to hear the ugly words and laughter of those that made fun of them. The brothers decided they would go live in the sky.

When spring came, the people went out for a big buffalo hunt, but like all the springs before, there were no yellow robes for the boys. The brothers agreed, "Now we shall go to the sky." One of the boys said, "When we get to the sky, let us take away all the water in the land for seven days and seven nights. Taking water from the people will be a good way to punish them for all the bad things they have said to us."

They prepared to go to the sky. The oldest brother took some weasel hairs and carefully he placed a few hairs on the backs of his brothers. Then he said to them, "Close your eyes and no matter what, do not open them until I tell you." The five younger brothers closed their eyes and kept them shut, just as they were told.

The oldest brother took a few more weasel hairs and put them in his mouth. Next, placing the hairs in his hands, he rubbed his palms together, then tossed the hairs up. Up into the air. A few moments passed, and the oldest brother spoke, "Now you may open your eyes."

The brothers were amazed, they were in the sky and they were in the lodge of the Sun and the Moon. Sun spoke to the boys, "Why have you come to the sky?" The boys told Sun about never having yellow robes like the others and how their people made fun of them because they were poor and had to wear brown robes. Sun then asked, "What do you want of me?"

"We ask that you punish the people for having treated us so badly. Take water away from all the people for seven days," said the boys.

Sun said nothing. But Moon took pity on the boys and began to weep. She told the boys she would help them, but explained that they would have to stay in the sky forever. Moon asked Sun to help the boys, but Sun said nothing, not a sound. She asked Sun again, but again Sun did not answer. Only when she asked a seventh time did Sun agree to help her.

The very next day, all the Earth was hot. Streams, rivers, creeks and lakes dried to nothing but sand. There was no water anywhere to be seen. That night, the people took two dogs and went to the dry riverbed. When they reached the bank of the river, the two dogs began to dig, and after a while, water came out of the hole they were digging. The dogs had made a spring. Water came from Mother Earth. This is the first time such a thing had happened.

The days continued to be hot and the people dug holes in the Earth. They lived in the holes for it was the only way to stay alive. During the next few days, the dogs made more springs. Then, on the sixth day, the dogs howled, sending their voices to Sun and Moon. The leader of the dogs was a medicine dog, and he prayed, "Sun and Moon, have pity on us." On the seventh day, Sun and Moon let it rain and water returned to the Earth.

Ever since that time, the six brothers have lived in the sky and as they were on Earth, so they are in the sky. They remain close to one another, a family of stars seen by all and called, "The Bunched Stars." Look for the Bunched Stars in the fall, the winter and the spring. Bunched together so closely, you can reach your hand to the sky and cover them with your thumb. The brothers cannot be seen in the summer. For by summer, the time for calving is over and the Earth is hot and dry. And that is the end of the story of the Bunched Stars.

**KEYWORDS:** *Buffalo robe, Sun, Moon, Earth*

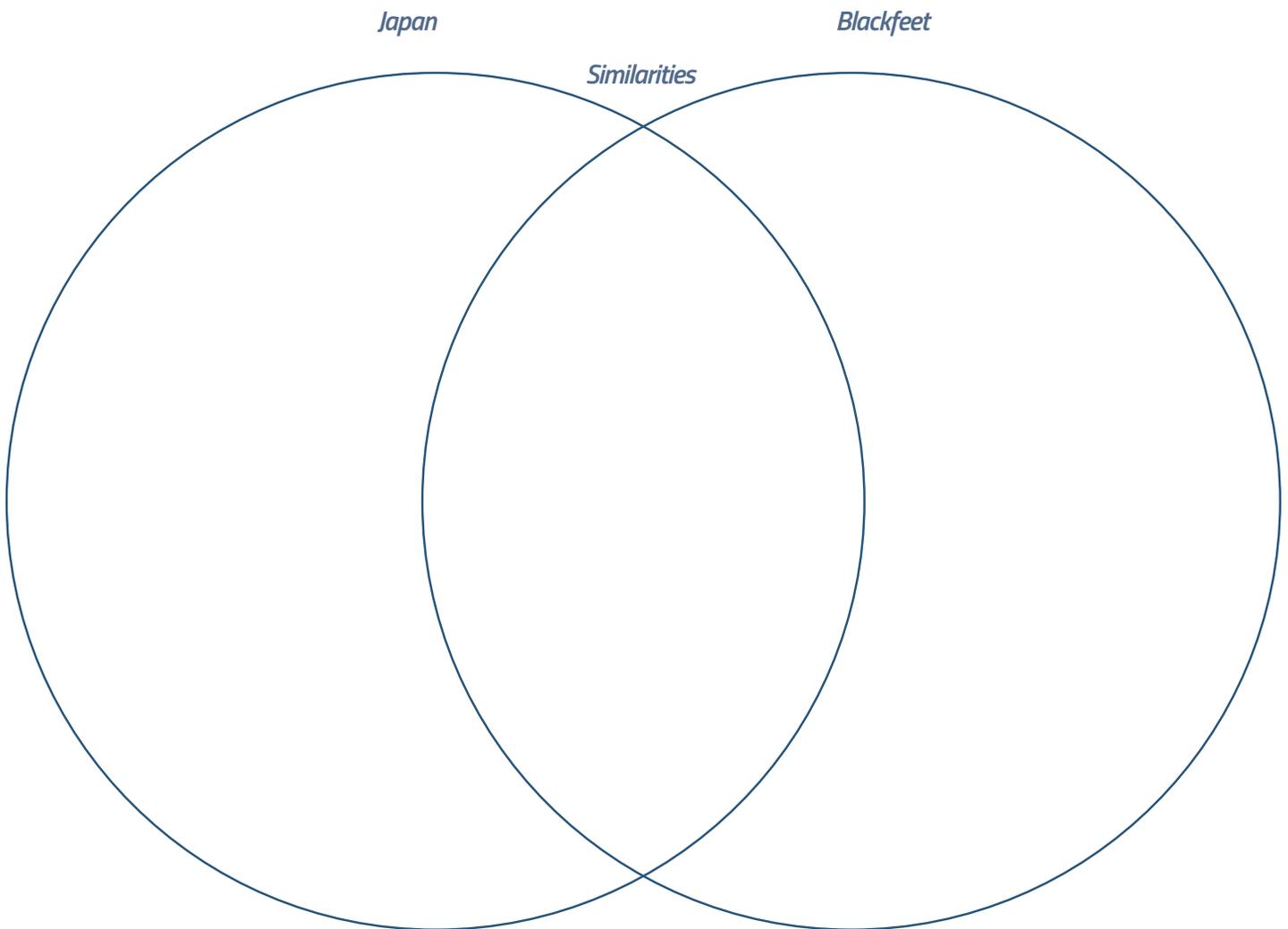
# STUDENT PAGE

## Astronomy Lesson 2: Starscapes & Star Charts

### COMPARE AND CONTRAST

Listen to the stories about Pleiades from Japanese and Blackfeet cultures. Write details that explain how the stories are different in the outer circles. Write details that tell how the stories are the same where the circles overlap.

### ANSWER

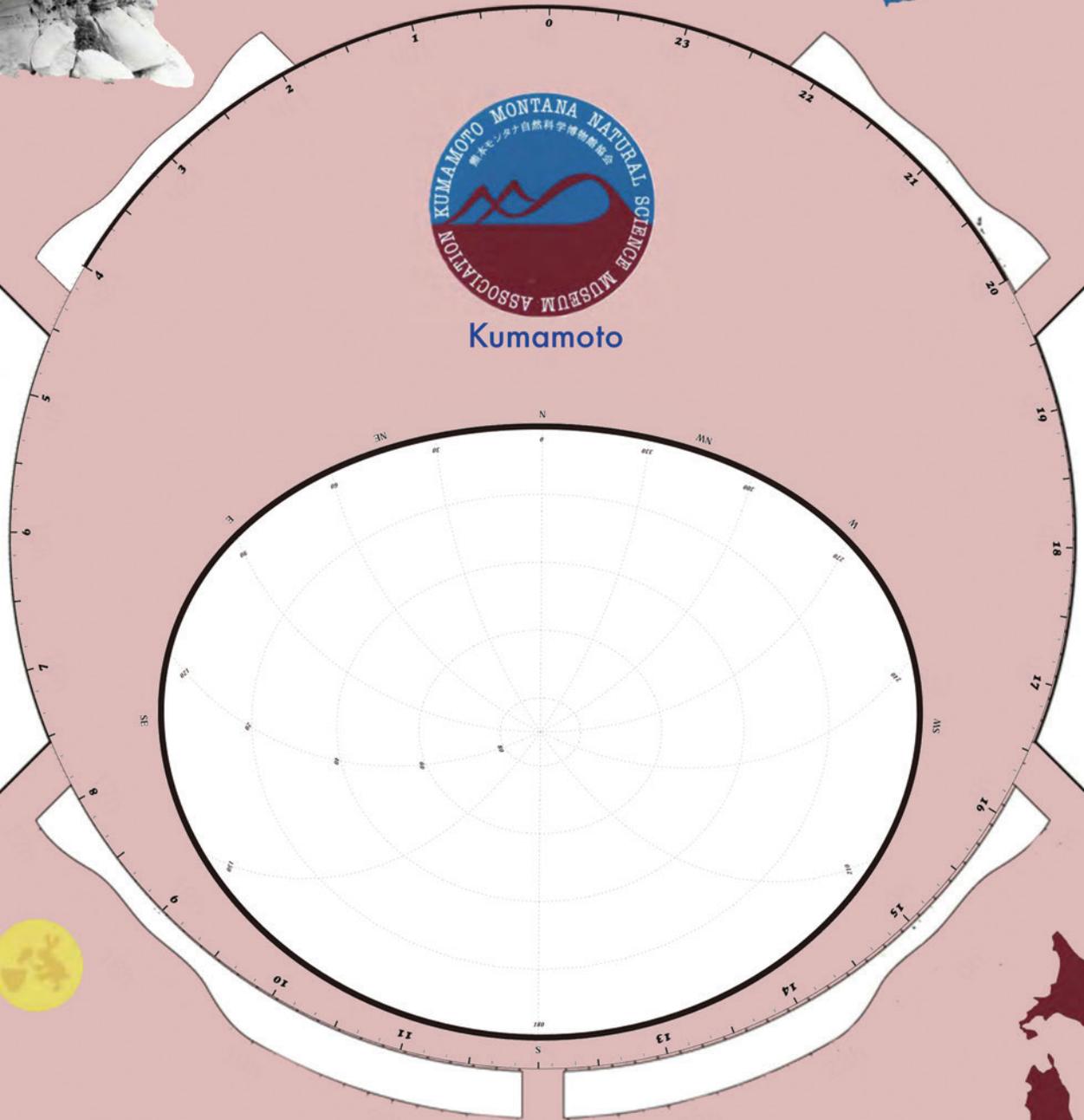


# Our Home, Our World

私たちのふるさと、私たちの世界

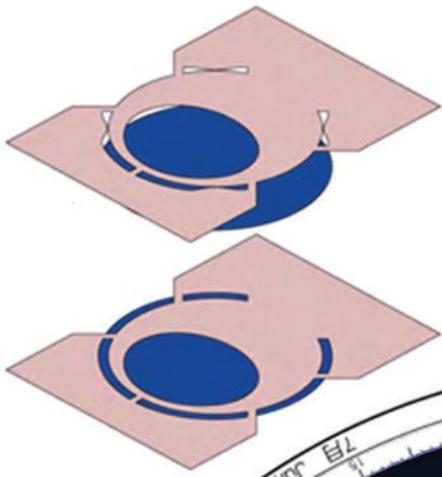


Kumamoto

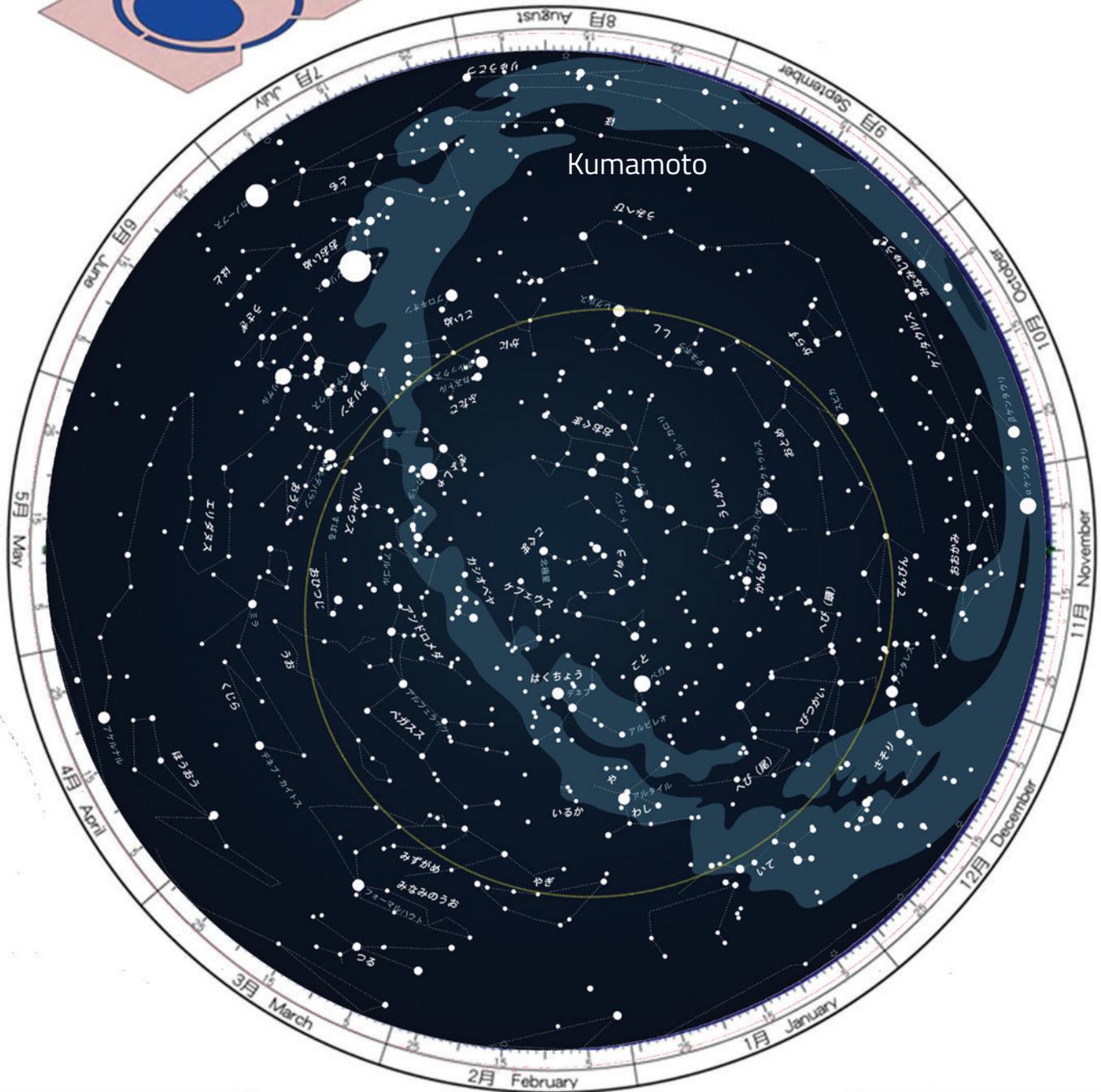


星座早見(熊本版)  
Personal Star Chart





1. Fold this paper in half on the vertical axis.
2. Cut out the star chart by trimming away the white portions.
3. Cut out the black star map by following the black line.
4. Arrange the chart as shown in the diagram.



## To use the chart:

Image by 星降る hoshifuru (hoshifuru.jp)

Adjust the scale of the date and the scale of the time to the date and time you want to see by turning the disk. Then the stars for that date and time will be visible from the window.

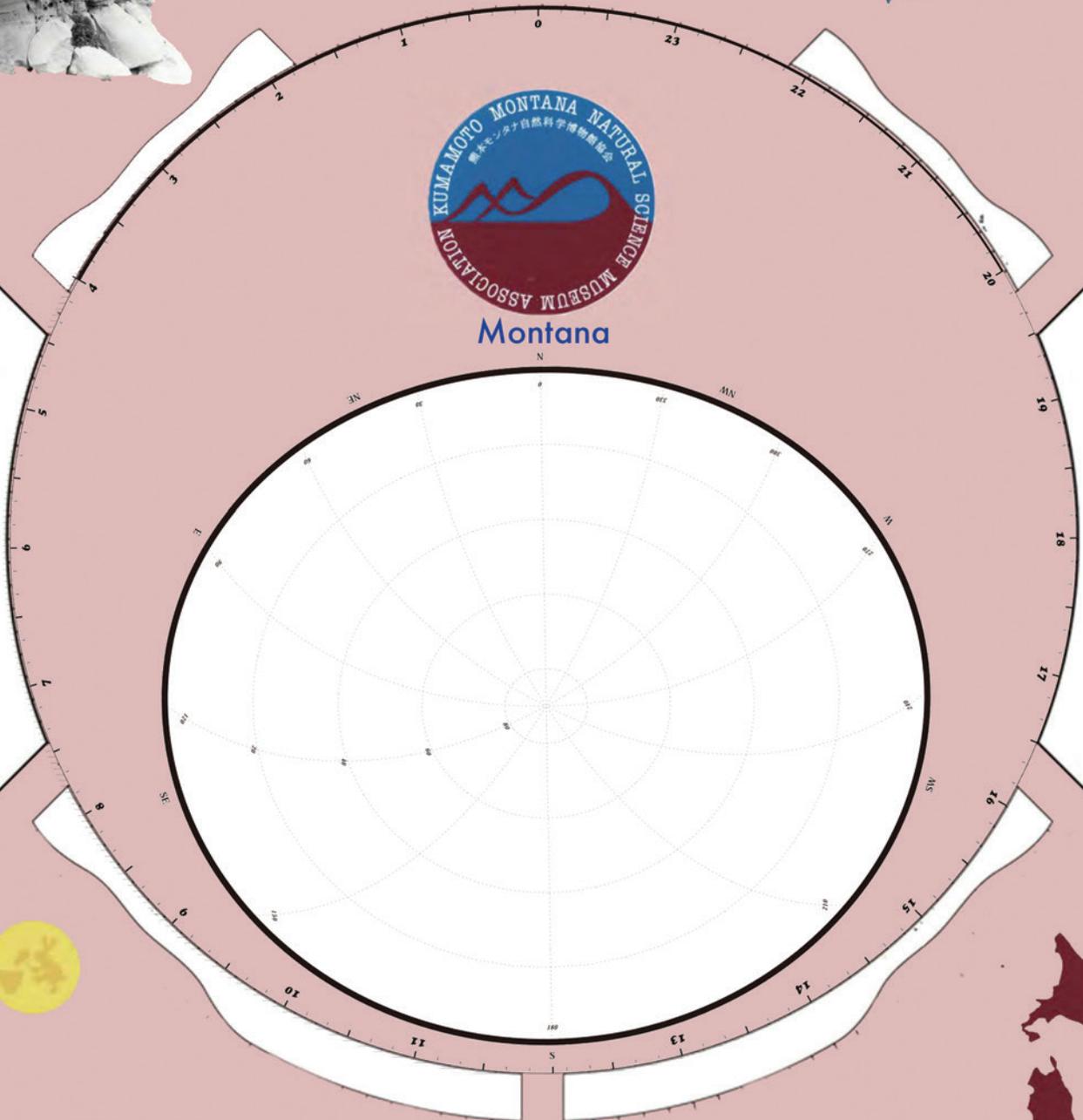


# Our Home, Our World

私たちのふるさと、私たちの世界

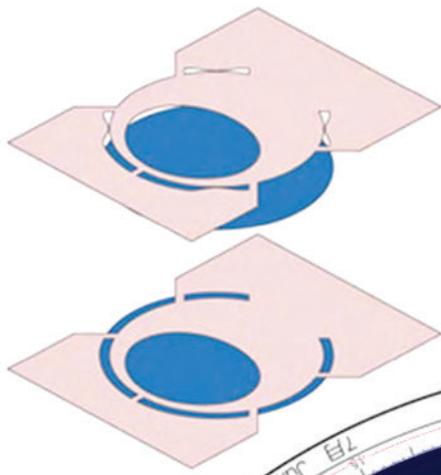


Montana

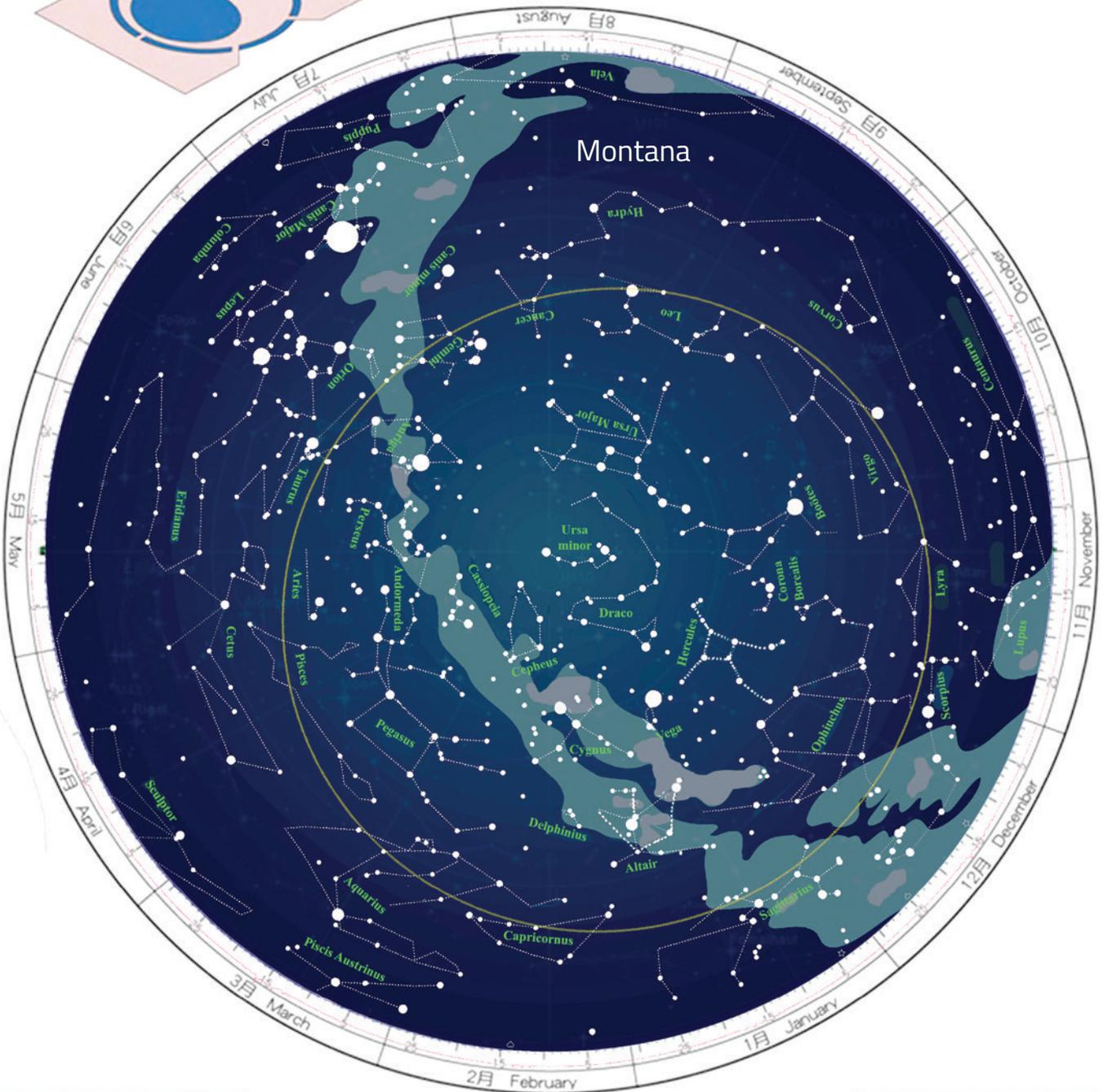


星座早見 (モンタナ版)  
Personal Star Chart





1. Fold this paper in half on the vertical axis.
2. Cut out the star chart by trimming away the white portions.
3. Cut out the black star map by following the black line.
4. Arrange the chart as shown in the diagram.



## To use the chart:

Image by 星降るhoshifuru (hoshifuru.jp)

Adjust the scale of the date and the scale of the time to the date and time you want to see by turning the disk. Then the stars for that date and time will be visible from the window.





# 3

## **ASTRONOMY LESSON 3** Colorful Constellations, Classifying Stars



# LESSON INSTRUCTIONS

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

### GOAL

Using the constellation Orion, students will continue to study cultural oral traditions while learning about scientific concepts including star color, size, brightness, and distance.

### OBJECTIVES

Students will be able to:

1. Describe how constellation stories are different for different cultures.
2. Explain why different stars have different colors.
3. Discuss how star brightness is related to type of star it is and its distance from Earth.

### ASSESSMENT

1. Use the Venn Diagram student pages to measure if students are able to identify similarities and differences between the various star stories.
2. During the discussion about the seven stars of Orion and labeling those stars, use discussion and students' coloring to measure understanding of star colors and types.
3. Use the activity of labeling the stars of Orion to assess through discussion student understanding of magnitude or brightness.

### MATERIALS

- o Video: "Glow On: Crash Course Kids #20.2" loaded onto a projection system
  - - <https://youtu.be/Zo-sKzMWYFA> (5:09 minutes)
- o Video: "Star Personalities: Crash Course Kids #25.2" loaded onto a projection system
  - - [https://youtu.be/2PO\\_jMgmLvs](https://youtu.be/2PO_jMgmLvs) (4:25 minutes)
- o Copies of "Student Pages," one per student (pages 82-88)

### PREPARATION

- o The Crow people do not tell stories in the summer and so it is, only in the deepest, coldest time of winter may their stories be told. Please plan to use this lesson in the winter months.
- o Familiarize yourself with the constellation Orion by visiting this website: <http://www.constellation-guide.com/constellation-list/orion-constellation/>. Load the video links for star brightness (5:09 min : <https://youtu.be/Zo-sKzMWYFA>) and properties (4:25 min : [https://youtu.be/2PO\\_jMgmLvs](https://youtu.be/2PO_jMgmLvs)).
- o Make copies of the student pages, one per student.
- o Preview and load the videos for later use in class.

# LESSON INSTRUCTIONS

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Tell students that they will be listening to stories about the Orion constellation from Japanese and Crow cultures. Have students follow along on the student pages as you read the Japanese and Crow stories. After the stories, have students complete a Venn Diagram to compare and contrast the stories.</p>	<p>Invite students to share the similarities and differences.</p>	<p>This gives teachers the opportunity to discuss how star stories can vary from culture to culture. Help students identify that the Japanese story focuses on Betelgeuse and Rigel, while the Crow story uses the three stars in Orion's belt.</p>
<p>Show the video about star brightness to the class. Use the H-R diagram to compare and contrast different stars, including Betelgeuse.</p>	<p>Link the topic back to the story from Japan by asking students why Betelgeuse is red and Rigel is blue. This is due to the star's temperature.</p>	<p>This provides the opportunity to introduce that colors, sizes, and the brightness of stars do not always relate.</p>
<p>Have students look at the chart of the properties of Orion's stars. As a class, identify the colors of the constellations' stars and their apparent magnitude (or brightness).</p>	<p>Expect that students will need help reading the magnitude column.</p>	<p>This gives the teacher the opportunity to introduce the table of Orion's stars and discuss light and distance in space.</p>
<p>Show the video about star properties to the class. Ask students to look at the table describing the properties of Orion's stars again. Identify the temperatures and size/type of the constellations' stars.</p>	<p>Expect students to need help linking the star type to its size.</p>	<p>This gives the teacher the opportunity to build on the previous discussion and compare and contrast the stars of Orion.</p>
<p>Have students use the Properties of Orion's Main Stars table to label and color the seven stars of Orion on the student page.</p>	<p>Expect students to have some difficulty labeling the stars. Use the meanings of the star names, their locations, and magnitude to help students with labeling.</p>	<p>This gives teachers the opportunity to continue to reinforce the concepts of how stars are classified while tying the stars back to stories.</p>
<p>Review the student page as a class. Ask the class why Betelgeuse is red and why the stars are drawn in different sizes.</p>	<p>Encourage students to share their answers with the class and discuss what they have learned.</p>	<p>This gives teachers the opportunity to check comprehension of the lesson and address questions.</p>

# BACKGROUND INFORMATION

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

### STAR COLOR AND BRIGHTNESS

Star color depends on its surface temperature, which is determined by its age and mass. A Hertzsprung–Russell (H-R) Diagram is a graph that plots the color of stars in relation to their absolute magnitude. Within the diagram, there are three different types of stars: main sequence (like our sun), giants and supergiants, and smaller stars known as white dwarfs.

The intensity distribution for each wavelength and type such as electromagnetic waves and sound waves is called a spectrum, and if you make the spectrum of a star's light, you can see why the star color varies with temperature.

Looking at the spectrum of a star's light, you can see what kind of light is emitted from a star and how strongly it is radiated. The star's light is said to be close to the "black body radiation spectrum" whose spectrum shape changes only with the temperature of the radiator (the one that is emitting light). The high temperature star has many components of blue light. The lower temperature star has more red light components. Due to this nature the color of the star is determined by the temperature.

At Orion's upper left is the bright red star Betelgeuse [BET-el- jooz, not beetle-juice]. This is a red supergiant star, one of the biggest stars known: 1000 times as big as the Sun, and 100,000 more luminous. Red supergiants have a great amount of volume but not a great amount of mass and they have fewer convection cells than our Sun, but those cells are much larger. This extra volume cools the star, making these red supergiants the least hot of the giant stars.

There are two kinds of "magnitude" which is a unit indicating the brightness of a star.

One is an "apparent magnitude" which is the brightness of the star seen from the Earth, and the star rating we normally use is this apparent grade. It is different from actual star brightness because it shows the brightness of the star as seen from the Earth. The brightest star in the constellations is minus 1.46 apparent magnitude. This star is called Sirius in Canis Major.

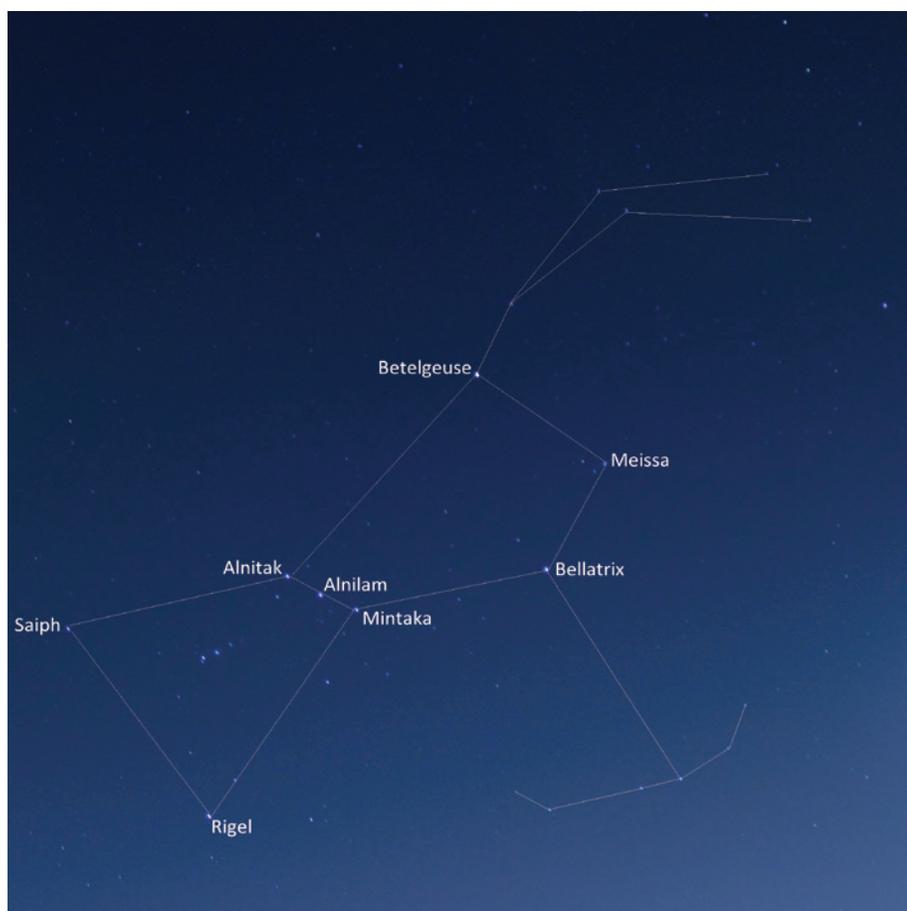
The other is "absolute magnitude" which is the apparent magnitude an object would have if it were located at a distance of 10 parsecs (about 3.26 light years). Since it does not take into consideration change of brightness by distance, it becomes a grade reflecting the original brightness of the star. For example, since the Sun is a celestial body very close to the Earth, it is extremely bright with a 26.75 apparent magnitude. It has an absolute magnitude of 4.83: how bright it would look to us at 10 parsecs.

Stars with lower magnitudes (even negative magnitudes) are brighter. Larger magnitudes are fainter stars.

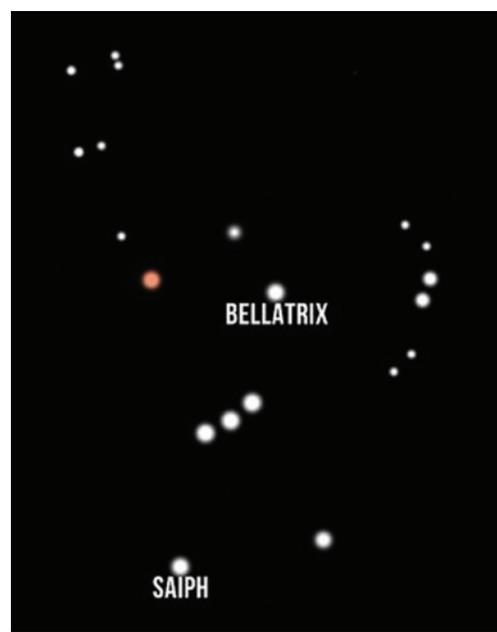
# BACKGROUND INFORMATION

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

CONSTELLATION/STAR	JAPANESE	GREEK	CROW
Orion	Genji and Heike	Orion	The Twins and the Hand Star



Images courtesy wikihow





# BACKGROUND INFORMATION

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

### VOCABULARY

Citation: Discovery Education, Merriam-Webster

#### NEBULA:

A cloud of interstellar gas and dust.

#### PROTOSTAR:

An early stage in the evolution of a star, after the beginning of the collapse of the gas cloud from which it is formed, but before sufficient contraction has occurred to permit initiation of nuclear reactions at its core.

#### STAR:

A natural luminous body visible in the sky especially at night; a self-luminous gaseous spheroidal celestial body of great mass which produces energy by means of nuclear fusion reactions.

#### RED GIANT:

An intermediate stage of a star's evolution during which the hydrogen fuel supply begins to run out the star's core contracts; the outer shell begins to expand and, because it is also cooling, glows red.

#### RED DWARF:

A star having substantially lower surface temperature, intrinsic luminosity, mass, and size than the sun.

#### WHITE DWARF:

A star, approximately the size of the Earth, that has undergone gravitational collapse and is in the final stage of evolution for low-mass stars, beginning hot and white and ending cold and dark.

#### SUPERNOVA:

The final explosion of a large star, caused by the gravitational collapse of the core, during which the star's luminosity increases by as much as 20 magnitudes and most of the star's mass is blown away at very high velocity, sometimes leaving behind an extremely dense core.

#### LIGHT-YEAR:

A unit of length in astronomy equal to the distance that light travels in one year in a vacuum or about 5.88 trillion miles (9.46 trillion kilometers).

#### APPARENT MAGNITUDE:

The luminosity of a celestial body (such as a star) as observed from the Earth.

#### ABSOLUTE MAGNITUDE:

A measure of the intrinsic luminosity of a celestial body (such as a star) expressed as the apparent magnitude the body would have if viewed from a distance of 10 parsecs.

#### BLACK HOLE:

A region of space having a gravitational field so intense that no matter or radiation can escape.

#### NEUTRON STAR:

The dense, compact core that remains after a supernova.

#### PULSAR:

A rapidly spinning neutron star that emits repeating pulses of energy.

## STUDENT PAGE

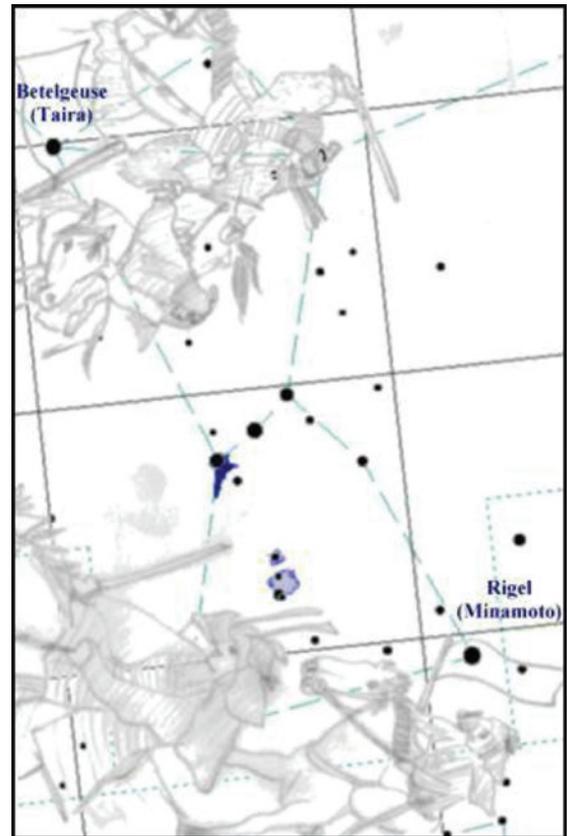
### Astronomy Lesson 3: Colorful Constellations, Classifying Stars

#### GENJI AND HEIKE (GIFU, JAPAN)

During the 12th century in Japan, a legendary war took place between the aristocratic Taira and Samurai Minamoto families. The largest battle took place in Okumino, Gifu Prefecture. The Minamoto family won the war which brought an end to the peaceful Heian era in 1192. In Japanese lore, the two brightest stars in the constellation Orion are named Heike (Betelgeuse) and Genji (Rigel). These two bright stars represent the colors of the families. Heike is the red star and represents the color of the Taira family, and Genji is the white star that represents the color of the Minamoto family.

It is believed that Heike and Genji continue to battle, with the three stars in Orion's belt keeping them apart. Because of the tremendous bravery and loyalty demonstrated by both families during the war, the colors red and white continue to have special significance in Japan, most notably the colors of the Japanese flag.

**KEYWORDS:** *Star color, Orion*



*A Genpei Battle pitting the family of Minamoto (Rigel) against that of the Taira (Betelgeuse).*

*Image by Saori Ihara and Steve Renshaw*

## STUDENT PAGE

### Astronomy Lesson 3: Colorful Constellations, Classifying Stars

#### THE TWINS AND THE HAND STAR (CROW NATION)

*NOTE: Story courtesy "Montana Skies: Crow Astronomy" by Lynn Moroney, OPI (2011)*

**The Crow people do not tell stories in the summer and so it is, only in the deepest, coldest time of winter is the following story told.**

Long ago, it was the custom for newly married couples to go out a ways and hunt antelope, deer and other kinds of animals. In this way, they were able to enjoy the meat of the season. And so it was that a certain young man and his wife was with child. He spent the days hunting and she went about the work of the lodge.

One day, the man returned home to find that his wife was dead and the child she carried was missing. The man built a funeral scaffold, placed his wife's body upon it and for a long time he wept and grieved the loss of his dear wife and child. A few years passed and they say that the man was inside his lodge preparing food when he heard a sound. He looked up, saw nothing. But he heard a child's voice, "Father, will you give me something to eat?" The man said, "Come out and show yourself." And out from the tipi lining appeared a little boy. The man gave food to the child. After that, the little boy stayed with the man.

The man was pleased to have a son. The boy played around the camp while the man went out to hunt each day. This went on for a while. One day when the boy was playing outside, he saw another boy just his age. The new boy had risen out of a nearby spring. The two boys played all day but when they heard the father returning home, the boy from the spring was frightened and ran back to the spring. The next day when the father left to hunt, the boy from the spring returned and the two new friends played each day after that.

The father had come to love the boy who had appeared from behind the tipi lining and often made small toys and carvings for him. In time, he made a set of arrows and gave them to the boy. The next day, the boy from the spring wished he might have arrows and that night, the boy from behind the tipi lining asked his father to make a second set. After that, each time the boy was given something, he always wanted one more, a second this, a second that. The father became curious and asked his son why he always wanted two of everything. "I have a twin brother," said the boy, "before we were born, an evil woman killed our mother. She threw me behind the tipi lining and my twin was thrown into a nearby spring. He has lived with the water animals and evil water creatures. He is like them."

The father knew then that the boy from the lining was truly his son and he wondered about his other son. But because the boy was raised by animals and was afraid of the father, the father had to make a plan to capture him. First, he built a sweat lodge and he said to his son from behind the lining, "Play with your bother as usual, but then grab him, call for me and I'll come running." That day, while the boys were playing, the boy from behind the lining waited for the right moment. He grabbed his brother and called out, "Father, come! I have him."

The father rushed to them and held the boy from the spring with all his might. He shouted to the boy from behind the lining, "Run! Run! Start the sweat!" He then took the son he was holding into the sweat lodge and held him there. The father poured water upon the hot stones. The lodge filled with steam and grew hotter and hotter. The boy screamed, "Father, I am burning! Father, let me go! I'll burn to death." But the father held the son in his arms and would not let go of him. At last, the boy remembered who he was. He realized that he was not a water being. He was not an animal. He remembered that he was a human being. After that, the three lived together. Each day the brothers played and the father

## STUDENT PAGE

### Astronomy Lesson 3: Colorful Constellations, Classifying Stars

went out to hunt. The boys were then named Thrown Behind the Tipi Lining and Thrown Into the Spring. One day, Thrown Into the Spring asked his brother, "Where is our mother?" Upon learning she was dead, Thrown Into the Spring said, "I can bring her back to life." They gathered up some of her belongings and went to the place where her body was on the scaffold. Thrown Into the Spring threw the mother's hatchet into the air and cried out, "Mother, be careful! Your hatchet might hurt you!" And her body moved a little. He tossed up her pestle, "Mother, your pestle will hit you." She moved a little more. He tossed up her mortar, "Mother, your mortar is going to hit you." She moved even more. Lastly, he tossed her comb and cried out, "Mother, get up! Comb your hair." And with that she sat up. She had returned to life!

When the father returned home that evening, it was a joyous reunion. The mother had prepared food, the lodge fire was burning, and once again, they were a family. The mother warned her children of all the evil things that were around and just waiting to harm them. When she told them about a bear who lived in a berry patch, the boys went forth and killed the bear. When she told them about a dangerous cougar, the boys went forth and killed the cougar. Then she told them about an elk who had captured the wind and when he opened his mouth, people flew into it. The boys went forth to kill the elk, but when they got close to the elk, he sucked them in and held them with others he had in his stomach. Thrown Into the Spring used his magic knife to stab the elk's heart. He cut the side of the elk open and all of those who had been captured were released.

Tired after all this, the brothers went into a deep sleep. Upon waking, Thrown Into the Spring was nowhere to be seen. No footprints, no signs at all. Thrown Behind the

Tipi Lining shot one of his magic arrows into the sky. He shot another and another. The arrows led him to a place in the sky where there lived an old woman, the Moon. They heard singing and drumming, the sky people had captured Thrown Into the Spring and were planning to kill and eat him.

Thrown Behind the Tipi Lining pretended he too wanted to join the feast. He and Moon went to the lodge where there was singing. Thrown Into the Spring was almost dead. He opened his eyes and saw his brother who had come to save him. Thrown Behind the Tipi Lining shouted at the leader who was known as The One With a Long Arm, "Let go of my brother, or I will destroy you!" He showed his power by using a magic arrow to shatter a rock into small pieces. Afraid, Long Arm let go of Thrown Into the Spring. Thrown Behind the Tipi Lining gathered up his brother and the two returned to Earth.

But they were not yet safe, for Long Arm wanted his revenge. He reached down to Earth and tried to grab Thrown Into the Spring. Thrown Into the Spring acted quickly. Using his magic knife, he cut off the hand of Long Arm and tossed the hand into the sky.

It can be seen even now, high above the winter's sky. Look for the hand in the sky. When you see it, remember the story of the twin brothers, how they had great power, and how the sweat lodge can heal those who forget who they are and who they belong to.

**KEYWORDS:** *Mortar, Pestle, Sweat Lodge, Burial Scaffold, Tipi*

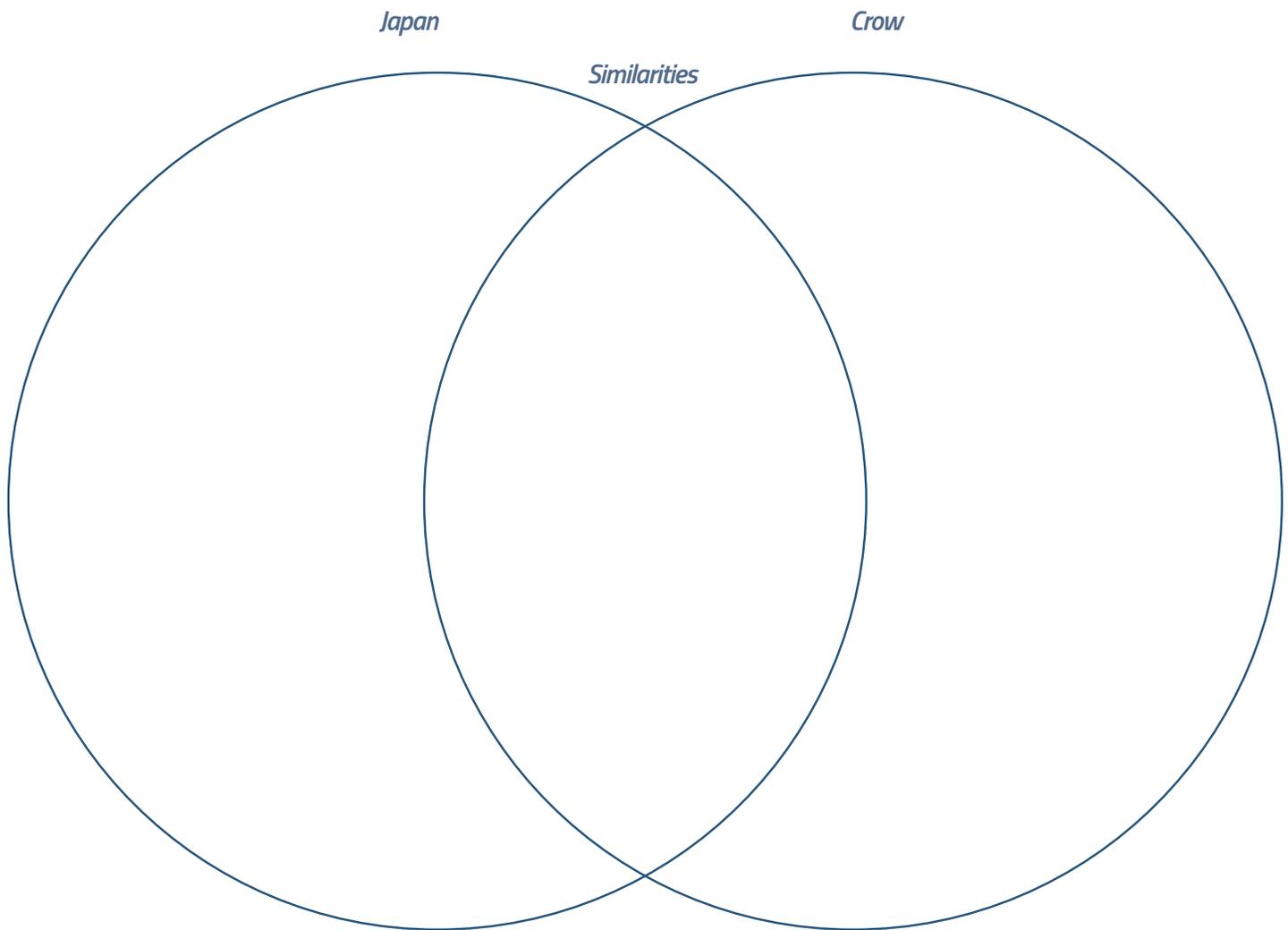
# STUDENT PAGE

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

### COMPARE AND CONTRAST

Listen to the stories about Orion from Japanese and Crow cultures. Write details that explain how the stories are different in the outer circles. Write details that tell how the stories are the same where the circles overlap.

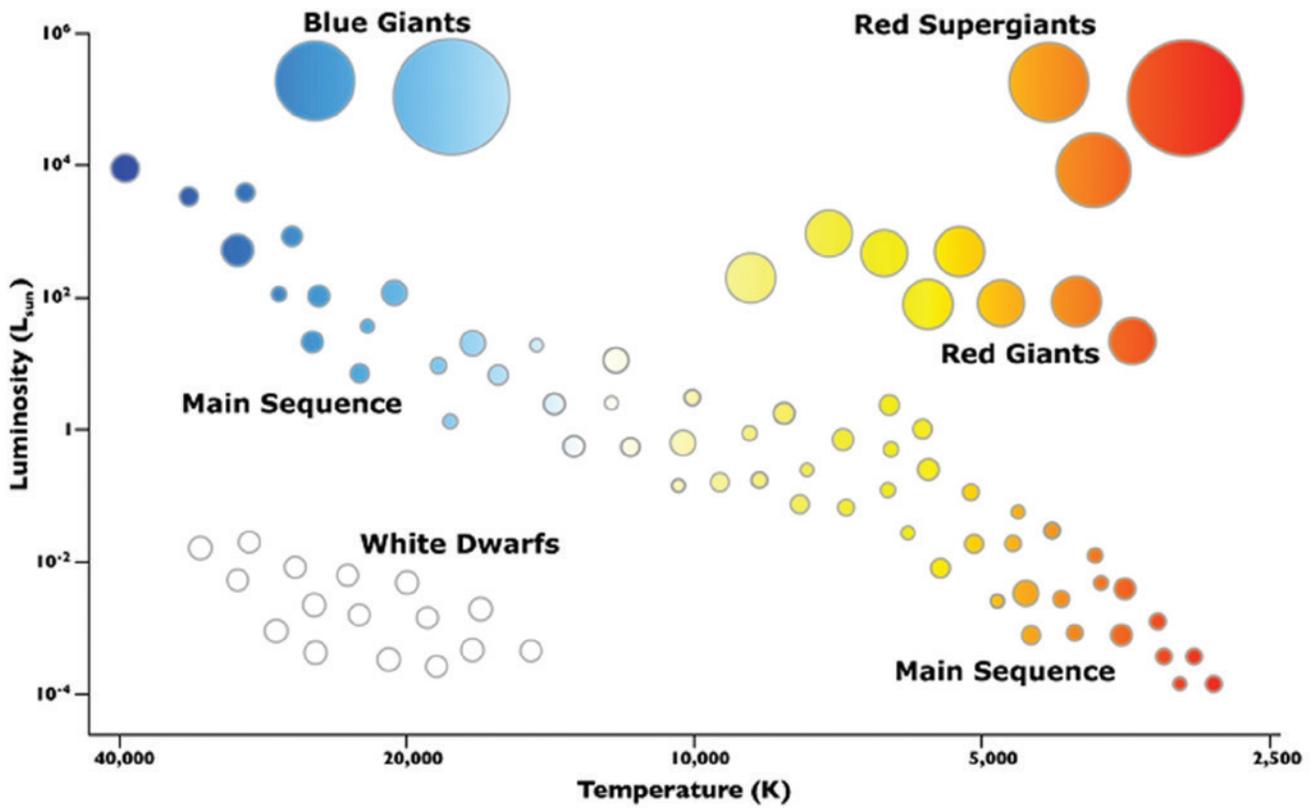
### ANSWER



# STUDENT PAGE

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

### HERTZSPRUNG-RUSSELL (H-R) DIAGRAM



*Image courtesy creative commons*

# STUDENT PAGE

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

### STAR COLOR AND BRIGHTNESS IN ORION

The three stars that form the belt of Orion make up a constellation in many cultures. In Australia, the belt is called the Saucepan, in South Africa, it's The Three Kings and in Spain and Latin America, The Three Marys. In the Crow tribe in Montana, the belt makes up the wrist in the constellation known as the Hand Star and in Japan, Betelgeuse and Rigel correlate to a tale of military history.

There are seven major stars in the constellation of Orion: Betelgeuse; Bellatrix; Alnitak; Alnilam; Mintaka; Saiph and Rigel. Betelgeuse and Rigel are the brightest stars in the constellation and eighth and sixth brightest in the night sky, respectively. The star properties are covered in the table below.

### PROPERTIES OF ORION'S MAIN STARS

STAR NAME	COLOR	TYPE	TEMPERATURE (celcius)	APPARENT MAGNITUDE* (BRIGHTNESS)	DISTANCE (Light Years)	NAME MEANING	LOCATION IN ORION
Betelgeuse	Red	Supergiant	3,000	0.42	643	Hand Of Orion	Right Shoulder
Rigel	Blue	Supergiant	10,000	0.18	860	Left Foot	Left Foot
Bellatrix	Blue	Giant	21,000	1.659 - 1.64	250	Female Warrior	Left Shoulder
Mintaka	Blue	Giant	33,000	2.23	1200	Belt	Belt ( Right )
Alnilam	Blue	Supergiant	27,000	1.64 - 1.74	2000	String of Pearls	Belt (Middle)
Alnitak	Blue	Triple Star	33,000	1.77	1260	Girdle	Belt (Left)
Saiph	White	Supergiant	26,000	2.09	650	Sword	Right Foot

*\*Stars with lower magnitudes are brighter. Larger magnitudes are fainter stars.*

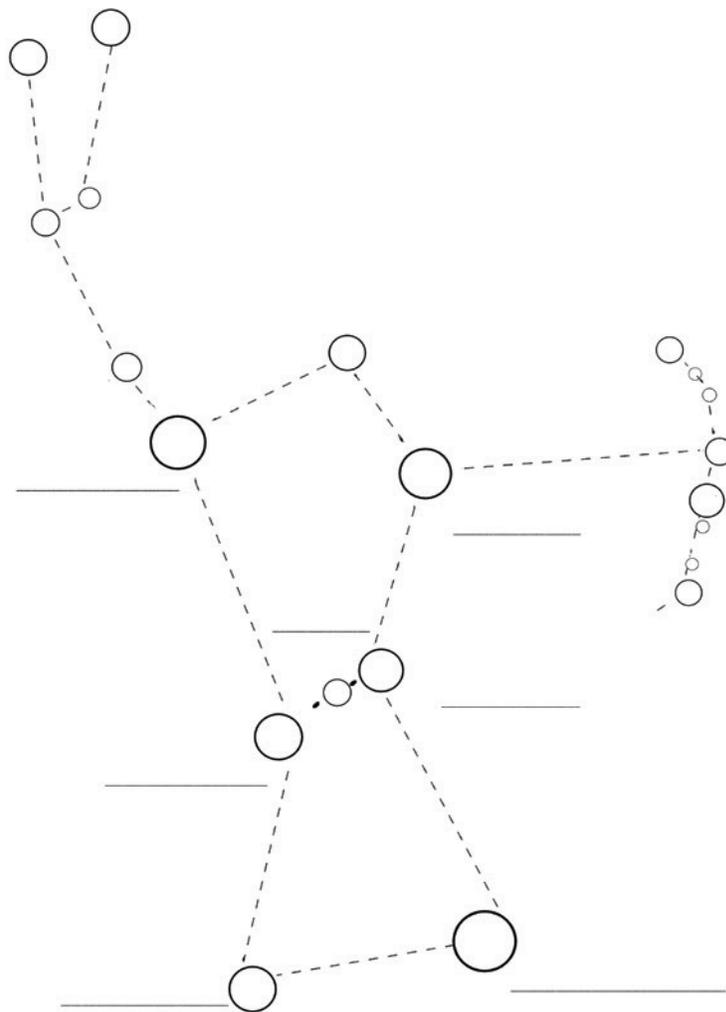
# STUDENT PAGE

## Astronomy Lesson 3: Colorful Constellations, Classifying Stars

### ORION'S MAIN STARS

#### INSTRUCTIONS

1. Use the PROPERTIES OF ORION'S MAIN STARS Table to find the names of the seven stars that make up the constellation Orion.
2. Using the magnitude and location, label the seven stars on the picture below.
3. Use colored pencils to color each star red, blue, or white.







# 1

## **GEOLOGY LESSON 1** Volcanic Landscapes



## LESSON INSTRUCTIONS

### Geology Lesson 1: Volcanic Landscapes

## GOAL

Students will explore how different types of volcanoes have different types of volcanic eruptions. In both Kumamoto and Montana, students will discover that Aso Volcano and Yellowstone Volcano are significant volcanoes to our homes and the world.

## OBJECTIVES

Students will be able to:

1. Chart four different types of volcanic eruptions.
2. Watch videos of volcanic eruptions.
3. Observe and describe volcanic rock samples to interpret the type of eruption that formed them.

## ASSESSMENT

1. Review students' work on the "Identification of Volcanic Eruption Types" to assess student understanding for the four types of volcanic eruptions.
2. Watch for students demonstrating active listening during the videos.
3. Assess students' work on the "Identification of Volcanic Rocks" page and student answers during the final large group sorting activity.

## MATERIALS

- o Copies of "Student Pages," one per student (pages 99-102)
- o Videos of volcanic eruptions (listed in background information) loaded onto a projection system
- o Five or more different types of volcanic rock samples
- o Optional: magnifying glasses or loupes
- o Pictures of the eruptions in Hawaii, Yellowstone, Mount St. Helens, and Aso printed on regular paper to post to a white board

## PREPARATION

- o Make copies of the student pages, one per student.
- o Preview and load the videos for later use in class.
- o Get samples of various volcanic rock types to use in the classification exercise for students.
- o Look at educational material available from the National Park Service on the geology of Yellowstone Park. Here is a link: <https://www.nps.gov/yell/learn/nature/geology.htm>
- o Look at educational material available for Aso Volcano. Here is a link: <http://www.aso-geopark.jp/en/charm/index.html>

# LESSON INSTRUCTIONS

## Geology Lesson 1: Volcanic Landscapes

LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Begin the lesson by asking students what they know about volcanoes .</p>	<p>Expect students to need a familiar landmark to get started. If you are located in Japan, show images of Aso Volcano and explain its significance (see student pages). If in the US, begin with Yellowstone.</p>	<p>This gives teachers the opportunity to uncover misconceptions to address later in the lesson. <b>Please note:</b> <i>This lesson is designed for a 45 minute period. For longer lessons and optional homework, ask students to research other types of volcanic eruptions and share with the class the next day.</i></p>
<p>Using the Identification of Volcanic Rocks page, have the class look at different rocks and fill out the worksheet as a group. Later, they will be learning how these rocks relate to different volcanoes.</p>	<p>Expect students to need a few questions to guide their learning. Encourage them to look at the texture and feel of the rock, as well as the color. A small magnifying glass or loupe may be a helpful tool for students to use while examining the rock.</p>	<p>This gives teachers the opportunity to engage student's senses. Ask students to volunteer to share their answers with the class. Lead a discussion for 2 minutes then move on to the videos.</p>
<p>Show the students the video clips provided for each type of volcanic eruption. After each video, have them use the student page to describe the eruption.</p>	<p>Expect students to need some guidance on what to look for in the videos. Teachers should explain the videos as they are shown and link the eruptions to the types of rocks they emit.</p>	<p>This gives teachers the opportunity to connect the two activities and check student's comprehension of the lesson by leading a short discussion.</p>
<p>On the board or poster board, write four types of volcanic eruptions and post images (located in student pages). Have students bring their rock sample images to the board and place it on the image of the eruption they think matches the rock.</p>	<p>Not all rocks will be placed correctly. Lead a short discussion with the class to explain why some rocks may be placed in a different place.</p>	<p>This gives teachers the opportunity to address the link between the rocks and volcanic eruptions as well as ensure that the lesson is understood by the full class.</p>
<p>Lead students in a discussion about what they have learned. Explain that there are different types of volcanoes all over the world, and that there are famous ones located in their own country.</p>	<p>Review the lesson by asking students to share where each image of a volcanic eruption is from (Aso, Yellowstone, or Hawaii) .</p>	<p>This gives teachers the opportunity to connect the lesson back to the student's lives and experiences, as well as expand knowledge of other places.</p>



## LESSON INSTRUCTIONS

### Geology Lesson 1: Volcanic Landscapes

## OPTIONAL EXTENSIONS:

### PLATE TECTONICS

1. Have students research where the plate tectonics are located as well as where the volcanoes are located using online digital maps or printed maps of the digital resource. Then have the students plot three tectonic plates and three volcanoes on a blank world map (Hint: most volcanoes are located where two plate tectonics meet or collide). Students may use computers, maps, or reference books for research. The approved website they can use:

· <http://earthquakes.volcanodiscovery.com/> and <http://www.worldatlas.com/aatlas/infopage/tectonic.htm>

2. Students will make observations about patterns they notice in the location of the plates and volcanoes in their science notebooks. Also have the students reflect on how living near a volcano might affect the people near Yellowstone Volcano and Aso Volcano. Is living on plates with active volcanoes an issue? Will the people live day to day in fear of an eruption? Have the students write about their responses in their science notebooks.

3. Then come back together and have students share their thoughts of what they think it would be like living near an active volcano.

4. Based on these findings, now zoom in on Yellowstone Volcano and Aso Volcano. Ask students: What tectonic plates control these volcanoes?

### EVACUATION PLAN

**Can scientists predict when Yellowstone Volcano and Aso Volcano will erupt again? Can we predict the paths of ejected material from either of the eruptions? How?**

1. Put students into small groups and have them research how scientists can predict future eruptions. Record what they discover in a Reflective Journal.

2. Give each of the students their own Eruption Path worksheet where they will research and record the previous eruption paths of the Aso and Yellowstone volcanoes. Have students analyze these paths and create a projectile path for where they think the volcanoes will erupt again.

3. Have students research hazard plans that exist for these regions in case of another eruption. Have students make a list of procedures that are necessary to evacuate the area or cope with an eruption in a Reflective Journal.

<http://www.protezionecivilewpj/sessionid=3DDAF6E6B2D6096A41CF68577C44324F?contentId=PDE12771>

4. Discuss an appropriate evacuation plan for Yellowstone (Wyoming and Montana) or the Aso Volcano area. What has the US government or Japanese government set up for disaster relief? (Homeland Security, FEMA, etc.) Consider things like air quality, magma flow, plant and animal life, and a safe location for people in the surrounding location to go to.

5. Based on their research have students design their own evacuation plan, emergency supply kit, or family emergency communication plan for their town/family in small groups.

6. Upon completion, students will present their evacuation plans to the class backing up their plan with what they've learned. Discuss if your evacuation plan is realistic or not. Do you see a moral or an ethical dilemma in having or not having an evacuation plan? Could this evacuation plan be adopted by the general public? Why or why not?

[https://volcanoes.usgs.gov/volcanoes/yellowstone/faqs\\_ash3d.html](https://volcanoes.usgs.gov/volcanoes/yellowstone/faqs_ash3d.html)



## BACKGROUND INFORMATION

### Geology Lesson 1: Volcanic Landscapes

## TYPES OF VOLCANIC ERUPTIONS

When volcanoes erupt they “give off a vast range of products from steam and gas to molten lava, ash, pumice, and boulders, all of which are ultimately derived from magma, the molten material that rises from beneath the Earth’s crust” (Scarth 2009).

In an oversimplified model, volcanic eruptions can be grouped under four main categories: mild, moderate, vigorous, and violent. The three major eruptions of Yellowstone Volcano are famous because they created the landscape and thermal features that became the first national park in the world.

Aso Volcano is famous because it is one of the most active volcanoes in the world and is the setting for the UNESCO Aso Geopark.

Scientific studies of the eruption provide information about the phases of the eruption supported by geologic layers of volcanic rock that show evidence of pyroclastic flows, ashfall, and lava flows. By analyzing the layers, the type of volcanic material they contain, and how the deposits were distributed, geologists have been able to reconstruct the different eruptions.

From this information, the time of the eruptions have been documented (and thus the frequency of eruptions can be determined), the types of eruptions that occurred during different time intervals interpreted, and from this it can be predicted over what time frame future eruptions might occur, how violent these eruptions might be, and the areal distribution of different impacts.

MILD	<b>GEYSER</b>	Hydrothermal, geysers, hot springs, mud pots. EXAMPLE: Yellowstone National Park: <a href="https://www.youtube.com/watch?v=USCvVndukjA">https://www.youtube.com/watch?v=USCvVndukjA</a>
MODERATE	<b>HAWAIIAN</b>	Explosive molten lava with very hot magma. EXAMPLE: Hawaii’s Big Island: <a href="https://youtu.be/_hyE2NO7HnU">https://youtu.be/_hyE2NO7HnU</a>
VERY VIOLENT	<b>PLINIAN</b>	Pyroclastic flows. Lots of gas! Vicious, cool magma, gas blasts out with enormous force. Explosions shatter the magma in dust and ash. Scorching, glowing clouds of ash and fumes that race down the sides. Pumice. EXAMPLE: Mount St. Helens disintegrates in enormous landslide: <a href="http://www.discovery.com/tv-shows/discovery-presents/videos/understanding-volcanoes-mt-saint-helens/">http://www.discovery.com/tv-shows/discovery-presents/videos/understanding-volcanoes-mt-saint-helens/</a>
VERY VIOLENT	<b>CALDERA</b>	Pyroclastic flows. Lots of gas! Vicious, cool magma, gas blasts out with enormous force. Explosions shatter the magma in dust and ash. Scorching, glowing clouds of ash and fumes that race down the sides. Pumice. Much, much larger and more violent than any other volcano type. EXAMPLE: · Aso Volcano caldera. Caldera simulation: <a href="https://youtu.be/BBGmXsZHlnw">https://youtu.be/BBGmXsZHlnw</a>

# BACKGROUND INFORMATION

## Geology Lesson 1: Volcanic Landscapes

### TYPES OF VOLCANIC ROCKS

Examine each rock sample provided. Describe the color and crystal size of each sample. Then draw a detailed picture of the rock.

#### ANSWER:

	COLOR	CRYSTAL SIZE	ERUPTION TYPE
RHYOLITE	Light in color (pink or grey).	Very small, hard to observe without a magnifying glass.	CALDERA
ANDESITE	Bluish grey or grey.	Large crystals that form slowly, deep in the earth or small crystals that form quickly at the surface.	VIOLENT/PLINIAN
BASALT	Grey to black, weathers to a brown or rusty red.	Very fine.	HAWAIIAN
PUMICE	Pale in color, white, cream, blue or grey. Sometimes brown.	Fine grained, may not contain crystals.	VIOLENT/PLINIAN
OBSIDIAN	Black	None, lacks crystals.	CALDERA



## BACKGROUND INFORMATION

### Geology Lesson 1: Volcanic Landscapes

#### FAST FACTS ABOUT VOLCANOES

- There are six main categories of volcanoes: flood or plateau basalts, calderas, composite or stratovolcanoes, shield volcanoes, cinder cones, and lava domes.
- Igneous rocks are classified based on composition and mode of occurrence. The major types of volcanic rocks are rhyolite, andesite, and basalt. Each of these rock types is associated with different categories of volcanoes.
- Aso Volcano had four major explosive eruptions from 270,000 to 90,000 years ago. These eruptions produced pyroclastic flows covering central Kyushu and formed a large caldera. Less violent post-caldera activity has continued since the last major eruption and more than seventeen central cones were formed. Volcanic eruptions at Aso volcano are very frequent events and eruptions occur every 10–20 years. Aso is one of the world's most active volcanoes.
- Yellowstone Volcano has had three major caldera eruptions at 2,100,000 years ago, 1,300,000 years ago, and 640,000 years ago. Pyroclastic flows from these eruptions covered a large area around Yellowstone and ashfall deposits covered large areas of the western United States. Post-caldera rhyolite and basalt lava flows occurred between 164,000 years ago and 72,000 years ago and have filled in much of the most recent caldera. Volcanic eruptions at Yellowstone are very infrequent events.

#### COMMON MISCONCEPTIONS

One type of volcanic hazard that most people think of first is lava flow, which is the flow of hot molten rock. Yet a lava flow is one of the least deadly of all of the volcanic processes. This is partly because lava flows do not move very fast, only traveling a few miles per hour. There is another type of flow that comes from a volcanic eruption that is much more dangerous than a lava flow, and that is a pyroclastic flow. A pyroclastic flow is a dense collection of fragments and gases from a volcanic eruption that flows down the slope of a volcano. A lava flow is something that might inch towards you giving you time to flee, while a pyroclastic flow is something that races down the side of a volcano, leaving little time to react. The high speeds at which a pyroclastic flow travels, which can be more than 100 miles per hour, make this volcanic hazard very dangerous. Not only are pyroclastic flows dangerous because of their speed, but also because they are very hot (1,000 degrees Celsius, 1839 degrees Fahrenheit) and contain toxic gases.

<http://study.com/academy/lesson/volcanic-hazards-definition-types-prevention.html#>

Video Link: Pyroclastic flow:

<http://www.discovery.com/tv-shows/discovery-presents/videos/ultimate-guide-to-volcanoes-pyroclastic-flow/>



## BACKGROUND INFORMATION

### Geology Lesson 1: Volcanic Landscapes

## VOCABULARY

### **PUMICE:**

A very light and porous volcanic rock.

### **PYROCLASTIC FLOW:**

Huge, glowing clouds of scorching hot gas and volcanic fragments, ranging in size from dust, ash, and pumice to large rocks which are expelled at great speed in a turbulent mass.

### **RHYOLITE:**

A volcanic igneous rock with a very high silica content. It is usually pink or gray in color with grains so small that they are difficult to observe without a hand lens. Rhyolite is made up of quartz, plagioclase, and sanidine, with minor amounts of hornblende and biotite.

### **ANDESITE:**

A volcanic rock intermediate in composition between rhyolite and basalt. Andesite lava is of moderate viscosity and forms thick lava flows and domes. The word andesite is derived from the Andes Mountains in South America, where andesite is common.

### **BASALT:**

A mafic volcanic rock, is the most widespread of all igneous rocks, and comprises more than 90% of all volcanic rocks. Because of its relatively low silica content, basalt lava has a comparatively low viscosity, and forms thin flows that can travel long distances. It is also found as intrusive dikes and sills. Many moon rocks brought back by Apollo astronauts are of basaltic composition.

### **VOLCANO:**

A mountain or hill, typically conical, having a crater or vent through which lava, rock fragments, hot vapor, and gas are being or have been erupted from the Earth's crust. Burning mountain, comes from the name of the Roman god, Vulcan, god of fire and the blacksmith of the gods.

### **MAFIC:**

Relating to, denoting, or containing a group of dark-colored, mainly iron and magnesian minerals such as pyroxene and olivine.

### **FELSIC:**

Relating to or denoting a group of light-colored minerals including feldspar, feldspathoids, quartz, and muscovite.

### **LAVA:**

1. Molten rock that reaches the earth's surface through a volcano or fissure.
2. The rock formed by the cooling and solidifying of molten rock.

### **MAGMA:**

Molten rock usually located deep within the mantle of the Earth that occasionally comes to the surface through cracks in the mantle or through the eruption of volcanoes.

# STUDENT PAGE

## Geology Lesson 1: Volcanic Landscapes

### TYPES OF VOLCANIC ERUPTIONS



#### MILD/ GEYSER ERUPTION

Hydrothermal, geysers, hot springs, mud pots.



#### MODERATE/HAWAIIAN ERUPTION

Explosive molten lava with very hot magma.



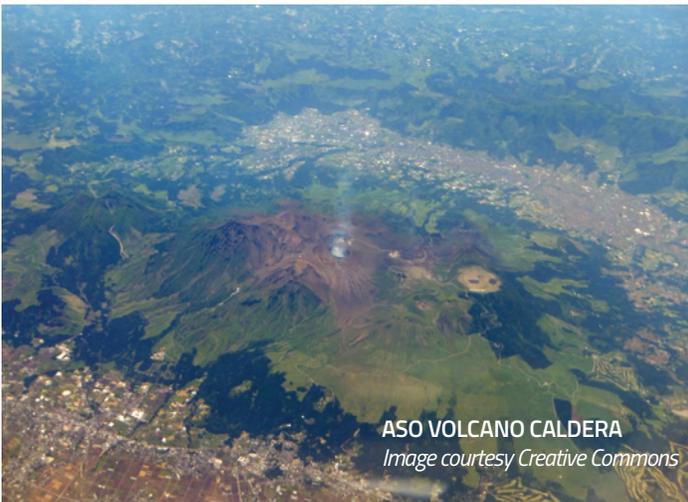
#### VIOLENT/ PLINIAN ERUPTION

Pyroclastic flows. Lots of gas! Vicious, cool magma, gas blasts out with enormous force. Explosions shatter the magma in dust and ash. Scorching, glowing clouds of ash and fumes that race down the sides. Pumice.

## STUDENT PAGE

### Geology Lesson 1: Volcanic Landscapes

## TYPES OF VOLCANIC ERUPTIONS (CONTINUED)



ASO VOLCANO CALDERA  
*Image courtesy Creative Commons*

### CALDERA ERUPTION

The present caldera in Aso Geopark was formed approximately 90,000 years ago by a huge eruption. Pyroclastic flow deposits from that eruption have been discovered in Yamaguchi Prefecture as well as across the Ariake Sea in Shimabara and Amakusa. Aso is one of the world's most active volcanoes.



Mt. Mazama Eruption  
*Image courtesy US National Park Service*

### VERY VIOLENT CALDERA ERUPTION

Pyroclastic flows. Lots of gas! Vicious, cool magma, gas blasts out with enormous force. Explosions shatter the magma in dust and ash. Scorching, glowing clouds of ash and fumes that race down the sides. Pumice. Much, much larger and more violent than any other volcano type.



# STUDENT PAGE

## Geology Lesson 1: Volcanic Landscapes

### IDENTIFICATION OF VOLCANIC ROCKS

Examine each rock sample provided. Describe the color and crystal size of each sample. Then draw a detailed picture of the rock.

#### ANSWER:

	COLOR	CRYSTAL SIZE	DRAW A PICTURE
SAMPLE 1			
SAMPLE 2			
SAMPLE 3			
SAMPLE 4			
SAMPLE 5			

# STUDENT PAGE

## Geology Lesson 1: Volcanic Landscapes



### IDENTIFICATION OF VOLCANIC ERUPTION TYPES

Watch videos showing the different types of volcanic eruptions. Write the name and location of one volcano of each type. Describe the eruption and indicate if there is lava or not. Then draw a detailed picture of the eruption.

#### ANSWER:

	ERUPTION	EXAMPLE	DRAW A PICTURE	DESCRIPTION ( INDICATE IF THERE IS LAVA)
MILD	GEYSER			
MODERATE	HAWAIIAN			
VIOLENT	PLINIAN			
VERY VIOLENT	CALDERA			





# 2

## **GEOLOGY LESSON 2** **Natural Disasters - Our Changing Landscape**



## LESSON INSTRUCTIONS

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

## GOAL

Students will explore how natural hazards research—based on detailed observations and improved understanding of the physical processes responsible for natural hazards—can help us to understand and reduce natural hazard risks.

## OBJECTIVES

1. Discuss how the Earth's landscape changes through the movement of plate tectonics, which creates earthquakes.
2. Apply their learning in a hands-on activity by creating buildings out of simple materials.
3. List factors that make buildings earthquake resistant.

## ASSESSMENT

1. Listen to student responses during the discussion to assess understanding of plate tectonics. Alternatively, use the student pages to have students underline main ideas in the text.
2. Observe students during the activity to ensure all students are engaged.
3. Assess students' work on the "Designing Earthquake-Resistant Buildings" page.

## MATERIALS

- o Copies of "Student Pages," one per student (pages 114-119)
- o Video of "Understanding Earthquakes" by National Geographic loaded onto a projection system (<https://youtube.be/cavq2HFBa-U>)
- o 30 toothpicks and 30 miniature marshmallows per student
- o 8-inch square disposable baking dishes (one per every four students with one additional pan for the display model)
- o Boxes of gelatin (one per every baking dish)

## PREPARATION

- o Make copies of the student pages, one per student.
- o Preview and load the videos for later use in class.
- o Prepare the gelatin in the disposable baking dishes the night before the lesson so students can begin the activity right away.
- o Make a model toothpick structure as an example.

# LESSON INSTRUCTIONS

## Geology Lesson 2: Natural Disasters - Our Changing Landscape

LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Tell students that they will be learning about natural hazards and disasters, with earthquakes as a focus. Lead a discussion on the differences between natural hazards and disasters.</p>	<p>Expect students to need examples. Teachers should reference the background information provided in the lesson plan.</p>	<p>This gives teachers the opportunity to discuss hazards and disasters in Montana and Kumamoto and engage students in talking about their own experiences.</p>
<p>Introduce the subject of earthquakes by showing the video link (2:57): <a href="https://youtu.be/cavq2HFBa-U">https://youtu.be/cavq2HFBa-U</a></p>	<p>Ask students to name some examples of earthquakes. Expect students in Japan to talk about the Kumamoto earthquakes of 2016 and Montana students to mention California and Yellowstone.</p>	<p>This gives teachers the opportunity to discuss the layers of the Earth, plate tectonics, and seismic waves.</p>
<p>Using the student pages, show the example of the 2016 Kumamoto earthquake and the earthquake studies in Yellowstone. Have students complete the Venn Diagram to compare and contrast the earthquake activity at Aso and Kumamoto with Yellowstone.</p>	<p>Expect students to need visuals for this portion. Encourage students to think about the frequency of earthquakes and their potential impact on communities.</p>	<p>This gives teachers the opportunity to use the earthquake student pages to discuss how earthquakes are measured according to magnitude and the causes of the one in Kumamoto.</p>
<p>Tell students they will now use what they have learned about earthquakes to make a building model and conduct an experiment to test it. Pass out toothpicks and marshmallows to each student and have them break into groups of four. Give each group a baking pan of gelatin.</p>	<p>Expect students to need some guidance on how to create their structures. Show them the example and tell students that each building must be at least 2 levels high, and contain at least one triangle and one square.</p>	<p>This gives teachers the opportunity to show students how surface waves and body waves from earthquakes effect buildings. Encourage students to test their buildings by shaking their baking dish. If there is time, rebuild them again.</p>
<p>Have students record their building design on the student page and explain what worked and what did not. Lead a short discussion of how we live with natural hazards to try to prevent natural disasters.</p>	<p>Link the discussion to the activity by asking students to examine their buildings. Ask why they think shorter buildings and those that incorporated more triangles (cross bracing) were more successful.</p>	<p>This gives teachers the opportunity to discuss construction practices in earthquake prone areas, as well as disaster mitigation practices such as evacuation planning, hazard mapping, and monitoring.</p>

## BACKGROUND INFORMATION

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

## NATURAL HAZARDS VERSUS NATURAL DISASTERS

Every year in the United States and Japan, natural hazard events threaten lives and property, resulting in deaths and billions of dollars in damage. The costs and consequences of natural hazards can be enormous, and each year more people and infrastructures are at risk. Natural hazards research—based on detailed observations and improved understanding of the physical processes responsible for natural hazards—can help us to understand and reduce natural hazard risks and to make and effectively communicate reliable statements about hazard characteristics, such as how often they occur, their magnitude, their extent, the consequences of these events, and when and where possible, the timing of future events.

### WHAT IS A NATURAL HAZARD?

A natural hazard is any naturally occurring event that poses a danger to human life or property. “Natural hazards” is a general term for events such as volcanoes, earthquakes and tsunamis. Types of natural hazards include: avalanche, earthquake, flood, forest fire, hurricane/typhoon/cyclone, landslide, thunderstorm/blizzard/ice storm, tornado, tsunami and volcano.

### WHAT IS A NATURAL DISASTER?

A natural disaster is any natural hazard that affects human lives or property. A natural hazard, such as an earthquake that occurs at the bottom of the sea and that no one feels, is not considered a natural disaster, while an earthquake such as the one in Pakistan in 2005 that killed nearly 100,000 people and destroyed many homes and roads was a terrible natural disaster.



An example of a natural hazard is a mudslide, pictured above.  
Images courtesy Aso Volcano Museum

## BACKGROUND INFORMATION

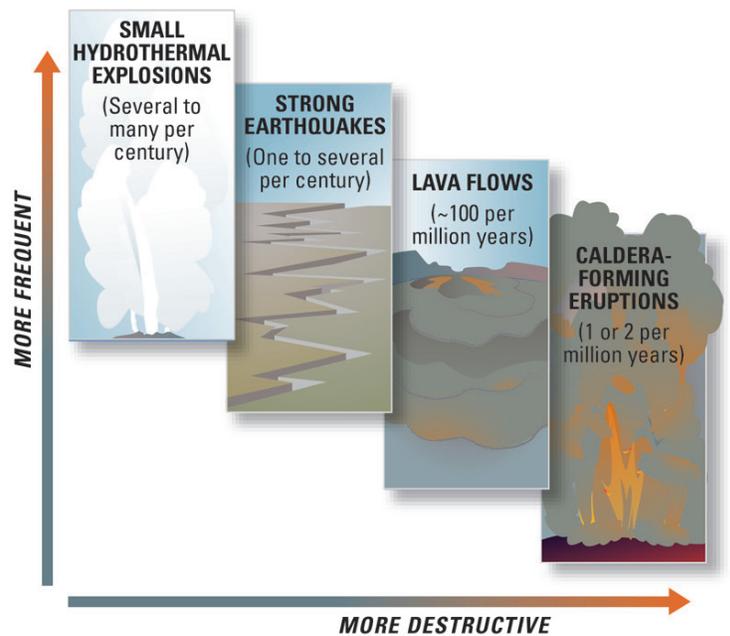
### Geology Lesson 2: Natural Disasters - Our Changing Landscape

## NATURAL DISASTERS AND HAZARDS IN MONTANA

Montana is a stunningly beautiful state of vast extent. It is mountainous to the west and high plains to the east. The rugged topography reflects a legacy of millions of years of dynamic geologic processes that include earthquakes along faults which created mountains and valleys, volcanic eruptions, glaciers that sculpted the surface, and rivers that eroded and flooded. The variable topography and position on the continent also creates extreme weather conditions leading to devastating storms, floods, and droughts that create dangerous fire conditions. These natural processes become disasters when they interact with people, or hazards when they have the potential to interact with people.

People first arrived on Montana's landscape about 12,500 years ago, so only those natural events that have occurred during the past 12,500 years can really be considered natural disasters. These have included fires, storms, floods, and earthquakes. Of these, the best known are those that have occurred during historical times. Fires, storms, and floods have occurred most frequently. However, Montana lies within the Intermountain Seismic Belt, and infrequent, disastrous earthquakes have occurred historically within Montana and are likely to occur in the future. The two most recent of these were the Helena earthquake of 1935 and the Hebgen Lake earthquake of 1959, both of which resulted in tremendous damage to human infrastructure and the loss of human lives.

Montana lies on the boundary of the dormant but still active Yellowstone Supervolcano. The Yellowstone Volcano has not erupted during the time humans have lived in Montana, but it still has the potential to erupt in the future, and this eruption would most certainly affect humans. Thus, it is classified as a geologic hazard. The Yellowstone Volcano erupted 2.1 million years ago, 1.3 million years ago, and 0.64 million years ago. These eruptions were of incredible violence but are very infrequent events. Thus, the chance of an eruption in the near future is extremely small.



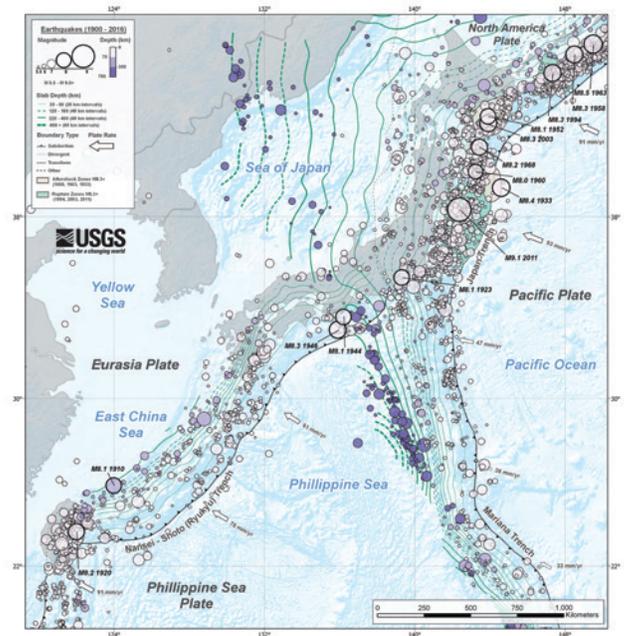
Images courtesy USGS

## BACKGROUND INFORMATION

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

## NATURAL DISASTERS AND HAZARDS IN KUMAMOTO DISASTERS CAUSED BY CALDERA TOPOGRAPHY AND GEOLOGICAL FEATURES

Many people are drawn to live in Aso by the beauty and natural bounty of the volcano. However, the region is vulnerable not only to eruptions but also to disasters related to its unique topographical features, such as the caldera, volcanic ash soil, and high altitudes. In July 2012, 25 people living in the caldera died when the caldera wall collapsed due to torrential rain. Disasters of a similar scale occur once every few decades, bringing serious damage to the region. Other examples of natural disasters typical to the Aso region are as follows:



Images courtesy USGS

### HIGH OVERALL RAINFALL AND FREQUENT TORRENTIAL RAINS

Aso is located in the center of Kyushu. Its highest point is Mt. Takaoka, at 1,592 m above sea level, with the caldera floor at 500-600 m and the outer rim of the somma almost 700-900 m. Because of its high vertical interval, annual total precipitation exceeds 3,000 mm.

### FLOODS ON THE CALDERA FLOOR

Aso Dani Valley in the north caldera has flat topography, making it particularly vulnerable to flooding when heavy rain causes the Kurokawa River to overflow.

### COLLAPSE OF THE CALDERA WALL

Because the caldera wall is steep, and its surface is covered with volcanic ash deposits, it collapses easily even in relatively low rain conditions.

### SURFACE MUDSLIDES IN THE GRASSLANDS

Volcanic ash soil is common in the grasslands. The juxtaposition of a highly compacted layer of volcanic ash and a softer soil layer creates conditions where erosion and mudslides occur easily.

### EARTHQUAKES CAUSED BY FAULT ACTIVITY

The caldera is bisected by the Dita-Kumamoto tectonic line, which runs from northeast to southwest Kyushu. Other faults run through the area surrounding the caldera, particularly to the southwest. Activity on these faults sometimes causes earthquakes. A recent example is the Northern Kyushu Earthquake that occurred in 1975, causing serious damage to buildings.

# BACKGROUND INFORMATION

## Geology Lesson 2: Natural Disasters - Our Changing Landscape

THE 2016 EARTHQUAKE IN KUMAMOTO, JAPAN, WAS CONSIDERED A NATURAL DISASTER DUE TO THE AMOUNT OF DAMAGE DESCRIBED IN THE TABLES BELOW:

THE AMOUNT OF DAMAGE	BILLION YEN
Building ( housing related )	2,037.7
Water Supply Facility	11.9
Electricity and Gas Facilities	28
Medical / Welfare Facilities	75.8
Public Civil Engineering Facility	268.5
Highway	34.2
Educational Facilities ( excluding cultural properties )	94.4
Other Public Facilities	73.6
Public Transportation	8.6
Agriculture, Forestry and Fisheries	148.7
Commercial Work Relationship	820
Cultural Property	93.6
Waste Treatment	90
<b>TOTAL</b>	<b>3,785</b>

CASUALTIES & INJURIES			
PREFECTURE	DEATHS	SERIOUS	MINOR
Fukuoka	0	1	16
Saga	0	4	9
Kumamoto	246	1,165	1,553
Oita	3	11	23
Miyazaki	0	3	3
<b>TOTAL</b>	<b>249</b>	<b>1,184</b>	<b>1,606</b>

PREFECTURE	LOSS OF STRUCTURES:			BUILDINGS		ETC.
	Complete	HOMES Half	Partial	Public	Other	Fire
Yamaguchi	0	0	3	0	0	0
Fukuoka	0	4	251	0	0	0
Saga	0	0	1	0	2	0
Nagasaki	0	0	1	0	0	0
Kumamoto	8,664	34,335	153,907	439	11,062	15
Oita	10	222	8,110	0	59	0
Miyazaki	0	2	39	0	0	0
<b>TOTAL</b>	<b>8,674</b>	<b>34,563</b>	<b>162,312</b>	<b>439</b>	<b>11,123</b>	<b>15</b>

Images from the disaster:



Images courtesy Aso Volcano Museum

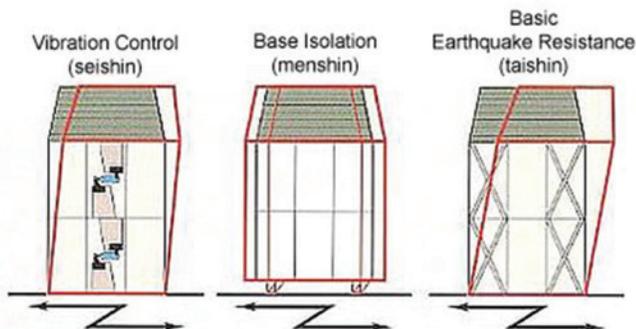
## BACKGROUND INFORMATION

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

## EARTHQUAKE-RESISTANT BUILDINGS

The proximity of Japan to the Ring of Fire means that it frequently experiences earthquakes of varying magnitude. Thus, the country has long required strict building codes for skyscrapers and other public buildings. Materials that are flexible and shock absorbent, coupled with modern technology to analyze the performance of a building has contributed to engineering practices that have put Japan among the most resilient in the world. Even some older buildings, like Kumamoto Castle in Kumamoto City, are being retrofitted to be more earthquake-resistant in the future.

#### The 3 *shin-taishin* Earthquake Resistance Construction Methods



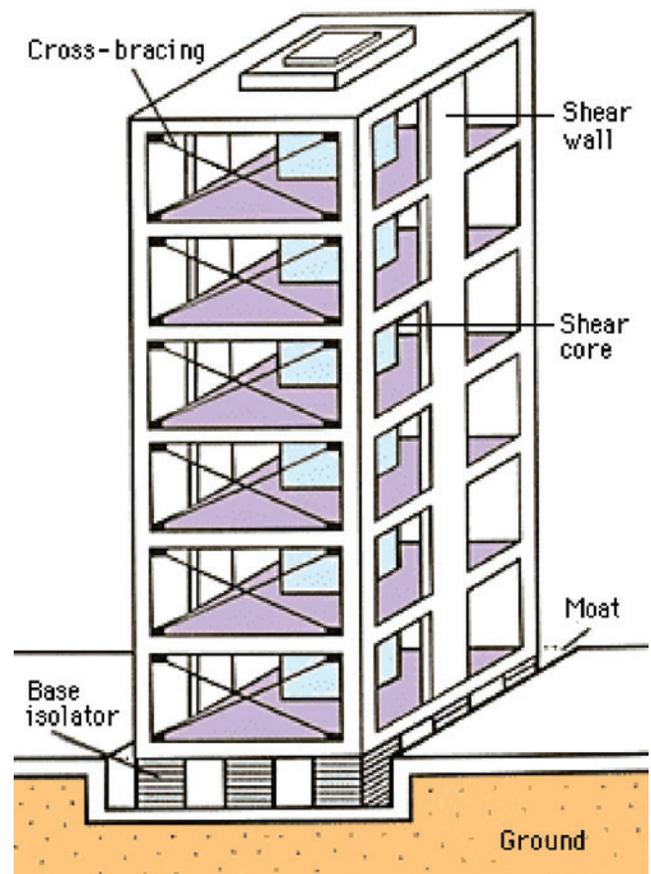
Earthquake resistant construction methods in Japan.  
Image courtesy Creative Commons



Restoration of Kumamoto Castle.  
Image courtesy muza-chan.net

Towers that incorporate earthquake resistant engineering take advantage of the physics of gravity; as the dead load of a tower pushes down, the ground pushes back up and small movements of air push from the sides. Including a foundation on a building distributes the load into the surrounding ground material, thus helping to balance the sideways wind force. The strength of the ground affects the size of the foundation. For example, a foundation placed in rock can be smaller than one placed in sand or mud.

To gain further background on the engineering involved in this activity, watch the TED talk "Build a Tower, Build a Team" at: [https://youtu.be/H0\\_yKBit08M](https://youtu.be/H0_yKBit08M).



Earthquake resistant design.  
Image courtesy Creative Commons



## BACKGROUND INFORMATION

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

## VOCABULARY

**CITATION:** Glossary of Geology, 2017, Edited by Klaus K.E. Neuendorf, James P. Mehl, Jr., and Julia A. Jackson, American Geosciences Institute

### **AVALANCHE:**

A large mass of snow, ice, soil, or rock, or mixtures of these materials, falling, sliding, or flowing very rapidly under the force of gravity. Velocities may sometimes exceed 500 km/hr.

### **EARTHQUAKE:**

A sudden motion or trembling in the Earth caused by the abrupt release of slowly accumulated strain.

### **FLOOD:**

A rising body of water (as in a stream, lake, or sea, or behind a dam) that overtops its natural or artificial confines and that covers land not normally under water.

### **FOREST FIRE:**

An uncontrolled fire in a forested area.

### **HURRICANE:**

A tropical cyclone, especially in the North Atlantic and eastern North Pacific basins, in which the sustained near-surface wind speed equals or exceeds 64 knots (73 mph).

### **LANDSLIDE:**

A general term covering a wide variety of mass-movement landforms and processes involving the downslope transport, under gravitational influence, of soil and rock material en masse. Terminology designating landslide types generally refers to the landform as well as the process responsible for it, e.g. rockfall, translational slide, block glide, avalanche, mudflow, liquefaction slide, and slump.

### **NATURAL DISASTER:**

A disaster affecting humans that is caused by a natural hazard.

**NATURAL HAZARD:** A natural event that could cause destruction.

### **THUNDERSTORM:**

A mesoscale weather system produced by strong convection currents surging to great altitudes within the troposphere. Consists of cumulonimbus clouds accompanied by lightning and thunder and often, locally heavy rainfall (or snowfall) and gusty surface winds.

### **TORNADO:**

A small-scale cyclone, generally less than 500 m in diameter and with very strong winds. Tornadoes commonly occur as dark funnel-like features suspended from low-lying cumulonimbus clouds.

### **TSUNAMI:**

A gravitational sea wave produced by any large-scale, short-duration disturbance of the ocean floor, principally by a shallow submarine earthquake, but also by submarine slumps, subsidence, or volcanic eruption.

### **TYPHOON:**

A tropical storm in the region of the Indian or western Pacific oceans.

### **VOLCANO:**

(a) A vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material.

(b) Any eruption of material, e.g. mud, that resembles a magmatic volcano.

## STUDENT PAGE

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

## EARTHQUAKES AS NATURAL HAZARDS

Video link (2:57): <https://youtube.com/cavq2HFBa-U>

Citation: <https://earthquake.usgs.gov/learn/kids/eqscience.php>

Earthquakes are one of the most damaging and dangerous natural disasters on Earth. This is because they occur with little or no warning, can cause catastrophic damage, and because some of the most populated places on Earth are in seismically active areas meaning they are very prone to earthquakes. The seismic waves associated with earthquakes cause ground movement which can cause buildings, roads and bridges to collapse, and catastrophic landslides and mud flows in areas of high relief.

An earthquake happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the Earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the Earth is called the epicenter.



<https://earthquake.usgs.gov/learn/kids/eqscience.php>

Image courtesy Wikipedia

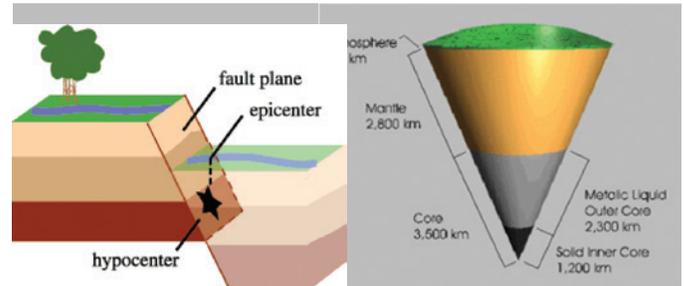


Image courtesy Creative Commons

The Earth has four major layers: the inner core, outer core, mantle and crust. The crust and the top of the mantle make up a thin layer on the surface of the Earth. But this cover is not one piece – it is made up of many pieces like a puzzle covering the surface of the Earth. These puzzle pieces are constantly moving because the part of the Earth underneath them is like a fluid. The plates sitting on top of this fluid move with the currents in this fluid, and over geologic time the plates are pulled apart (like east Africa), pushed together (like the Himalayas), or scrape past each other (like southern California). We call these puzzle pieces tectonic plates, and the edges of the plates are called the plate boundaries. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur on these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. Finally, when the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake.

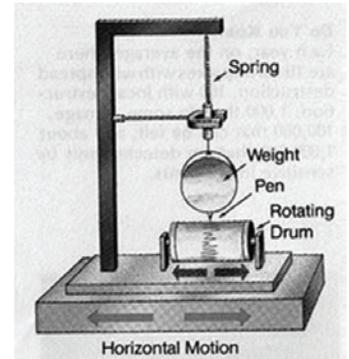
Think of it as if you're playing a game of tug-of-war with a friend. You're both pulling hard on the rope from each end and suddenly your friend lets go of the other side of the rope. All the tension quickly leaves the rope and you fall to the ground. The release of energy during an earthquake is very similar.

## STUDENT PAGE

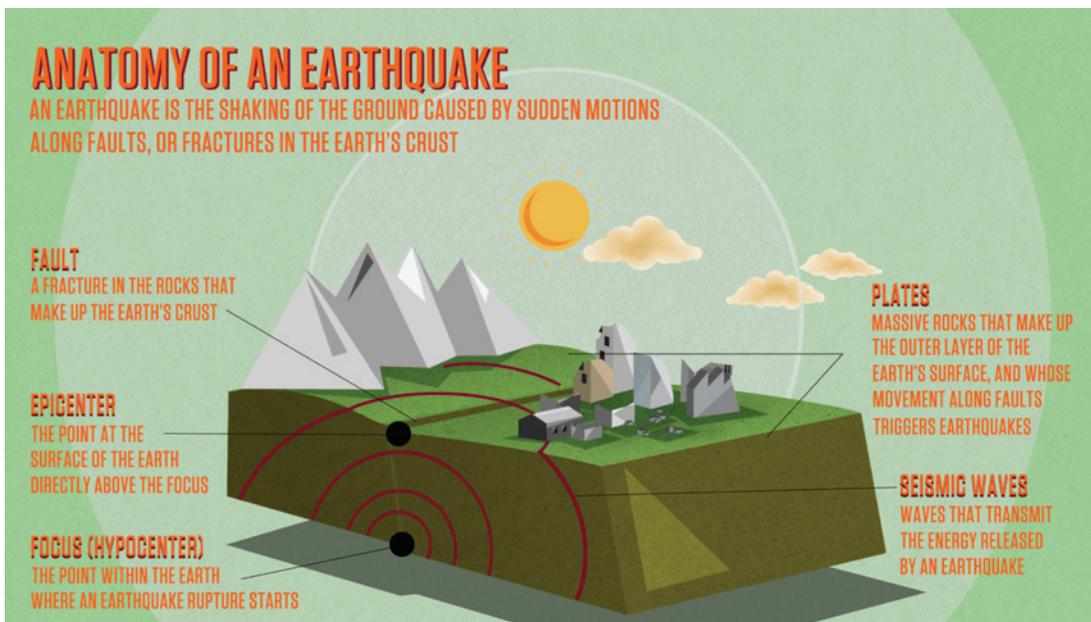
### Geology Lesson 2: Natural Disasters - Our Changing Landscape

#### HOW ARE EARTHQUAKES RECORDED?

Earthquakes are recorded by instruments called seismographs. The recording they make is called a seismogram. The seismograph has a base that sets firmly in the ground, and a heavy weight that hangs free. When an earthquake causes the ground to shake, the base of the seismograph shakes too, but the hanging weight does not. Instead the spring or string that it is hanging from absorbs all the movement. The difference in position between the shaking part of the seismograph and the motionless part is what is recorded. (<https://earthquake.usgs.gov/learn/kids/eqscience.php>)



Images courtesy Creative Commons



#### HOW DO SCIENTISTS MEASURE THE SIZE OF EARTHQUAKES?

The size of an earthquake depends on the size of the fault and the amount of slip on the fault, but that's not something scientists can simply measure with a measuring tape since faults are many kilometers deep beneath the Earth's surface. So how do they measure an earthquake? They use the seismogram recordings made on the seismographs at the surface of the Earth to determine how large the earthquake was. A short wiggly line that doesn't wiggle very much means a small earthquake, and a long wiggly line that wiggles a lot means a large earthquake. The length of the wiggle depends on the size of the fault, and the size of the wiggle depends on the amount of slip.

The size of the earthquake is called its magnitude. There is one magnitude for each earthquake. Scientists also talk about the intensity of shaking from an earthquake, and this varies depending on where you are during the earthquake.

## STUDENT PAGE

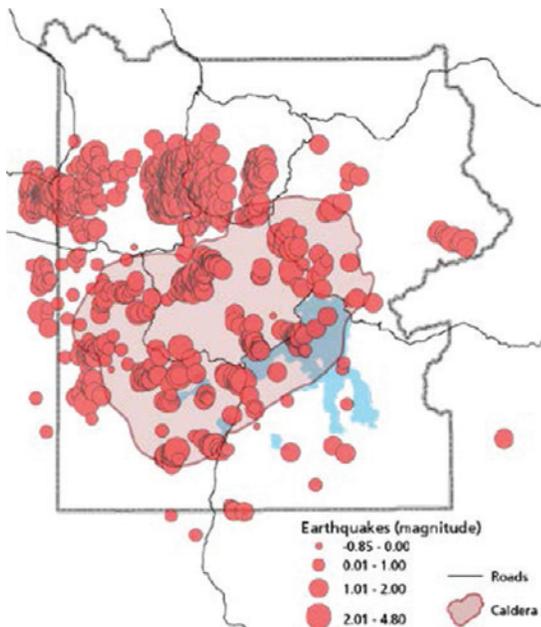
### Geology Lesson 2: Natural Disasters - Our Changing Landscape

#### MONITORING EARTHQUAKES IN YELLOWSTONE NATIONAL PARK

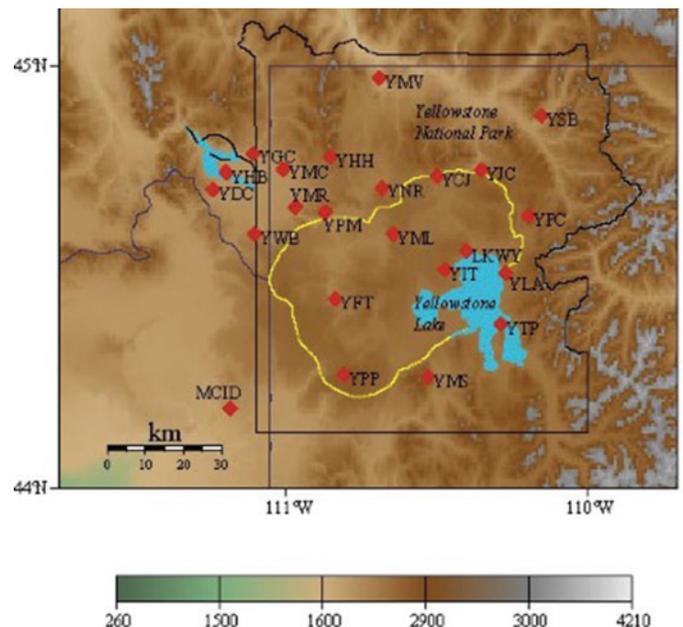
Yellowstone is one of the most seismically active areas in the United States. Approximately 1,000 to 3,000 earthquakes occur each year in the Yellowstone area; most are not felt. They result from the enormous number of faults associated with the volcano.

Scientists closely monitor earthquakes in Yellowstone Park to better understand the geology of the Yellowstone Volcano and associated thermal features.

They do this through The Yellowstone Seismic Network (YSN). The YSN is operated cooperatively by the University of Utah, the US Geological Survey's Volcano Hazards Program, and the National Park Service. The network covers the seismically and volcanically active Yellowstone National Park and surrounding area. It is designed to monitor volcano and geyser-related earthquake activity and for studying the subsurface processes of Yellowstone.



Approximately 2,000 earthquakes occurred in Yellowstone in 2014. Red dots = earthquakes. NPS map. Earthquake data provided courtesy University of Utah. <https://www.nps.gov/yell/learn/nature/earthquakes.htm>



Location map of the YSN monitoring network. ([http://www.uu.satr.utah.edu/RBSMITH/public\\_html/IMAGES/ys-seisnet.jpg](http://www.uu.satr.utah.edu/RBSMITH/public_html/IMAGES/ys-seisnet.jpg))

## STUDENT PAGE

### Geology Lesson 2; Natural Disasters - Our Changing Landscape

#### EARTHQUAKES IN ASO

Inside the caldera in Aso there are frequent volcanic tremors and volcanic earthquakes caused by volcanic activities such as the movement of magma. Volcanic activity in Aso causes volcanic earthquakes to occur several dozen times a day, and sometimes hundreds of times a day. This shows that the movement of magma and volcanic gas is constant. However, magma of Mt. Nakadake, the only active volcano in Aso, is basaltic, so large scale volcanic earthquakes seldom occur.

In the Aso area, a foreshock of magnitude 5.5 occurred at 13:40 on January 22, 1975. The main shock of magnitude 6.1 occurred at 23:19 on the next day, followed by several magnitude 5 aftershocks. Ten people were injured, roads were damaged in 12 places, there were 15 landslides, 16 houses were completely destroyed, 17 were partially destroyed, and 181 were slightly destroyed by the earthquake. These earthquakes are thought to be caused by an active fault and not by volcanic activities.

#### EARTHQUAKES IN KUMAMOTO

In Kumamoto, inland earthquakes frequently occur because many active faults are distributed there.

In the Kumamoto area, a series of earthquakes known as the 2016 Kumamoto Earthquake occurred between Kumamoto Prefecture and Oita Prefecture starting at 21:26 on April 14, 2016. The two largest of these earthquakes had a seismic intensity of 7 on the Meteorological Agency seismic intensity class and occurred on the night of April 14 and the early morning of April 16, 2016. The quakes damaged more than 190,000 houses, including 8,000 that were completely destroyed. In 2017, a report listed the death toll at approximately 225, including those who died over the past year of indirect causes due to illness exacerbated by evacuation (a number that is three times that of those who were killed by direct causes). There were also many aftershocks associated with these earthquakes.

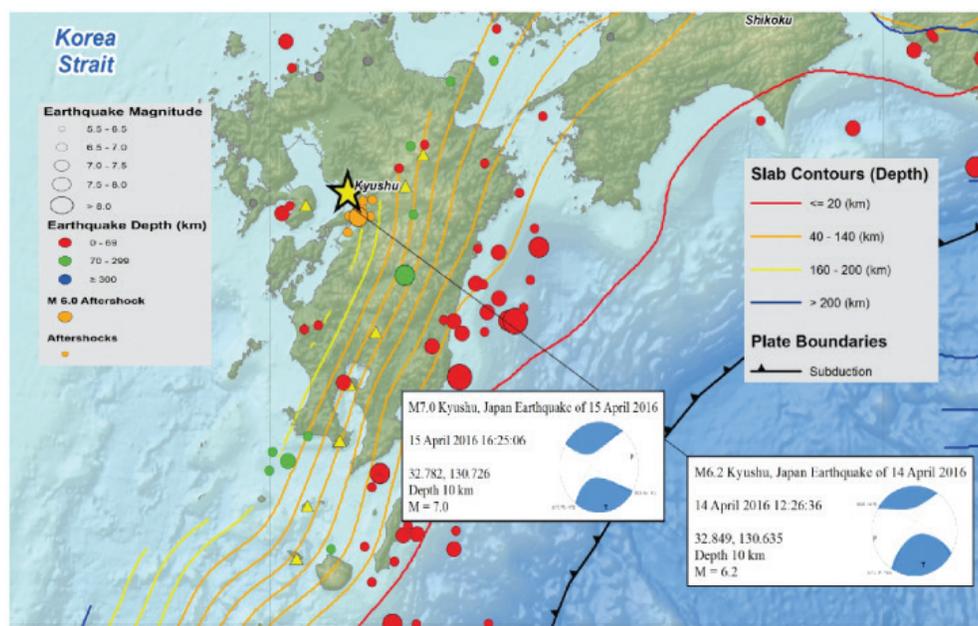


Image courtesy USGS

## STUDENT PAGE

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

#### COMPARE AND CONTRAST

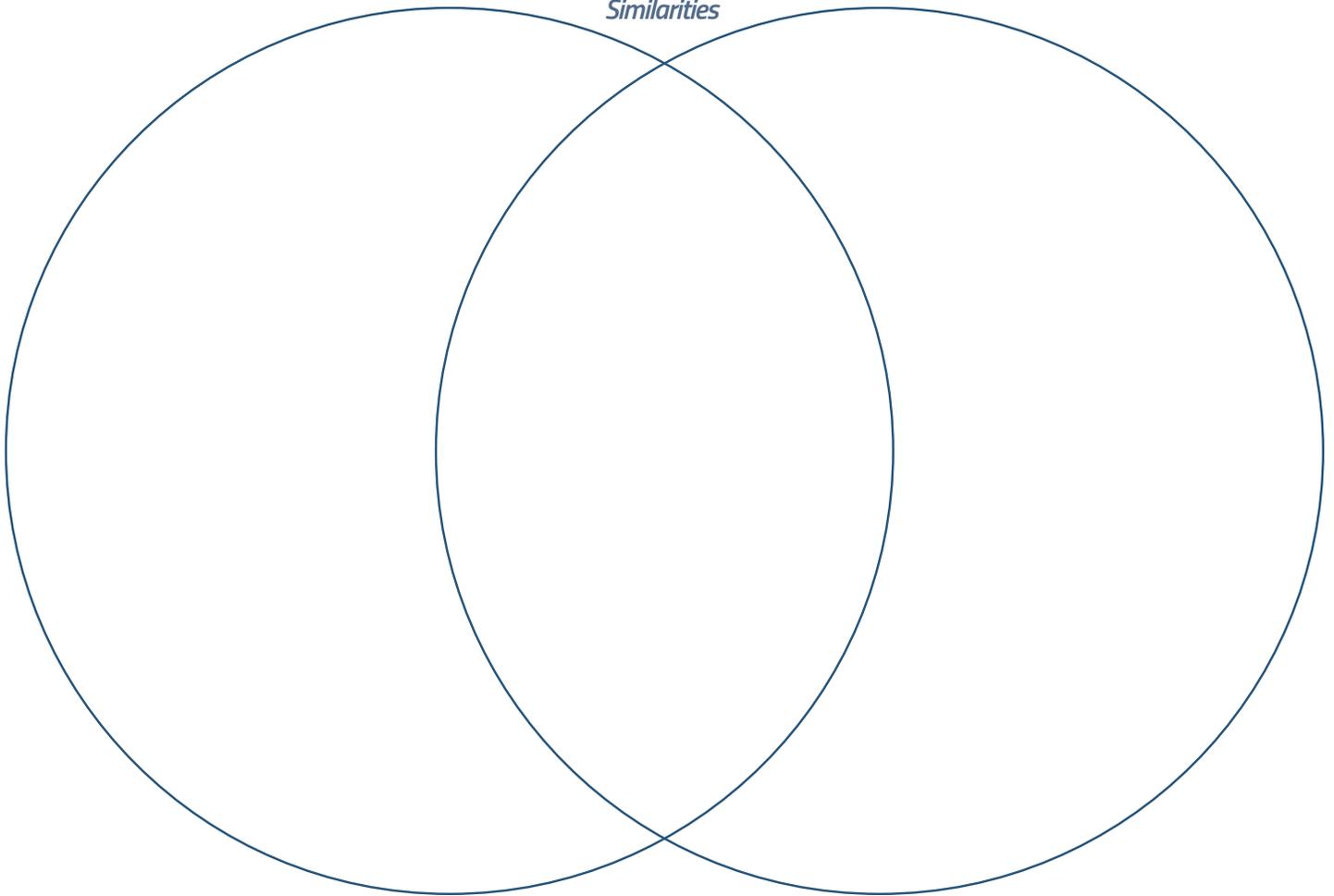
Learn about earthquakes in Aso and Kumamoto and earthquakes near Yellowstone National Park. Write details that explain how earthquakes in these two regions are different in the outer circles. Write details that tell how our regions are the same where the circles overlap.

#### ANSWER

*Aso/Kumamoto*

*Yellowstone*

*Similarities*





## **STUDENT PAGE**

### Geology Lesson 2: Natural Disasters - Our Changing Landscape

#### **ACTIVITY 1**

Draw a picture of your marshmallow and toothpick building design.

#### **ACTIVITY 2**

Describe what design features made your building more earthquake-resistant.

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#### **ACTIVITY 3**

How would you modify your design next time to make it more earthquake-resistant?

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# 3

## **GEOLOGY LESSON 3** **Sedimentology - Building Our Landscape**



## LESSON INSTRUCTIONS

### Geology Lesson 3: Sedimentology - Building our Landscape

## GOAL

Students will explore sedimentology, the study of modern sediment such as sand, silt and clay and the processes that result in their formation, transport, desposition and post-despositional changes that transform sediment into sedimentary rocks.

## OBJECTIVES

Students will be able to:

1. Explain how sedimentary rocks are different from other types of rocks.
2. Describe how sedimentary rocks are formed.
3. Draw the three main types of rocks using notes.

## ASSESSMENT

1. Listen to student responses during the discussion to assess understanding of the different rock types. Alternatively, use the student pages to have students underline main ideas in the text.
2. Review students' answers on the worksheet pages.
3. Assess students' work on the student pages.

## MATERIALS

- o Copies of "Student Pages," one per student (pages 116-121)
- o Clear, plastic water bottles with lids (one per student)
- o Materials to fill the bottles including soil, sand, gravel, leaves, roots, small sticks, and/or dead plant material (consider having students gather as homework prior to the lesson)

## PREPARATION

- o Make copies of the student pages, one per student.
- o Gather the materials and make sure there is enough for each student. Divide the materials into piles using bowls or plates to distribute.

# LESSON INSTRUCTIONS

## Geology Lesson 3: Sedimentology - Building our Landscape

LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Read students the section on "What are Sedimentary Rocks and How are they Made?" Lead a short discussion to emphasize the main ideas of sedimentary rock formation.</p>	<p>Encourage students to revisit their student pages to look for main ideas. Tell students they will be doing an activity that will show them the process of making a sedimentary rock.</p>	<p>This gives teachers the opportunity to help students understand basic concepts of sedimentology before the hands-on activity.</p>
<p>Give each student a water bottle and have them layer the gravel, sand, soil and plant material inside the bottle (in that order).</p>	<p>Ask students: How are our bottles like sedimentary depositional environments? How are they NOT like them? Ask students to draw a picture of their bottle.</p>	<p>This gives teachers the opportunity to encourage students to think critically and check their comprehension of the material.</p>
<p>Have students pour water into their bottles and make a prediction on their student page about how the bottle will look after it is shaken.</p>	<p>After students make a prediction, have students shake the bottle and put it on their table.</p>	<p>This gives teachers the opportunity to check student's comprehension of the lesson.</p>
<p>After 5 minutes, have students record what their bottle looks like.</p>	<p>Expect students to need some guidance in evaluating their predictions. Encourage them to refer to their earlier drawing.</p>	<p>This gives teachers the opportunity to discuss the students predictions.</p>
<p>Read the section on "sedimentary rocks" and have students draw examples of the rock types on their student pages.</p>	<p>Expect students to have some trouble coming up with examples of each type. Have students refer to the examples provided.</p>	<p>This gives teachers the opportunity to introduce other types of rocks and guide students through the "how to identify types of rocks" image.</p>
<p>Have students draw another sketch of their bottle and lead a class discussion on what has changed and how the sediment has settled.</p>	<p>Expect students to need some guidance in the discussion. Ask "What do you notice about how the layers are forming?" and "Why do you think they're forming this way?" to get started.</p>	<p>This gives teachers the opportunity to check comprehension of the lesson and have students reflect on how the lesson relates to the activity.</p>



## BACKGROUND INFORMATION

### Geology Lesson 3: Sedimentology - Building our Landscape

## ROCK TYPES

Rocks are solid masses that occur naturally as part of our planet and other planetary bodies. Geologists put rocks into three fundamentally different categories: **IGNEOUS ROCKS, SEDIMENTARY ROCKS, METAMORPHIC ROCKS**

### SEDIMENTARY ROCKS

Igneous rocks make up the bulk of the Earth's crust, but they're often covered by layers of sedimentary rock. Sedimentary rocks record the continuous erosion of the Earth's surface and the products of this process, and their transportation to their current resting place in the rock record. As the name suggests, sedimentary rock is formed from sediments or debris transported by liquid water, ice, or wind that become compacted and cemented together. Sedimentary rocks are secondary rocks, as they are formed from the accumulation of small pieces of pre-existing rock - that is, parent rock. There are three main types of sedimentary rocks, based on the source of the sediment.

**CLASTIC** sedimentary rocks are made up of fragments of preexisting rocks. Weathering and erosion of previously formed rocks form clastic particles called detritus, and detrital sedimentary rocks are accumulations of detritus. For example, particles of gravel weathered from older rock forms conglomerate, particles of sand weathered from older rock forms sandstone, and particles of mud (silt and clay) weathered from older rocks forms siltstone and shale.

**CHEMICAL** sedimentary rocks are derived from dissolved material carried in solution to lakes and oceans. When conditions are favorable, material precipitates out of solution and settles to the bottom where it accumulates as sediment. Precipitation may occur due to physical processes such as evaporation or through the biologic activity of living organisms. For example, limestone is the most abundant chemical sedimentary rock. It's typically formed either when calcite precipitates from seawater, or more often, from shells and other carbonate skeletal material produced by living organisms is deposited on lake or ocean bottoms to form sedimentary rocks. Most limestones are of biological origin.

**ORGANIC** sedimentary rocks form when organic matter (carbon-based organic material from living organisms) is deposited upon the death of the organism. These organic-rich deposits come from varied types of life at all scales; microscopic microbes and algae, leaves, roots, and soft parts of animals. Coal (mostly formed from cellular plant material in swamps) is an example of an organic sedimentary rock.



## BACKGROUND INFORMATION

### Geology Lesson 3; Sedimentology - Building our Landscape

#### IGNEOUS ROCKS

Igneous rocks are crystalline solids that form directly from cooling magma. Magma is molten rock made by the partial melting of rocks in the Earth's interior under conditions of high temperature and high pressure. As rock melts, it becomes less dense and rises towards the Earth's surface. Magma that reaches the Earth's surface is called lava. Many lava flows are quiet, like the eruption of Hawaiian volcanoes, but some can be violent, such as the eruption of Mount St. Helens back in 1980.

Igneous rock that forms at the surface of the Earth is referred to as extrusive or volcanic rock. These are named after the Roman fire god, Vulcan. Basalt is a good example of extrusive igneous rock.

Magma that cools, hardens, and forms igneous rock before it reaches the Earth's surface is called intrusive or plutonic after Pluto, the Roman god of the Underworld. These rocks cool over long periods of time and, thus, develop large crystal structures, as we see in granite. Some intrusive rocks are subsequently exposed to the surface - but only after uplifting or erosion of the Earth's surface, otherwise they would remain buried.

#### METAMORPHIC ROCKS

Metamorphism is the transformation of one rock type into another rock type. Metamorphic rocks are formed from exposing pre-existing igneous, sedimentary, and even other metamorphic rocks to extreme temperatures and/or pressures deep within the Earth.

Rocks that become deeply buried under the Earth are exposed to increased temperature and pressure.

This heat and pressure causes mineralogical changes in the pre-existing rock to forms more stable under the increased heat and temperature environment. Crystals form but are elongated and oriented reflecting the direction of the pressure under which they form. Common metamorphic rocks include gneiss, schist, slate and marble.

#### SUMMARY

In summary, rocks are solid masses occurring naturally as part of our planet. Rocks can be put into three fundamentally different types: igneous, sedimentary and metamorphic rock.

**IGNEOUS** rocks are crystalline and form directly from cooling magma, which is molten rock made by partial melting of rocks in the Earth's interior. Lava is magma that reaches the Earth's surface. Extrusive or volcanic rock is igneous rock that forms at the surface of the Earth, while intrusive or plutonic rock is igneous rock formed beneath the Earth's surface.

**SEDIMENTARY** rocks form from sediments or debris that settle out of water and become cemented together. Clastic sedimentary rocks form from solid particles of weathered and eroded rock. Chemical sedimentary rocks form from material carried in solution to lakes and oceans. Organic sedimentary rocks are formed from carbon-rich organic matter deposited upon the death of once living organisms.

**METAMORPHIC** rock is formed from pre-existing rock. As such, both sedimentary and metamorphic rock are secondary rocks, as they are formed from other rocks.

## STUDENT PAGE

### Geology Lesson 3: Sedimentology - Building our Landscape

## WHAT ARE SEDIMENTARY ROCKS AND HOW ARE THEY MADE?

Think about how a sandwich is made: a bottom layer of bread, layers of cold cuts and cheese, and then another piece of bread on top. In a similar fashion, sedimentary rocks are made from layers just like a sandwich. The layers are originally laid down horizontally (law of original horizontality) and the layers below are older than the layers above (law of superposition).

Sedimentary rocks are made when erosion, or the breaking down of the land around you, takes place. The particles of rock that break down are called sediment. The sediment can be grains of sand, mud, pebbles, minerals, fossils or plants.

Previously formed rocks are weathered at the Earth's surface, eroded to form sedimentary particles, and then transported by water, ice, and/or wind.

The sediment moves until the energy carrying it is no longer great enough to move the particles and they are deposited and accumulate over time. The regions where the particles are deposited are called sedimentary depositional environments. Sedimentary depositional environments include areas such as river basins, lakes, coastal swamps, or oceans. Organisms that live in these environments are deposited with the sediment when they die and may be preserved as fossils. Layers upon layers are formed on top of one another with time and eventually the layers harden and turn to rock.

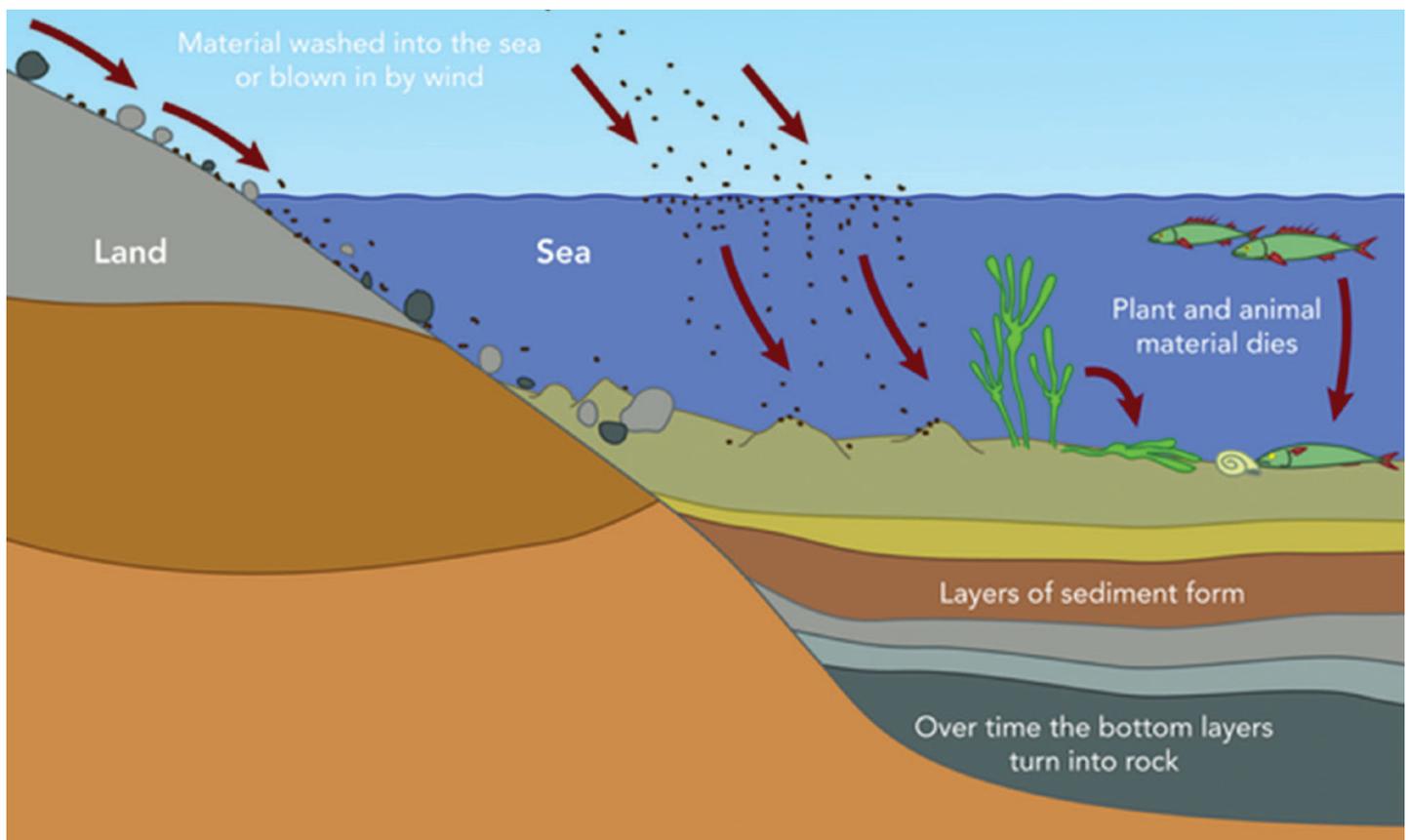


Image courtesy creative commons

# STUDENT PAGE

## Geology Lesson 3; Sedimentology - Building our Landscape

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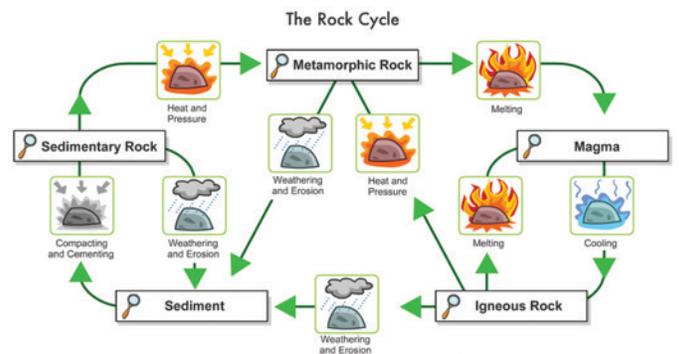
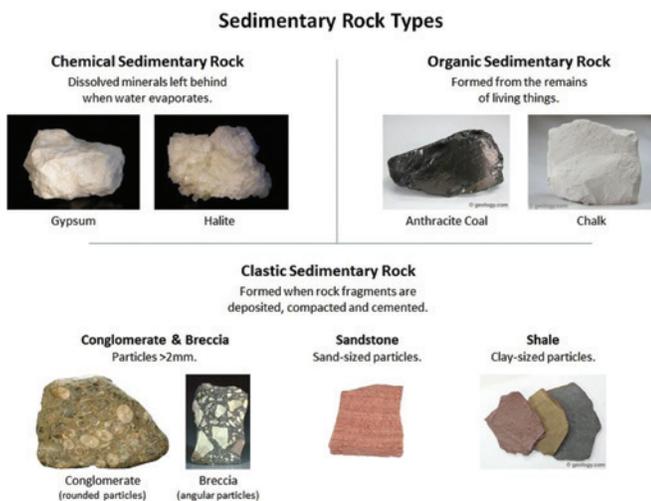
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**CHEMICAL** sedimentary rocks are derived from dissolved material carried in solution to lakes and oceans. When conditions are favorable, material precipitates out of solution and settles to the bottom where it accumulates as sediment. Precipitation may occur due to physical processes such as evaporation or through the biologic activity of living organisms. For example, limestone is the most abundant chemical sedimentary rock. It's typically formed either when calcite precipitates from seawater, or more often, from shells and other carbonate skeletal material produced by living organisms is deposited on lake or ocean bottoms to form sedimentary rocks. Most limestones are of biological origin.

**ORGANIC** sedimentary rocks form when organic matter (carbon-based organic material from living organisms) is deposited upon the death of the organism. These organic-rich deposits come from varied types of life at all scales; microscopic microbes and algae, leaves, roots, and soft parts of animals. Coal (mostly formed from cellular plant material in swamps) is an example of an organic sedimentary rock.



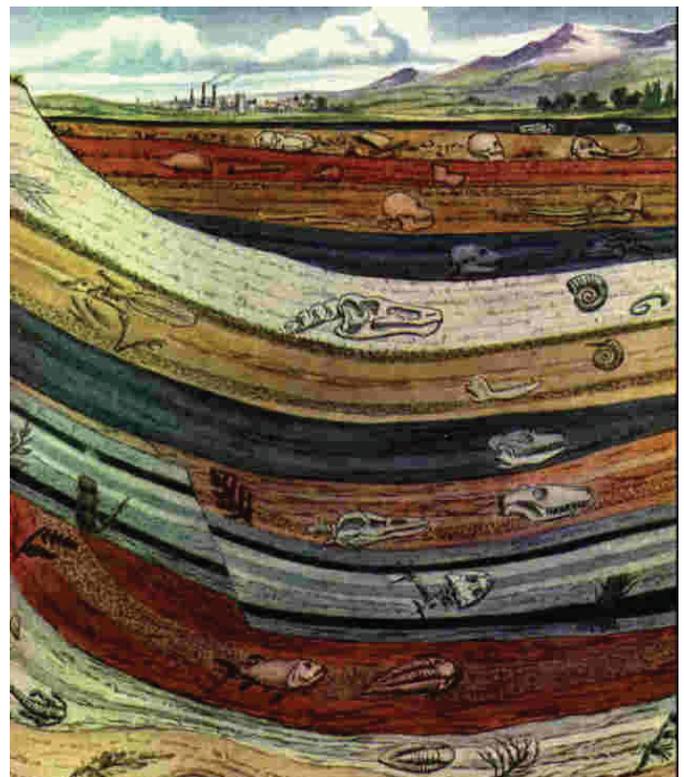
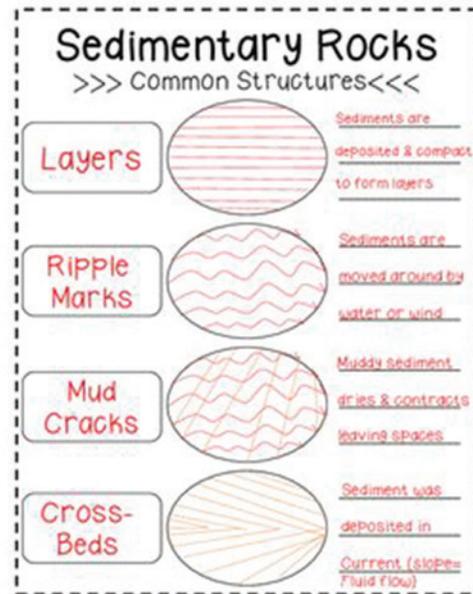
Images courtesy creative commons

# STUDENT PAGE

## Geology Lesson 3: Sedimentology - Building our Landscape

### FUN FACTS

- The layers in sedimentary rocks are called strata.
- When sediment is buried it compacts and is cemented together to form rock. This process is called lithification.
- Within sedimentary rocks, you will often find fossils or plants millions of years old.
- Sedimentary rocks are helpful in learning about Earth's past.
- Table salt that you may put on your food is from a chemical sedimentary rock called halite.
- Chalk for a chalkboard comes from a form of limestone.
- Sedimentary rocks are being made every day upon Earth's surface. They are formed when layers and layers of sediment get compressed together and eventually harden into rock.
- The three types of sedimentary rocks are clastic (formed from rocks that are broken down to form sediment and that sediment is transported and deposited), chemical (formed when dissolved minerals precipitate from water) and organic (formed from broken down plant and animal organic matter). The layers in sedimentary rocks are called strata, and they can help scientists learn about Earth's past.



Images courtesy creative commons

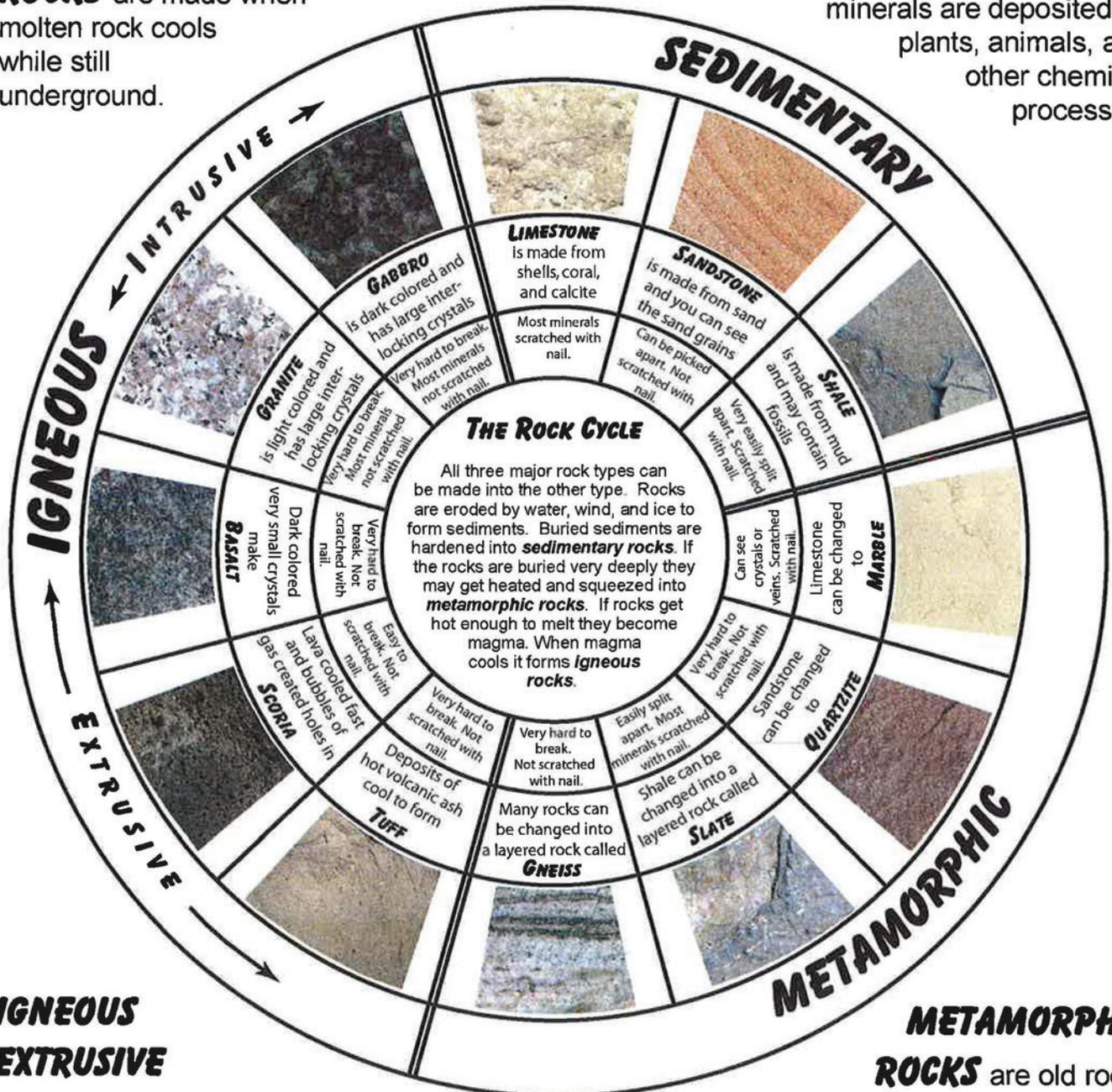
# HOW TO IDENTIFY ROCKS

## IGNEOUS INTRUSIVE

**ROCKS** are made when molten rock cools while still underground.

## SEDIMENTARY ROCKS

are made when pieces of rocks settle from the water or when minerals are deposited by plants, animals, and other chemical processes.



## IGNEOUS EXTRUSIVE

**ROCKS** are made when molten rock flows on the land surface or is thrown into the air and then is cooled into rock.

## METAMORPHIC ROCKS

are old rocks that have been squeezed and heated but not melted. What new rock is made depends on what the original rock was and on the amount of heat and pressure.

Source: Bill Langer, U.S. Geological Survey.



## STUDENT PAGE

### Geology Lesson 3: Sedimentology - Building our Landscape

#### MAKING SEDIMENTARY ROCKS

Draw a picture of your water bottle after each step and label each layer with the following words: Plants, Gravel, Sand and Soil.

Before adding water	After adding water & shaking	After water has settled

Write a prediction of what your bottle will look like after you shake it:

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# STUDENT PAGE

## Geology Lesson 3; Sedimentology - Building our Landscape

There are three types of sedimentary rocks. Use your student pages to find the names of these three rock types. Write them in the boxes below and draw a picture of a rock that matches each type.

Rock type: _____	Rock type: _____	Rock type: _____

Look at your water bottle and explain how it demonstrates the formation of sedimentary rocks.

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# 1

## **PALEONTOLOGY LESSON 1** Practices of Paleontology



## LESSON INSTRUCTIONS

### Paleontology Lesson 1: Practices of Paleontology

## GOAL

Students will explore the many specific steps and techniques that are followed from asking permission and discovering a fossil to museum research and display. These steps make up the practices of paleontology and differ depending on the environment where the fossil is found.

## OBJECTIVES

Students will be able to:

1. Describe the basic steps in the practices of paleontology.
2. Compare and contrast the practices of paleontology in Montana and Kumamoto.

## ASSESSMENT

1. Use the case study review pages to assess student understanding of the practices of paleontology in Montana and Kumamoto.
2. During the class discussion and by assessing student work using the Venn Diagrams, evaluate the students' abilities to compare and contrast the practices of paleontology in Montana and Kumamoto.

## MATERIALS

- o Power Point slides of the practices of paleontology loaded onto a projection system
- o Copies of "Student Pages," one per student (pages 138-152)
- o Optional: Examples of paleontology tools from the vocabulary lists on the student pages

## PREPARATION

- o Make copies of the student pages, one per student.
- o Preview and load the Power Point presentation for later use in class.
- o Gather any examples of paleontology tools from the vocabulary lists on the student pages.

# LESSON INSTRUCTIONS

## Paleontology Lesson 1: Practices of Paleontology



LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Using the provided powerpoint and images, explain the process of paleontology to the class.</p>	<p>Expect students to need clarification on some of the steps. Teachers can use the powerpoint to illustrate the steps.</p>	<p>This gives teachers the opportunity to introduce the practices of paleontology and cover the steps: Permission, Discovery, Excavation, Transportation and Display. This will prepare students to read their case studies.</p>
<p>Divide the class into four or more groups. Assign each group one of the four case studies. Explain to the students that two of the studies are from Montana, and two are from Kumamoto. Ask students to read the student page that describes the practices of paleontology in the area of their case study.</p>	<p>Expect students to need clarification on new vocabulary.</p>	<p>This gives teachers the opportunity to teach students about geography.</p>
<p>Ask students to read the case studies and answer the questions about it as a group.</p>	<p>Expect students to need clarification on new vocabulary. Use examples of the tools if possible.</p>	<p>This gives teachers the opportunity to incorporate the vocabulary terms for the unit into the lesson. Students should connect the tools to one or more of the steps (discovery, excavation, transportation, preparation or display).</p>
<p>Ask one student from each group to share what they learned from their case study by reviewing their answers to each question.</p>	<p>Expect students to discover that the Montana and Kumamoto sides have differences in the tools that are taken into the field.</p>	<p>This gives teachers the opportunity to guide students to share what they have learned and discover the differences.</p>
<p>Lead a discussion of the differences in the field seasons and the practices of paleontology between Montana and Kumamoto. Have students record similarities and differences on the Venn Diagram student page.</p>	<p>Expect students to wonder about why some tools are the same for Montana and Kumamoto and why some are different.</p>	<p>This gives teachers the opportunity to discuss fossil environments in Kumamoto and Montana. For example, in Kumamoto, some sites are located on islands, hence the necessity for transportation by ship and the need for tide tables.</p>



## BACKGROUND INFORMATION

### Paleontology Lesson 1: Practices of Paleontology

## PRACTICES OF PALEONTOLOGY

To find fossils, you first need to know where to look. For example, if you want to find a *Tyrannosaurus rex* you will need to find rocks that were deposited at the time that *T. rex* lived. Geologists study the Earth and make detailed maps that show where different ages of rocks are exposed at the Earth's surface. By studying a geologic map, you may identify a promising location to look for a *T. rex*. Before you can dig up a dinosaur, you need to make sure you have **permission** to do so. Often you will need a special permit to excavate fossils. Once you have obtained permission, you can then go out and look for fossils. This is called **prospecting and discovery**. When paleontologists are prospecting, they spend a lot of time hiking outdoors, searching the ground for pieces of fossils. Sometimes, you may find pieces of fossil bone on the ground that eroded out of a hill. If you can find the spot where the bone fragments originated, you may have an important **discovery**. At this point, it may be difficult to determine what exactly is in the hill. It could be a fossilized rib, or an entire skeleton. The only way to find out is to dig into the hill and begin excavating the fossil.

Paleontologists must be very careful when they **excavate** a fossil, because they are often very fragile. Shovels, hammers, and picks may be used to remove rock, but smaller brushes and chisels are used when working close to the fossil. Once the fossils are exposed, they might be coated with glues or hardeners to help keep them together during the excavation. Before the specimens are removed from the ground, it is very important to record as much information as possible about how they are positioned in the rocks. This may help you figure out how the fossil was preserved, or how the animal died. Paleontologists take detailed notes and photographs, measurements of depth and orientation, and draw maps of how the fossils are positioned in the ground.

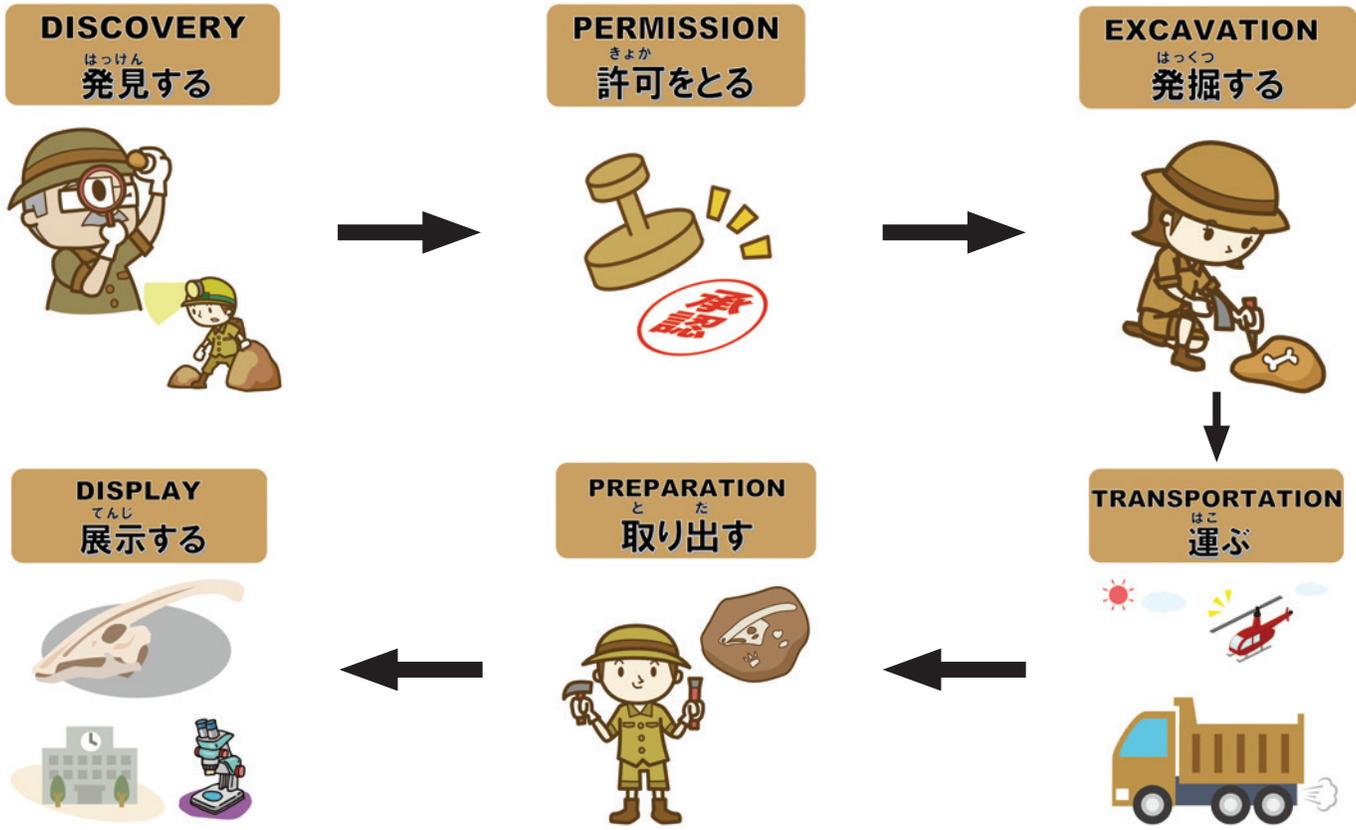
Once all this information is collected, it is time to carefully remove the fossils from the ground. To do this, paleontologists typically encase fossils in layers of burlap and plaster, called a field jacket. A field jacket is similar to the cast a doctor might put around a broken arm; just as that cast is made to protect a broken bone, a field jacket is made to protect the fossil as it is transported from the field back to the museum. The size of a field jacket depends on what's inside; sometimes a field jacket is very small, and you can carry it out of the field in your hand; sometimes a field jacket is so large and heavy that a helicopter is required to lift it and carry it to a truck for **transport** back to the museum.

Back at the museum, the field jackets are opened, and the remaining rock must be carefully removed from around the fossil. During **preparation**, scientists use picks and brushes to carefully remove the rock that has encased the fossil for millions of years. Sometimes, if the rock is very hard, they may need to use more powerful tools, such as an air scribe, which is like a small jack-hammer that chips away hard rock bit by bit. Preparators fit together any broken pieces of the fossil, so it can be studied. Sometimes fossils can take weeks, months, or even years to prepare, depending on how fragmented they are and the hardness of the rock in which they are encased.

Once the fossil is prepared, it goes into the museum's fossil collections. The collections area is like a library, but instead of books, it contains fossils. Each specimen is assigned a number and entered into a computer database. This allows the museum to keep track of each fossil. The fossil is stored on a shelf or in a cabinet. Now that the fossil is cataloged, it can be available for research, education, or **display** in a museum exhibition.

# BACKGROUND INFORMATION

## Paleontology Lesson 1: Practices of Paleontology



Images courtesy Mifune Dinosaur Museum

### EXCAVATING FOSSILS IN JAPAN: A NOTE ON OBTAINING PERMISSION

Fossils are important evidence for understanding evolution and paleoenvironments. In Japan, people are usually allowed to look for fossils that are on the surface without permission from a landowner unless the landowner prohibits it. However, to excavate fossils on someone's land, permission must first be granted. Paleontologists contact landowners through a local Board of Education or museum near the area where the fossils were discovered. After permission is received, excavation can proceed.

With the abundance of surface soil and vegetation in Japan, outcropping of Mesozoic rocks is rare. Although we can predict the occurrence of fossils based on geologic data, it is difficult to decide specifically where to obtain permission without evidence of fossils appearing on the surface.

Although there are laws that provide protection for archaeological and historical resources, laws protecting paleontological resources are inadequate. Fossils specified as natural resources and their localities can be protected through an agreement with the landowner. However, sometimes there are multiple landowners of a locality and it may be difficult to obtain permission from them all.

## STUDENT PAGE

### Paleontology Lesson 1: Practices of Paleontology

## PALEONTOLOGY IN MONTANA



*Images courtesy Museum of the Rockies*

In Montana, people who study fossils, called paleontologists work in the field during the summer season. This is because there is too much snow in winter. The climate is dry and hot, and paleontologists must be sure to take a hat and sunscreen to the field, as well as plenty of water.

In Montana, the end of the Age of Dinosaurs is represented by the geologic unit called the Hell Creek Formation. Paleontologists use a geologic map to find where the formation is located across the state. Once you have located areas where the Hell Creek Formation is exposed, you will want to determine who owns or manages that land. On public lands, it is necessary to obtain an official permit to collect fossils.

Once a field team has made a discovery and obtained permission to excavate the fossil, they will then get tools to dig up the fossil. These may include a rock hammer, shovel and chisels. You will also need small plastic bags to store small pieces of fossils. A notebook will be needed to record information about the excavation. Paleontologists use a special compass to record details about how the fossils are oriented in the ground, which can lead to clues

about how the dinosaur was preserved. A special stick, called a Jacob's Staff, is used to measure where the fossil is found in the rock layer and will help paleontologists understand when the dinosaur lived. Sometimes, the fossils of dinosaurs can be covered by a lot of hard rock, so a jack hammer can be necessary.

In order to protect the fossils once they have been exposed to air, paleontologists use layers of burlap and plaster to make field jackets. First, cover the fossil in paper towels or aluminum foil; this will help to separate the fragile fossils from the plaster that will protect them during transportation. To mix the plaster in the field, fill a shallow bucket with water. Combine the plaster powder and water in the bucket and then dip your burlap in the mixture.

Once the fossils are fully encased in field jackets, paleontologists transport them back to the museum using a truck and trailer. Sometimes, a field jacket is so big that you might even need a helicopter to lift it onto a flatbed truck. Once the fossils are on the truck, it's time to drive them back to the museum where they can be prepared by fossil preparators, studied by researchers, and maybe put on exhibit.

## STUDENT PAGE

### Paleontology Lesson 1: Practices of Paleontology

## PALEONTOLOGY IN KUMAMOTO



*Images courtesy Mifune Dinosaur Museum*

In Kumamoto Prefecture, Japan, paleontologists are able to work in the field year-round due to a temperate climate. Unlike Montana, paleontologists in Kumamoto Prefecture often have to remove layers of plant matter, or vegetation, to get to the fossil layer. In many cases, like Goshoura in Amakusa, a boat or ship are necessary to reach fossil sites.

In Kumamoto, fossil dinosaurs are located within the Mifune Group. Paleontologists use a geologic map of Kumamoto Prefecture to find where the formation is located. Places like Goshoura Island also have their own geological maps that show the area in greater detail. Once a fossil is discovered, paleontologists must get permission from the person or manager of the land. In Japan, landowners are contacted through the local Board of Education or local museum.

Once a field team has permission to excavate the fossil, they will need to gather the right tools for the field. Depending on where the fossil is located, a grass cutter to remove plants may be needed. If it is near an ocean or marine environment, it is necessary to bring a list of tide tables to determine safe times to excavate. Plastic bags

will store small pieces of fossils, and a rock hammer will enable you to split open hard rock.

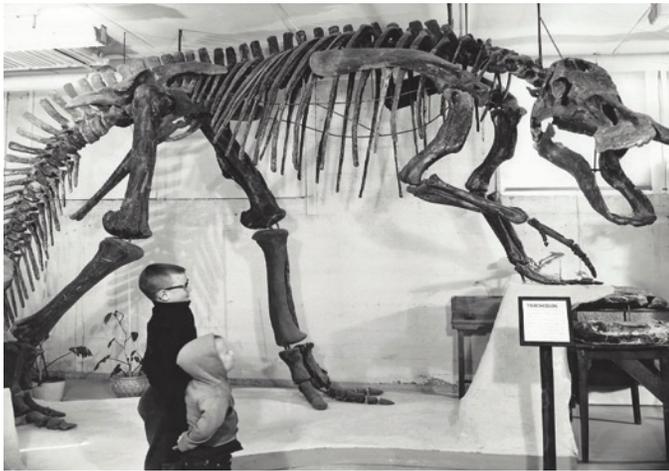
High pressured water is used to keep the site clean and to enable paleontologists to locate additional fossils. An air compressor is needed to use this tool and the jackhammer. Once a fossil is exposed, it is covered in consolidant and protected with a field jacket made from plaster soaked burlap, or wrapped with foam and packing tape.

Once the fossils are excavated, they will need to be transported back to the museum either by truck overland, or ship if there is water. The fossils are then prepared by fossil preparators, studied by researchers, and may even be placed on exhibit.

*Fun fact: Dinosaur discoveries are very new in Japan. This means that paleontologists are often finding new species that they can name!*

# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology



Images courtesy Carter County Museum

### CASE STUDY - CARTER COUNTY MUSEUM, MONTANA, USA:

CCM V-1938.8

*Edmontosaurus annectens*

#### MEANING OF NAME:

Giant Duck

#### LOCATION FOUND:

Winkley Ranch, Carter County, Montana

#### ROCK FORMATION:

Hell Creek Formation

#### YEAR DISCOVERED:

1933

#### YEAR FIRST DISPLAYED:

1954 in the basement of the old Carter County High School in Ekalaka, Montana.

### PERMISSION

Bill and Carol Winkley, ranchers in Carter County, gave permission for Walter Peck (the museum director) and his crew to excavate the fossil from their private land.



### DISCOVERY

Orville Carrol reported the discovery of fossil bones by landowner William "Bill" Winkley to Walter Peck on July 13, 1938. The crew of the Carter County Geological Society used a **geologic map** to locate the bones in the Hell Creek Formation.



### EXCAVATION

Three members of the Carter County Geological Society set out for the site on August 1, 1938. Here, Ted Snyder uses a **chisel** and **pick** to scrape away the dirt to reveal the bone. The **foil** is to keep bone fragments together. He is wearing a **hat** to protect himself from the sun.



# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology

Once the bones were exposed, Walter Peck identified them as bones belonging to the hadrosaur or duck-billed dinosaur family.



The image at right shows a femur exposed, with **rock hammer** to show the scale.

It took a full week to excavate these bones. They were then treated with **consolidant**, covered in layers of **paper towel**, **burlap** and **plaster** (pictured right).



Excavation of the full skeleton was completed in early October, 1938.

### TRANSPORTATION

The field jackets were loaded into a **truck & trailer** on October 2, 1938 and taken to a storage building in Ekalaka.



### PREPARATION

Marshall Lambert, the museum Director from 1946 to 1996 and a science teacher at Carter County High School (CCHS), finished the prep work on the *Edmontosaurus* fossil after Peck's death in 1946. He is pictured above using a small **brush** to clean the skull before display.



### DISPLAY

This dinosaur was first displayed in the basement of the old Carter County High School (CCHS) in 1954. Marshall Lambert enlisted the help of other members of the Carter County Geological Society to mount the specimen. The exhibit opening was covered as a part of the 1954 Life Magazine article "The Town that Hunts Bones."

In 1976 the specimen was remounted in the museum's new building by Marshall Lambert and community members. It can still be seen on display at the Carter County Museum.



Images courtesy Carter County Museum

# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology



Images courtesy Museum of the Rockies

### CASE STUDY - MUSEUM OF THE ROCKIES, MONTANA, USA:

MOR 555

Wankel *Trex* (Nation's *Trex*)

*Tyrannosaurus rex*

#### MEANING OF NAME:

Tyrant Lizard King

#### LOCATION FOUND:

Nelson Creek area of Fort Peck Lake,  
McCone County, Montana

#### ROCK FORMATION:

Hell Creek Formation

#### YEAR DISCOVERED:

1988

#### YEAR FIRST DISPLAYED:

1990 in a temporary preparation lab at Museum of the Rockies

### PERMISSION

Museum of the Rockies had to obtain a permit from two federal agencies because the skeleton was located on Army Corps of Engineers land within the Charles M. Russell National Wildlife Refuge.



The permit applications took three weeks to approve for each of the two years (1989 & 1990) that the fossil was excavated.

### DISCOVERY

With this fossil, the discovery happened when Kathy Wankel found fragments of arm bones in 1988. She brought the bones to the paleontology staff at the Museum of the Rockies and had them identified.



### EXCAVATION

MOR staff began excavation on September 9, 1989. Since there was limited time, the crew decided to cover the exposed bones with a winter field jacket made from plaster soaked burlap.



# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology

The field jacket protected the exposed bone until the crew could return the following year. This first phase of the excavation process took 14 days.



MOR staff returned to continue excavation on June 4, 1990. It was summer, and crew members needed a **hat, drinking water,** and **sunscreen** to protect themselves during the hot days.



Since most of the skeleton was articulated, the crew had to make several large field jackets with **plaster** soaked **burlap**. The largest field jacket containing the pelvis and left leg weighed almost 4 tons. The excavation was completed on July 1 after a period of 25 days. Progress on the excavation was recorded in **notebooks**.

### TRANSPORTATION

On July 2, the field jackets were lifted with a large **front-end loader** and placed on a small **flatbed truck** where they were shuttled to a main road.



On July 3, it took 7 hours to transport all the field jackets to the Museum of the Rockies.

### PREPARATION

Preparation of the arm took approximately two weeks by one preparator. Preparation of the skeleton took approximately two years.



Fossil preparators at Museum of the Rockies used **picks** and **brushes** to carefully remove the rock that had encased the fossil for millions of years. Sometimes, if the rock is very hard, they may need to use more powerful tools, such as an **air scribe**, which is like a tiny **jack-hammer** that chips away hard rock bit by bit.

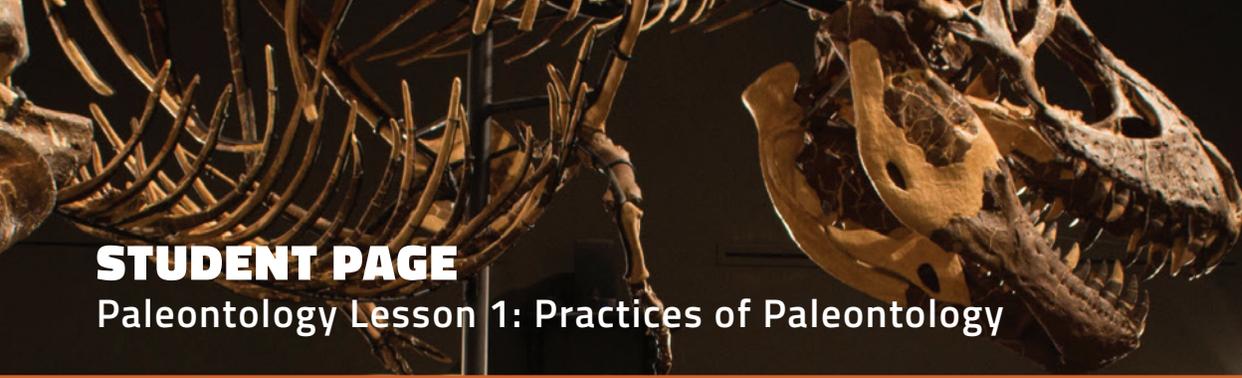
### DISPLAY

The Wankel *T. rex* was originally displayed from 1990 to 1992 in a temporary viewing lab, so the public could watch how the bones were being prepared. In September 2001, a bronze replica of the skeleton was installed in the front of the Museum of the Rockies. The actual fossils were on display in their original death pose in the Hall of Horns and Teeth at the Museum of the Rockies from 2005 to 2014.

There are more than 25 replicas of the Wankel *T. rex* skeleton and skull exhibited in museums around the world. A replica skull is currently on display as part of a *T. rex* ontogenetic series in the Tyrant Kings exhibit at the Museum of the Rockies.

In April 2014, the real Wankel *T. rex* specimen was transported to the Smithsonian National Museum of Natural History in Washington D.C.

*Images courtesy Museum of the Rockies*



# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology

### MONTANA CASE STUDY REVIEW

Read the case studies for paleontological work in Montana and use the vocabulary box to answer the following questions.

### VOCABULARY

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GEOLOGIC MAP

SUNGLASSES/HAT

CHISEL

JACK HAMMER

PAPER TOWELS

DRINKING WATER

NOTEBOOK

BURLAP

FLATBED TRUCK & TRAILER

BACKPACK

ROCK HAMMER

PLASTIC BAGS

PLASTER

SUNSCREEN

SHOVEL

JACOB'S STAFF

ALUMINUM FOIL

FRONT-END LOADER

BRUSH

PICKS

AIR SCRIBE

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1. In what season can you dig for fossils in Montana?

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2. What tool helps a scientist choose where to look for fossils?

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**STUDENT PAGE**

**Paleontology Lesson 1: Practices of Paleontology**

3. What tools do you need to excavate fossils?

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4. What tools do you need to protect the fossil during transportation?

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5. What tools do you need to transport a fossil?

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6. What tools do you need to prepare fossils in a museum?

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# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology



Images courtesy Mifune Dinosaur Museum

### CASE STUDY - MIFUNE DINOSAUR MUSEUM, KUMAMOTO, JAPAN:

*Therizinosaurid*

MDM 1942

#### MEANING OF NAME:

Scythe Lizard

#### LOCATION FOUND:

Amagimi Quarry, Mifune Town, Kamimashiki County, Kumamoto Prefecture

#### ROCK FORMATION:

"Upper Formation", Mifune Group

#### DISCOVERED:

March 1998

#### YEAR FIRST DISPLAYED:

2004 at Mifune Dinosaur Museum

### PERMISSION

Prior to acquiring access to the Amagimi Quarry fossil locality, the Mifune Dinosaur Museum had to obtain permission from a private landowner. A contract between Mifune Town and the private landowner was written and signed by both parties. This process took one week.



### DISCOVERY

The braincase of this dinosaur was discovered during excavation of the Amagimi Quarry site. A crewmember recognized bone fragments in a rock in the quarry and brought them back to the museum for identification and preparation.



### EXCAVATION

Preparing the quarry for excavation required removing vegetation (trees, bushes, grass) with **grass cutters** to expose the rock layers. A **backhoe** followed by **jackhammers, hammers** and **chisels** were used to remove the surface rock and to locate fossil specimens in the sandstone bonebed.



# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology

**High pressured water** was used routinely to keep the site clean which helped to locate additional fossil specimens. Both the **jackhammer** and high-pressured water required the use of an **air compressor**.

Exposed fossils encased in matrix were stabilized with a **consolidant**, then protected with either field jackets made from **plaster soaked burlap**, or wrapped with foam and **packing tape**.

The Mifune Dinosaur Museum field crew worked 7 to 10 days each year over a period of five years. During that period, other specimens (isolated teeth, humerus and other skeletal material) belonging to the *therizinosaurid* were discovered.

### TRANSPORTATION

The specimens were placed in large **plastic containers**, then transported by **truck** back to the Mifune Dinosaur Museum.



### PREPARATION

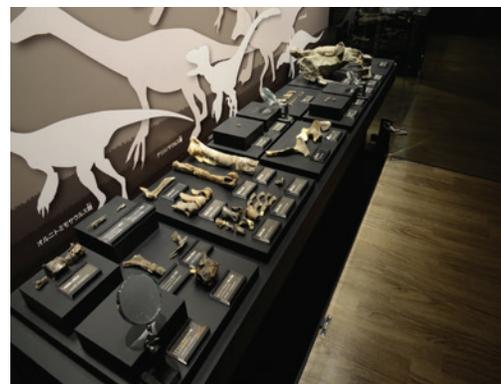
Fossil preparation of the braincase and additional therizinosaurid specimens occurred over a three-year period. **Air scribes** were used to remove the hard matrix from the fossils.



Final preparation was completed in 2003.

### DISPLAY

The braincase and associated fossil specimens are on display in the Cretaceous Age exhibit at the Mifune Dinosaur Museum.



Images courtesy Mifune Dinosaur Museum

# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology



Images courtesy Goshoura Cretaceous Museum

### CASE STUDY - GOSHOURA CRETACEOUS MUSEUM, KUMAMOTO, JAPAN:

#### GCM-VP66

The largest carnivorous dinosaur tooth discovered in Japan.

#### LOCATION FOUND:

The quarry is known as The Cretaceous Wall, Goshoura Island, Amakusa, Kumamoto Prefecture.

#### ROCK FORMATION:

Eboshi Formation, Goshoura Group

#### DISCOVERED:

March 1997

#### YEAR FIRST DISPLAYED:

July 1997 at the Goshoura Cretaceous Museum's Grand opening ceremony.

### PERMISSION

Prior to acquiring access to the fossil locality where the tooth was discovered, the Goshoura Cretaceous Museum had to obtain permission from a stone-quarrying company before any work took place.



### DISCOVERY

The Mayor of Goshoura commissioned a research team from Kochi University to explore Cretaceous sediments on Goshoura Island for one week. There were seven members of the research team. They could only access the fossil locality areas by **water taxi** or **ship** as these areas cannot be reached by car. One of the team members discovered a black colored fossil on the rock surface in the quarry. The team realized that there were serrations on the edge of the fossil indicating it was a large tooth from a carnivorous dinosaur.



# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology

### EXCAVATION

The fossil tooth was embedded in a large rock that could not be moved. The large rock was split into a smaller size by one of the quarry workers using a **backhoe** or **power shovel**.



Team members then used **hammers** and **chisels** to remove a smaller piece of rock with the tooth still embedded in the matrix.



### TRANSPORTATION

The specimen and matrix were hand carried and taken by **ship** to the mainland where it was transported by **car** to Kochi University.



### PREPARATION

The rock containing the fossil was brought to the laboratory at Kochi University. Preparation of the specimen was extremely difficult because of the hardness of the rock.



Using small **chisels** and **hammers**, it took one month to expose one side of the tooth. The specimen was exhibited in matrix for a few years before it was completely removed from the rock with **air scribes** and **air chisels**.

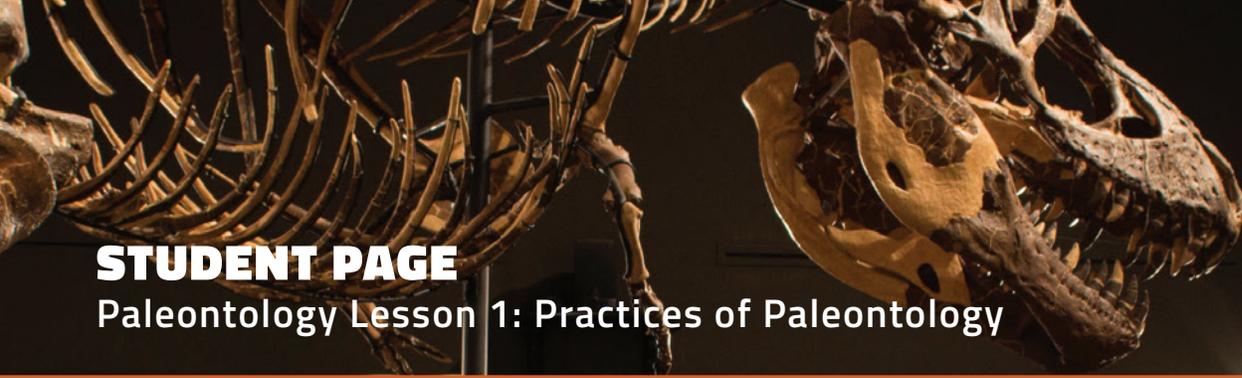
### DISPLAY

The specimen is on display in the first exhibition room at the Goshoura Cretaceous Museum.

A replica of the tooth is on exhibit at the Fukui Prefectural Dinosaur Museum in Katsuyama, Japan.



Images courtesy Goshoura Cretaceous Museum



# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology

### KUMAMOTO CASE STUDY REVIEW

Read the case studies for paleontological work in Kumamoto and use the vocabulary box to answer the following questions.

### VOCABULARY

GEOLOGIC MAP

CHISEL

BURLAP

GRASS CUTTER

BRUSH

NOTEBOOK

BACKHOE

HIGH PRESSURE WATER

PACKING TAPE

JACKHAMMER

AIR COMPRESSOR

TRUCK

ROCK HAMMER

PLASTER

PLASTIC CONTAINER

AIR CHISEL

AIR SCRIBE

1. In what season can you dig for fossils in Kumamoto Prefecture?

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2. What tool helps a scientist choose where to look for fossils?

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**STUDENT PAGE**

**Paleontology Lesson 1: Practices of Paleontology**

3. What tools do you need to excavate fossils?

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4. What tools do you need to protect the fossil during transportation?

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5. What tools do you need to transport a fossil?

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6. What tools do you need to prepare fossils in a museum?

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# STUDENT PAGE

## Paleontology Lesson 1: Practices of Paleontology

### COMPARE AND CONTRAST

After reviewing the different case studies from Montana and Kumamoto with your class, write details that explain how the practices of paleontology are different between our two countries in the outer circles. Write details on how the practices are the same where the circles overlap.

*Kumamoto*

*Montana*

*Similarities*

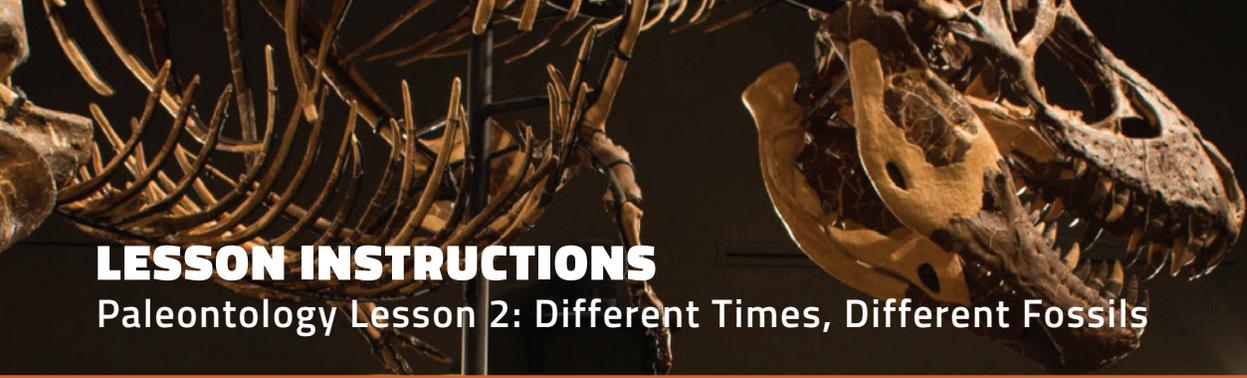
A Venn diagram consisting of two overlapping circles. The left circle is labeled 'Kumamoto' and the right circle is labeled 'Montana'. The overlapping area in the center is labeled 'Similarities'. Each of the three regions (left, center, and right) contains five horizontal lines for writing.





# 2

## **PALEONTOLOGY LESSON 2** Different Times, Different Fossils



## LESSON INSTRUCTIONS

### Paleontology Lesson 2: Different Times, Different Fossils

## GOAL

The Earth and its landscapes change over time. Scientists use the fossil record to understand Earth's environments and climates millions of years ago. By creating two stratigraphic columns and comparing them, students will learn that both places are needed to tell the story of geologic time.

## OBJECTIVES

Students will be able to:

1. Match ancient creatures to their location in the fossil record.
2. Compare and contrast the fossil record and stratigraphy of Montana and Kumamoto.

## ASSESSMENT

1. Check student pages for the correct placement of creatures on the stratigraphy pages.
2. Evaluate student answers on the "Comparing Stratigraphy of Montana and Kumamoto" student page to assess students' ability to compare and contrast the fossil records.

## MATERIALS

- o Copies of "Student Pages," one per student (pages 160-177)
- o Optional: Video – "PBS Eons: A Brief History of Geologic Time" loaded on to a projection system  
<https://www.youtube.com/watch?v=rWp5ZpJAIAE&t=118s>
- o Scissors and glue/tape for each student

## PREPARATION

- o Make copies of the student pages, one per student.
- o Preview and load the video for later use in class.

# LESSON INSTRUCTIONS

## Paleontology Lesson 2: Different Times, Different Fossils

LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
Introduce students to the activity by connecting the lesson to “Practices of Paleontology.” Tell students that they will learn how scientists find dinosaurs using geologic maps.	Expect students to need a visual reference. Teachers can reference the geologic maps for Montana and Kumamoto and go through the layers.	This gives teachers the opportunity to tell students how geologic maps show the rocks present on the Earth’s surface and categorize them by the age of the rocks and the type of rocks present (called rock formations).
Describe the process of Geologic time.	Expect students to need a visual reference. Teachers can use the provided video link.	This gives teachers the opportunity to describe how the landscape changed over time and affected the organisms that lived upon it. The type of sedimentary rocks are determined by the environments of deposition that are responsible for their formation.
Explain the process of fossilization and show students examples of fossils that come from different formations in Montana and Kumamoto described in the student pages.	Expect students to need a visual of the process. Show the image of the formation of a <i>Triceratops</i> fossil provided in the background information.	This gives teachers the opportunity to connect fossilization to sedimentology through the formation of stratigraphic layers.
Connect the lesson to the worksheet material by asking students what period the dinosaurs lived in (Mesozoic, including the Triassic, Jurassic, and Cretaceous Periods) and have them point out where the rock outcrops for this period are in Montana and Kumamoto.	Take this opportunity to explore examples of dinosaurs from Montana, Mifune and Amakausa as described in the student pages.	This gives teachers the opportunity to discuss how the geologic maps can help students place the fossils in time.
Have students cut out the creature cards and glue/tape them to the appropriate location on the stratigraphy pages.	Expect students to need some guidance with arranging the fossils. Teachers should reference the worksheet keys to help students.	This gives teachers the opportunity to have the class work in groups and complete the project together.
Have students complete the final worksheet with reflective questions. Lead a class discussion of the material using these questions as a guide.	Expect students to need guidance to complete the worksheet.	This gives teachers the opportunity to check student comprehension of the lesson and address any misunderstandings.



## BACKGROUND INFORMATION

### Paleontology Lesson 2: Different Times, Different Fossils

#### GEOLOGIC TIME

Video link (12:07 min): <https://www.youtube.com/watch?v=rWp5ZpIAIE&t=18s>

When you think of time, you may think of the time you can see passing by on a clock. Seconds, minutes, hours. Or perhaps the time you can keep track of on a calendar: days, weeks, months, or even years. But evidence in rocks indicates that time is far more vast than what can be seen on a clock or even a typical calendar.

In order to explore questions like the age of the dinosaurs and the age of the Earth, we must consider geologic time. Geologists (scientists who study the Earth) have divided the history of the planet into a geologic time scale, which relates the different layers of rock on the planet to periods of time. Studies of the rocks indicate that many rock formations were formed over millions of years. Evidence from geology reveals that the Earth is approximately 4.5 billion years old.

This huge amount of time has been divided into time periods in a similar way to how years are divided into weeks and months.

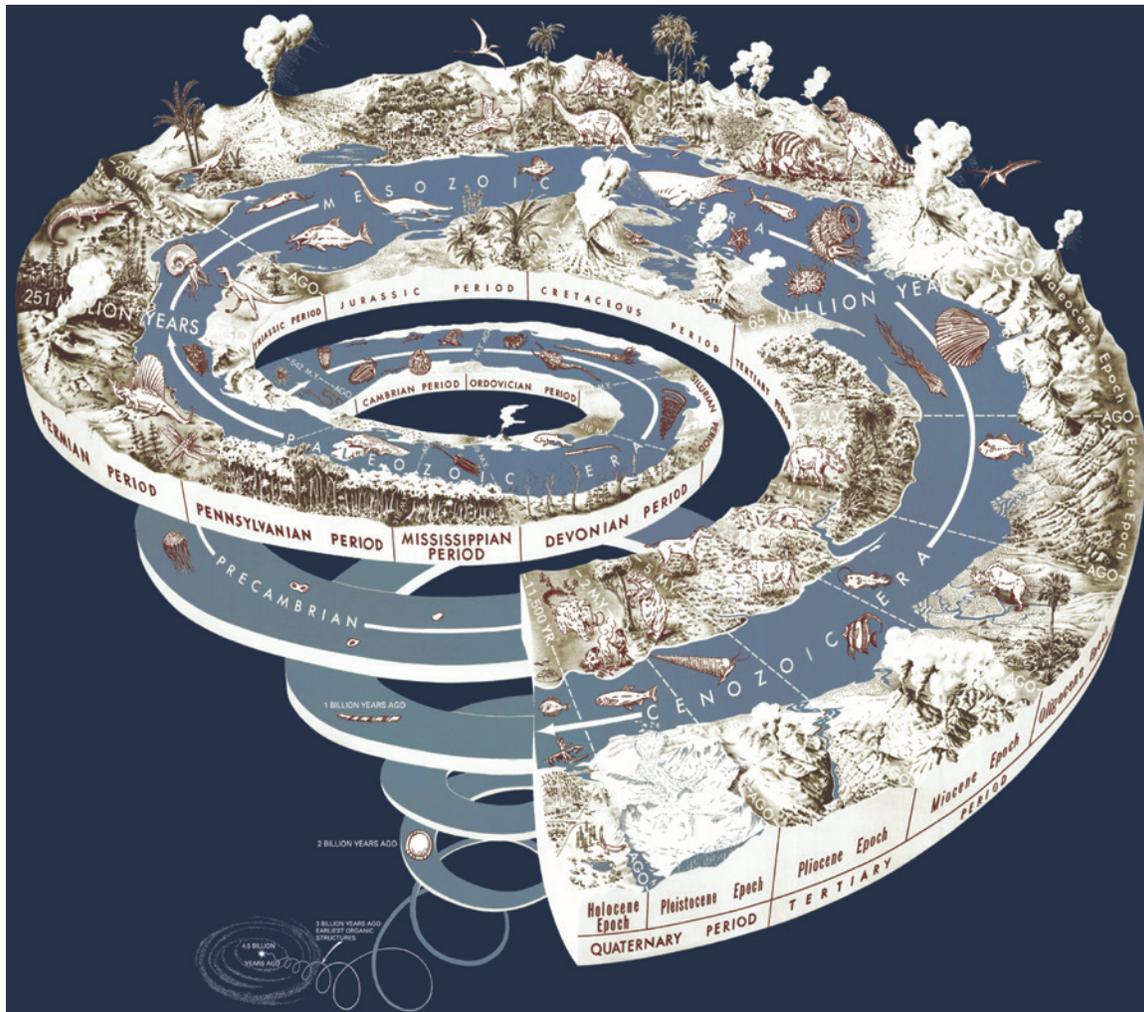


Image courtesy Wikipedia

# BACKGROUND INFORMATION

## Paleontology Lesson 2: Different Times, Different Fossils

For example, the Age of Dinosaurs is known as the Mesozoic Era and it lasted from ~252 until 66 million years ago. The Mesozoic Era is divided into: the Triassic Period (which lasted from approximately 252 to 201 million years ago), the Jurassic Period (201 to 145 million years ago), and the Cretaceous Period (145 to 66 million years ago).

The Mesozoic Era was followed by the Cenozoic Era, which is sometimes called the Age of Mammals. We are still living in the Cenozoic Era today.

This Era is divided into the Paleogene Period (from approximately 66 million years ago until 23 million years ago), the Neogene Period (from approximately 23 million years ago until 2.5 million years ago), and the Quaternary Period (approximately 2.5 million years ago until the present day).

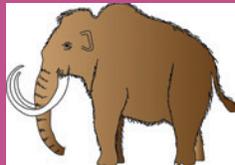
Recorded human history accounts for only the last few thousand years of the millions and millions of years of Earth's history. The overwhelming majority of the planet's past is represented in geologic time.



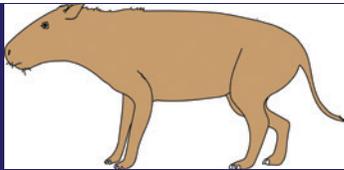
Image courtesy Wikipedia

# STUDENT PAGE: ANSWER KEY

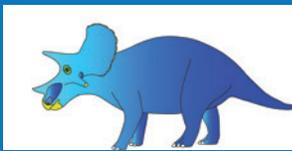
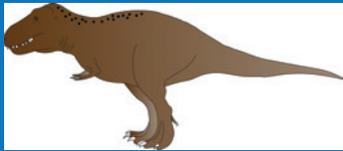
## Paleontology Lesson 2: Different Times, Different Fossils



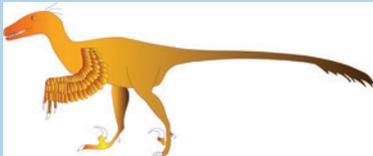
NEOGENE (0.018MA)



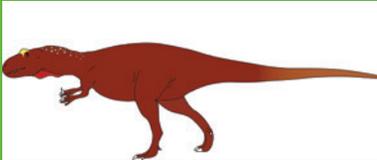
PALEOGENE (32MA)



LATE CRETACEOUS (66MA)



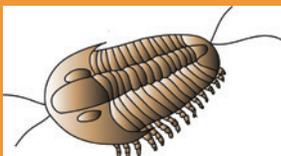
EARLY CRETACEOUS (109 MA)



LATE JURASSIC (150MA)



CARBONIFEROUS (318MA)



CAMBRIAN (500MA)

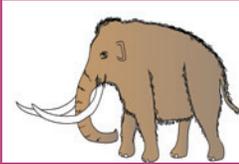


PRE-CAMBRIAN (700MA)

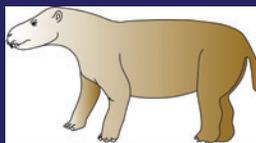
# STUDENT PAGE: ANSWER KEY

## Paleontology Lesson 2: Different Times, Different Fossils

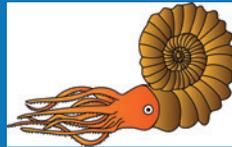
AMAKUSA



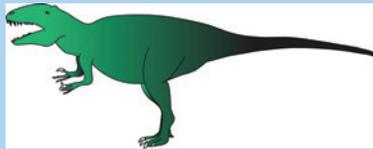
NEOGENE (0.18MA)



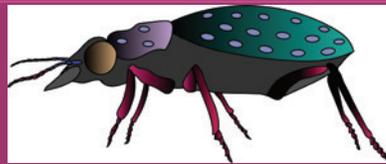
PALEOGENE (49MA)



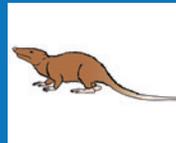
LATE CRETACEOUS  
(100-66MA)



EARLY CRETACEOUS  
(101MA)



PLEISTOCENE (.018MA)



LATE CRETACEOUS  
(100-66MA)

MIFUNE



LATE TRIASSIC  
(220MA)



LATE PERMIAN (255MA)

## STUDENT PAGE

### Paleontology Lesson 2: Different Times, Different Fossils

## THE PROCESS OF FOSSILIZATION (DINOSAURS)

### STEP 1: DEATH

Dinosaurs that die near water or in a windy area have a greater chance of becoming a fossil because water and wind carry sand and mud which can bury the dinosaur.

### STEP 2: BURIAL

The river's current pushes sand and mud over the dinosaur's body, completely covering it. The burial step is one of the most important steps, because it allows the dinosaur's body to be preserved and protects its remains from scavengers. Frequently, paleontologists find incomplete fossilized skeletons. Sometimes the dinosaur's remains are scattered by scavengers, predators, or water currents before burial occurs.

### STEP 3: PERMINERALIZATION

Minerals can sometimes soak into the bones of the dinosaur. In living animals' bones (including human bones), blood vessels travel through these tiny tunnels, nourishing the bone and allowing it to strengthen and grow. When the animal dies, the blood vessels often deteriorate leaving the holes behind. These holes are what allow the bones to absorb the surrounding minerals. Fossils may be replaced by minerals and those minerals are the ingredients of rocks. But sometimes the original material of long extinct creatures can still be recovered. For example, the frozen remains of woolly mammoths have been discovered and largely intact ancient insects have been found trapped in amber (fossil tree resin).

### STEP 4: TIME PASSES

In order for the fossil to last for millions of years, it must stay completely covered. With time and exposure to weather, fossils can erode and disintegrate.

### STEP 5: UPLIFT AND EROSION

The layers of our Earth are constantly in motion! In order for the fossil to be discovered, the layer in which the fossil is buried must be pushed closer to the surface, or the layers covering it must be worn away.

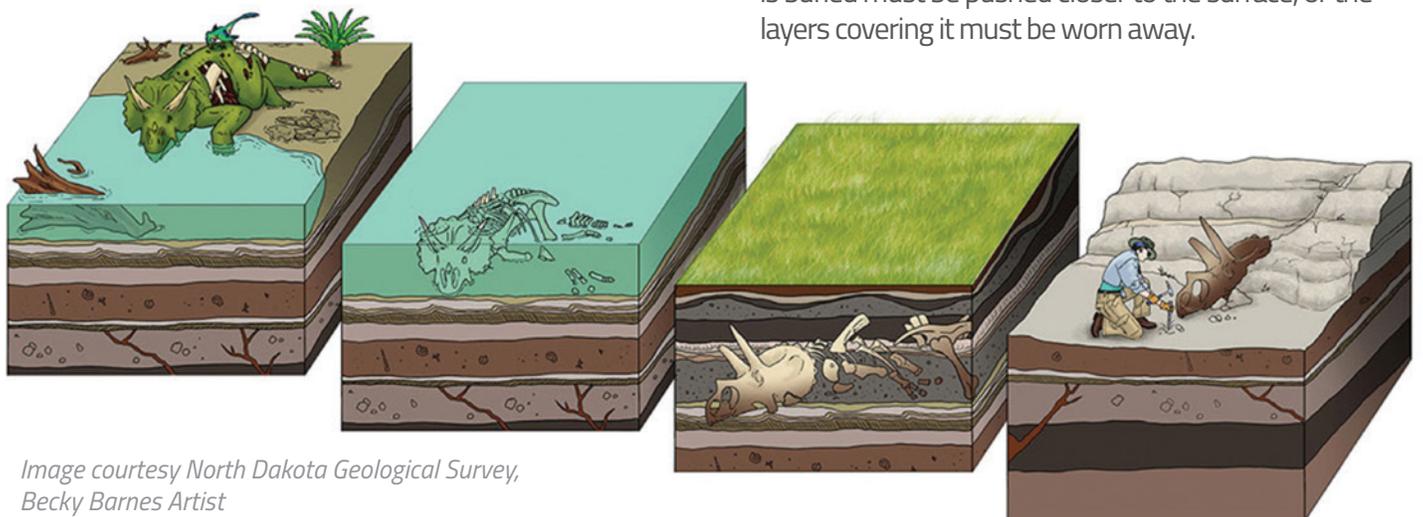


Image courtesy North Dakota Geological Survey, Becky Barnes Artist

## STUDENT PAGE

### Paleontology Lesson 2: Different Times, Different Fossils

#### BIOSTRATIGRAPHY

Rocks record time. When you see layers of rocks in hillsides, cliffs, and mountains, you are actually looking back in time because the rocks that make up those hillsides, cliffs, and mountains were deposited or formed a long time ago, and different layers of rocks formed at different times. If you wish to find a certain kind of fossil, you need to first find rocks that were deposited during the time period that that creature existed on this planet. To find a *Tyrannosaurus rex* fossil, you will need to first find rocks that were deposited during the Cretaceous period, the time that *Tyrannosaurus rex* lived on Earth. If you want to find a *Velociraptor*, you will need to look in

much older rocks. Not only did these dinosaurs live at different times, but they also lived in different places. *Tyrannosaurus rex* lived in North America and *Velociraptor* lived in Asia. Some time periods are not preserved as rock everywhere. Some rocks represent ancient oceans and some rocks represent ancient land. Different rock layers may contain the fossils of very different creatures, but only by comparing and considering the fossils found throughout all the rock layers can we complete our view of what types of animals were found across the planet as the Earth has changed over time.



Rock layers in Grand Canyon National Park, USA  
Image courtesy Creative Commons

# STUDENT PAGE

## Paleontology Lesson 2: Different Times, Different Fossils

### FOSSILS OF MONTANA

#### PRE-CAMBRIAN DEPOSITS AND THEIR FOSSILS

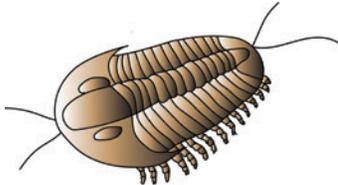
Pre-Cambrian aged rocks are common in western Montana and contain evidence of some of the earliest life forms known on Earth. *Stromatolites* are groups of bacteria that lived in colonies and formed distinctive, mound like colonies. Their fossils are found in Pre-Cambrian rocks in Montana and living stromatolites can still be found on Earth today.



*Stromatolite*

#### PALEOZOIC DEPOSITS AND THEIR FOSSILS

Fossils from the Paleozoic Era are found throughout Montana. Some of the earliest fossils from the Paleozoic are trilobites from the Cambrian Period (~ 500 million years ago). Trilobites like *Elrathiella* were some of the earliest relatives of modern insects and spiders. Later in the Paleozoic, in the Carboniferous (~ 318 million years ago) shallow lagoons covered Montana and were filled with strange sharks and other fishes. Today, these lagoon deposits are called the Bear Gulch Limestone and one of the fishes found there is *Echinochimaera meltoni*, a relative of modern ratfishes.



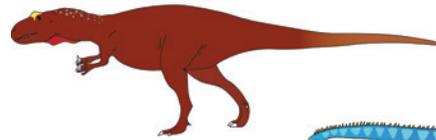
*Elrathiella*



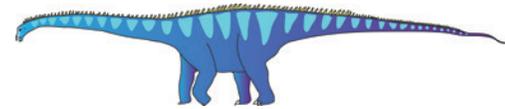
*Echinochimaera meltoni*

#### JURASSIC DEPOSITS AND THEIR FOSSILS

Montana is a good place to find fossils from the late Jurassic Period (~ 150 million years ago). The Morrison Formation is a Jurassic geologic unit that is exposed in parts of Montana and contains fossils of many long-necked sauropod dinosaurs, such as *Diplodocus carnegiei*. Also found in the Morrison Formation are the fossils of meat-eating theropod dinosaurs, like *Allosaurus fragilis*.



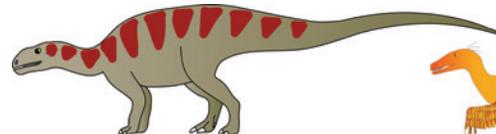
*Allosaurus fragilis*



*Diplodocus carnegiei*

#### CRETACEOUS DEPOSITS AND THEIR FOSSILS

Rocks from the Cretaceous period are found in much of Montana and give paleontologists a great view of what the area was like through the last period of the Age of Dinosaurs. Two Cretaceous formations that have been the sites of many fossil discoveries are the Cloverly Formation and the Hell Creek Formation. Many important fossils have been discovered in the Early Cretaceous (~ 109 million years ago) Cloverly Formation of Montana. When *Deinonychus antirrhopus* was discovered in Montana in the 1960's, it had many features that were very bird-like and showed paleontologists that dinosaurs were very different from slow, cold-blooded lizards. Another common dinosaur found in the Cloverly Formation is the plant-eater, *Tenontosaurus tilletti*. *Tenontosaurus* and *Deinonychus* fossils have been found together and *Tenontosaurus* may have been one of the favorite foods of *Deinonychus*.



*Tenontosaurus tilletti*



*Deinonychus antirrhopus*  
Images by Kari Scannella

## STUDENT PAGE

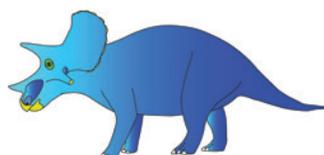
### Paleontology Lesson 2: Different Times, Different Fossils

#### HELL CREEK FORMATION

The Hell Creek Formation is the geologic unit that represents the very end of the Mesozoic Era in Montana and surrounding regions. It is where the fossils of some of the last non-avian dinosaurs, including *Tyrannosaurus rex* and *Triceratops*, are found. The Hell Creek Formation is made up of many layers of rock; the layers at the bottom were deposited first and are the oldest. The layers at the top were deposited last and are the youngest. As you go up through the layers of the Hell Creek Formation you are going up through time. The bottom of the Hell Creek Formation is marked by a large sandstone unit called the basal sandstone. Overlying the basal sandstone are many layers of mudstone. Above these mudstones is another large sandstone unit, called the JenRex sandstone (it is named after a specimen of *T. rex* that was discovered in it). Everything below the JenRex sandstone is considered the lower unit of the Hell Creek Formation. Above the JenRex sand is another series of mudstones and then another large sandstone called the Apex sandstone. Everything from the base of the JenRex sandstone to just underneath the Apex sandstone is considered the middle unit of the Hell Creek sandstone. Above the Apex sandstone are another series of mudstones. There is another thick sandstone which typically occurs approximately 10 meters below the top of the Hell Creek Formation; this sandstone is called the "10 meter sandstone". At the very top of the Hell Creek Formation there is a prominent dark line, which consists of coal. This is called the Z-coal and often marks the boundary between the Hell Creek Formation and the overlying Fort Union Formation.



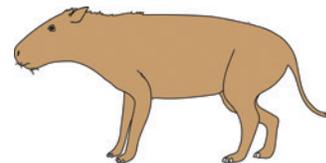
*Tyrannosaurus rex*



*Triceratops prorsus*

#### PALEOGENE DEPOSITS AND THEIR FOSSILS

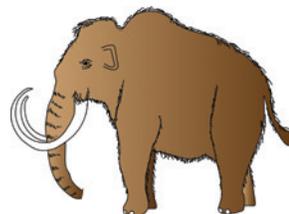
Mammals and dinosaurs first appeared at about the same time, in the Triassic Period (~ 230 million years ago). Dinosaurs were the dominant land animals during the Mesozoic Era, but after the Age of Dinosaurs ended, mammals became the dominant land animals. The Cenozoic Era (66 million years ago to today) is sometimes called the Age of Mammals, and rocks from this Era are found across much of Montana. The first part of the Cenozoic Era was the Paleogene period, which lasted until ~ 23 million years ago. During the Paleogene, there were already a wide variety of different mammal species. One of the most common fossil mammal groups is a group of animals called the oreodonts. Many species of oreodonts are known, including the giant species *Megoreodon grandis*. These animals would have looked something like a combination of modern pigs, sheep, and camels.



*Megoreodon grandis*

#### QUATERNARY DEPOSITS AND THEIR FOSSILS

We live in the Cenozoic Era today. Rocks deposited in the most recent part of the Cenozoic Era (called the Quaternary Period) are also common throughout Montana. Fossils from 18,000 years ago reveal animals that looked very similar to animals alive today. *Bison antiquus* was an ancient relative of modern bison, and *Mammuthus primigenius* was related to modern elephants, although today elephants are not native to Montana.



*Mammuthus primigenius*



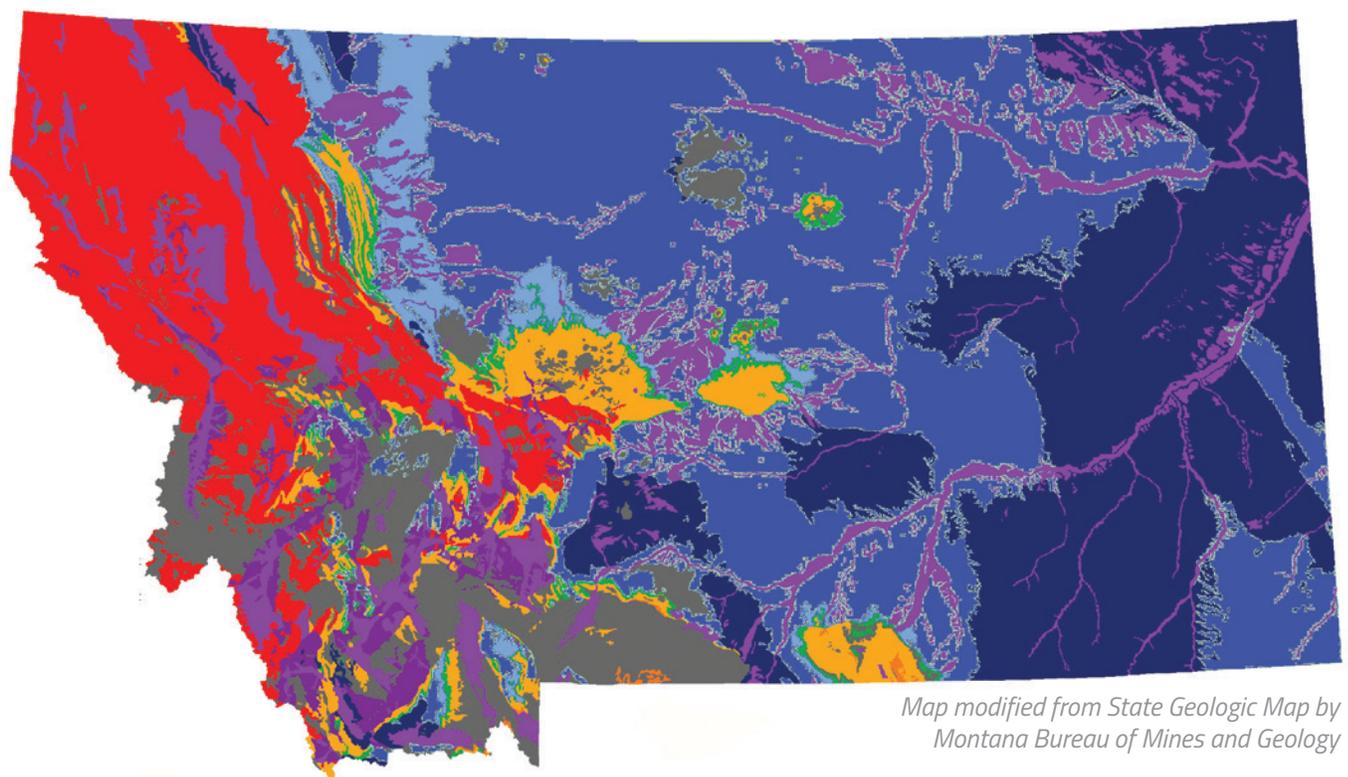
*Bison antiquus*  
Images by Kari Scannella



# STUDENT PAGE

## Paleontology Lesson 2: Different Times, Different Fossils

### GEOLOGIC MAP OF MONTANA



Map modified from State Geologic Map by Montana Bureau of Mines and Geology

- NEOGENE AND/OR QUATERNARY ROCK
- PALEOGENE ROCK
- UPPER CRETACEOUS ROCK
- LOWER CRETACEOUS ROCK
- JURASSIC ROCK
- UPPER PALEOZOIC ROCK
- LOWER PALEOZOIC ROCK
- PRECAMBRIAN SEDIMENTARY ROCK
- NON-SEDIMENTARY ROCK

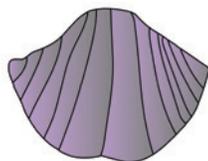
# STUDENT PAGE

## Paleontology Lesson 2: Different Times, Different Fossils

### FOSSILS OF MIFUNE

#### PALEOZOIC DEPOSITS AND THEIR FOSSILS

The Mizukoshi Formation in Mifune Town was deposited during the Late Permian Period (~ 255 million years ago). Fossils from this formation include the ancient shelled creature, *Alispiriferella lita*.



*Alispiriferella lita*

#### TRIASSIC DEPOSITS AND THEIR FOSSILS

Fossils from the Triassic Period, the first period of the Age of Dinosaurs, have been found in the Konose Group, in the east side of Kumamoto Prefecture. The ancient clam, *Dicerocardium kuwagataforme*, lived 220 million years ago, and its fossils are found in the Konose Group.



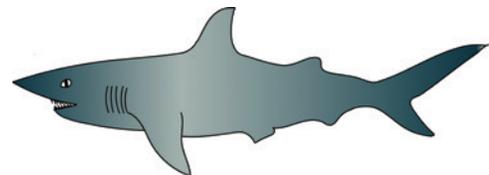
*Dicerocardium kuwagataforme*

#### CRETACEOUS DEPOSITS AND THEIR FOSSILS

The Upper Cretaceous Mifune Group in this area yields dinosaur fossils. The Mifune Group is divided into three parts: the Basal, Lower, and Upper Formations.

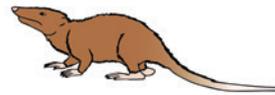
The BASAL FORMATION (96-95 MA) consists mainly of nonmarine molluscan fossils in the upper part of the formation and include the brackish-water mollusks *Conorbis* (Gastropoda) and *Nipponicorbula* (Bivalvia).

The LOWER FORMATION (95-93 MA) consists mainly of sandstone and siltstone deposited in a shallow sea, and contains abundant bivalves and gastropods. The estuarine and coastal deposits contain brackish-water and shallow marine mollusks. The middle Cenomanian ammonite *Eucalycoceras* sp. cf. *E. spathi* was reported from the middle part of the formation. The Mifune bivalve fauna is comprised of 52 species representing 37 genera, and is important in correlating the international marine system with the nonmarine continental system in Asia.

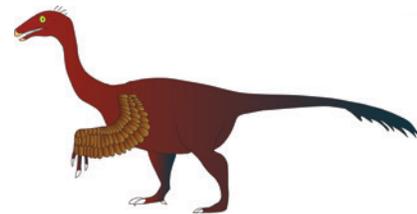


*Squalicorax* (Lower Formation)

The UPPER FORMATION (93-90 MA) consists of abundant vertebrate remains, freshwater mollusks, and plant fossils.



*Sorlestes* (Upper Formation)



*Therizinosaur* (Upper Formation)

#### QUATERNARY DEPOSITS AND THEIR FOSSILS

Very recent fossils (~ 18,000 years old) are known from the Tsumori Formation of Mashiki Town in the east side of Kumamoto. The insect *Elaphrus japonicus* is commonly found in this area.



*Elaphrus japonicus*  
Images by Kari Scannella

# STUDENT PAGE

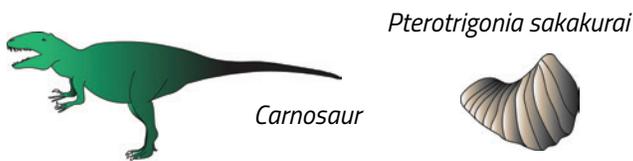
## Paleontology Lesson 2: Different Times, Different Fossils

### FOSSILS OF AMAKUSA

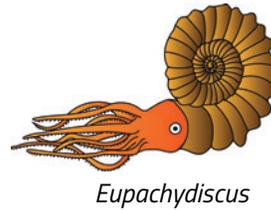
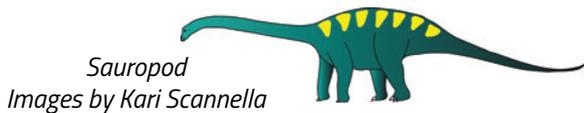
The sediments of the Goshoura area consist of the Cretaceous Goshoura Group and Lower Subgroup of the Himenoura Group, the Paleogene Miroku Group and Hondo Group, and the Quaternary Takeshima Formation.

#### CRETACEOUS DEPOSITS AND THEIR FOSSILS

The mid Cretaceous (100 million years ago) Goshoura Group consists of non-marine and shallow marine environments that contain many fossils. Characteristic rocks in the Goshoura Group are red rocks deposited in the floodplain environment, and Trigonina sandstone containing many kinds of shallow marine molluscan fossils. There are also other sediments containing mollusks. These fossil-bearing rocks can be found on the coast and in a small river valley. Dinosaur fossils also occur in this sediment, where a theropod dinosaur (*Carnosaur*) and ornithopod dinosaur (*Iguanodon*) have been found. A plesiosaur fossil has also been found from the Goshoura Group on Shishijima Island near Goshoura Island.



The late Cretaceous (85 million years ago) Lower Subgroup of the Himenoura Group consists of offshore, deep sea marine deposits. It is characterized by the alternation of sandstone and mudstone beds which were deposited in the deep sea by turbulent mudstone flows that accumulated offshore. Fossils found in this group include cephalopods such as ammonites and inoceramus, shark teeth, coprolites, and fish. From this formation in the Amakusa Kamijima area, ungula of a theropod dinosaur and a *Mosasaurus* tooth have been discovered.



Ammonites, inoceramus, trigonia, and dinosaurs are index fossils, and Trigonina is a facies fossil that indicates a shallow marine environment.

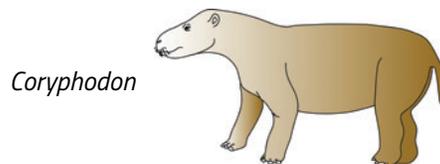
#### PALEOGENE AND THEIR FOSSILS

The Paleogene (49 million years ago) Miroku Group contains sediment that has accumulated from terrestrial and shallow marine environments. Red beds deposited from terrestrial environments are common in this group. Mammalian fossils including the oldest large mammal *Trogosus coryphodontid*, *Perissodactyla*, roots and other trace fossils are found in the Miroku Group. Mammal fossils from this group have been found in Kumamoto Prefecture and Kagoshima Prefecture, indicating that a variety of mammals existed here during the Eocene. A benthic foraminiferous (*Numrites*) found in the sandy shallow marine deposits is a facies fossil indicating a warm climate during the Eocene.

The Paleogene (46 million years ago) Hondo Group sediment was deposited in a deep sea environment. The alternation of sandstone and mudstone deposits can be seen. Fossils such as trace fossils and radiolarians have been found in these deposits. Molluscan and coral fossils have been found from this group outside the Goshoura area.

#### QUATERNARY DEPOSITS AROUND GOSHOURA

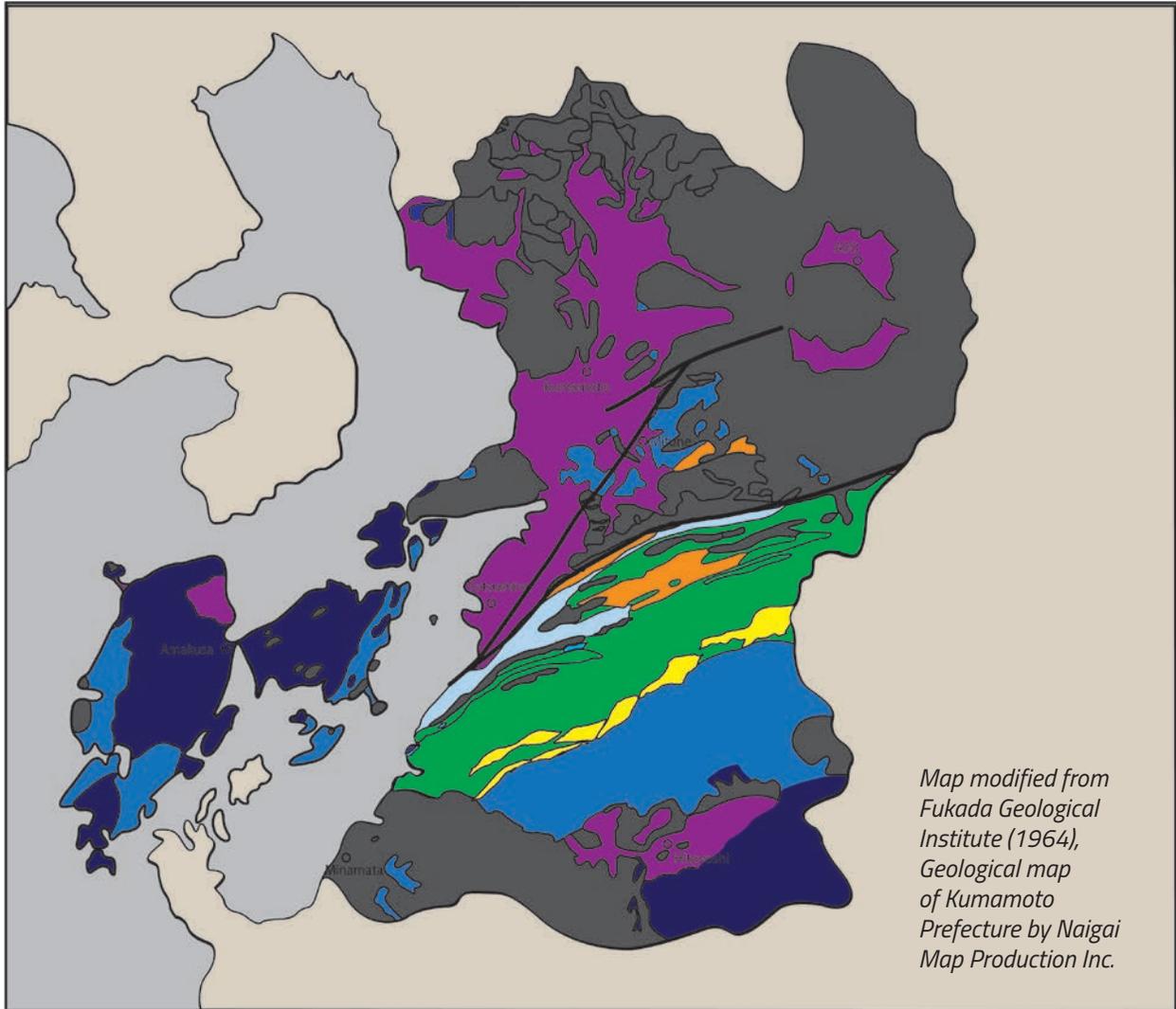
The Quaternary (5,000 years ago) Takeshima Formation is a terrestrial marsh deposit, found in small areas on Takeshima Island. Plant fossils such as trees, leaves, seeds, pollen, and fossil roots are found on the coast of Takeshima.



# STUDENT PAGE

## Paleontology Lesson 2: Different Times, Different Fossils

### GEOLOGIC MAP OF KUMAMOTO PREFECTURE



**NEOGENE AND/OR QUATERNARY ROCK**

**PALEOGENE ROCK**

**UPPER CRETACEOUS ROCK**

**LOWER CRETACEOUS ROCK**

**JURASSIC ROCK**

**TRIASSIC ROCK**

**UPPER PALEOZOIC ROCK**

**LOWER PALEOZOIC ROCK**

**NON-SEDIMENTARY ROCK**

# STUDENT PAGE

## Paleontology Lesson 2: Different Times, Different Fossils

### COMPARING STRATIGRAPHY OF MONTANA AND KUMAMOTO

After completing the stratigraphy activity, answer the following questions to compare the geologic layers and fossils of Montana and Kumamoto.

Put an "X" in the appropriate boxes to show the rock layers in the three different areas studied in the activity.

	Pre-Cambrian	Cambrian	Carboniferous	Triassic	Late Jurassic	Early Cretaceous	Late Cretaceous	Paleogene	Pleistocene	Neogene
Montana										
Amakusa, Kumamoto										
Mifune, Kumamoto										

What age of rocks found in Montana commonly contain fossils, but are NOT found in Kumamoto?

---

What age of rocks are found in Kumamoto, but are not found or do not commonly produce fossils in Montana?

---

What age of rocks commonly produce fossils in all three areas?

---

In this rock layer found in all three areas:

- Are the fossils found in Montana, Amakusa, and Mifune the same? \_\_\_\_\_
- Are there different creatures found in the different areas? \_\_\_\_\_
- What do the fossils tell us about the landscape in each area and the Earth as a whole? \_\_\_\_\_

Why do scientists compare the fossil records in areas that are so far away (like Montana and Kumamoto)? What can we learn from this?

---



## **STUDENT PAGE**

### Paleontology Lesson 2: Different Times, Different Fossils

## **STRATIGRAPHY OF MONTANA**

**NEOGENE AND/OR QUATERNARY (0.018MA)**

**PALEOGENE (32MA)**

**LATE CRETACEOUS (66MA)**

**EARLY CRETACEOUS (109 MA)**

**LATE JURASSIC (150MA)**

**CARBONIFEROUS (318MA)**

**CAMBRIAN (500MA)**

**PRE-CAMBRIAN (700MA)**

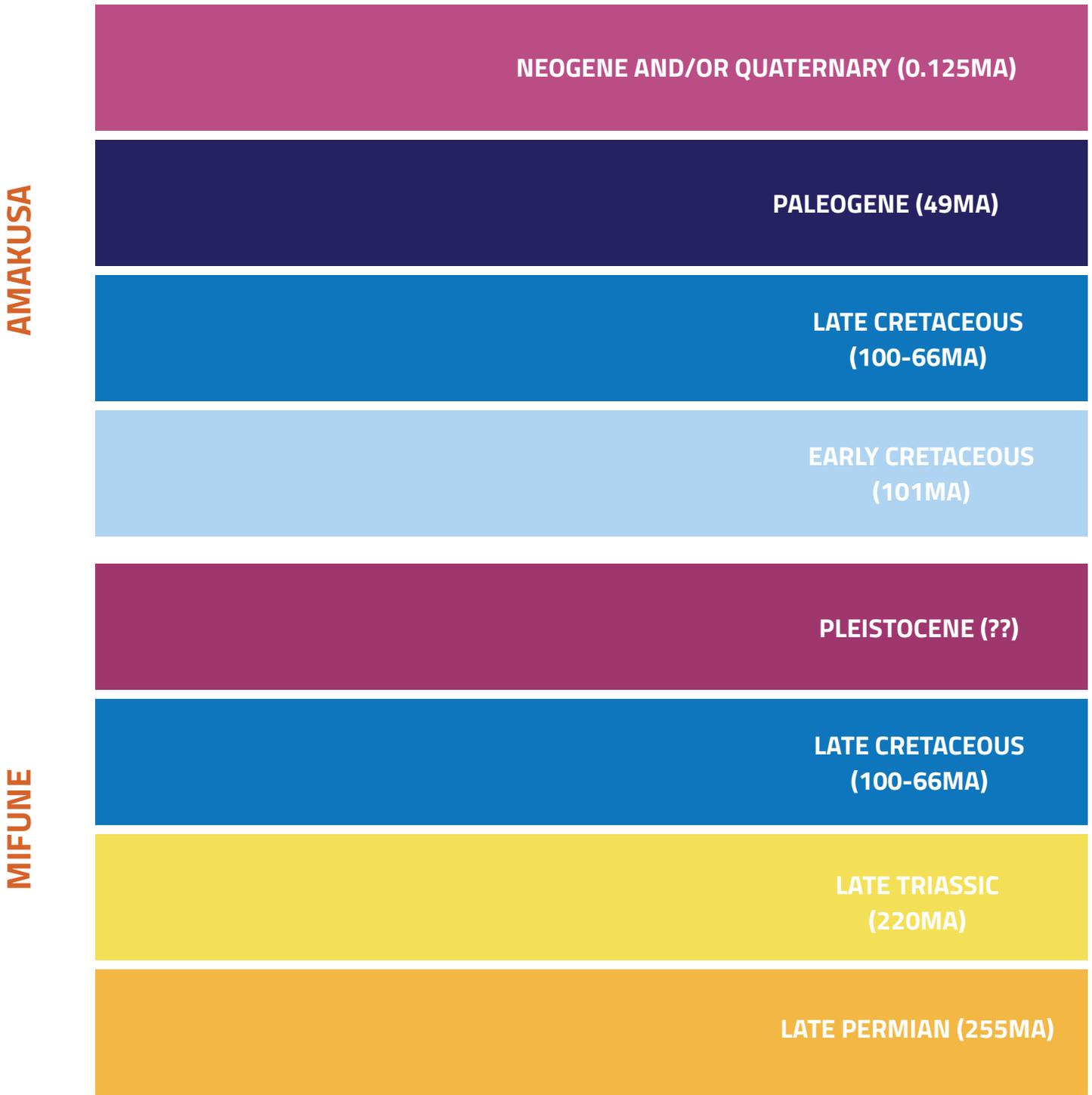
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# STUDENT PAGE

## Paleontology Lesson 2: Different Times, Different Fossils

### STRATIGRAPHY OF KUMAMOTO



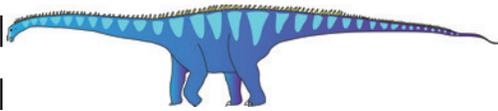
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# STUDENT PAGE: CREATURE CARDS MONTANA

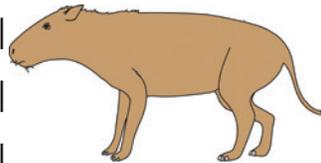
Paleontology Lesson 2: Different Times, Different Fossils

## CREATURE CARDS MONTANA

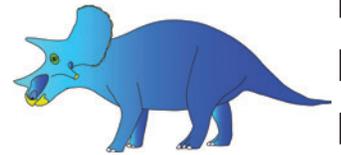
Cut out each "creature card." Glue or tape the creature cards to the Stratigraphy Charts using the background color and the fossil's location (Montana, Mifune, or Amakusa) as a guide.



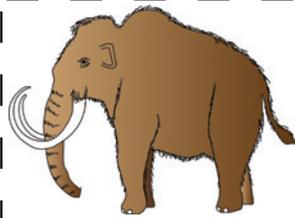
*Diplodocus carnegii*  
**MONTANA**



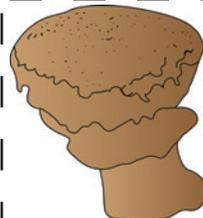
*Megaloceros giganteus*  
**MONTANA**



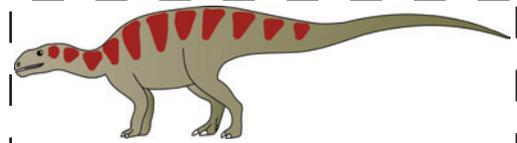
*Triceratops prorsus*  
**MONTANA**



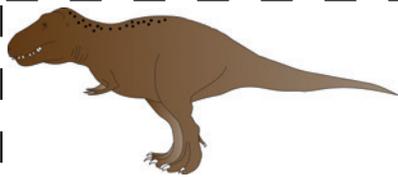
*Mammuthus primigenius*  
**MONTANA**



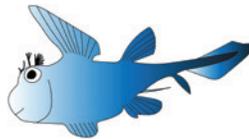
stromatolite  
**MONTANA**



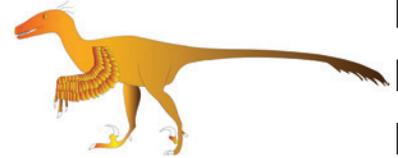
*Tenontosaurus tilletti*  
**MONTANA**



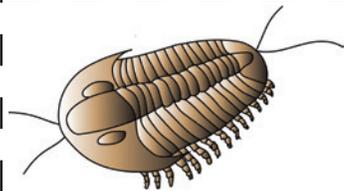
*Tyrannosaurus rex*  
**MONTANA**



*Echinocichmaera meltoni*  
**MONTANA**



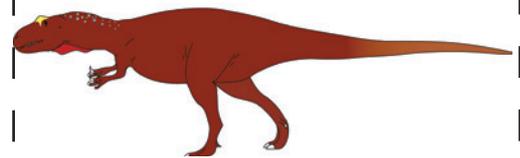
*Deinonychus antirrhopus*  
**MONTANA**



*Elrathia*  
**MONTANA**



*Bison antiquus*  
**MONTANA**



*Allosaurus fragilis*  
**MONTANA**

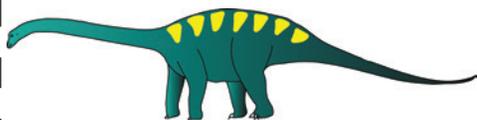
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# STUDENT PAGE: CREATURE CARDS KUMAMOTO

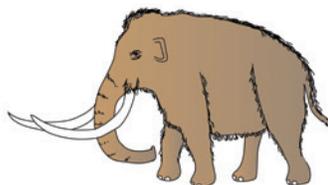
## Paleontology Lesson 2: Different Times, Different Fossils

### CREATURE CARDS KUMAMOTO

Cut out each "creature card." Glue or tape the creature cards to the Stratigraphy Charts using the background color and the fossil's location (Montana, Mifune, or Amakusa) as a guide.



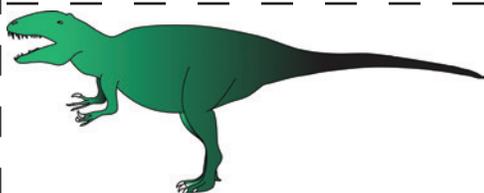
*Sauropoda*  
**AMAKUSA**



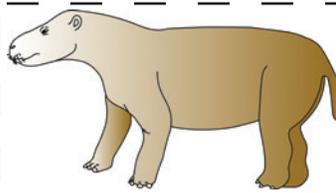
*Palaeoloxodon naumanni*  
**AMAKUSA**



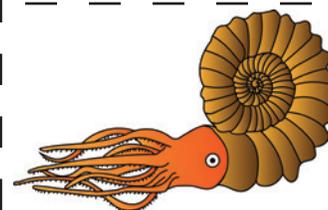
*Pterotrigonia sakakurai*  
**AMAKUSA**



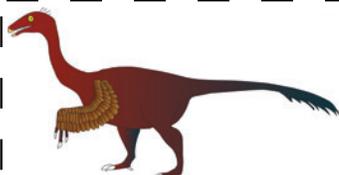
*Carnosauria*  
**AMAKUSA**



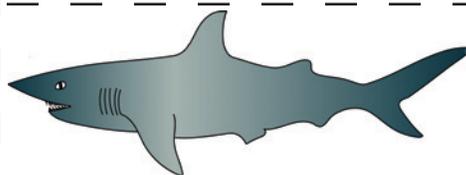
*Coryphodon*  
**AMAKUSA**



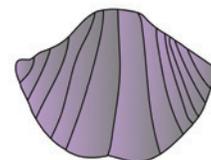
*Eupachydiscus*  
**AMAKUSA**



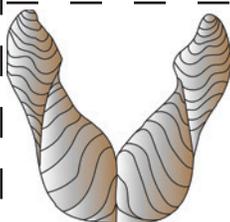
*Therizinosauridae*  
**MIFUNE**



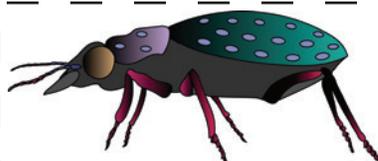
*Squalicorax*  
**MIFUNE**



*Alispiriferella lita*  
**MIFUNE**



*Dicerocardium kuwagataforme*  
**MIFUNE**



*Elaphrus japonicus*  
**MIFUNE**

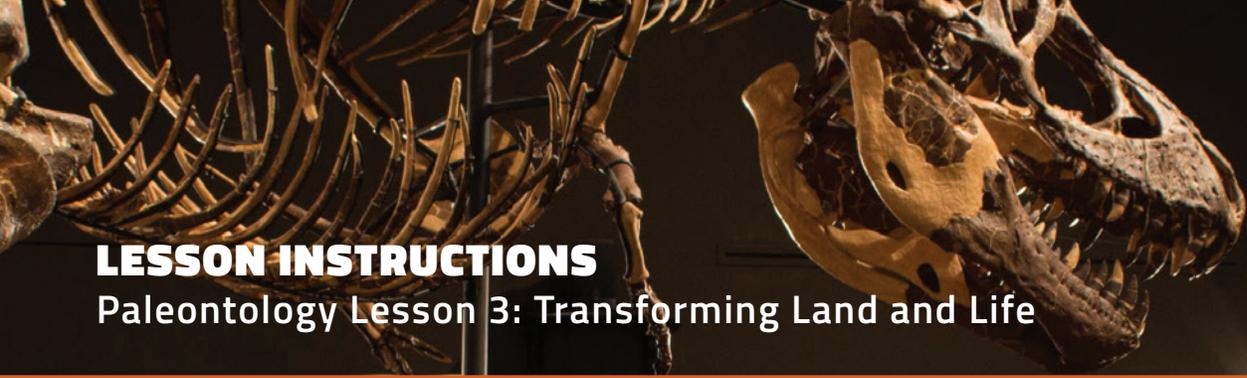


*Sorlestes mifunensis*  
**MIFUNE**



# 3

## **PALEONTOLOGY LESSON 3** Transforming Land and Life



## LESSON INSTRUCTIONS

### Paleontology Lesson 3: Transforming Land and Life

## GOAL

Organisms change over time as a result of changes in physical or behavioral traits that are passed down through generations. These changes can be a result of the transformation of environment.

## OBJECTIVES

Students will be able to:

1. Describe how natural selection causes species to evolve.
2. Identify how *Triceratops* and *Pterotrionia* changed over time.

## ASSESSMENT

1. Through the class discussions, listen for student responses that show an understanding of natural selection.
2. Use the student pages to measure if students are able to describe how *Triceratops* and *Pterotrionia* changed over time.

## MATERIALS

- o Copies of "Student Pages," one per student (pages 184-195)
- o Prepared fossil pieces (see preparation)

## PREPARATION

- o Make copies of the student pages, one per student.
- o Make copies of the fossil pieces pages and cut out the shapes. These will be distributed to small groups of students, with each group getting both species of the *Triceratops* or *Pterotrionia* at one time. A class size of 24 students (divided into six groups of four students) would need three sets of *Triceratops* pieces and three sets of *Pterotrionia* pieces for this activity.
- o Optional: Video – Evolution of the Eye  
. <https://youtu.be/4SXHMm51-68>

# LESSON INSTRUCTIONS

## Paleontology Lesson 3: Transforming Land and Life



LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>As a class, read the "Introduction to Evolution." Lead a short discussion about the bird beaks described to reinforce the concept of natural selection. Explain to the students that they will be doing an activity to see how a fossil from Montana (<i>Triceratops</i>) and one from Japan (<i>Pterotrigonia</i>) evolved over time.</p>	<p>Expect students to have some questions about what they're hearing. Use the images provided in the background information to help them visualize concepts.</p>	<p>This gives teachers the opportunity to invite questions after the reading and to ask students to give examples of other animals that have been artificially and naturally selected.</p>
<p>Divide your class into multiple groups. For each group, pass out the combined <i>Triceratops</i> or <i>Pterotrigonia</i> fossil pieces. Have students work together to discover on their own that the fossils are from two different species of the same type of animal. Ask students to arrange the fossil pieces on their table to make it as complete as possible.</p>	<p>Expect students to have some difficulty building the animal. Encourage students to use their student pages to reference the complete fossil shape.</p>	<p>This gives teachers the opportunity to explain that fossils are not often complete and there are different species of common fossils, including <i>Triceratops</i> and <i>Pterotrigonia</i>.</p>
<p>Have students complete the student page to help them describe the differences they see between the two species.</p>	<p>Expect students to need some help with the questions. Use the answer key and background information to guide students through answering the questions.</p>	<p>This gives teachers the opportunity to assess what the students have learned throughout the lesson.</p>
<p>Once the students have completed the activity with one set of fossil pieces, have groups switch cards and repeat the activity with the other animal.</p>	<p>Expect students to have some difficulty building the animal. Encourage students to use their student pages to reference the complete fossil shape.</p>	<p>This gives teachers the opportunity to explain that fossils are not often complete and there are different species of common fossils, including <i>Triceratops</i> and <i>Pterotrigonia</i>.</p>
<p>Have students complete the student page to help them describe the differences they see between the two species.</p>	<p>Expect students to need some help with the questions. Use the answer key and background information to guide students through answering the questions.</p>	<p>This gives teachers the opportunity to assess what the students have learned throughout the lesson.</p>
<p>Once all students have completed the activity for both organisms, lead a discussion about what they learned during the activity.</p>	<p>Students should describe that organisms, including <i>Triceratops</i> and <i>Pterotrigonia</i> changed over time, creating two different species.</p>	<p>This gives teachers the opportunity to assess what the students have learned throughout the lesson.</p>

## BACKGROUND INFORMATION

### Paleontology Lesson 3: Transforming Land and Life

## MORPHOLOGICAL EVOLUTION OF *TRICERATOPS* FROM THE HELL CREEK FORMATION IN MONTANA, USA



#### WHAT IS *TRICERATOPS*?

*Triceratops* was one of the last of the large horned dinosaurs, or ceratopsids, that lived during the Mesozoic Era. Ceratopsid dinosaurs lived during the late Cretaceous period. Remains of ceratopsids have been found in North America and Asia.

*Triceratops* is commonly found in the uppermost Cretaceous sediments in Montana. The name "*Triceratops*" is derived from three Greek terms (tri = three), (kéras=horn), and (ops = face). *Triceratops* translates to "Three-horned face"; this animal had two large horns above the eyes and one horn above the nose (the nasal horn).

The horns of *Triceratops* have been hypothesized to have been used for defense from predators, for fighting with other *Triceratops*, or as display structures to help *Triceratops* recognize other *Triceratops* or to show off, like the tail of a peacock.

The skull of *Triceratops* changed as it grew from a baby to an adult. Juvenile *Triceratops* had horns that curved backwards and as *Triceratops* aged, the horns curved forwards. Also, young *Triceratops* had triangular spikes around the large bony crest at the back of their skulls but as they matured, the spikes became flattened and less noticeable.

Sediments from the Hell Creek Formation were deposited between approximately 67.5 and 66 million years ago. *Triceratops* is found throughout the Hell Creek Formation and in sediments of similar age in surrounding regions.

*Triceratops* was a herbivore (plant-eater) and used its parrot-like beak and numerous teeth to shear through vegetation in its environment.

*Triceratops* shared its environment with several other dinosaurs, including the giant carnivore *Tyrannosaurus rex*, the large duck-billed dinosaur *Edmontosaurus*, the dome-headed *Pachycephalosaurus*, and the armored dinosaur *Ankylosaurus*.

Currently there are two known species of *Triceratops*: *Triceratops horridus* and *Triceratops prorsus*. The skulls of these two species are slightly different; *Triceratops horridus* has a small nasal horn and shallow beak while *Triceratops prorsus* has a long nasal horn and deeper beak. *Triceratops horridus* has been found in the lower layers of the Hell Creek Formation and *Triceratops prorsus* has been found in the upper layers of the Hell Creek Formation.

It has been hypothesized that *Triceratops horridus* evolved into *Triceratops prorsus* over time.



Images courtesy Carter County Museum (left) and Museum of the Rockies (above)

## BACKGROUND INFORMATION

### Paleontology Lesson 3: Transforming Land and Life

## MORPHOLOGICAL EVOLUTION OF *PTEROTRIGONIA* FROM THE GOSHOURA AND MIFUNE GROUPS, KUMAMOTO PREFECTURE JAPAN



### WHAT ARE TRIGONIIDAE?

Trigoniidae are bivalves that thrived during the Mesozoic Era. They diversified during the Jurassic and Cretaceous periods. They are named for their triangular-shaped shell. Only one group, *Neotrigonia*, remains living today in the ocean near Australia.

### *PTEROTRIGONIA* OF THE CRETACEOUS PERIOD

*Pterotrigonia* is commonly found in lower to middle Cretaceous sediments in Japan.

There are approximately thirty species named in Japan. The name "*Pterotrigonia*" is derived from two Latin terms (Ptero = Wing), (Trigonia = Triangle). They are discovered from marine sediments all over the world. These facies fossils help paleontologists to understand the age of marine sediments and paleo-environments world-wide.

### *PTEROTRIGONIA* FROM THE GOSHOURA GROUP AND MIFUNE GROUP

Sediments from the Goshoura Group are 100 million years old, and sediments from the Mifune Group are 90 million years old. *Pterotrigonia* are often discovered from these two geologic groups. There have been twelve species discovered from the Goshoura Group on the islands of Goshoura and Shishi-jima.

Three species have been found in the Mifune Group, one of which is the same species found in the Goshoura Group. Two species described here evolved over time, *Pterotrigonia amakusensis* from the Goshoura Group and *Pterotrigonia higoensis* from the Mifune Group.

*Pterotrigonia amakusensis* is named after the Amakusa region, and *Pterotrigonia higoensis* refers to "Higo," which is Kumamoto's older name. *Pterotrigonia amakusensis* is found in marine sediments and are deposited dozens of meters below sea level. *Pterotrigonia higoensis* is found in shallow marine tidal deposits. *Pterotrigonia amakusensis* changed its shape and evolved into *Pterotrigonia higoensis* as it adapted to a different marine environment.



Images courtesy Goshoura Cretaceous Museum

## STUDENT PAGE

### Paleontology Lesson 3: Transforming Land and Life

#### INTRODUCTION TO EVOLUTION

If you walk outside in the area where you live, you will encounter familiar plants and animals. If you travel to a nearby town, the types of plants and animals you find will still be very familiar to you. But, if you travel to another continent, you will find many plants and animals that are different from those you find back home. The further away from home you are, the more unusual the creatures you encounter will seem.

If you were to travel back through time, you would find more unfamiliar creatures the further back you traveled. If you were transported to your hometown 50 years ago, you probably wouldn't notice many major differences in the plants and animals. But travel back ten million years into the past and you will find yourself with numerous creatures that aren't there anymore. If you were to travel back 66 million years into the past, you would find yourself surrounded by many large dinosaurs, huge marine reptiles in the seas, and exotic vegetation on land.

We don't have a machine that can take you back through time, but you can still see the plants and animals that inhabited the world in the past by exploring the fossil record. The sedimentary rocks of the Earth are found in layers (called **strata**). If you walk down a hill, you will walk down the different layers of rocks that were deposited over time. Typically, the lowest layers of the hill are the oldest (they were deposited first) and the highest layers of the hill are the youngest (they were deposited last).

Notice that fossil creatures exhibit changes as you go from one layer to another. This change in the populations of living things over the course of generations is called **evolution**. Evolution can be fast or slow and can occur in different ways. Dinosaurs, like all animals, evolved from earlier forms.

If you look around you, you will see differences between



Photos by Sabre Moore

people. There are different genders, different hair colors, different eye colors, different shapes and sizes. All of the people you see are members of the same species: *Homo sapiens*. The differences you see between individuals is called variation in a population. When there is **variation** in a population, it is possible for certain traits to be "selected".

For example, many people today breed a type of fish called Japanese Koi. Koi are known for their beautiful and elaborate colors. Koi breeders pick the fish with the most beautiful colors and have them produce baby koi, so that the next generation of koi will contain more fish with the colors that they like. Over time, many of the koi in the population will carry with them the tendency to have the beautiful colors that their parents had. This process of selecting which varieties will be increased in a population and which will be decreased is called **artificial selection**.



TRANSFORMING LAND AND LIFE

## STUDENT PAGE

### Paleontology Lesson 3: Transforming Land and Life

Natural selection is the same process, except instead of people selecting which individuals will produce the next generations, the creatures' ability to survive in their environment is the deciding factor. Imagine there is a population of birds living in an area and eating the seeds of the local plants; this population has variation in the size and shape of their beaks. Some have thin, long beaks and some have thicker, stronger beaks. If some of these birds were to fly to a nearby island where the seeds all have very thick shells, only the birds with strong beaks would be able to break open the shells and eat the seeds. Because the strong-beaked birds can best survive, they would have the most baby birds and these baby birds would carry their parents' tendency to have strong beaks. Over time, the population of birds on the island would come to be dominated by birds with thick, strong beaks. The thick-beaked birds have been naturally selected for on this island. Eventually, these thick-beaked birds may become so different from the population of birds on the mainland that they would be considered a new species.

When you look at the plants and animals in the fossil record, you can see the traits that were selected for over time. Some dinosaurs have big, strong teeth. Some have long, narrow necks. Some have large claws, or strong legs, or long tails. All of these traits gave these groups of animals advantages that helped them to better survive in their environments and have baby dinosaurs.

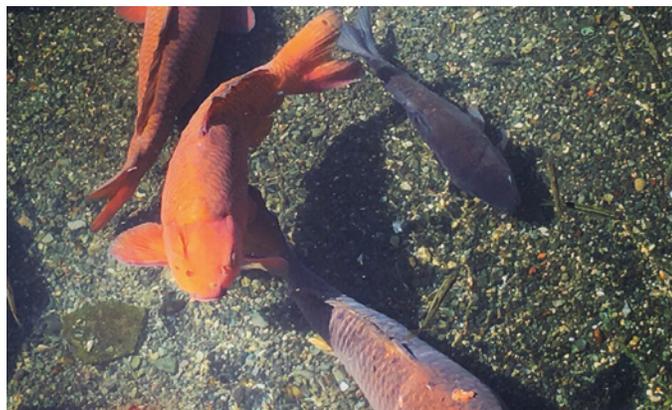


Photo by Sabre Moore

It is the same way that the birds with thicker beaks were better able to survive on the island, or the Koi with the nicest colors were artificially selected to produce more Koi. In this way, life has evolved (or changed) over the course of the millions of years of the history of the Earth.

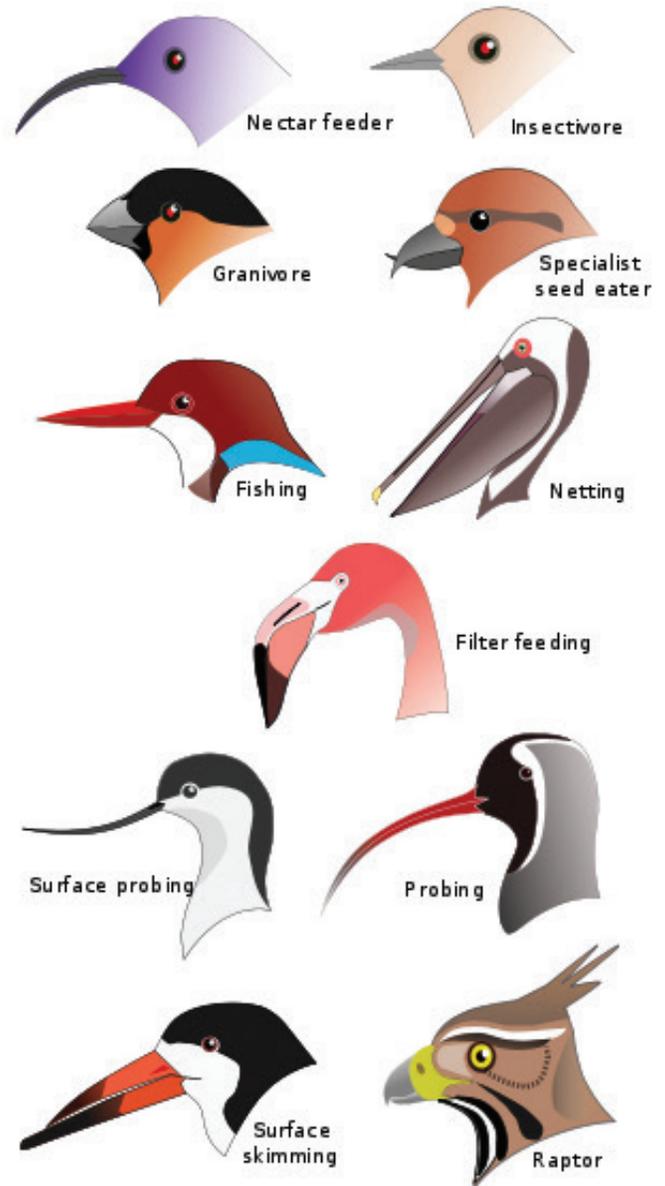


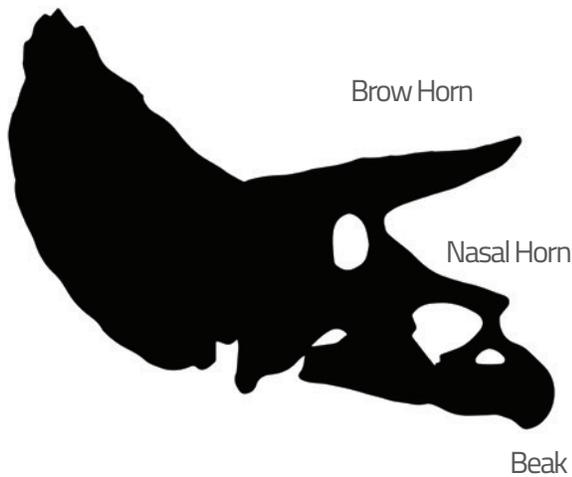
Image courtesy Wikipedia

## STUDENT PAGE

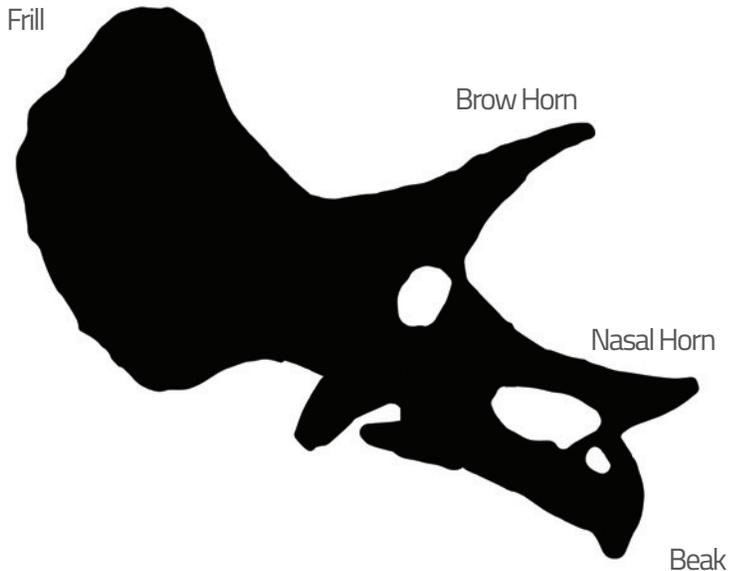
### Paleontology Lesson 3: Transforming Land and Life

## EVOLUTION OF *TRICERATOPS*(MONTANA)

Frill Spikes



Frill



### *TRICERATOPS HORRIDUS*

- Found in the lower Hell Creek Formation
- Small nasal horn
- Nasal horn positioned farther from beak than in *Triceratops prorsus*

### *TRICERATOPS PRORSUS*

- Found in the upper Hell Creek Formation
- Large nasal horn
- Nasal horn positioned more directly above beak than *Triceratops horridus*

*Triceratops* existed until the end of the Mesozoic Era (the Age of Dinosaurs). At that time, *Triceratops prorsus* appears to have been the last species of *Triceratops* that remained and it went extinct with many other dinosaurs approximately 66 million years ago.



Images courtesy Museum of the Rockies



## STUDENT PAGE

### Paleontology Lesson 3: Transforming Land and Life

#### EVOLUTION OF *TRICERATOPS*(MONTANA)

Use the skulls pictured on the previous page to answer the following questions:

*Triceratops horridus* and *Triceratops prorsus* are recognized as two species based on the shapes of the horns and beak. What are some similarities between these *Triceratops* species?

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Why might *Triceratops* have evolved a larger nasal horn over time?

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*Triceratops* changed as it evolved, but the skull of *Triceratops* also changed as it grew from a baby to an adult. Look at the two example *Triceratops* skulls. One belongs to an older (more mature) *Triceratops* than the other. Which skull belongs to an older *Triceratops* and which parts of the skull reveal this?

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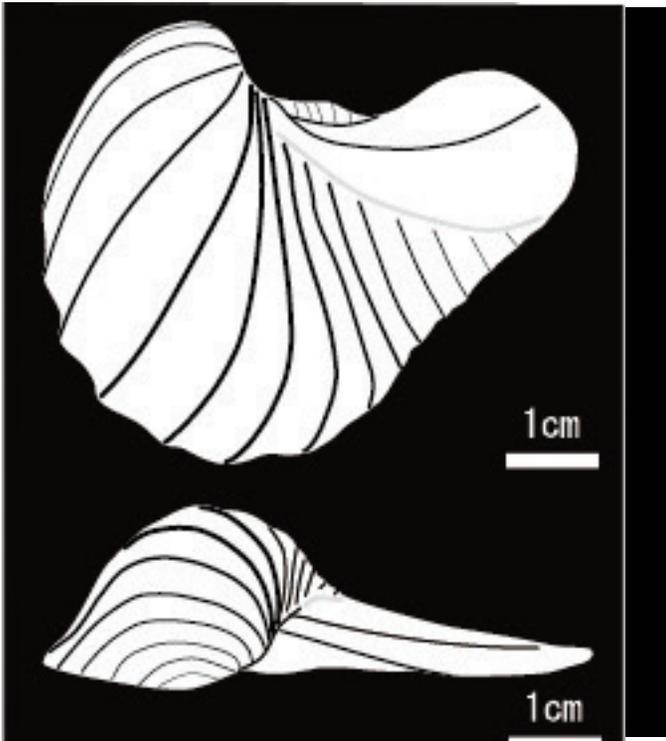
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## STUDENT PAGE

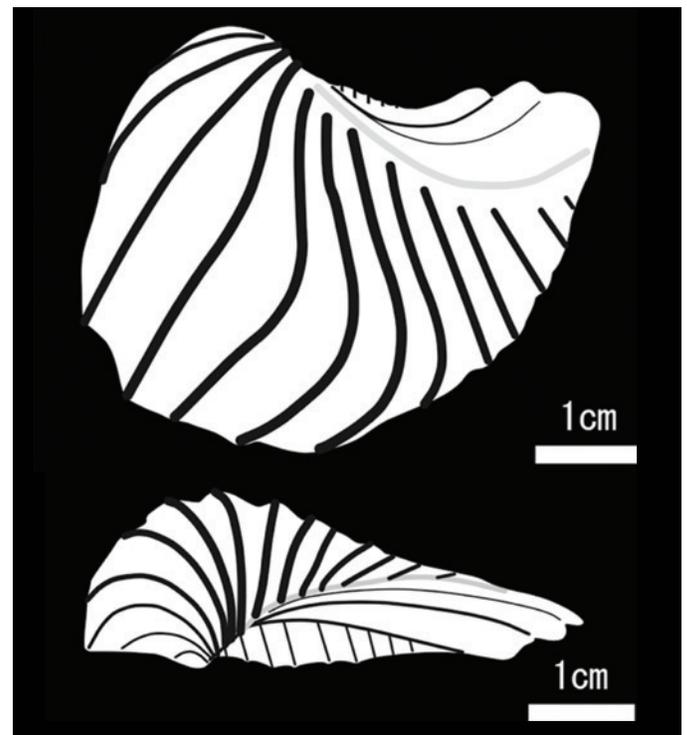
### Paleontology Lesson 3: Transforming Land and Life

#### EVOLUTION OF *PTEROTRIGONIA* (KUMAMOTO)



#### *PTEROTRIGONIA AMAKUSENSIS*

- Costellae (band): A little bit thin
- Area (flat portion): Two halves
- Inflated bivalve: Not as inflated as *Pterotrigonia higoensis*, thin shell



Images by Koji Hirose

#### *PTEROTRIGONIA HIGOENSIS*

- Costellae (band): thicker than *Pterotrigonia amakusensis*
- Area (flat portion): ruffled, divided into three segments
- More inflated bivalve: puffed up, thick shell
- Found in shallow marine environments

*Pterotrigonia* were abundant 100 million years ago (Goshoura Group) and their populations declined significantly 90 million years ago (Mifune Group) when they became extinct. After their extinction, a different group of Trigonina emerged. This group is called Apitrigonia and Yaadia. They are found in the Amakusa area in Kumamoto Prefecture, Japan.



Photos by Sabre Moore



**STUDENT PAGE**

**Paleontology Lesson 3: Transforming Land and Life**

**EVOLUTION OF *PTEROTRIGONIA* (KUMAMOTO)**

**Use the shells pictured on the previous page to answer the following questions:**

Which species lived in a river or tidal flat environment, and which lived in deep marine environments?

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What changes can occur when a species is living in a shallow marine environment and is affected by water flow and wind that causes wave motion?

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How did the shape of the shell change over time?

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## STUDENT PAGE - ANSWER KEY

### Paleontology Lesson 3: Transforming Land and Life

## EVOLUTION OF *TRICERATOPS*(MONTANA)

Use the skulls pictured on the student page to answer the following questions:

*Triceratops horridus* and *Triceratops prorsus* are recognized as two species based on the shapes of the horns and beak. What are some similarities between these *Triceratops* species?

Both species have three horns on their skull. Larger horns (brow horns) are found over the eyes and the horn above the nose (nasal horn) is smaller than the brow horns. Both species have a large bony frill at the back of the skull and a sharp beak at the front of the skull.

Why might *Triceratops* have evolved a larger nasal horn over time?

*Triceratops* lived at the same time as a large carnivorous dinosaur, perhaps the bigger nasal horn was for better defense against *T. rex* or maybe it helped *Triceratops* to compete with and win fights against other *Triceratops*. Maybe it was used to display to other *Triceratops* (visual communication) and *Triceratops* with larger nasal horns were more successful than those with smaller nasal horns.

*Triceratops* changed as it evolved, but the skull of *Triceratops* also changed as it grew from a baby to an adult. Look at the two example *Triceratops* skulls. One belongs to an older (more mature) *Triceratops* than the other. Which skull belongs to an older *Triceratops* and which parts of the skull reveal this?

By comparing the two skulls, we can see that the *Triceratops horridus* skull has horns above its eyes that curve slightly backwards and slightly more pointed spikes around the frill at the back of its skull. These features indicate that it was less mature than the *Triceratops prorsus* skull, in which the horns curve forwards and the spikes around the frill are flattened.



## STUDENT PAGE - ANSWER KEY

### Paleontology Lesson 3: Transforming Land and Life

## EVOLUTION OF *PTEROTRIGONIA* (KUMAMOTO)

Use the shells pictured on the student page to answer the following questions:

Which species lived in a river or tidal flat environment, and which lived in deep marine environments?

*Pterotrigonia amakusensis* is found in marine sediments and are deposited dozens of meters below sea level, whereas *Pterotrigonia higoensis* is found in shallow marine tidal deposits.

What changes can occur when a species is living in a shallow marine environment and is affected by water flow and wind that causes wave motion?

Hint - tidal flats are affected by water because they are shallow and near land.

How did the shape of the shell change over time?

- Increased thickness of the shell.
- Strengthening the costal (As in thickening of bone).
- Folds in the shell make it stronger (Like a ridged sheet of metal).
- Environmental changes over time can lead to adaptations in the shell structure.

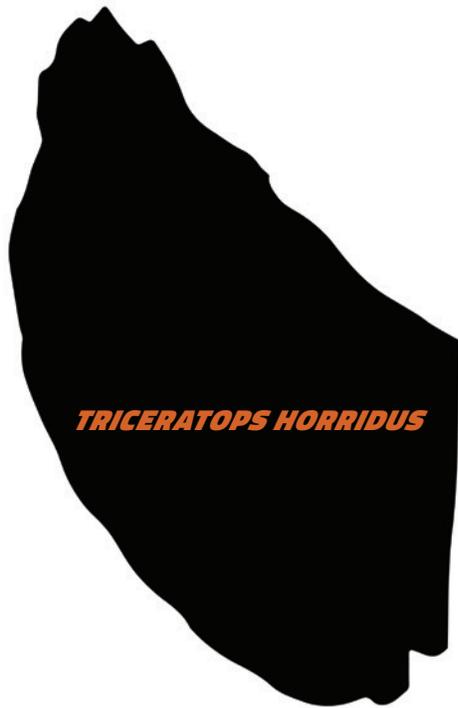


**LESSON MATERIALS: *TRICERATOPS HORRIDUS***

Paleontology Lesson 3: Transforming Land and Life

***TRICERATOPS HORRIDUS***

Cut out these pieces carefully for the matching activity.

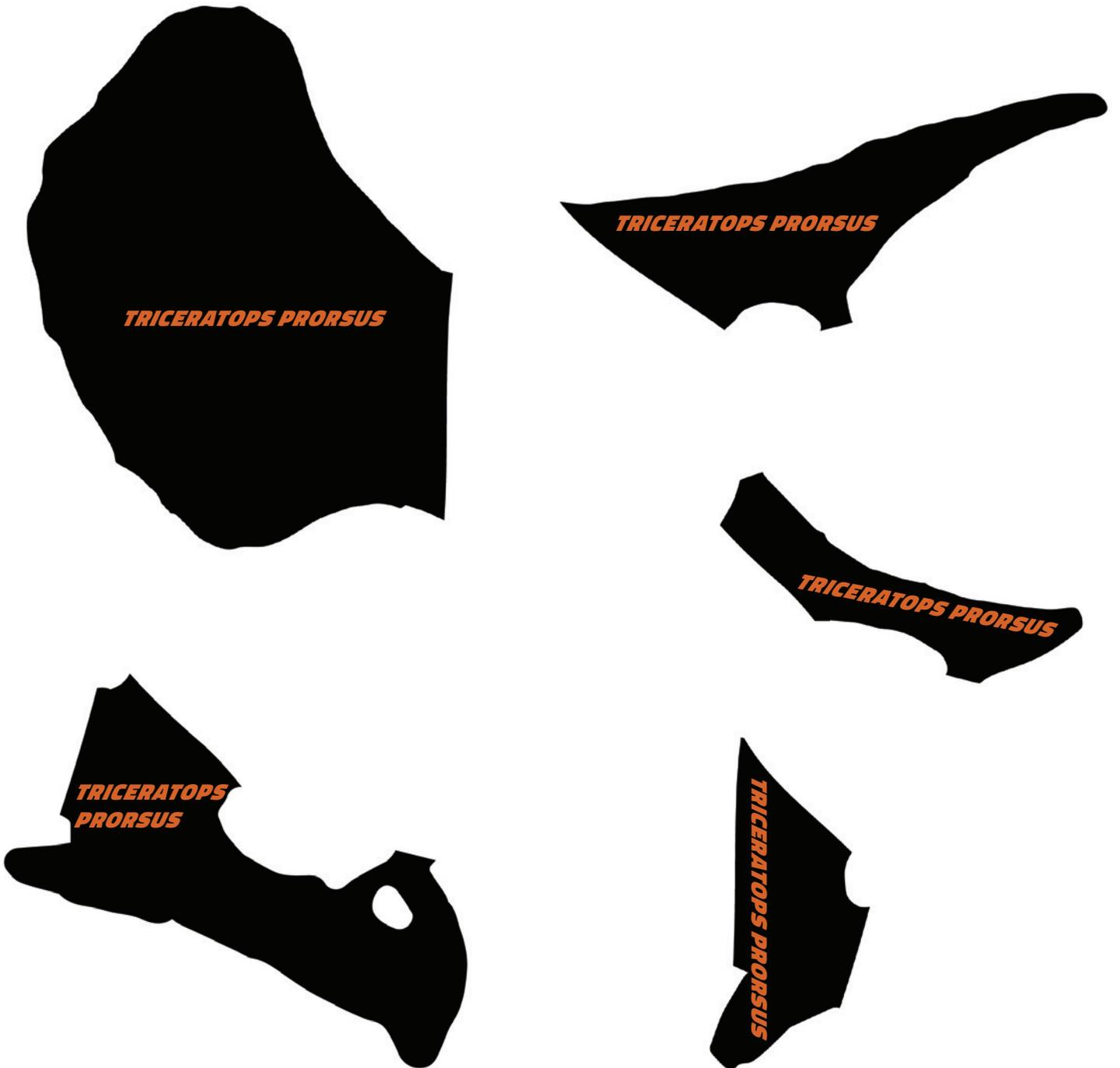




**LESSON MATERIALS: *TRICERATOPS PRORSUS***  
Paleontology Lesson 3: Transforming Land and Life

***TRICERATOPS PRORSUS***

Cut out these pieces carefully for the matching activity.





**LESSON MATERIALS: *PTEROTRIGONIA AMAKUSENSIS***  
Paleontology Lesson 3: Transforming Land and Life

***PTEROTRIGONIA AMAKUSENSIS***

Cut out these pieces carefully for the matching activity.





**LESSON MATERIALS: *PTEROTRIGONIA HIGOENSIS***

Paleontology Lesson 3: Transforming Land and Life

***PTEROTRIGONIA HIGOENSIS***

Cut out these pieces carefully for the matching activity.





# CLOSING

**CLOSING LESSON**  
Our World



## LESSON INSTRUCTIONS

### Closing Lesson: Our World

## GOAL

People and cultures are influenced by their landscapes. While we have differences, the people of Montana and Kumamoto share similar landscapes and cultures. This lesson will help students explore the culture of their sister-state through activities related to the three units of this curriculum.

## OBJECTIVES

Students will be able to:

1. Complete one or more cultural activities related to their units of study in this curriculum.
2. Evaluate the importance of the sister-state relationship between Montana and Kumamoto in building our shared understanding of earth and space science.

## ASSESSMENT

1. Ensure all students participate in the selecting closing activities.
2. Throughout the final discussion and student pages, listen and look for student comments that reflect the importance of our sister-state relationship in contributing to the shared nature of science.

## MATERIALS

- o Copies of "Student Pages," one per student (pages 202-208)
- o Origami paper
- o Rulers (one per student)
- o Colored pencils
- o Images of star quilts and shapes
- o Optional: Video – Assiniboine and Sioux (3:00)  
<https://youtu.be/2Dgvx1a9hQc>

## PREPARATION

- o Make copies of the student pages, one per student.
- o Optional: Video loaded onto a projection system

# LESSON INSTRUCTIONS

## Closing Lesson: Our World



LEARNING ACTIVITIES	EXPECTED STUDENT REACTION/TEACHER RESPONSES	GOALS OF THIS SEGMENT/METHODS OF EVALUATION
<p>Tell students that they have learned about an aspect of our world during the previous lessons (astronomy, geology or paleontology). Now they are going to tie this knowledge into activities that incorporate language, art and geometry.</p>	<p>Expect students to need a strong link between the closing lesson and the material they have covered. Ask students to share what they have learned about geology, paleontology, and/or astronomy.</p>	<p>This gives teachers the opportunity to link the upcoming activities to the earlier lessons.</p>
<p>Select one or more appropriate closing activities based on the units covered:                      Astronomy: Star Quilt Activity                      Geology: Kanji Activity                      Paleontology: Origami Activity</p>	<p>Expect students to need some guidance on the Origami and Star Quilt activities. Review basic shapes and properties for this lesson and have a model sauropod ready.</p>	<p>This gives teachers the opportunity to show images of different shapes and cover basic mathematical properties of figures. The Star Quilt section gives teachers the opportunity to show the provided video and explain the reservation system in Montana.</p>
<p>After completing the appropriate activities, have students complete the final reflection worksheet and lead a discussion on what the students learned about their sister-state throughout the curriculum.</p>	<p>Encourage students to give examples of their favorite topics or activities.</p>	<p>This gives teachers the opportunity to answer any final questions and address any misconceptions.</p>
<p>Lead a discussion on the importance of Montana and Kumamoto's sister-state relationship. Ask the students to identify how this relationship can help us build a greater understanding of Earth and space science.</p>	<p>Encourage students to think about the lessons they completed and what they learned about earth and space science in their sister-state. Ask students how knowledge from their sister-state can help them understand their home landscape.</p>	<p>This gives teachers the opportunity to emphasize the importance of the sister-state relationship in building our shared knowledge of our world.</p>

## BACKGROUND INFORMATION

### Closing Lesson: Our World

#### Kanji

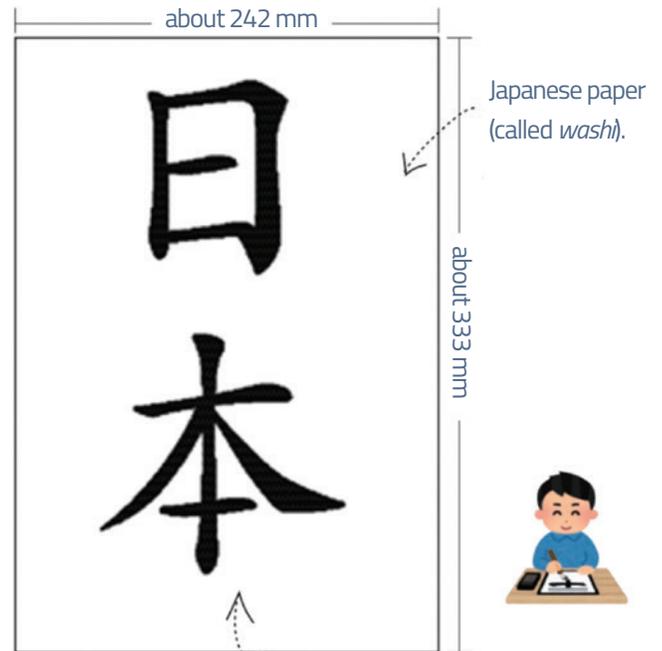
Kanji are Chinese characters adopted and used in the Japanese written language. The term means “Han characters”, from the Chinese “hanzi” or writing system. Prior to the introduction of Chinese characters, Japanese had no written form. Between 593 to 628, during the reign of Empress Suiko, the Japanese court sent full scale diplomatic missions to China, resulting in an increased Chinese literacy. The oldest written kanji in Japan dates back to the 7th century and is a record for trading cloth and salt stenciled onto a thin, rectangular shape of wood.

During the Heian period (794 to 1185) a system called kanbun was developed and involved using Chinese text with marks that allowed Japanese speakers to restructure the characters to the rules of Japanese grammar. In modern Japanese, kanji are used to write nouns and adjective and verb stems.

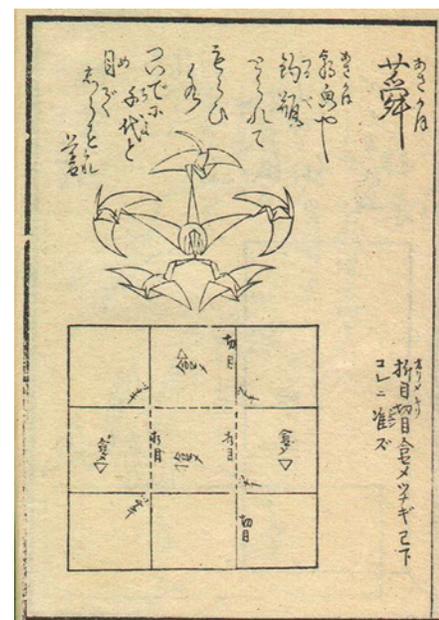
#### Origami

Handmade paper was brought to Japan by monks from China in the sixth century and was a luxury item. In ancient times, paper folding was used for ceremonial or religious purposes but by the Edo period (1603-1868) it became recreational as well. This was helped along by the mass production of paper, and in 1797, written instructions for the art form first appeared in Akisato Rito’s Sembazuru Oriката or “Thousand crane folding”. By the late 1800s, the term for this type of art went from orikata (folded shapes) to “origami,” a combination of the Japanese words oru (to fold) and kami (paper).

Traditional origami is made up of folding patterns passed down from generation to generation, either orally or annotated. Modern origami sometimes features models created by designers, which can be copyrighted material. It also prioritizes a puzzle aspect and involves folding a single square of paper without the use of cuts or glue.



(Dinosaur)



Page from Sembazuru Oriката depicting crane folding pattern

## BACKGROUND INFORMATION

### Closing Lesson: Our World

#### STAR QUILT TRADITION

Star quilts are one of the traditional art forms of the Assiniboine and Sioux tribes of northeastern Montana. In the mid 1800s, millions of bison were killed by bison hunters to supply the growing global demand for bison hides. By 1881, bison herds were gone from northern Montana and missionaries were visiting the newly established Fort Peck reservation. They introduced fabric and sewing to the Assiniboine and Sioux women, who adapted the “Morning Star” pattern to quilts. The quilt served in place of the traditional red buffalo robe at their funerals and ceremonies.

Today, the quilts are used in Yuwipi, or “give-away” ceremonies, and are one of the most valued gifts of Northern Plains Nations. They may be given to honor a new family member, newly married couple, or to a family to honor a loved one who has died. It has become a tradition on some Montana reservations to give a star quilt to girls and boys on basketball teams to indicate respect, honor, and admiration for that person.

The eight pointed star is a sacred symbol and a star quilt stands for honor and protection. The Assiniboine and Lakota Sioux nations believed the planet Venus to be a guiding star as it represented the direction from which spirits travel to Earth.

#### MATHEMATICS OF STAR QUILTS

Star quilts are made from material cut into pieces that resemble a diamond, or rhombus shape. The rhombus is formed by a single isosceles triangle reflected across its non-congruent side. Eight rhombi are used to make up the eight pointed star.

#### THE ASSINIBOINE, SIOUX, AND FORT PECK RESERVATION

*Video link: <https://youtu.be/2Dgvx1a9hQc>*

Fort Peck Reservation is located in northeastern Montana and is home to members of the Assiniboine and Sioux nations. It was established in 1871 and the agency was relocated to its present day location in Poplar, Montana. About 6,800 people live on the Fort Peck Reservation, with another 3,900 tribal members living off the reservation. It includes more than 2 million acres or 2.4 trillion tsubos of land.

The seal of the Fort Peck tribe features a buffalo hide and incorporates the colors red, yellow, and black, which are sacred to the Assiniboine and Sioux tribes.



*The buffalo symbol in the middle of the seal is actually a map of the waterways on the reservation.*

**STUDENT PAGE: KANJI**  
Closing Lesson: Our World

**KANJI**

People sometimes name things after the way they look. For example, the state of Montana comes from the Spanish "Montaña" meaning "mountain" or "mountainous country". The symbols for the word "Japan" in the writing system known as Kanji come from the Chinese characters for "origin of the sun." This is because Japan is located east of China.

**Copy the symbol for Japan in the box below.**

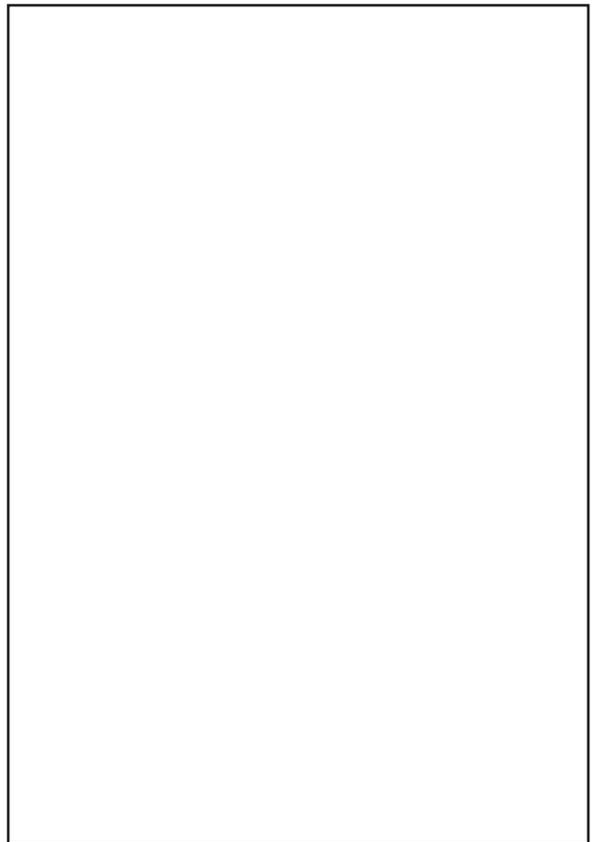


Japanese paper  
(called *washi*).

about 333 mm

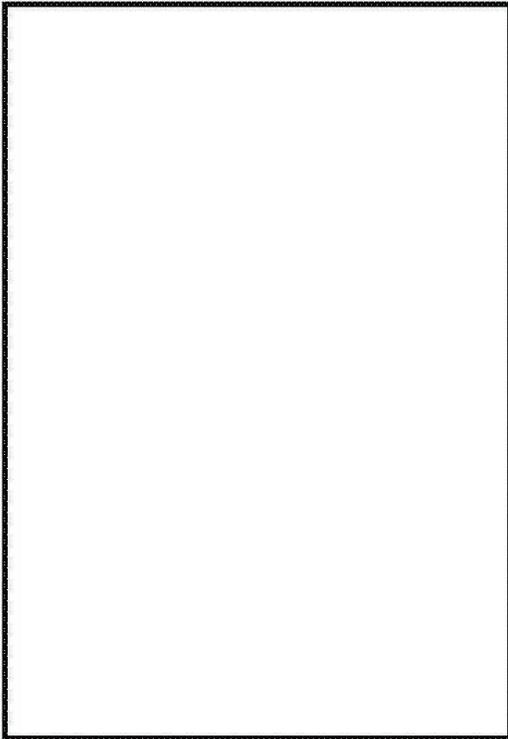
about 242 mm

Children write kanji  
with brush and india ink  
(called *shuui* or *shodou*).

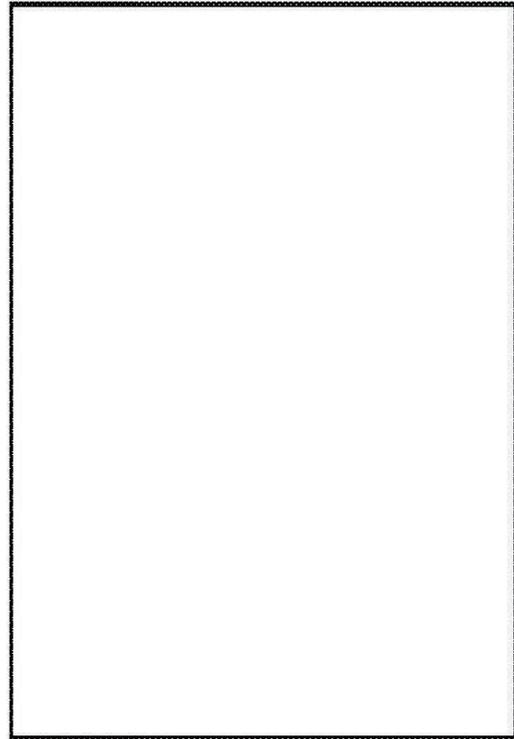


**STUDENT PAGE: KANJI**  
Closing Lesson: Our World

Copy the symbols in the provided boxes.



**(MONTANA)**



**(KUMAMOTO)**



**(MONTANA)**



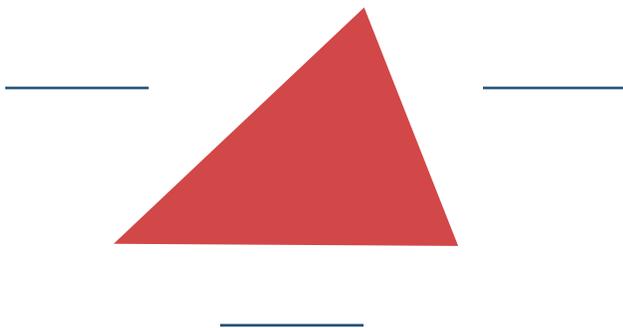
**(KUMAMOTO)**

# STUDENT PAGE: STAR QUILTS

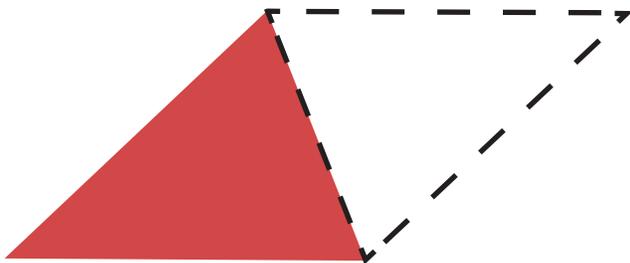
## Closing Lesson: Our World

### MATHEMATICAL CONCEPTS IN STAR QUILTS

The people of the Sioux and Assiniboine tribes in Montana create star quilts, which feature an eight pointed star that represents the Morning Star, also known as the planet Venus. This pattern uses triangles to make a rhombus, or diamond shape. This shape incorporates lines of equal length to create symmetry, or balance. Indigenous science looks at this balance between the land and the animals and people that live upon it.



Measure the sides of the triangle at left and write them in the spaces provided. Circle the sides that are equal.



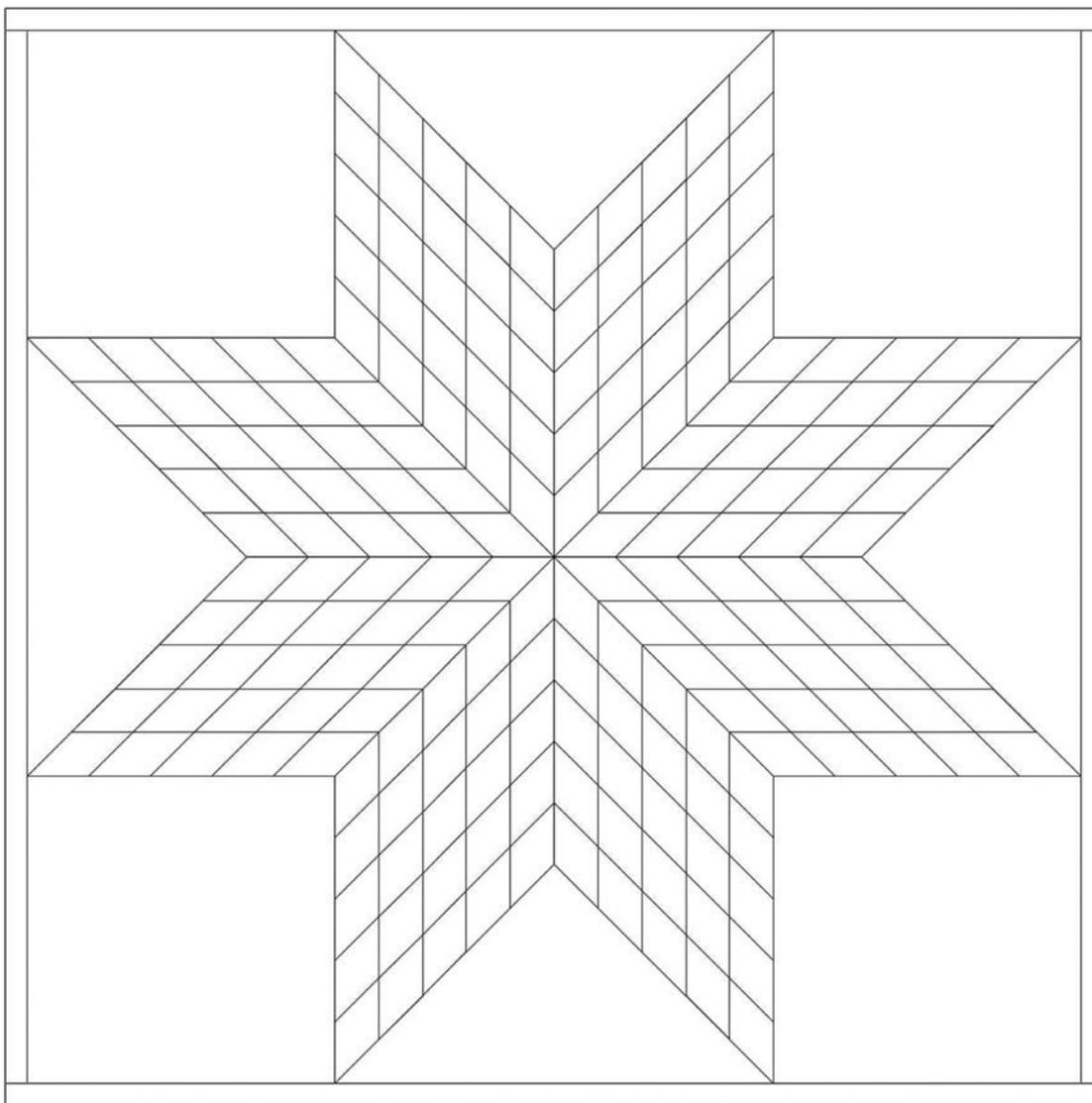
Trace the dotted line to make your triangle into a rhombus.



The colors red, black, and yellow are symbolic colors for the Lakota Sioux. Use the coloring template on the next page to make your own star quilt.

# STUDENT PAGE: STAR QUILTS

Closing Lesson: Our World



*Quilt block models: Almira Buffalo Bone Jackson (Assiniboine), National Museum of the American Indian, and Mary Youngman (Sioux)*

*Images courtesy Creative Commons*

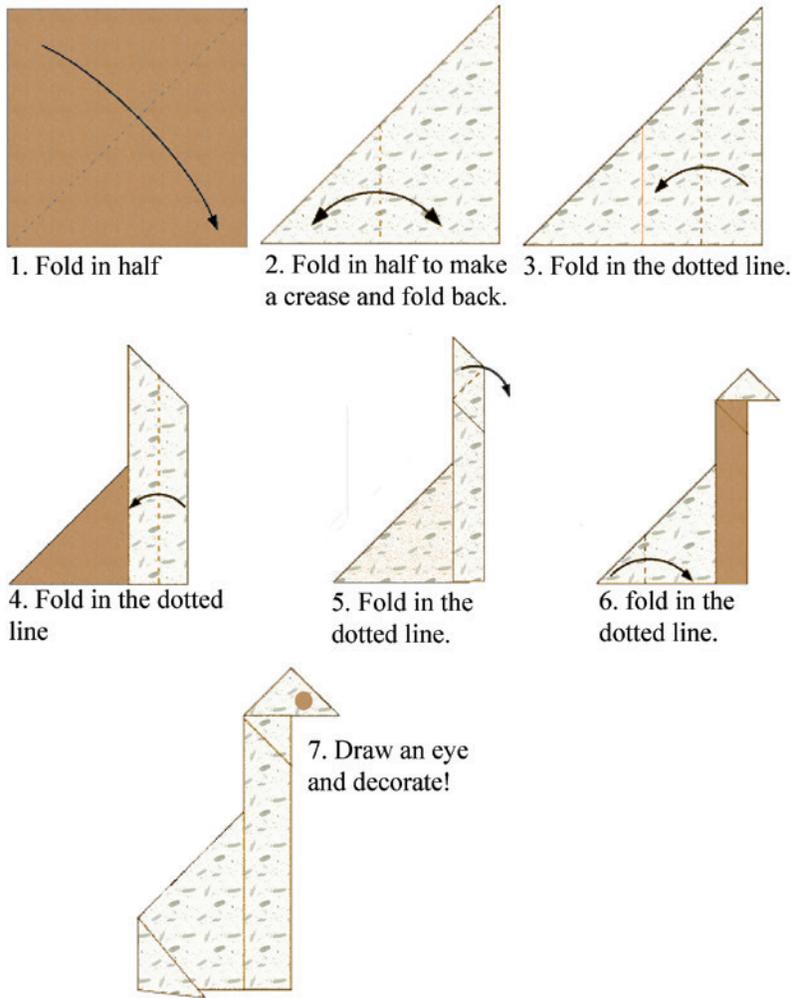


# STUDENT PAGE: ORIGAMI

## Closing Lesson: Our World

### ORIGAMI SAUROPOD

*Sauropods* were long-necked dinosaurs that lived in the Jurassic and early Cretaceous period. They have been discovered in Montana and Kumamoto Prefecture. Below are directions to make your own sauropod using the Japanese art of origami. The word "origami" comes from the Japanese words oru (to fold) and kami (paper).



There are many different shapes used in origami. They have been colored brown. Use the instructions to answer the following questions:

1. What shape is in step one? \_\_\_\_\_
2. What shape is in step four? \_\_\_\_\_
3. What shape is in step six? \_\_\_\_\_
4. What shape is in step seven? \_\_\_\_\_

# STUDENT PAGE: ORIGAMI

Closing Lesson: Our World

## ORIGAMI CRANE

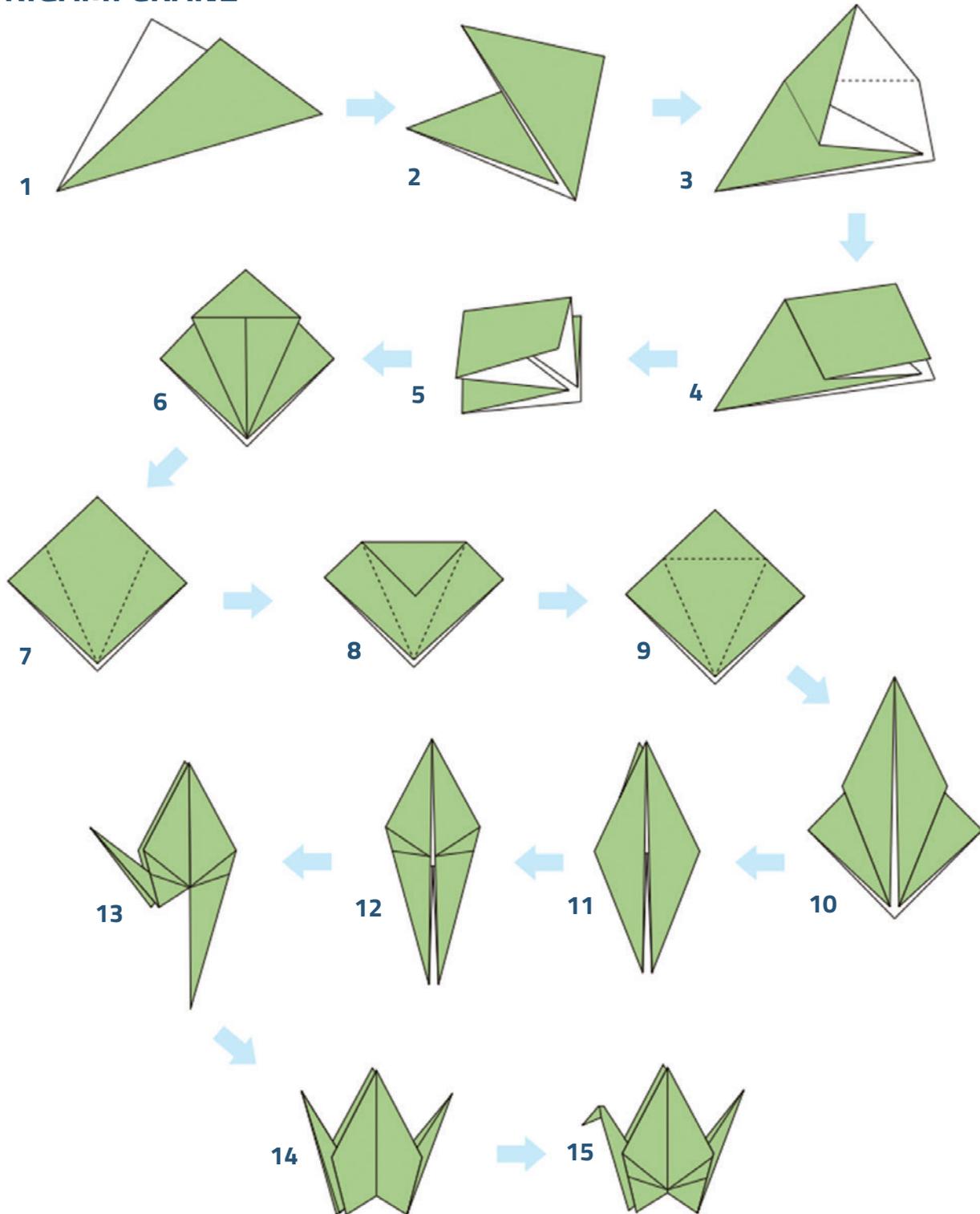


Illustration courtesy Mifune Dinosaur Museum



## STUDENT PAGE

### Closing Lesson: Our World

#### FINAL REFLECTION

Sister-state's name: \_\_\_\_\_

Describe one reason it is important:

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Draw a picture of why it is important:





## REFERENCES & APPENDICES

### OUR HOME, OUR WORLD

#### OPENING LESSON

#### OUR HOME

<https://youtu.be/T4-Qg9wpWcy>

<https://youtu.be/c7XYzOd8R01>

<https://youtu.be/R4-ZbVlzMVM>

<https://youtu.be/KCvy3Pcp7ul>

<https://youtu.be/MINNGeusB7M>

<https://youtu.be/c7XYzOd8R01>

<https://youtu.be/R4-ZbVlzMVM>

<https://www.youtube.com/watch?v=CHjqJKbjAHA&sns=em>

#### ASTRONOMY LESSON 1

#### ONE SKY, MANY STORIES

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Moroney, L. 2011. Montana Skies: Crow Astronomy. Montana Office of Public Instruction. pp. 39.

Uchida, T.1973. Star dialects and folklore. Iwasaki Bizyutsusya. pp. 288-230.

<http://hoshifuru.jp>

<https://vimeo.com/49771618>

<https://vimeo.com/74325278>

<https://youtu.be/N7fLb29bWM8>

<https://youtu.be/nzMIjr1XP38>

#### ASTRONOMY LESSON 2

#### STARSCAPES AND STAR CHARTS

Moroney, L. 2011. Montana Skies: Crow Astronomy. Montana Office of Public Instruction. pp. 39.

Renshaw, S.L. 2012. 'The Inspiration of *Subaru* as a Symbol of Cultural Values and Traditions in Japan', eds. Nicholas Campion and Rolf Sinclair, *Culture and Cosmos*, Vol. 16 nos. 1 and 2, pp. 175-191.

<http://hoshifuru.jp>

<https://youtu.be/DUkZdEocUzY>

#### ASTRONOMY LESSON 3

#### COLORFUL CONSTELLATIONS, CLASSIFYING STARS

Renshaw, S., Ihara, S. 1999. Yowatashi Boshi; Stars that Pass in the Night. Japan's Cultural Heritage Reflected in the Star Lore of Orion. Volume 63, Number 10, pp. 2-17. *Griffith Observer*.

<https://youtu.be/Zo-sKzMWYFA> (5:09 minutes)

[https://youtu.be/2PO\\_jMgmLvs](https://youtu.be/2PO_jMgmLvs)

<http://www.constellation-guide.com/constellation-list/orion-constellation/>

<https://youtu.be/Zo-sKzMWYFA>

[https://youtu.be/2PO\\_jMgmLvs](https://youtu.be/2PO_jMgmLvs)



## REFERENCES & APPENDICES

### OUR HOME, OUR WORLD

#### GEOLOGY LESSON 1

#### VOLCANIC LANDSCAPES

<https://www.nps.gov/yell/learn/nature/geology.htm>

<http://www.aso-geopark.jp/en/charm/index.html>

<http://earthquakes.volcanodiscovery.com/>

<http://www.worldatlas.com/aatlas/infopage/tectonic.htm>

<http://www.protezionecivilewp.jsessionid=3DDAFAE6B2D6096A41CF68577C44324F?contentId=PDE1771>

[https://volcanoes.usgs.gov/volcanoes/yellowstone/faqs\\_ash3d.html](https://volcanoes.usgs.gov/volcanoes/yellowstone/faqs_ash3d.html)

<https://www.youtube.com/watch?v=USCvVndukjA>

[https://youtu.be/\\_hyE2NO7HnU](https://youtu.be/_hyE2NO7HnU)

<http://www.discovery.com/tv-shows/discovery-presents/videos/understanding-volcanoes-mt-saint-helens/>

<https://youtu.be/BBGmXsZHlnw>

<http://study.com/academy/lesson/volcanic-hazards-definition-types-prevention.html>

<http://www.discovery.com/tv-shows/discovery-presents/videos/ultimate-guide-to-volcanoes-pyroclastic-flow/>

#### GEOLOGY LESSON 2

#### NATURAL HAZARDS – OUR CHANGING LANDSCAPE

*Glossary of Geology*, 2017, Edited by Klaus K.E. Neuendorf, James P. Mehl, Jr., and Julia A. Jackson, American Geosciences Institute

<https://earthquake.usgs.gov/learn/kids/eqscience.php>

[https://www.teachengineering.org/activities/view/cub\\_natdis\\_lesson03\\_activity2](https://www.teachengineering.org/activities/view/cub_natdis_lesson03_activity2)

<https://www.nps.gov/yell/learn/nature/earthquakes.htm>

[http://www.uusatrg.utah.edu/RBSMITH/public\\_html/IMAGES/ys-seisnet.jpg](http://www.uusatrg.utah.edu/RBSMITH/public_html/IMAGES/ys-seisnet.jpg)

[https://volcanoes.usgs.gov/volcanoes/yellowstone/hazard\\_earthquakes.html](https://volcanoes.usgs.gov/volcanoes/yellowstone/hazard_earthquakes.html)

[https://www.teachengineering.org/activities/view/cub\\_natdis\\_lesson03\\_activity1](https://www.teachengineering.org/activities/view/cub_natdis_lesson03_activity1)

[https://www2.usgs.gov/natural\\_hazards](https://www2.usgs.gov/natural_hazards)

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Minami, T., and Kubotera, A. 1977. Activity form of the Aso caldera northern part earthquake (1975), *Jishin* 2, 30:73–90.



## REFERENCES & APPENDICES

### OUR HOME, OUR WORLD

## GEOLOGY LESSON 2 - CONTINUED

### NATURAL HAZARDS – OUR CHANGING LANDSCAPE

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Ono, K., Watanabe, K., Hoshizumi, H., and Ikebe, S. 1995. Ash eruption of the Naka-dake 20 crater, Aso volcano, southwestern Japan. *J. Volcanol. Geotherm. Res.* 66: 137-148.

The Fukuoka District Meteorological Observatory 1975. An investigation report on the earthquake in the northeastern part of Kumamoto Prefecture, *Kenshinjihou* 40:55-72.

Watanabe, T., Momikura, Y., and Tsuruta, K. 1979. Active Faults and Parasitic Eruption Centers on the West Flank of Aso Caldera, Japan, *The Quaternary Research* 18:89-101.

## GEOLOGY LESSON 3

### SEDIMENTOLOGY – BUILDING OUR LANDSCAPE

Barker, R.M. 1990. Collecting rocks; 1990; USGS *Unnumbered Series*; GIP.

Geological Map of Yellowstone Park by Robert L. Taylor and Joseph M. Ashley with R. A. Chadwick, S. G. Custer, D. R. Lageson, W. W. Locke, D. W. Mogk, and J. G. Schmitt, Cartographic Assistance: Jay B. Erickson. Department of Earth Sciences, Montana State University

[http://media.wfyi.org/IndianaExpeditions/IDEXSeason2\\_2009/IDEX202/IDEX202SedimentJarLesson.pdf](http://media.wfyi.org/IndianaExpeditions/IDEXSeason2_2009/IDEX202/IDEX202SedimentJarLesson.pdf)

[https://www.usgs.gov/faqs/what-are-sedimentary-rocks-0?qt-news\\_science\\_products=0#qt-news\\_science\\_products](https://www.usgs.gov/faqs/what-are-sedimentary-rocks-0?qt-news_science_products=0#qt-news_science_products)

## PALEONTOLOGY LESSON 1

### PRACTICES OF PALEONTOLOGY

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## CLOSING LESSON

### OUR WORLD

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