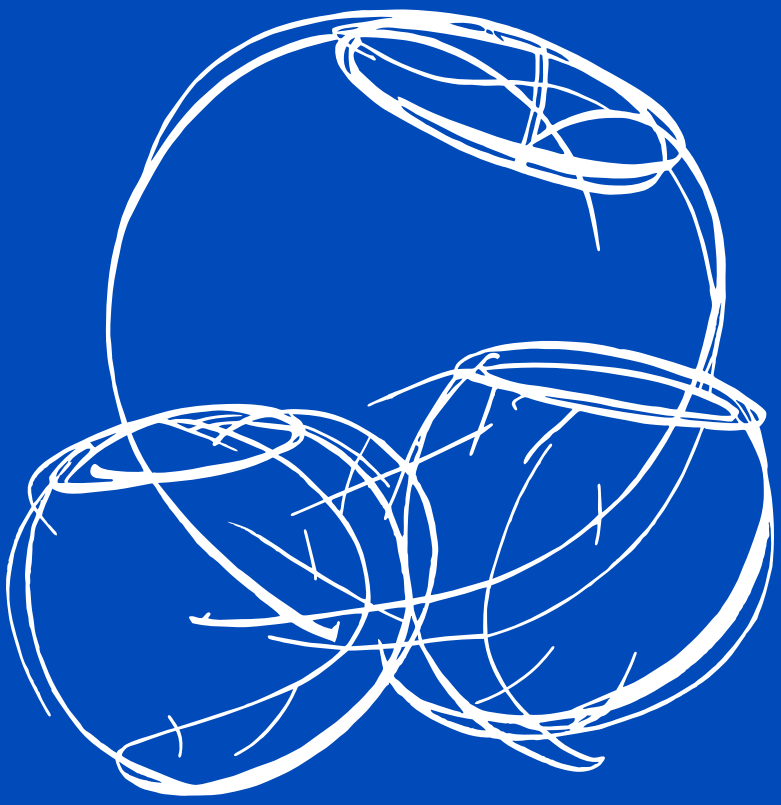


Nature of Glass Curriculum

CHIHULY | GARDEN AND GLASS

Introduction

Since opening in 2012, *Chihuly Garden and Glass* has partnered with Seattle Public Schools to enhance learning using the artwork of Dale Chihuly. *The Nature of Glass* is an innovative sixth-grade science curriculum that immerses students in Chihuly's installations and provides teaching resources aligned with the Next Generation Science Standards (NGSS)*. The Nature of Glass Curriculum enables students to appreciate the science and engineering behind the creation and exhibition of works of art created in glass.

Summary

The Nature of Glass Curriculum is divided into three sections:

- Pre-visit Resources
- Visit Resources
- Post-visit Resources

The Curriculum Resources Chart lists all components. Each resource has a companion teacher's guide with lesson plans, evaluation tools, and teaching tips to facilitate its use. Using the pre-visit resources and the Student Visit Booklet, students examine aspects of the essential question: what is the nature of glass? The post-visit resources help students understand and apply their experiences with glass while exploring connections to other science, engineering, and art content. The visit resources are organized around three NGSS Crosscutting Concepts that link glass to broader scientific topics:

- Patterns
- Energy and Matter
- Structure and Function

The Nature of Glass Curriculum provides an efficient and exciting science, technology, engineering, arts and mathematics (STEAM) learning opportunity to Seattle's sixth graders.

*Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product.

Key Features

1. Accessible

   The Nature of Glass Curriculum is easy for teachers and students to use. Background information is explained in concise pre-visit resources. Optional pre-visit exercises introduce or review ideas and skills found in the Student Visit Booklet. The pre-visit Teacher's Guides suggest quick formative assessments to review prior knowledge and correct misconceptions. The Student Visit Booklet helps students see the science and engineering and engage with the artwork during their visit. The post-visit resources offer many opportunities to extend the *Chihuly Garden and Glass* experience into students' current courses. Curriculum components have clear instructions and answer keys to simplify evaluation.

2. Adaptable

The Nature of Glass Curriculum is designed for diverse schools and learners. Pre-visit and post-visit resources are stand-alone learning tools that can be selected, extended, or abridged based on the priorities and schedules of participants. Although each pre-visit resource enhances student learning, there are no prerequisites for the Student Visit Booklet. Resources can be introduced, omitted, or revisited whenever appropriate. For maximum adaptability, the Teacher's Guides suggest many variations. Components can often be assigned as homework. Responses can be by class discussion, group sharing, or individual writing. Assignments can be tailored to meet the needs and interests of individual students. Teachers are encouraged to select the curriculum resources that best suit their students. The sequence and delivery method can be altered with the support of the Teacher's Guides.

3. Aligned with the Next Generation Science Standards

The Nature of Glass Curriculum is built on the three dimensions of NGSS:

- Science and Engineering Practices
- Crosscutting Concepts
- Disciplinary Core Ideas

Nature of Glass resources provide students opportunities to use all the NGSS Science and Engineering Practices. The Student Visit Booklet focuses on three NGSS Crosscutting Concepts that bridge the natural sciences. Numerous NGSS Disciplinary Core Ideas are also included in the resources. While general science, physical science, and engineering topics predominate in the pre-visit resources, the post-visit resources allow deeper examination of topics in life science and Earth/ space science. Each Nature of Glass resource lists related NGSS Disciplinary Core Ideas and middle school performance expectations in its Teacher's Guide. Many related Washington State Arts Essential Academic Learning Requirements (EALRs) are also noted in the Teacher's Guides. Connections to the NGSS dimensions are compiled in charts within the Curriculum Overview. For more information on these standards visit:

Next Generation Science Standards: www.nextgenscience.org
Washington State Arts EALRs: www.k12.wa.us/arts/standards

HISTORY OF GLASS TIMELINE
DALE CHIHULY'S ART HANDOUT
NATURE OF GLASS GLOSSARY
SCIENCE VOCABULARY EXERCISE
ART GLASS VOCABULARY EXERCISE
PROPERTIES FF GLASS
ENGINEERING DESIGN PROCESS DIAGRAM

GLASS VIDEOS
VIDEO VIEWING EXERCISE

GLASS IN YOUR ENVIRONMENT LAB
DISTINGUISHING CHARACTERISTICS LAB

HISTORY OF GLASS

Summary

This timeline provides background information on the history of glass for reading and class discussion. It includes important periods, events, and people in glass art and glass technology. It can be displayed for discussion or given as a handout.

Objectives:

- Identify glass as a naturally occurring substance that is further refined for human use.
- Recognize that glassmaking has been an evolving technology over thousands of years.
- Cite and correctly sequence important discoveries and developments in the history of glass.

Standards:

NGSS Disciplinary Core Ideas PS1.A, ESS1.C, ESS3.A

Supports NGSS performance expectations MS-PS1-3, MS-ESS3-4 & Arts EALRs 1.3, 4.4

Recommended Sequence:

This is an optional stand-alone resource that can be used at any time. It can be assigned as a homework reading and/or used for class discussion. Sharing this resource with social studies teachers can help students connect glass to their studies of other societies and times.

Materials & Set-up:

Print a class set of the History of Glass Timeline, if using as a handout.

Timing & Setting:

5 minutes for reading in class or as homework, 5-10 minutes for discussion in class

Introductory Discussion Prompts:

- How old is glass?
- Who invented glass?
- What is the oldest glass object you can think of?
- What's the oldest glass object you have ever seen?
- Is glass the same now as it has always been? How has it changed? How has it remained the same?
- How have different civilizations used glass?
- What are some of the earliest examples of glass engineering?

Variations: (requiring additional time)

- Build a classroom "Glass Timeline" instead of handing out this resource. Post a range of dates on a board or wall in the classroom. Ask students to guess where some events fit on the classroom Glass Timeline or whether something happened before or after another event. See how many are correct when you reveal the dates and display the events in the correct order.
- Make the classroom Glass Timeline more participatory. Follow the variation above, except students hold signs with an event from the timeline. They begin by standing next to their first guess. Then move along the timeline with hints of "older" or "newer" until finding the right place.

Evaluation Tools:

After the History of Glass Timeline has been read and discussed, ask some of the suggested introductory discussion prompts as short-answer questions.

Extensions:

- Social Studies: Research the importance of glass as a trade good in societies throughout history.
- Science and Social Studies Glass Timeline Class Research Project: Assign each student an event on the timeline to research for homework. Have students summarize what they learned to the class as you write out the timeline together.
- Science and Social Studies: Have students think of and research important scientific inventions and discoveries that used glass. A "History of Glass Technologies Timeline" can be created.

Examples Include:

*Also see the post-visit Visual Arts Extensions and the Resources for Further Study

bottles/jars	stained glass	planes	sextants	Pyrex
mirrors	fiber optics	test tubes	windows	TV tubes
fiberglass	microscopes	syringes	Petri dishes	diving bells
telescopes	photography	sunglasses	clocks/watches	bulletproof glass
magnifying glasses	light bulbs	eyeglasses	glass floats	cars

NAME: **DATE:**

HISTORY OF GLASS

Prehistory-Present Natural glass forms as molten sand cools: obsidian (volcanos), fulgurites (lightning), tektites (meteorites).

700,000 BCE	Stone Age humans begin to make and later trade obsidian arrowheads and cutting tools.
3000-2000 BCE	First known manufactured glass, faience, is used in Egypt and Mesopotamia for jewelry including beads.
50 BCE	Glassblowing is invented in Syrian/Iraqi part of the Roman Empire; Roman glass manufacturing greatly expands.
100 CE	Romans cut and engrave decorative glass and construct buildings with glass, including cast translucent windows.
600s	Glass windows are used in Anglo-Saxon churches and monasteries across England.
1100s	Stained glass becomes common for ornamental windows in secular and religious buildings.
1226	Broad sheet, an early type of hand-blown window glass, is first produced in England.
1300s	Murano becomes the center of Venetian glassmaking and fine glass production flourishes.
1330	Crown glass, another hand-blown window glass, is produced in France and exported along with broad sheet.
1600s	The invention of microscopes and telescopes using glass lenses and mirrors propels the Scientific Revolution.
1620	Blown plate, a hand-blown flattened glass, is produced in London and used for mirrors and coach plates.
1700s - 1800s	Glass is a popular product in Europe and American; decorative styles are cut, engraved, and painted.
1820s	American-invented pressing machines make glass much more affordable.
1843	Early form of float glass (uniform glass planes) is invented in the UK by pouring glass onto liquid tin.
1851	The Great Exhibition shows international glass goods in London's architectural glass marvel, The Crystal Palace.
1870s-1910s	Art Nouveau movement produces new styles of decorative art glass, often inspired by nature.
1878-1933	Decorative glass is produced by Tiffany Studios, designers include Louis Comfort Tiffany and Clara Driscoll.
1888	Machine rolled glass develops and this technology is used to produce patterns on glass.
1900	Modernism art movement brings its ideals of utility and affordability to glass-making.
1950s	Float glass, the standard method for modern flat glass production, is perfected by Pilkington Glass in the UK.
1962	American Studio Glass movement begins in Ohio by artist Harvey Littleton and scientist Dominick Labino.
1971	Dale Chihuly founds Pilchuck Glass School in Washington and art glass innovation ensues.
1980s	Reusable spacecraft are made possible by thermal-shock resistant glass windows and frit-glazed heat shields.
1990s	Glass fiber-optic communication networks revolutionize data transfer and speed the information age.
2000s	US glassmaker Corning engineers tough, lightweight Gorilla Glass for smart phones, touch screens, etc.
2010s	Emerging technologies include very energy efficient architectural glass and paper-thin glass for electronic displays.

DALE CHIHULY'S ART

Summary:
This reading provides background information on Dale Chihuly and his artwork.

Standards:
Arts EALRs 1.3, 4.5

Objectives:
Students will be able to recognize and discuss Chihuly's artwork and series.

Recommended Sequence:
This pre-visit resource provides context for Chihuly's artwork and is highly recommended as an introduction before the visit. It is also useful as a post-visit reference sheet.

Materials & Set-up:
Class set of Chihuly Art Handouts

Timing & Setting:
5 minutes for reading in class or as homework, 5-10 minutes for discussion in class

Ideas for introduction:
Survey the class to find out what they already know about Chihuly and his art.

Instructions for use:
Students read this summary to gain background information about Chihuly's artwork in preparation for their visit to *Chihuly Garden and Glass*. This sheet can also serve as a reference for post-visit discussions and extensions.

Variations:
Use www.chihulygardenandglass.com and/or www.chihuly.com to find photographs to represent the exhibitions and series. Hide any labels from selected examples, and ask students to guess the series or exhibition.

Extensions:
Visual Arts/ Social Studies:

- Research the names of Chihuly's series and find out their meanings and origins.
- Research the collections students will be seeing in the *Northwest Room* including Native American woven baskets, Edward S. Curtis photogravures of Native Peoples, and Pendleton trade blankets.
- Also see the post-visit Visual Arts Extensions and the Resources for Further Study.

NAME: **DATE:**

DALE CHIHULY'S ART

Born in 1941 in Tacoma, Washington, Dale Chihuly was introduced to glass while studying interior design at the University of Washington. After graduating in 1965, Chihuly enrolled in the first glass program in the country, at the University of Wisconsin. He continued his studies at the Rhode Island School of Design (RISD), where he later established the glass program and taught for more than a decade.

In 1968, after receiving a Fulbright Fellowship, he went to work at the Venini glass factory in Venice. There he observed the team approach to blowing glass, which is critical to the way he works today. In 1971, Chihuly cofounded Pilchuck Glass School in Washington State. With this international glass center, Chihuly has led the avant-garde in the development of glass as a fine art. His work is included in more than 200 hundred museum collections worldwide. He has been the recipient of many awards, including twelve honorary doctorates and two fellowships from the National Endowment for the Arts.

Chihuly has created more than a dozen well-known series of works, among them Cylinders and Baskets in the 1970s; *Seaforms*, *Macchia*, *Venetians*, and *Persians* in the 1980s; *Niijima Floats* and *Chandeliers* in the 1990s; and *Fiori* in the 2000s. He is also celebrated for large architectural installations. In 1986, he was honored with a solo exhibition, *Dale Chihuly objets de verre*, at the Musée des Arts Décoratifs, Palais du Louvre, in Paris. In 1995, he began *Chihuly Over Venice*, for which he created sculptures at glass factories in Finland, Ireland, and Mexico, then installed them over the canals and piazzas of Venice.

In 1999, Chihuly started an ambitious exhibition, *Chihuly in the Light of Jerusalem*; more than 1 million visitors attended the Tower of David Museum to view his installations. In 2001, the Victoria and Albert Museum in London curated the exhibition *Chihuly at the V&A*. Chihuly's lifelong fascination for glasshouses has grown into a series of exhibitions within botanical settings. His *Garden Cycle* began in 2001 at the Garfield Park Conservatory in Chicago. Chihuly exhibited at the Royal Botanic Gardens, Kew, near London, in 2005. Other major exhibition venues include the de Young Museum in San Francisco, in 2008, and the Museum of Fine Arts, Boston, in 2011. *Chihuly Garden and Glass* opened at Seattle Center in 2012.

GLASS FORESTS

PERSIANS

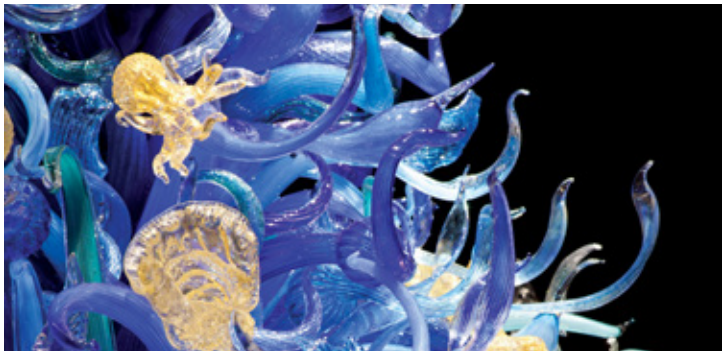
NAME: **DATE:**

BASKETS

IKEBANA

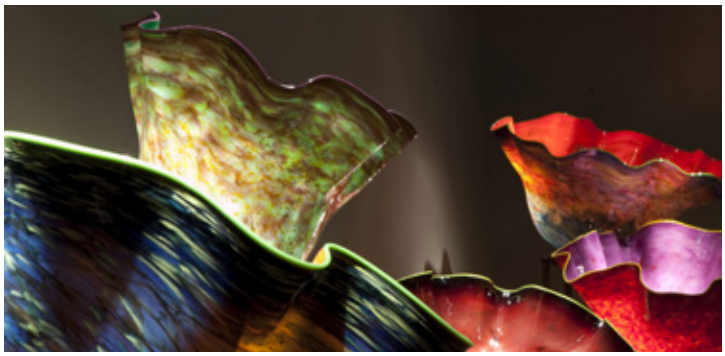
SOFT CYLINDERS

NIIJIMA FLOATS



SEAFORMS

CHANDELIERS



MACCHIA

DRAWINGS

NATURE OF GLASS

Summary:
Definitions of glass-related science and art terms used in the Nature of Glass Curriculum.

Objectives:
Understand science and art vocabulary used in an art glass or glass technology context.

Standards:
NGSS Disciplinary Core Ideas
PS1.A, PS1.B, PS2.A, PS3.A, PS4.B

Supports NGSS performance expectations MS-PS1-3 & Arts EALR 1.1

Recommended Sequence:
The glossary's art and science sections can be used independently or together.
They each help students to complete the related pre-visit vocabulary exercises, if assigned.

Materials & Set-up:
Class set of Nature of Glass Glossary (Science and Art)

Timing & Setting:
15 minutes for reading at home or in class, 15 minutes for discussion in class

Introductory Discussion Prompts:

- What words do scientists/artists use to communicate about glass?
- What words do we need to understand glass?
- How do you understand something new?
- If you created something that had never been done before, how would you name it?

Instructions for use: Students can be asked to

- Underline any words that they have heard before and think they understand.
- Circle words that are unfamiliar.
- Share where they have encountered a word before, remembering some words have different meanings in a particular context such as science or art.
- Predict how some of these words would be used in a scientific context.
- Create sentences or images that will help the class remember the meaning of a word.
- Introduce definitions and then find examples.
- Discuss similar words: centrifugal/centripetal, reflection/refraction, gravity/weight, mass/matter, translucent/transparent, homogeneous/heterogeneous, light/energy, science/engineering…

Variations:

- As an introduction, list just the words (no definitions) for class discussion.
- Use either science or art sections alone if desired.

Evaluation Tools:

- Definitions can be turned into assessment questions where students match the correct words.
- To assess their prior knowledge, students may have a first attempt at the vocabulary exercises without the related glossary. Then allow students to use the glossary to complete and self-correct the vocabulary exercises.

NAME: **DATE:**

NATURE OF GLASS - SCIENCE GLOSSARY

amorphous solid:	a solid which has a disordered atomic structure and therefore a malleable shape
biomimetic:	integrating designs, systems, or processes of nature into art or technology
centrifugal force:	the force that pulls a substance away from its center of rotation; reaction to centripetal force
centripetal force:	any force acting on an object to produce curved motion
chemical change:	a chemical reaction producing new substances, chemical bonds are formed or broken
compound:	a pure chemical substance with two or more different elements bonded in a fixed ratio
element:	a pure substance consisting of only one type of atom
energy:	the ability to do work; forms include mechanical, thermal, chemical, electrical, radiant, and nuclear
engineering:	a process of solving problems and reaching goals by designing and building
glass:	an amorphous solid usually made from a heated mixture of silica, soda, and lime
glass transition:	the transformation of a glass-forming liquid into a solid glass upon cooling
gravity:	an attractive force between objects proportional to their masses; often refers to Earth's gravity
industrial glass:	glass type with added elements to make it hard and durable, designed for use not beauty
light:	a form of radiant energy, refers to the wavelengths of the electromagnetic radiation visible to people
lime:	calcium oxide and calcium hydroxide mixture, a natural inorganic substance used in glass production
melting point:	the temperature at which a solid changes to liquid under normal atmospheric pressure
opaque:	not allowing light to pass through
physical change:	a change producing no new substances; includes cutting, changing state, mixing, and dissolving
pressure:	a measure of force per area, includes the force of gas molecules striking a surface
reflection:	a change in direction of waves at the boundary between two media sending some waves back
refraction:	a change in the direction of waves as they enter a new medium to pass through it
scale:	the ratio of measurements in a drawing or model to the actual measurements; a device to measure weight
soda:	sodium oxide, a naturally occurring salt that acts as a flux for silica in glass production
silica (silicon dioxide):	a compound that forms both glass (amorphous solid) and quartz (crystalline solid)
technology:	tools, machines, crafts, methods, and systems used to achieve human goals
translucent:	allows some light to pass through, but may scatter the photons obscuring images
transparent:	see-through, allows most light to pass through without scattering; clear, but may also be colored
viscous:	resisting flow, liquids that flow slowly have high viscosity and are said to be "thick"

NAME: **DATE:**

NATURE OF GLASS - ART GLOSSARY

abstract:	art that breaks away from traditional representation of physical objects; it explores the relationship between forms and colors
aesthetic:	a set o principles underlying and guiding the work of a particular artist or artistic movement
anneal:	the process of cooling the glass, reliving the stress caused by thermal imbalances from the inside of the glass to exterior
batches:	quantity of goods produced at one time
biomimetic:	a study of artificial system that mimic structures and formations found in natures
blowpipes:	tools used to blow a bubble of air into a gather of molten glass
cane:	glass which has been drawn out into a rod
casting:	a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, then allowed to solidify
frit:	crushed glass, often colored, can be incorporated in many ways to color hot glass
gaffer:	the lead person who directs the glassblowing team
gathering:	method of removing molten glass from the furnace by dipping pipe of punty in it and turning
installation:	three-dimensional works that are often site-specific and designed to transform the perception of a space
medium:	a material used by an artist or designer to create a work
mixed-media:	an artwork in which more than one medium has been employed
punties:	an iron rod used to hold or shape soft glass
series:	a group of related things arranged in order
sketch:	a rough or unfinished drawing, often made to assist the making of a more finished project
symmetric:	agreement in dimensions, due to proportion, refers to a sense of harmonious and beautiful proportions and balance
thermal shock:	a temperature differentiation within a piece of glass that causes a crack, check or even an explosion happened, typically, when the exterior is cooled at a faster pace than the interior of the piece
wrap:	process of adding a hot blob of glass around another piece of glass

SCIENCE VOCABULARY EXERCISE

Summary:
This fill-in-the-blank sheet reviews vocabulary from the Nature of Glass Glossary (Science).

Objectives:
Understand and distinguish words that define and describe matter, energy, and glass.

Standards:
NGSS Disciplinary Core Ideas
PS1.A, PS1.B, PS2.A, PS3.C, PS4.B

Supports NGSS performance expectations MS-PS1-1, MS-PS1-4, MS-PS1-5, MS-PS2-

Recommended Sequence:
This resource should be used after or alongside the Nature of Glass Glossary (Science). If given alone for pre-assessment, students use the glossary later to complete it.

Materials & Set-up:
Class set of Science Vocabulary Exercise and Nature of Glass Glossary (Science)

Timing & Setting:
30 minutes in class or as homework

Instructions for use:
Students may find this exercise challenging depending on their prior knowledge. Allow them to ask questions and to use the Nature of Glass Glossary to find the scientific meanings.

Variations:
Students may work in groups and/or use dictionaries and other reference tools.
Answer Key (1 point each = 24 points total)

Answer Key:
Glass is an inorganic material usually made from silicon dioxide, soda, and lime. It is called ***heterogeneous*** when some of its ingredients, such as colorants, are not uniformly incorporated. Unlike pure substances, its properties can vary widely depending on the additives used. Because its particles are not in a consistent pattern it is a(n) ***amorphous solid*** . Instead of liquefying at a set temperature it slowly becomes less ***viscous*** as it heats. This allows it to be shaped in numerous ways: rotation can spread it by ***centrifugal force*** , air can expand it by ***pressure***, and it can be pulled downwards by ***gravity***, sometimes filling a mold.

Scientists study the ways energy interacts with matter including all forms of glass. Electromagnetic radiation that we can see is called visible ***light***. Photons bounce off the surface of a material by ***reflection***. Some photons can pass through ***translucent*** materials. Materials that we can see clear images through are called ***transparent***. Engineers select types of glass with these optical properties to design new products that are useful to society and scientists.

NAME: **DATE:**

SCIENCE VOCABULARY EXERCISE

Select the best word to fill each blank below. No term should be used more than once.

reflection	physical change	pressure	amorphous solid	force	gravity
translucent	viscous	energy	glass	centrifugal	
melting point	engineering	transparent	light	compounds	

_____ is an inorganic material usually made from silicon dioxide, soda, and lime. It is called _____ when some of its ingredients, such as colorants, are not uniformly incorporated. Unlike pure substances, its properties can vary widely depending on the additives used. Because its particles are not in a consistent pattern it is a(n) _____ . Instead of liquefying at a set temperature it slowly becomes less _____ as it heats. This allows it to be shaped in numerous ways: rotation can spread it by _____ , air can expand it by _____, and it can be pulled downwards by _____, sometimes filling a mold.

Scientists study the ways energy interacts with matter including all forms of glass. Electromagnetic radiation that we can see is called visible _____. Photons bounce off the surface of a material by _____. Some photons can pass through _____ materials. Materials that we can see clear images through are called _____.

Engineers select types of glass with these optical properties to design new products that are useful to society and scientists.

ART GLASS VOCABULARY EXERCISE

Summary:
This worksheet reviews vocabulary from the Nature of Glass Glossary (Art).

Standards:
Supports Arts EALRs 1.1, 1.3, 4.5

Objectives:
Identify tools, materials, and methods of glassblowing and descriptive art terms.

Recommended Sequence:
This resource should be used after or alongside the Nature of Glass Glossary (Science). If given alone for pre-assessment, students Recommended Sequence: This resource should be used after or alongside the Nature of Glass Glossary (Art). It may be attempted before the glossary for pre-assessment, if students are then allowed to use the glossary to successfully complete the exercise. This resource can be used before the pre-visit Glass Videos to help students understand and name some of what they are seeing.

Materials & Set-up:
Class set of Art Glass Vocabulary Exercise and Nature of Glass Glossary (Art)

Timing & Setting:
20-30 minutes in class or as homework

Ideas for introduction:
Show pictures or video of glassblowing from the Resources for Further Study.

Instructions for use:
Students may find this exercise challenging depending on their prior knowledge. Give them opportunities to ask questions. If assigned as homework, have students use the pre-visit Nature of Glass Glossary (Art).

Answer Key:

1=D	4=J	7=A	10=Q	13=B	16=K	19=E
2=M	5=F	8=I	11=R	14=N	17=P	20=O
3=H	6=G	9=S	12=C	15=T	18=L	

NAME: **DATE:**

ART VOCABULARY EXERCISE

Select the best match for each term and place its letter in the blank. All matches will be used only once.

___ 1. **batches**	A. appearing the same when turned or reflected
___ 2. **series**	B. can be used to add lines of various sizes and colors
___ 3. **punties**	C. can be found on the mouth of bowls, glasses, and vases
___ 4. **casting**	D. contain the raw materials that will form glass
___ 5. **gaffers**	E. used to shape glass pieces by internal air pressure
___ 6. **anneal**	F. heat shields are often used to protect them
___ 7. **symmetric**	G. computer controlled ovens are used to do this
___ 8. **aesthetic**	H. used to hold and move the glass, but NOT necessarily hollow
___ 9. **gathering**	I. Chihuly's is described as organic, asymmetric, and avant-garde
___ 10. **abstract**	J. especially useful for producing multiples of a specific shape
___ 11. **biomimetic**	K. hot glass absorbs these small shards producing colored flecks
___ 12. **wraps**	L. often used to communicate a plan for the artwork
___ 13. **canes**	M. Chihuly's include *Cylinders*, *Baskets*, *Seaforms*, *Floats*, etc.
___ 14. **medium**	N. Chihuly's is mainly glass; also uses ice, metal, paper and polyvitro
___ 15. **installations**	O. Chihuly's glass/paint drawings and neon ice sculptures
___ 16. **frits**	P. can cause glass to break or shatter
___ 17. **thermal shock**	Q. art that uses the imagination more than figurative art does
___ 18. **sketches**	R. Chihuly's pieces that have living things as references
___ 19. **blowpipes**	S. can be done with a pipe or punty within the furnace
___ 20. **mixed-media**	T. Chihuly creates temporary and permanent ones, indoors and out

PROPERTIES OF GLASS

Summary:
This reading describes the structure, composition, production, and properties of glass

Objectives:
Define glass and recognize its common properties at atomic and macroscopic levels

Standards:
NGSS Disciplinary Core Ideas PS1.A, PS1.B, PS3.A, PS4.B, ESS2.A, ESS3.A

Supports NGSS performance expectations MS-PS1-1, MS-PS1-3, MS-PS1-4, MS-PS4-2

Recommended Sequence:
This resource can be used alone or with the Glass in Your Environment Lab.
Materials & Setup: Properties of Glass may be copied as a 2-sided class handout.
(Optional) Bring quartz and glass samples as visual aids: sand, bottles, light bulbs, lenses, glass beads...

Timing & Setting:
5 min. introductory discussion in class, 15 min. reading in class or as homework

Introductory Discussion Prompts:
What is glass?
Is it a liquid or a solid?
What is it made of?
Is all glass alike?
What are some types of glass?

Instructions for use:
As you discuss glass properties address these common misconceptions.

- Amorphous solid are true solids, and not supercooled liquids. An analogy is often drawn between the two because of their disordered arrangement of atoms. Scientifically they are not equivalent, even though glass is frequently and misleadingly described as a supercooled liquid.

- In 1998, materials engineer Edgar Zanotto published research disproving the myth that glass flows enough over long-periods of time to see a difference with the naked eye. Solid glass has no perceptible flow even over centuries. Antique windows are often thicker at the bottom due to traditional manufacturing and installation practices.

- Scientists use the term glass to describe any material that forms a solid without long-range crystals, not just silicon dioxide structures. In this wider scientific definition, glass includes every solid that possesses an amorphous (non-crystalline) structure and that exhibits a glass transition before liquefying. Technically speaking many plastics and even metals are "glass".

- Silicate compounds are an exception to the normal definition of compounds because they do not have exact formulas. These crystalline compounds form most of the Earth's crust. They vary by the type and amount of elements trapped within the crystal structure.

- Cut lead glass is often called "crystal" (such as Swarovski's), but it is not actually crystalline.

- Precise definitions and examples can help students distinguish between commonly confused properties: reflection and refraction, translucent and transparent, porous and permeable.

Evaluation Tools:
Reuse some of the introductory discussion prompts as short-answer questions. Have students apply this table of glass properties in the pre-visit Glass in Your Environment Lab.

NAME: **DATE:**

PROPERTIES OF GLASS

What is glass?

Glass is an amorphous solid. In other words, glass contains closely-packed atoms in a disordered arrangement.
The most common form of glass (silica glass) is made of silicon dioxide, often combined with smaller amounts of other elements.

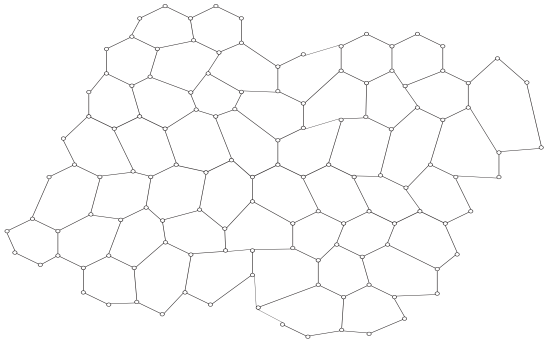


Figure 1 Glass is an amorphous solid:
Silicon dioxide bonded to form a random-looking structure.

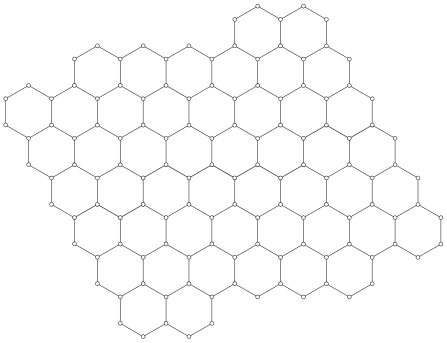


Figure 2 Quartz is a crystalline solid:
Silicon dioxide bonded in a repeating 3-dimensional pattern.

Is glass more like a liquid or a solid?

Scientists consider glass to be a solid, but the amorphous atomic structure of glass (Figure 1) is dramatically different from the precise repeating patterns found in crystalline solids such as quartz (Figure 2). The atomic structure of glass looks similar to a liquid's when particle motion is not considered. However, at an atomic level glass does not move like a liquid. At room temperature, the particles of a glass do not flow past one another. Like all solids, glass is made of atoms that vibrate around fixed positions and stay in place. Glass has the mechanical properties of a solid because it is rigid and does not flow. Glass remains a solid unless it is heated above 500 oC.

How is glass unique?

Glass differs from other solids because it undergoes a glass transition, so-named because this behavior is a distinguishing characteristic of all glass. In a glass transition a heated solid gradually becomes less viscous and starts to flow (imagine heated wax slowly softening before it begins to drip). This phase change, extending over a range of temperatures, differs from the abrupt melting seen in crystalline solids at their specific melting points (imagine ice quickly turning to water when it reaches 0 oC).

How is glass made?

The main ingredient of most glass is silica (silicon dioxide) obtained from the mineral quartz. Quartz is readily available around the world in the form of sand. When quartz (crystalline silica) melts at 1700 oC, its ordered atomic structure disappears. As it cools, molten silica can re-solidify as glass. A flux (soda or potash) is usually added to the starting mixture (the batch) to lower the melting point. Other chemical ingredients are selected to color, harden, or otherwise alter the glass. If glass cools quickly or unevenly, it can recrystallize and shatter. Often lime is added to batches supplying calcium to stabilize the solidified glass. Annealing ovens are used to slowly cool newly-formed glass. Annealing preserves the atoms' amorphous arrangement and produces a durable solid glass.

There are many kinds of glass.

Glass is an incredibly versatile material. Glass's adaptable atomic arrangement allows many elements to be incorporated into the silicon dioxide structure in varying amounts. The numerous forms of natural glass, art glass, and industrial glass each have different compositions.

Any amorphous solid that undergoes a glass transition is technically a glass, but the word "glass" normally refers to silica glass. Soda-lime glass is the most common form of silica glass. It has been produced by humans for thousands of years and engineered for many purposes. The raw ingredients that go into each batch and specialized manufacturing techniques can produce a wide range of physical and chemical properties in the final product. As a batch is heated, colorants and refining agents undergo chemical changes bonding to the silicon dioxide and releasing gases. The resulting glass then undergoes physical changes as it is "worked" by people and machines to create glass objects. When hot, glass can be blown, poured, stretched, cast, fused, pressed, slumped, and flameworked. After annealing, the cool glass can be cut, engraved, etched, ground, polished, coated, and painted.

The properties of glass can vary widely depending on the chemical composition and manufacturing process.

MOST GLASS

is recyclable, but not biodegradable (will not rot)
has high viscosity when molten (slow flow rate)
has low thermal expansion (will not swell or shrink much)
is stain resistant and water resistant
is nonporous and impermeable
breaks into fragments with sharp edges
is chemically nonreactive and durable
can be tinted or coated
is relatively incompressible
is inorganic (not carbon-based)
is very malleable when heated; can be molded and bent
is nontoxic and easy to sterilize
is translucent (some visible light passes through)
is solid at normal temperatures
is an insulator for electricity, heat, and sound
is not magnetic and not flammable
is produced in factories or glassblowing studios
is tasteless and odorless
is made from natural materials available in many locations
is slightly elastic and will give before breaking

SOME GLASS

is very durable; other glass is incredibly fragile
is transparent; other glass is translucent; other glass is opaque
is smooth; other glass is highly textured
is easy to cut; other glass is strengthened or scratch resistant
is low density; other glass is high density
is very expensive; other glass is very inexpensive
is compatible with certain other glass types for combination
is designed to break into small round fragments (tempered)
is crack resistant; other glass is very brittle
withstands extreme hot and cold
shatters when heated or cooled
has been known since ancient times
is engineered as recent technology
is easily mass produced: cast, blown or pressed by machine
requires expert skill to create: fine art, hand blown, or hand cut
is produced in nature by volcanoes, lightning, or meteorites
is able to reflect, scatter, refract, absorb and/or transmit light
is able to withstand extreme pressures (high and low)
is embedded in other materials or has materials placed within it
is hazardous or deadly: poisonous, carcinogenic, or razor-sharp

ENGINEERING DESIGN PROCESS DIAGRAM

Summary

This resource presents the engineering design process as a list of detailed steps.

Objectives:

- Understand the engineering design process and the importance of each step.
- Distinguish the meaning of *engineering* from *science* and *technology*.
- Identify glassmaking practices as parts of an engineering design process.

Standards:

NGSS Disciplinary Core Ideas
ETS1.A, ETS1.B, ETS1.C & Arts
EALRs 4.2, 4.5

Recommended Sequence:

This diagram supports the pre-visit Glass Videos and Glass in the Environment Lab, and the post-visit Extension Projects and Engineering Extensions.

Timing & Setting:

5 minutes for reading in class or as homework, 10 minutes for discussion in class

Introductory Discussion Prompts:

- *List three ways that cars have changed since their original design: answers will vary*
- *Why have they changed? improve safety (human and environment), efficiency (cost and fuel), consumer demand…*
- *Who made the changes? manufacturers, engineers, designers, legislators, inventors, consumers…*
- *How were the changes decided? research, tests, inventions, new technologies, regulations, market forces…*
- *What problem did each design change try to solve or what goal did it pursue? answers will vary*

Instructions for use:

Explain to students the differences between science, engineering, and technology:

- Scientists seek knowledge about the natural world.
- Engineers solve problems that help people reach their goals.
- *Technology* means all human-made tools, systems, and methods.

Technology is created when science, math, engineering, art, and other fields of knowledge are applied to solve problems by a society. In this context, "technology" refers to more than computers and communication devices.

Just like the scientific method, the engineering design process is a description summarizing a common progression, not a set of strict rules. Explain to students that not all the steps are used by engineers every time, just like scientists don't use every step of the scientific method or follow an exact sequence in every investigation.

Use some of the following prompts to discuss the Engineering Design Process Diagram:

- What are some similarities between the engineering design process and the scientific method? Differences?
- What are some similarities between this process and the creative process used by artists? Differences?
- Choose one of the steps and explain why it is valuable to the overall process.
- Give an example of a step that might be done out of order and explain why this might be done.
- How could math be used in the engineering design process and in which step(s)?
- How could technology be used in the engineering design process and in which step(s)?

Evaluation Tools:

In the following application students can record their answers on paper as you read out tasks for a graded assignment. Alternatively, students can hold up the number of fingers to show the steps they choose for a quick assessment.

Match parts of Chihuly's creative process to the most closely related engineering design process steps:

What Chihuly's team does:	**Matching**
Meet with a museum curator to find out the focus and funding for an upcoming show	1
Measure a gallery (including its entrances) to inform the design of the installation	1
Make a tentative list of artwork that could be incorporated into an exhibition	2
Build a model of a large Tower	2
Measure an outdoor structure's wind resistance	3
Check for any bubbles, stones, cracks, or flaws in the glass using a light box	3
Rearrange the pieces in a chandelier create a better balance	4
Sketch a metal structure that can support the weight of the glass artwork	2
Adjust the lighting to highlight the translucent glass	4
Work in a team where each member has an assigned role	1,2,3,4
Make three batches and compare how they flow	2,3
Reheat a glass piece to smooth out a wrinkle	4
Make a series of paintings to see which colors combinations are preferred	2,3
Select glass rods that will be compatible for fusing	2
Try casting in various molds	3
When glass is too stiff, more lime is added to the next batch to increase its viscosity.	2,3,4
Identify an inspiration	1
Write a report	1,2,3,4

Extensions:

See the post-visit Engineering Extensions and all the post-visit Extension Projects.

NAME: **DATE:**

ENGINEERING DESIGN PROCESS DIAGRAM

The engineering design process is used to achieve human needs or desires:

1

Identify the Problem or Goal:
ask questions and research problems
precisely define the purpose and criteria
evaluate current and previous solutions
define constraints that limit possible solutions

2

Develop Possible Solutions:
imagine, sketch, brainstorm
explore possibilities, consider approaches
generate, plan, and select ideas
create procedures and designs
build models and prototypes

3

Test the Solution(s):
experiment and analyze data
evaluate under a range of conditions
run simulations
rank possible solutions

4

Improve the Design:
apply the results of the tests to make changes
optimize, remove flaws and inefficiencies
make trade-offs, troubleshoot, debug
revise, refine, and redesign (repeat Steps 1,2,& 3 as needed)

- Scientific and mathematical knowledge are applied during the engineering design process.
- Collaboration and communication occur throughout the process.
- Technology is frequently used and invented in this pursuit of new solutions to problems.

NATURE OF GLASS

Summary:

Two short videos.

1) Dale Chihuly Video, 2) What Is Glass "Video from Bullseye Glass"

Objectives:

Students see how glass is made and identify glass types, ingredients, tools, and techniques.

Standards:

NGSS Disciplinary Core Ideas PS1.A, PS3.B

Supports NGSS performance expectation: MS-PS1-3, & Arts EALRs 1.1, 2.3, 4.2, 4.5

Recommended Sequence:

These videos can be used alone or with the Video Viewing Exercise and/or Engineering Design Process Diagram.
The Nature of Glass Glossary can be introduced prior to this.

Materials & Set-up:

Video playing software and speakers; test visibility and audibility prior to showing.

Timing & Setting:

10 minutes for (each) videos in class and 10 minutes for class discussion

Introductory Discussion Prompts:

Where is glass manufactured? (studios and factories) Have you ever seen glassblowing?

Instructions for use:

- Ask students to record some observations and questions during the videos. They can also note any unfamiliar equipment, techniques, and vocabulary used in these videos.
- After the video, students may share their observations and questions. Discuss the changes in temperature, heat transfer, and the glass transitions. If your students are also using the pre-visit Engineering Design Process Diagram, ask them if the glassmaking process they saw represents an engineering design process. They should be able to find similarities and differences and make an argument based on evidence in the videos.

Variation:

Use either video alone, if desired.

Evaluation Tools:

pre-visit resource Video Viewing Exercise, Glass Videos:

- "All About Glass" clips: http://www.cmog.org/research/all-about-glass?page+3&f[0]+bundle%Avideo
- Intro to glassblowing: http://www.cmog.org/video/glass-blowing
- "Dale Chihuly: Glass Master": http://www.youtube.com/watch?v=0rZBv1oRwto

VIDEO VIEWING EXERCISE

Summary:

Ten short-answer questions about the glass-making process.

Objectives:

Analyze parts of the glass-making process and cite examples from the videos.

Standards:

NGSS Disciplinary Core Ideas: PS1.A, PS1.B, PS2.A, PS3.B, ETS1.A, ETS1.B

Supports NGSS performance expectations MS-PS1-2, MS-PS1-3 & Arts EALRs 1.1, 2.3, 4.2, 4.5

Recommended Sequence:

Use with either or both of the pre-visit Glass Videos, and after the Nature of Glass Glossary and Engineering Design Process pre-visit resources (if used).

Materials:

Class set of Video Viewing Exercise handouts and video playing device with speakers.

Timing & Setting:

15 minutes in class, directly after viewing the Glass Videos

Instructions for use:

After viewing the video(s), students use their notes to respond to these questions.

Variations:

Students can work in groups to answer these questions and/or they can be used for class discussion.

Answer Key: (2 points each for 20 points total)

1. Answers may include furnace, ovens, and blowtorches fueled by gas and electricity. These do the work of melting the sand and additives, breaking chemical bonds, softening the glass to continue forming it, slowing the cooling process (annealing). Human muscles fueled by food also do the work of lifting, moving, turning, forming, and manipulating the glass.
2. Discussions, signs, sketches, hand signals, teamwork, planning together, offering encouragement, evaluation…
3. Answers will vary. You may want to point out the safety equipment used including eye protection.
4. Melting (glass transition), solidifying, mixing, stretching, cutting, rolling, flattening, heating, cooling, etc.
5. The change from sand to glass. Chemical changes occur when heated metal oxides release oxygen and deposit the metals into the glass, but this has already occurred when the color is added as colored glass.
6. Temperature, masses of ingredients, thickness, cost, time (for cooling), refraction (to see stress)…
7. Modifiers lower the former's melting point, make the glass more durable, and color the glass.
8. Colorful, "soft", malleable, moldable, durable…
9. Centripetal force applied by pole turners prevents drooping. Force of gravity fills molds and shapes glass. Force of air pressure expands the glass in glassblowing. Stirring homogenizes the glass. Forces applied with tools cut and shape the glass. The force of friction is used to grind it. Force is also used to pull and stretch it. Artists carefully apply force to break the glass off the punty…
10. Answers will vary. Annealing and additives prevent cracking. Safety equipment prevents injury and fires.

Extension:

Use these questions for Chihuly Fire and Light, a video that streams from Seattle Public Library

NAME: **DATE:**

VIDEO VIEWING EXERCISE

1. What sources of energy are shown, and what work does the energy do?

2. List a few examples of collaboration and communication seen in the video(s).

3. List 4 tools or pieces of equipment shown in the video(s) and what you think their purposes are. (Describe them if you don't know their names)

4. What physical changes did you observe in the video(s)?

5. Do you think any chemical changes were occurring? ____ Why or why not?

6. Identify two or more measurements that are necessary in the glass-making process.

7. Why are modifiers added to the sand?

8. What properties are important for art glass?

9. Describe the forces you saw applied to the glass and their effects.

10. Identify one thing that could go wrong in the processes you observed and suggest how that problem could be prevented or corrected.

GLASS IN YOUR ENVIRONMENT LAB

Summary:
Students observe glass in their surroundings and identify its properties and purposes.

Objectives:
Identify glass properties and applications and use the engineering design process.

Standards:
NGSS Disciplinary Core Ideas PS1.A, ESS3.A, ESS3.C, ETS1.A, ETS1.B, ETS1.C

Supports NGSS performance expectations MS-PS1-3, MS-ESS3-3, MS-ETS1-2

Recommended Sequence:
Use with the pre-visit resource Properties of Glass. This lab is best suited to be homework after class discussions of Properties of Glass and the Engineering Design Process Diagram.

Materials & Set-up:
Class set of Properties of Glass handouts and Glass in Your Environment Lab. If using in school, preselect an environment where enough objects are visible such as a lab space with lots of equipment out, or an area with a view of cars, streetlights, buildings...

Timing & Setting:
Part A: 5 minutes in class or as homework; Part B: 30 minutes in a school setting where many glass objects are visible, or as homework; Part C: 10 minutes in school or as homework

Introduction Idea:
Use the pre-visit resource Properties of Glass to prepare for this lab.

Instructions for use:
Either select a school environment for making observations that has enough varieties of glass objects, or allow students to complete this individually as homework.

Variations:
Students may work in lab groups or individually to complete this activity. Any or all sections may be done as a class exercise with guided class discussion. Suggested Scoring (42 points total)

- Part A (6 points total, 1 point for each correct match)
  art glass = C / glass fibers = D / float glass = A / safety glass = E / borosilicate glass = F / chemically strengthened glass = B
- Part B (24 points total, 3 points for each row)
  Objects= ½ pt each / Locations= ½ pt each / Applications= 1 pt each / Properties= 1 pt for each object's list of properties
- Part C (12 points total, 2 points for each question # answered completely and reasonably)

Extensions:
See post-visit Physical Science, Earth and Space Science, and Engineering Extensions.

NAME: **DATE:**

GLASS IN YOUR ENVIRONMENT LAB

Introduction:

Twenty-first century humans constantly interact with glass. Over the last several centuries, scientists have discovered many varieties of glass with unique properties. Glass artists and designers have crafted countless distinct glass forms. Engineers have formulated many useful types of glass and designed structures and technologies that take advantage of their attributes. Glass plays an important role in almost every human-designed environment, including schools and homes.

Purpose:

Identify the properties and uses of the glass in your daily surroundings.

PART A: Identifying Glass Applications

Some common types of glass are listed below. Use their key properties to match them with a set of applications. Match the corresponding applications letter in the best suited column.

Glass Types & Key Properties

___ ART GLASS: malleable, multicolored, can be blown and hand-cut, often prepared to be exceptionally clear and sparkling

___ GLASS FIBERS: transmits light signals over long distances, durable; thermal insulator, nonflammable, lightweight, mold resistant

___ FLOAT GLASS: level planes, smooth surface, precise and uniform; thicknesses, weather resistant, insulator for heat and sound, strong, durable, easy to clean, can be made with a large surface area

___ SAFETY GLASS (laminated or tempered): trong, transparent, can be tinted, weather resistant, recyclable, easy to clean; produces tiny round pieces when broken if tempered; stays intact when shattered if laminated

___ BOROSILICATE GLASS (Pyrex): easy to clean, very clear, very resistant to chemicals, very resistant to thermal shock, nontoxic, can be blown, pressed or cast to make consistent shapes, nonreactive, impermeable, recyclable, nontoxic, waterproof

___ CHEMICALLY STRENGTHENED GLASS (Gorilla Glass): thin, lightweight, transparent, durable, nonreactive, waterproof, can be coated, scratch resistant, hard, crack resistant, shatter resistant

Applications

A. architectural uses, windows, skyscrapers

B. display screens for smart phones, laptops, and handheld digital devices

C. decorative crafts, sculptures, museum and collector pieces

D. building insulation, optical communication wires

E. vehicle windows, diving masks, sliding glass doors, tabletops, skylights

F. cookware (stovetop pans, baking dishes) and laboratory glassware (beakers, test tubes, Petri dishes)

PART B: Glass in Your Environment

Locate 8 glass or part-glass objects. Then fill in the chart below with information about each one.

An example has been completed for you.

Object	Location	Application (Use/ Purpose)	Properties that make this glass a good design choice for this:
juice glass example	kitchen shelf	holding and delivering juice to drink	tasteless, nontoxic, inexpensive, easy to clean, water and acid resistant, nonporous, recyclable, can be molded, solid at normal room and dishwater temperatures
1			
2			
3			
4			
5			
6			
7			
8			

PART C: Glass in Your Environment Lab Questions

1. Based on your data in Part B, what properties of glass are frequently used to solve problems?

2. What are some challenges and limitations to using glass for the purposes you identified in Part B?

3. Choose one glass object that you listed in Part B and explain a problem that could arise due to other properties of the glass or its environmental impact. (See the Properties of Glass handout for ideas.)

4. Suggest two materials (including other types of glass) that might eliminate this problem:

5. Briefly describe one measurement or test that could help to determine whether these materials are superior to glass for this application. Be sure to suggest any tools, instruments or other technology that would be used to evaluate them.

6. Is either material you suggested in question 4 currently being used for this purpose? _____
   If no or not sure, why might that be? If yes, why do you think it wasn't used in the object you observed?

VISIT OVERVIEW

During the visit, each student will receive a Student Visit Booklet from the *Chihuly Garden and Glass* staff. The following version is for teacher reference. It shows the gallery and garden descriptions and questions with answers, suggested point values, and related standards. Additional transportation, chaperone, and logistical information will be sent to each school when a visit is reserved.

STUDENT VISIT BOOKLET
GLASS FOREST
NORTHWEST ROOM
SEALIFE ROOM
PERSIAN CEILING
MILLIE FIORI
FLOAT BOAT, IKEBANA, & DRAWINGS
CHANDELIERS
MACCHIA FOREST
THEATER
GLASSHOUSE
GARDEN
CHANDELIER WALKWAY

STUDENT VISIT BOOKLET

Summary:
The full version of the Student Visit Booklet contains a map and general instructions along with short sections for the parts of *Chihuly Garden and Glass* that will be visited. Each indoor gallery has a Booklet section containing a description and several short-answer questions. These questions invite students to observe the artwork closely and explore the science and engineering connections.

Recommended Sequence:
Booklets are distributed as students enter the Exhibition and collected at the end of the visit. They can then be graded and used for post-visit discussion and activities.

Materials & Set-up:
None. Booklets and pencils are provided by *Chihuly Garden and Glass* at the visit.

Timing & Setting:
90 minutes at *Chihuly Garden and Glass*

Introduction Ideas: Let the students know that they will be using the Student Visit Booklet to document their field learning. Prior to the visit, use the pre-visit resources to introduce any vocabulary or concepts that may be unfamiliar.

Objectives:
- Observe and analyze patterns in the properties and designs of Chihuly's artwork.
- Hypothesize about techniques behind the glass forms and the engineering design in its display.
- Examine interactions between energy and matter: light and glass, physical/chemical changes.
- Identify and interpret examples of realistic and abstract art and its inspirations.
- Compare the artwork to the natural and engineered objects it references.

Standards:
See Student Visit Booklet Sections with Answers & Related Standards.

Instructions for use:
Students fill out their names and class information on the cover upon receipt. Then complete as many questions as possible while visiting each section with their chaperone. General instructions are printed inside the cover.

Variations:
- Direct students to focus on specific NGSS Crosscutting Concepts as marked by icons.

- Students can work collaboratively with partners or lab groups.
- In inclement weather, omit the Garden questions (11A) to spend more time in the Theater (9).

Extensions:

See Nature of Glass post-visit resources.

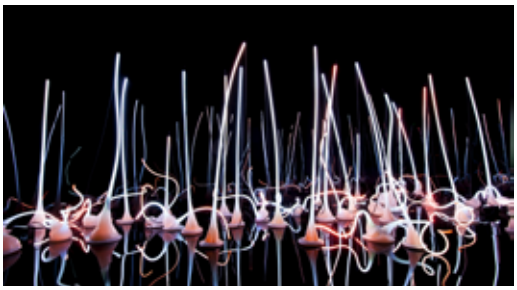
Visit Booklet Answers & Related Standards:

Guidelines for awarding points:

- no points if blank or no serious attempt to respond
- partial points for partially complete or partially correct
- full points for complete and correct answers
- If students do not complete all sections due to lack of time, poor weather, or other extenuating circumstances adjust the expected total points accordingly.

Question #	possible points
booklet heading	2 (on cover)
1.1	3
1.2	2
1.3	2
2.1	3
2.2	2
2.3	3
3.1	3
3.2	3
3.3	3
3.4	1
4.1	3
4.2	3
5.1	3
5.2	3
5.3	3
5.4	2
6.1	4
6.2	3
6.3	3
7.1	3
7.2	2
7.3	2
7.4	2
8.1	3
8.2	2
8.3	4
9.1	3
9.2	2
9.3	2
9.4	2
10	2
10	2
10	2
Total Points =	87

Section 1 GLASS FOREST #5



Early installations played an important role in the development of Chihuly's work, like this Glass Forest #5, which is similar to one he and a student of his, James Carpenter, exhibited in 1971. The forest of white forms was blown with the help of gravity and illuminated with neon. Throughout his career Chihuly would continue to experiment with room-sized installations as he showed that glass art could exist as large architectural statements.

Glass Forest #5, 2012, 7′ x 28′ x 16′, Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

1.1 Observe the colors within the glass forms and describe their appearance in the space below. Be sure to note the positions of the colors and any patterns among the tubes.

PATTERNS

(3 points) Students should describe where they see blue, red-pink, purple, or white areas. There is overlap and some variety, but numerous stems are reddish on top and purplish below. Some base pods are pinkish as well.

NGSS Disciplinary Core Ideas PS1.A

Supports NGSS performance expectations MS-PS1-4

1.2 In this mixed-media installation, noble gases continuously absorb electric energy and then emit this energy as colored light. Neon (reddish) and argon (purplish) are made of monatomic (single atom) gas particles. The lower the density of a substance, the greater its buoyancy. Based on these principles and your observations compare the densities of the two gases. Then make an educated guess about which gas has heavier atoms.

ENERGY & MATTER

(2 points) Students should indicate that neon (observed mainly in the upper parts of the stems) is less dense than argon. Argon has heavier atoms and is seen in the middle and lower parts because argon is denser. If they have these switched, give some credit if inferences are based on their observations in question 1.1 above.

NGSS Disciplinary Core Ideas PS1.A, PS3.A, PS4.B

Supports NGSS performance expectations MS-PS1-1

1.3 How do the shapes and purposes of Chihuly's glass stems compare to the shapes and purposes of plant stems?

STRUCTURE & FUNCTION

(2 points) Glass stems: enclose the electrified gases, create vertical sculpture, allow the colored light to pass through them… Plants stems: transport water/nutrients by capillary action, support the plant's upper parts, help leaves reach sunlight…

NGSS Disciplinary Core Ideas LS1.A, ETS1.A

Supports NGSS performance expectations MS-ETS1-2 & Arts EALR 1.3

Section 2 NORTHWEST ROOM

Northwest Room, 2012, Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

Chihuly has been influenced by the baskets of the Northwest Coast Native Americans. His glass Baskets as are asymmetrical just as are the woven one are; he is also experimenting with thinness and collapsibility with these forms.

The artist has also been influenced by trade blankets made by Pendleton and other manufactures. Both the blankets' color combinations and patterns can be found on the artwork in this and other rooms at the exhibition.

2.1 Native American baskets (made from plants and dyes) and the Chihuly glass baskets (made from silica and additives) are displayed side-by-side on the shelves. Carefully observe these two art forms and identify 3 similarities and 3 differences.

PATTERNS

(3 points) *Similarities: (3 for ½ point each), shapes, colors, sizes, structures, stripes, lines, hollow, open, containers, fragile…* *Differences: (3 for ½ point each), ridges vs. smooth, gaps vs. solid structure, rigid vs. bendable, reflective vs. dull, translucent vs. opaque, ages, weights,the woven baskets have handles and ties…*

NGSS Disciplinary Core Ideas PS1.A
Supports NGSS performance expectations MS-PS1-3, MS-ETS1-3

2.2 As the woven baskets and wool blankets are used over time their appearance is altered by physical and chemical changes. How do Chihuly's glass designs reference and mimic these changes to appear old?

ENERGY & MATTER

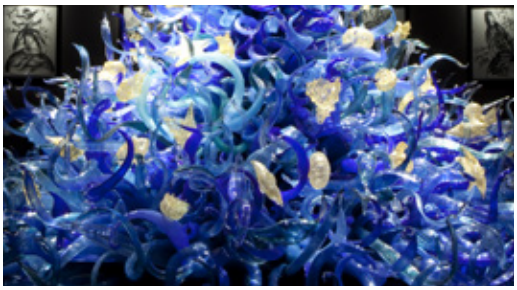
(2 points) Answers may include: distressed, worn, sagging, bent, stretched, tinted, wrinkled, asymmetric, colors look faded, colors added to look like stains…
NGSS Disciplinary Core Ideas PS1.B
Supports NGSS performance expectations MS-PS1-2

2.3 What was the original purpose of the blankets and baskets? What might the purpose of the patterns on them be?

STRUCTURE & FUNCTION

(3 points) baskets: storage and transport for daily or seasonal moves, taking goods to market...
blankets: warmth, clothing, bedding, saddle, carpet, trade, bartering…
patterns: decoration, beauty, mark of tribal affiliation and ownership, indication of status, hide imperfections...
NGSS Disciplinary Core Ideas PS1.A, ESS3.A, ETS1.A
Supports NGSS performance expectations MS-PS1-3, MS-ETS1-1

Section 3 SEALIFE ROOM



The Sealife Tower rises from its base like an underwater kelp tree. But more than representation, the Tower captures the sensual, gestural quality of life from the sea. The blue and green arms of the Tower, especially, give the effect of an animated, underwater world.

Sealife Tower, 2011, 16' x 12' x 12', Chihuly Garden and Glass, Seattle| Photo by: Terry Rishel

3.1 Carefully study the details of the 15-foot Sealife Tower. Describe the resources and biodiversity that are represented in this marine system.

PATTERNS

(3 points) Answers may include: shells, nautiluses, sea stars (starfish), sea urchins, sea anemones, rays or skates, octopus, waves, seaweed, bubbles, kelp…

NGSS Disciplinary Core Ideas ESS2.A, ESS3.A, LS2.A, LS2.

Supports NGSS performance expectations MS-LS2-3

3.2 Which parts of the Sealife Tower are more figurative (realistic) and which are more abstract (less realistic)?

PATTERNS

(3 points) Figurative: the animals, the scale, the animal's shapes… Abstract: the colors, waves, water, quantities…

NGSS Disciplinary Core Ideas PS1.A

Supports Arts EARL 1.1, 1.3

3.3 Identify three or more steps involved in making the Sealife Tower.

STRUCTURE & FUNCTION

(3 points) planning, designing, selecting, glassblowing individual pieces in the hot shop, transporting, building, assembling the tower…

NGSS Disciplinary Core Ideas ETS1.A

Supports NGSS performance expectations MS-ETS1-1

3.4 Each glass component weighs 3-4 pounds. How do you think the pieces and the entire installation are structurally supported?

STRUCTURE & FUNCTION

(1 point) Answers may include: internal supports, glass fused together, glue…

NGSS Disciplinary Core Ideas ETS1.A, ETS1.B

Supports NGSS performance expectations MS-ETS1-1, MS-ETS1-2

Section 4 PERSIAN CEILING

There is something about putting the pieces overhead, on top of plate glass, that makes you think of the sea—it's a sort of reverse of having the glass underwater. There's a feeling of water—at least there is to me. I suppose somebody else could think it's something they might have seen in the sky or in a dream. **- Chihuly**

Persian Ceiling, 1999, 35′ x 14½′, Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

4.1 Locate one of the many areas in the gallery where the colors of the glass are seen on the walls. Carefully compare the colors of the glass above and the color on the wall. What is happening to the light? Record your observations:

ENERGY & MATTER

(3 points) Answers may include: reflection, refraction, shadows, color absorption, color transmission, light, shapes and colors are projected on the walls and floor, light is dimmed and scattered as it passes through the glass

NGSS Disciplinary Core Ideas PS4.B

Supports NGSS performance expectations MS-PS4-2

4.2 Approximately 1,000 glass pieces decorate the ceiling. Hypothesize about how engineers solved the challenges of displaying so much glass overhead. Record three challenges and the possible solutions here:

STRUCTURE & FUNCTION

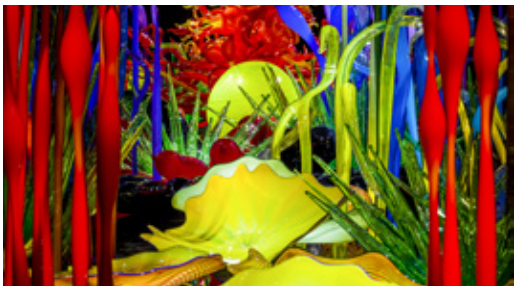
(2 points) *Challenges: holding the weight, lighting, stacking fragile glass, transporting, installing….* *Solutions: metal support beams, safety glass ceiling, padding, spot lights, assembled from above in layers…*

NGSS Disciplinary Core Ideas ETS1.A, ETS1.B

Supports NGSS performance expectations MS-ETS1-1, MSETS1-2

Appearance	Element	Symbol	Sources
deep dark blue	cobalt	Co	cobalt II carbonate
emerald green	chromium	Cr	chromium II oxide
wide range or blues and greens, ruby red	copper	Cu	copper II carbonate
oranges, deep red	cadmium	Cd	cadmium sulfide, cadmium selenium
greens and browns	iron	Fe	iron oxides
yellows, blues	silver	Ag	silver nitrate
ruby red	gold	Au	gold chloride
purple, blue-violet, browns	manganese	Mn	manganese oxides

Section 5 MILLE FIORI



With the *Mille Fiori* (Italian for "a thousand flowers") Chihuly combines new elements with forms and techniques that have appeared throughout his career. Extending the idea of placing glass within a botanical setting, here the glass in effect becomes the garden.

Mille Fiori (detail), 2012, 10' x 56' x 12', Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

5.1 Locate examples of transparent, translucent, and opaque glass, and describe or sketch the shape of the glass displaying each degree of light transmission. Transparent (see-through) Translucent (some light goes through) Opaque (no light goes through)

ENERGY & MATTER

(3 points) answers vary, some shapes have multiple transmission types

NGSS Disciplinary Core Ideas PS4.B

Supports NGSS performance expectations MS-PS4-21

5.2 Using the TABLE OF TRANSITION METAL COLORS, label the garden objects you noted in 5.1 and the shapes you found in 5.2 with the chemical symbols of elements that may be causing the colors that you observed. (Example: dark blue water bird = Co)

ENERGY & MATTER

(3 points) answers vary, can be labeled here or above and should use correct atomic symbols to match the colors

NGSS Disciplinary Core Ideas PS1.A

Supports NGSS performance expectations: MS-PS1-3 & Arts EALR 2.3

5.3 How do you think the parts of this installation are being held and secured?

STRUCTURE & FUNCTION

(2 points) internal metal posts, glue, they extend into the plastic base …

NGSS Disciplinary Core Ideas ETS1.B

Supports NGSS performance expectations MS-ETS1-2

Section 6 FLOAT BOAT & IKEBANA, DRAWING WALL

Float and Ikebana Boats, 2012, Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

This gallery features two wooden boat installations. One contains spheres inspired by the handblown Japanese fishing floats Chihuly would find washed up on Washington shores when he was a child. The other boat is filled with a variety of glass forms, some of which Chihuly calls Ikebana, referring to the traditional Japanese art of flower arranging. A group of Chihuly's Burned Drawings is also on view.

6.1 These two Boats filled with glass have origins in a spontaneous moment when Chihuly was working in Finland, near a river. For the fun of it he tossed large, hollow, glass forms into the water to watch them float downstream. He asked local teenagers to gather up the glass in rowboats, and it was probably then that Chihuly saw the opportunity for a new installation.

PATTERNS

ENERGY & MATTER

Consider the design and scale of both installations. List several ways that the displays realistically recreate Chihuly's inspirations described above. Also record several abstract aspects that add imagination to the properties and behaviors found in the natural world.

(4 points)

Realistic/ Figurative (at least 3 examples)
float shape, the boats, the float material, "water" reflections, some Ikebana shapes, boats sinking into the water…

Abstract/ Nonrealistic (at least 3 examples)
larger quantities, bigger scale, no movement, extreme colors, floats on top of the water, nonrealistic plant and water materials…

NGSS Disciplinary Core Ideas PS1.A, PS2.A
Supports Arts EALRs 1.1, 1.3, 3.1

6.2 Closely examine the wall-mounted Drawings where Chihuly has combined metallic paint on watercolor paper with the use of a blowtorch.. Chihuly has invented his own style of mixed-media art by using a blowtorch on metallic paint and watercolor paper. How do you think the pigments were applied to the paper? Describe any evidence of physical and chemical changes that occurred in the creation of these paintings.

ENERGY & MATTER

(3 points) Applied by brush, dropping, splattering, spraying… Physical changes: paper torn, cut, soaked; paint mixed, spread, dried…Chemical changes: singed or burnt…
NGSS Disciplinary Core Ideas PS1.B, ETS1.B
Supports NGSS performance expectations MS-PS1-2

6.3 Chihuly often uses his drawings to communicate his ideas to his glassblowing team. Describe at least three ways that these drawings differ from the pictures that engineers and architects use to communicate their plans.

STRUCTURE & FUNCTION

(3 points) Answers may include: not to scale, abstract, freehand, not linear, no labels, more colorful, not digital...
NGSS Disciplinary Core Ideas ETS1.B
Supports NGSS performance expectations MS-ETS1-3 & Arts EALR 3.1

Section 7 CHANDELIERS

Chandelier Room, 2012, Chihuly Garden and Glass, Seattle| Photo by: Terry Rishel

This gallery presents several *Chandeliers* and a Tower. Chihuly has said: "What makes the *Chandeliers* work for me is the massing of color. If you take hundreds of blown pieces of one color, put them together, and then shoot light through them, now that's going to be something to look at! When you hang it in space, it becomes mysterious, defying gravity, becoming something you have never seen before."

7.1 Choose one chandelier and estimate its total glass weight by filling in this chart *(3 points)*

ENERGY & MATTER

Brief description of your selected chandelier: *color and/or other distinguishing characteristics*

Approximate number of pieces: *(count a fourth or eighth and then multiply) check for correct math*

Estimated weight (assuming the weight of each piece is 3 pounds): *check for correct math (these ultimately weigh 900-1100 pounds including the metal components)*

NGSS Disciplinary Core Ideas PS1.A, ETS1.A

Supports NGSS performance expectations MS-ETS1-1

7.2 On the central, colorless chandelier and tower, examine the base of the transparent spiral pieces. What might be holding these parts together?

STRUCTURE & FUNCTION

(2 points) they are attached to a white central column by internal white supports, also stainless steel wires

NGSS Disciplinary Core Ideas ETS1.B

Supports NGSS performance expectations MS-ETS1-2

7.3 Examine the acrylic base below one of the chandeliers. What additional perspectives do you gain when you look down into this surface and why? What happens when you step five feet away?

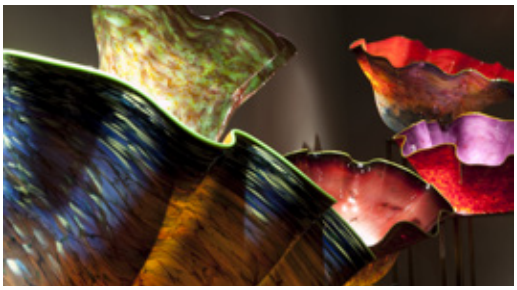
PATTERNS

(2 points) You see the reflection upside down. You see the bottom looking up. As you step away this view disappears.

NGSS Disciplinary Core Ideas PS4.B, ETS1.A

Supports NGSS performance expectations MS-PS4-2, MS-ETS1-1

Section 8 MACCHIA FOREST



Chihuly began the Macchia series with the desire to use all 300 colors available to him in the hot shop. Each work is speckled The Macchia are spotted with colors, which comes from rolling the molten glass in small shards bits of colored glass (frit) during the blowing process. Chihuly separated the interior and exterior colors by adding a white layer in-between — a "cloud". As he mastered the technical complexities, he pushed the scale up to four feet in diameter.

Macchia Forest (detail), 2012, Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

8.1 How are the glass peices attached to the pedestals?

STRUCTURE & FUNCTION

(3 points) Answers may include all of the metals listed.

NGSS Disciplinary Core Ideas PS1.A, ETS1.A

Supports NGSS performance expectations MS-ETS1-1

8.2 How do you think the characteristic "ruffle" [waves, or undulations] at the edge of each Macchia is achieved?

(2 points) Answers may include: spinning, gravity, bent with tools, drooping from weight…

ENERGY & MATTER

NGSS Disciplinary Core Ideas PS2.A, ETS1.B

Supports NGSS performance expectations MS-ETS1-2

8.3 Select one Macchia and indicate areas that are opaque, translucent, and transparent by adding labels to the diagram below. Is this pattern repeated in any others? _____

PATTERNS

(4 points) Transparent base, translucent middle, opaque lip. Yes, this pattern is repeated in other Macchia.

NGSS Disciplinary Core Ideas PS4.B

Supports NGSS performance expectations MS-PS4-2

Section 9 GLASSHOUSE

The centerpiece of *Chihuly Garden and Glass* is the *Glasshouse*. A 40-foot tall, glass and steel structure covering 4,500 square feet of light-filled space, the *Glasshouse* is the result of Chihuly's lifelong appreciation for conservatories. The design of the *Glasshouse* draws inspiration from two of his favorite buildings: Sainte-Chapelle in Paris and the Crystal Palace in London. The installation in the *Glasshouse* is an expansive 100-foot long sculpture in a color palette of reds, oranges, yellows and amber. Made of many individual elements, it is one of Chihuly's largest suspended sculptures. The perception of the artwork varies greatly with natural light and as the day fades into night.

Glasshouse Sculpture, 2012, 27' x 100' x 23', Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

10.1 Observation uses all your senses, not just vision. Close your eyes and silently observe the glasshouse environment for a moment. Then record what you sense below. (If there are any hands-on displays available here, record your observations for them in this space as well.)

PATTERNS

(3 points) Answers may include temperature, sounds, smells, air currents…

NGSS Disciplinary Core Ideas PS1.A

Supports Arts EALR 2.3

10.2 Suggest two or more ways that building a house of glass could yield energy savings.

ENERGY & MATTER

(2 points) Answers include natural light, windows open for cooling, heating by solar radiation, insulating…

NGSS Disciplinary Core Ideas PS3.B, PS4.B, ESS3.C, ETS1.B

Supports NGSS performance expectations MS-PS3-3, MS-PS4-2, MS-ETS1-2, MS-ESS3-3

10.3 Chihuly designed this avant-garde artwork to push the boundaries of art glass. List two design constraints which have been overcome by the design, creation, and location of this piece.

STRUCTURE & FUNCTION

(2 points) size of the room, limit to the weight glass can hold, doorway size, attachment to a single internal support or flat surface, no metal visible, cost, height of ceiling, amount of light available, need for electric lights, limited support beams to attach to, artwork size restrained by the fragility and weight of glass, structures limited by artists working alone, glassblowers having limited metalworking skills...

NGSS Disciplinary Core Ideas ETS1.A, ETS1.B

Supports NGSS performance expectations MS-ETS1-1, MSETS1-2

10.4 Describe the role metal plays in this sculpture and its glasshouse.

STRUCTURE & FUNCTION

(2 points) frame and structural support for glass in both; holds the art in secure, rigid, 3-d curving positions…

NGSS Disciplinary Core Ideas PS1.A, ETS1.A

Supports NGSS performance expectations MS-ETS1-1

Section 10 GARDEN

Chihuly has said, "I want my work to appear as though it came from nature so if someone found it… they might think it belonged there." Elements of his work have plant-like influences to them, so in the garden the glass and the plants compliment each other. The striking centerpiece outdoors is the Pacific Sun, radiating yellow and orange.

Chihuly Garden and Glass, Seattle | Photo by: Terry Rishel

If inclement weather prevents your group from visiting the main garden, go directly to Section 11B.

11A.1 Does the glass blend in or stand out from its environment? Give brief descriptions of two examples below.

PATTERNS

(2 points) most of the glass stands our through color, height, and size

NGSS Disciplinary Core Ideas PS1.A *Supports Arts EALR 2.3*

11A.3 What properties make glass appropriate for outdoor display while many other media are not?

STRUCTURE & FUNCTION

(2 points) resistant to water, will not fade in sunlight, durable, hard, will not decompose, nonporous, easy to clean, unharmed by temperature and humidity changes…

NGSS Disciplinary Core Ideas PS1.A, PS1.B *Supports NGSS performance expectations MS-ETS1-2*

11A.4 Do you see any evidence of physical and chemical changes in the glass possibly caused by its exposure to the elements? Explain

ENERGY & MATTER

(2 points)Looks pristine, very little evidence of change unless temporarily wet or dirty.

NGSS Disciplinary Core Ideas PS1.A, PS1.B *Supports NGSS performance expectations MS-PS1-2*

Section 11 THEATER

Enjoy watching 5 different video clips that highlight a few of Dale Chihuly's inspirations, installations, and processes. Each video is approximately 4 minutes each.

1. Chihuly Over Venice - Nuutajärvi, Finland
2. Chihuly Over Venice – Venice, Italy
3. Making a Chandelier
4. Chihuly in the Light of Jerusalem
5. Garden and Glass

POST-VISIT RESOURCES

GLASS REFLECTIONS

EXTENSIONS

- PHYSICAL SCIENCE EXTENSION
- LIFE SCIENCE EXTENSION
- EARTH & SPACE SCIENCE EXTENSION
- ENGINEERING EXTENSION
- VISUAL ARTS EXTENSION

BIBLIOGRAPHY & RESOURCES FOR FURTHER STUDY

GLASS REFLECTIONS

Summary:

Open-ended concluding questions prompt students to consider their field learning experiences at *Chihuly Garden and Glass* and connect glass to their own interests.

Objectives:

Students will generate questions and ideas about the glass artworks they have seen. Students will identify connections between glass and their lives and interests.

Recommended Sequence:

Following the visit, either the same day or the next day.

Materials & Set-up:

1 copy of Glass Reflections per student, may be given directly after the visit

Timing & Setting:

20 minutes following the visit: at Seattle Center, as homework, or in class

Instructions for use:

- Explain that these are open-ended questions with no specific right answers.
- Students should independently write a personally relevant response for each prompt.

Evaluation Tools:

This exercise may be evaluated by completion, and students can be invited to share and discuss their responses.

Extensions:

Using the Resources for Further Study, have students research glass topics of interest revealed in these reflections.

Standards:

NGSS Disciplinary Core Ideas ETS1.A, ETS1B

Supports NGSS performance expectations MS-ETS1-1 & Arts EALR 2.3

NAME: **DATE:**

GLASS REFLECTIONS

1. If I could ask Dale Chihuly anything about his art, what question(s) would I pose?

2. What were most interesting parts of the visit to me?

3. What were most puzzling parts of the visit to me?

4. Glass-related topics I'd like to find out more about:

5. If it weren't for glass…

6. Ideas I have about glass:

7. Glass is especially useful in my life because…

8. What tools or instruments would I like to use to study Chihuly's artwork?

9. Many of Chihuly's artworks are biomimetic because the designs mimic living things. If I were designing a new series of biomimetic glass artworks, the part of nature that I would choose for an inspiration is…

EXTENSIONS

Summary:

Short-answer questions, report topics, and projects relate glass to additional concepts within the specified disciplines. Most extensions overlap a combination of science, engineering, and art content

Objectives:

- Connect the *Chihuly Garden and Glass* experience to topics in science, engineering, and visual arts.
- Apply knowledge and understanding of glass to answer questions and design solutions.
- Research and report on additional glass-related topics.

Standards:

Physical Science Extensions:
NGSS Disciplinary Core Ideas PS1.A, PS3.A, PS3.B, PS4.B, ETS1.A, ETS1.B, ETS1.C
Supports NGSS performance expectations MS-PS1-3, MS-PS3-3, MS-ETS1-1 & Arts EALRs 4.2

Life Science Extensions:
NGSS Disciplinary Core Ideas LS1.A, LS1.B, LS2.A, LS2.B, LS2.C, LS4.C, LS4.D, ETS1.A, ETS1.B, ETS1.C
Supports NGSS performance expectations MS-LS1-4, MS-LS4-4, MS-ETS1-1 & Arts EALRs 1.1, 2.1, 3.2, 4.2

Earth and Space Science Extensions:
NGSS Disciplinary Core Ideas PS1.A, PS3.B, ESS1.B, ESS2.A, ESS3.A, ESS3.B, ESS3.C, ETS1.A, ETS1.B, ETS1.C
Supports NGSS performance expectations MS-PS1-3, MS-ESS1-3, MS-ESS2-1, MS-ETS1-1
Supports Arts EALRs 1.1, 2.1, 3.2, 4.2

Engineering Extensions:
NGSS Disciplinary Core Ideas PS1.A, ETS1.A, ETS1.B, ETS1.C
Supports NGSS performance expectations MS-ETS1-1, MS-ETS1-2 & Arts EALRs 1.1, 4.2

Visual Arts Extensions:
Supports Arts EALRs 1.1, 1.3, 2.1, 4.2, 4.4, 4.5

Recommended Sequence:

Extensions can be used at any time after the *Chihuly Garden and Glass* visit.

Materials & Set-up:

Select and distribute the Extension parts you wish to assign.

Timing & Setting:

These can be homework or in class. Times depend on the number and format assigned.

Instructions for use:

- Questions, reports, and projects can be extracted or combined from these sheets as needed.
- Questions can be used for discussion or short-answer in any number and combination.
- Reports can be assigned as oral or written in any format and length and scored as desired.
- Projects can be done as teams or individually and altered and scored as desired.

EXTENSIONS ANSWER KEY:

Physical Science Extension Questions

1. *Answers may include the design and purpose of any light powered by electricity including current generated by motors, batteries, hand cranks, solar cells, etc.*
2. *Glass can be transparent or translucent, doesn't conduct electricity, is a good insulator so it doesn't heat up quickly, it's durable, can be made thin and lightweight, waterproof, inexpensive, readily available, won't rot or rust, a high melting point, won't burn…*
3. *Glass is waterproof and resists corrosion, impermeable to trap air for buoyancy, hard and durable, inexpensive, won't rot, nontoxic to the environment…*

Life Science Extension Questions

1. *Answers will vary. Providing electric power will likely be cited as the biggest challenge.*
2. *A garden is designed by people for human goals (fruits, vegetables, flowers, decoration, beauty). Gardens depend on human intervention of land, plants, and animals. Gardeners both assist and impede growth and populations of plants and animals. Wilderness is not human designed and doesn't depend on human plans or efforts. Wilderness areas often undergo succession changing their biodiversity over time.*
3. *Answers may include camouflage, identification to species members, warnings, predator /prey, courtship display, attracting pollinators and seed spreaders…*
4. *Answers may include endoskeletons, exoskeletons, muscles, wings, relying on some external supporting medium such as water (jelly fish) or another plant or geologic feature (vines, moss, lichen)…*
5. *Possible answers include: snowshoe hare/snowshoes, dandelion seeds/parachutes, webbed feet/diving flippers, bird wing/airplane wing, plant burrs/ Velcro, kelp bubble/ flotation device…*

Earth and Space Science Extension Questions

1. *Depending on their definition of nature resources students may argue either way. Silica is a natural resource and obsidian was once used in its natural form, but most glass is a manufactured material made from natural ingredients.*
2. *Glass is melted down and reused through recycling; other discarded glass becomes sea glass or mixes with soils.*
3. *Answers will vary, for LEED features see www.usgbc.org/projects/chihuly-garden-and-glass-exhibition*

Engineering Extension Questions

1. *Answers will vary.*
2. *Unlike the glass portion, metal is opaque and can bend farther without breaking. The metal strips and bars can hold more weight without adding too much weight themselves. While the glass must be completed prior to installation, metal pieces can be connected and adjusted with fasteners and welding during building construction. Metal provides a framework to secure the glass and hold its weight. If the Glasshouse's safety glass windows break, the metal will hold them in place. Metal gives additional strength to the structure for forces from wind and earthquakes. Metal serves a similar purpose in bridges (trusses), concrete (rebar) and sky scrapers (steel frames)…*

TEACHER'S GUIDE

Visual Arts Extension Questions

1. *artistic expression, decoration, patterns connect them to the Native art, mimic other material's properties, add color…*
2. *Glass artworks can be large and heavy and is often stacked vertically or hung. Designing a structure that highlights and protects the art without distracting from its beauty becomes part of the artistic endeavor.*
3. *Answers will vary.*

More Extensions:

See the extensions in the pre-visit Teacher's Guides and Resources for Further Study.

NAME: **DATE:**

PHYSICAL SCIENCE EXTENSIONS

Questions:

1. In the *Glass Forest #5* electrical energy is absorbed and then emitted as visible light. Think of another device that changes invisible energy into visible light energy and explain its design and purpose.

2. What properties of glass make it suitable for light bulbs compared to other materials like plastic, wood, or metal?

3. Floats are used to mark locations and hold up nets in bodies of water. What properties of glass make it useful as a float-making material?

Report Topic:

Years before he discovered the periodic table of chemical elements, Dmitri Mendeleev was inspired by the time he spent in his family's glass factory. He was fascinated by the properties of the elements used to color glass. Research what elements Mendeleev included in the original periodic table. Were all the elements Chihuly uses to color glass known to Mendeleev?

Project:

One of the problems that glass artists face is keeping the glass at an ideal working temperature. Design a device than could slow the cooling of glass as the artist works with it. Include the size, shape, and composition of your device, and write instructions for its use. Then propose a test that could evaluate the design's effectiveness and safety.

NAME: **DATE:**

LIFE SCIENCE EXTENSIONS

Questions:

1. Compare the *Glass Forest #5* at *Chihuly Garden and Glass* to a real forest by making a list of similarities and differences. What do you think would be the biggest challenges for installing the *Glass Forest #5* in a real forest environment?

2. Reflect on the real and glass gardens at *Chihuly Garden and Glass*, and compare a garden to wilderness. Identify key differences. Why do they look the ways they do and how do they function?

3. In the Garden, you considered whether the glass stood out from its environment. Discuss ways that animals and plants blend in and stand out within their habitats. Why do they want to be found and why do they want to hide?

4. The Exhibition had lots of examples of creative structural support. How do plants and animals solve the problem of support to overcome gravity?

5. Both artists and engineers are inspired by natural shapes and processes producing many examples of biomimetic objects. List a few examples of natural forms each paired with a technology designed to mimic it and serve a similar function.

Report Topic:

Use Plant List & Garden Map available in the Garden section of www.chihulygardenandglass.com to research how a particular plant changes over time. Predict how the changes might affect the artwork.

Project:

Chihuly Garden and Glass includes many glass representations of flora (plants) and fauna (animals). Select an ecosystem and sketch 5 glass art pieces that could be part of an installation referencing that ecosystem. Write a summary of your design addressing these aspects: scale, production method, display structure, colors and chemicals, lighting, texture, and degree of realism. What are some advantages of using glass representations compared real specimens? (Include properties of glass in your response.) How could you test the design before construction? After your initial plan is complete, it is announced that funding constraints prevent art glass from being used for this project. Redesign your ecosystem model with a new plan that uses industrial glass and other materials that will create effects similar to art glass.

NAME: **DATE:**

EARTH AND SPACE SCIENCE EXTENSIONS

Questions:

1. Is glass a natural resource? Why or why not?

2. How does glass cycle through our environment?

3. *Chihuly Garden and Glass* has been awarded a Leadership in Energy & Environmental Design (LEED) Silver rating. Did you notice any energy saving design features on your visit?

Report Topic:

The types and uses of glass in NASA Space Shuttles

Project:

The Pacific Sun in the *Chihuly Garden and Glass* outdoor area is one of many Chihuly art pieces inspired by the Sun. Select a planet from our Solar System, and design your own art glass model addressing these aspects: scale, production method, display structure, colors and chemicals, lighting, texture, and surface features.

What are some benefits and challenges of using glass compared to other materials for this model? How could you test the design before construction?

After your initial design, it is announced that funding constraints will prevent art glass from being used for this project. Redesign your planetary model making a new plan that uses industrial glass and other materials to create effects similar to art glass.

NAME: **DATE:**

ENGINEERING EXTENSIONS

Questions:

1. The pedestal display structure in the *Macchia Forest* allows light to flow through each artwork, provides stability, and can place the works at various heights. What other display method could be used for Macchia and what would be its benefits and challenges in comparison to the pedestals?

2. During the visit, you were asked to look at the metal parts of the *Glasshouse* architecture and sculpture. How does the metal differ from glass? What problems are these metal pieces solving? What other structures might use metal in a similar way?

Report Topic:

Research the assembly and support structures of Chihuly's chandeliers. Compare these methods to the ways architects and engineers solve similar issues in their structural designs.

Project:

Select one artwork from *Chihuly Garden and Glass* that was inspired by a functional object (such as woven baskets, lighting chandeliers, fishing floats). Research the object that inspired Chihuly. Which features are functional and which are ornamental? Identify any features that Chihuly changed or added for artistic reasons. If the original object had Chihuly's features added, would it be less effective or even ineffective in fulfilling its purpose? Propose an experiment to test your hypothesis.

NAME: **DATE:**

VISUAL ARTS EXTENSIONS

Questions:

1. In the Northwest Gallery of *Chihuly Garden and Glass*, you reflected on the purpose of the baskets and blankets and their patterns. What do you think is the purpose of the Chihuly glass baskets? What is the purpose of the patterns on them?

2. Based on your observations at *Chihuly Garden and Glass*, why would learning about structural engineering be important to a glass artist?

3. Use the color wheel and definitions below to interpret the color pattern on one of the Chihuly artworks pictured or described in your Student Visit Booklet:

Monochromatic: One hue with tints (hue + white) and shades (hue + black), same wedge of the wheel

Complimentary: Two hues that are directly opposite each other on the color wheel

Analogous: Two to three hues that are directly next to each other on the wheel, not the same wedge

Triadic: Three hues equally spaced on the color wheel, forming an equilateral triangle

Report Topic:

1. Compare the life and work of Dale Chihuly to the life and work of Louis Comfort Tiffany
2. Roman Glass, Venetian Glass, Forest Glass, Art Nouveau Glass, or any other art glass
3. Harvey Littleton and the Studio Glass Movement

Project:

Do virtual glassblowing at the Interactive School By Fire from the Museum of Glass: http://museumofglass.org/virtual-museum/virtual-hot-shop

BIBLIOGRAPHY & RESOURCES FOR FURTHER STUDY

Websites:

Chihuly Garden and Glass	www.chihulygardenandglass.com
Chihuly Official Website	www.chihuly.com
The Children's Museum of Indianapolis	www.childrensmuseum.org
Corning Museum of Glass	www.cmog.org
Museum of Glass	museumofglass.org
Next Generation Science Standards	www.nextgenscience.org
Pilchuck Glass School	www.pilchuck.com
Pilkington Glass	www.pilkington.com/pilkington-information
Toledo Museum of Art	www.toledomuseum.org
Washington State Arts Standards	www.k12.wa.us/arts/standards
Wikipedia	en.wikipedia.org/wiki/Glass

Books:

Chihuly, Dale. *Chihuly Garden and Glass*. Seattle: Portland Press, 2012.

Ellis, William S. *Glass*. New York: Avon Books, 1998.

Macfarlane, Alan and Gerry Martin. *Glass A World History*. Chicago: The University of Chicago Press, 2002.

Warmus, William. *The Essential Dale Chihuly*. New York: Harry N. Abrams, 2000.

Whitehouse, David. *Glass A Short History*. Washington D. C.: Smithsonian Books, 2012.

Newman, Harold. *An Illustrated Dictionary of Glass*. New York: Thames & Hudson, 1987.

CURRICULUM RESOURCES CHART

NATURE OF GLASS COMPONENTS	DESCRIPTION	CENTRAL QUESTION
PRE-VISIT		
History of Glass Timeline	Reading / reference	How has glass art and technology developed?
Chihuly Art Handout	Reading / reference	What is Chihuly's art?
Nature of Glass Glossary	Science & art definitions/ reference	What vocabulary explains glass?
Science Vocabulary Exercise	Worksheet with science terms	How do scientists communicate about glass?
Art Glass Vocabulary Exercise	Worksheet with glass and art terms	How is glass artwork created and described?
Properties of Glass	Reading / reference	What is the nature of glass?
Engineering Design Process Diagram	Diagram/ definitions/ reference	What is the engineering design process?
Glass Videos	Videos/ discussion questions	What is glass and how is it made?
Video Viewing Exercise	Worksheet for Glass Videos	How does glass artwork relate to science?
Glass in Your Environment Lab	Activity/ no extra supplies needed	Where, how, and why is glass used?
Distinguishing Characteristics Lab	Activity/ no extra supplies needed	What are distinguishing characteristics?
Teacher's Guides for all pre-visit resources	Objectives, standards, tips, instructions, evaluation tools	What are the Nature of Glass pre-visit resources, & how can they best be used?
STUDENT BOOKLET		
Section 1 *Glass Forest #5* Section 2 Northwest Room Section 3 Sealife Room Section 4 Persian Ceiling Section 5 Mille Fiori Section 6 Float Boat, Ikebana, & Drawings Section 7 Chandeliers Section 8 Macchia Forest Section 9 Theater Section 10 Glasshouse Section 11A Garden Section 11B Chandelier Walkway	The Student Visit Booklet contains information and instructions for each section of the galleries and garden. It prompts students to carefully observe and hypothesize about the artwork. Students communicate and analyze information and ideas about glass, science, engineering, and art. Each student receives this booklet on the visit.	What is the nature of Chihuly's glass, and how do science and engineering relate to his artwork?
STUDENT BOOKLET		
Teacher's Guide for the Student Visit Booklet	Objectives, standards, tips, instructions, evaluation tools	What will students do when they visit? How can they be prepared and assessed?
Glass Reflections	Concluding reflection questions	What about glass interested or puzzled me?
Life Science Extensions	Questions, report topics, and projects to apply and extend the Nature of Glass field learning experience, grouped for teacher selection	How does glass relate to living things?
Physical Science Extensions		How does glass relate to matter and energy?
Engineering Extensions		How does glass relate to engineering?
Earth/Space Science Extensions		How does glass relate to the planets?
Visual Arts Extensions		How do art concepts apply to Chihuly's glass?
Teacher's Guides for all post-visit resources	Objectives, standards, tips, instructions, evaluation tools	What are the Nature of Glass post-visit resources, and how can they best be used?

SUGGESTED RESOURCE SELECTIONS BY FOCUS AREA

FOCUS AREA	PRE-VISIT RESOURCES	VISIT RESOURCES	POST-VISIT RESOURCES
Physical Science	History of Glass Timeline Chihuly Art Handout Nature of Glass Glossary (Science & Art) Science Vocabulary Exercise Properties of Glass Glass Videos, Video Viewing Exercise Distinguishing Characteristics Lab Glass in Your Environment Lab	Student Visit Booklet	Glass Reflections Physical Science Extensions
Engineering	History of Glass Timeline Chihuly Art Handout Nature of Glass Glossary (Science & Art) Properties of Glass Engineering Design Process Diagram Glass Videos, Video Viewing Exercise Glass in Your Environment Lab	Student Visit Booklet	Glass Reflections Engineering Extensions
Life Science	History of Glass Timeline Chihuly Art Handout Nature of Glass Glossary (Science & Art) Engineering Design Process Diagram Properties of Glass Glass Videos, Video Viewing Exercise Distinguishing Characteristics Lab	Student Visit Booklet	Glass Reflections Life Science Extensions
Earth and Space Science	History of Glass Timeline Chihuly Art Handout Nature of Glass Glossary (Science & Art) Engineering Design Process Diagram Properties of Glass Glass Videos, Video Viewing Exercise Glass in Your Environment Lab	Student Visit Booklet	Glass Reflections Earth and Space Science Extensions
Visual Arts	History of Glass Timeline Chihuly Art Handout Nature of Glass Glossary (Art) Art Glass Vocabulary Exercise Glass Videos, Video Viewing Exercise Distinguishing Characteristics Lab	Student Visit Booklet	Glass Reflections Visual Arts Extensions

Connections To NGSS Crosscutting Concepts/ Science & Engineering Practice

		Crosscutting Concepts							Science & Engineering Practices							
		Patterns	Cause & Effect	Scale, Proportion & Quantity	Systems & System Models	Energy & Matter	Structure & Function	Stability & Change	Asking Questions & Defining Problems	Developing & Using Models	Planning & Carrying Out Investigations	Analyzing & Interpreting Data	Using Math & Computational Thinking	Constructig Explanations & Designing Solutions	Engaging in Argument from Evidence	Obtaining, Evaluating & ommunicating Information
Pre-Visit	History of Glass Timeline		•	•		•	•			•		•				•
	Chihuly Art Handout															•
	Properties of Glass	•	•	•		•	•	•		•					•	•
	Engineering Design Process				•					•					•	•
	Nature of Glass Glossary					•	•									•
	Science Vocabulary Exercise					•	•									•
	Art Glass Vocabulary Exercise						•									•
	Glass Videos		•			•		•	•						•	•
	Video Viewing Exercise		•			•		•	•						•	•
	Glass in Your Environment Lab		•			•	•		•		•	•		•	•	•
	Distinguishing Characteristics Lab	•		•						•	•	•			•	•
Visit Resources	1 *Glass Forest #5*	•	•	•	•	•	•			•	•	•	•	•		•
	2 Northwest Room	•				•	•			•	•	•		•		•
	3 Sealife Room	•			•		•			•	•	•		•		•
	4 Persian Ceiling					•	•		•		•	•		•		•
	5 Mille Fiori	•				•	•			•	•	•		•		•
	6 Float Boats, Ikebana, Drawings	•	•	•		•	•	•		•	•	•		•		•
	7 Chandeliers	•		•		•	•				•	•	•	•	•	•
	8 Macchia Forest	•	•			•				•	•	•		•		•
	10 Glasshouse	•				•	•		•		•	•		•		•
	11A Garden	•				•	•	•			•	•		•	•	•
	11B Chandelier Walkway	•		•						•	•	•	•		•	•
	Glass Reflections						•		•							•
Post-Visit	Physical Science Extensions	•				•	•	•		•	•	•	•	•		•
	Life Science Extensions	•		•	•	•	•	•	•	•		•		•		•
	Earth/Space Science Extensions	•		•	•	•	•	•	•	•	•		•	•	•	•
	Engineering Extensions		•			•	•		•	•	•			•	•	•
	Visual Arts Extensions	•	•				•		•	•		•		•	•	•

Connections to NGSS Disciplinary Core Ideas: Physical Science & Engineering

Disciplinary Core Ideas [Engineering (ETS) & Physical Science (PS)]

		PS1.A Structure & Properties of Matter	PS1.B Chemical Reactions	PS2.A Forces and Motion	PS2.B Types of Interactions	PS3.A Definitions of Energy	PS3.B Conservation of Energy & Energy Transfer	PS3.C Relationship Between Energy & Forces	PS4.B Electromagnetic Radiation	ETS1.A Defining & Delimiting an Engineering Problem	ETS1.B Developing Possible Solutions	ETS1.C Optimizing the Design Solution
Pre-Visit	History of Glass Timeline	•										
	Properties of Glass	•	•			•			•			
	Engineering Design Process									•	•	•
	Nature of Glass Glossary	•	•	•	•	•			•			
	Science Vocabulary Exercise	•	•	•	•	•		•	•			
	Glass Videos	•					•					
	Video Viewing Exercise	•	•	•			•			•	•	
	Glass in Your Environment Lab	•								•	•	•
	Distinguishing Characteristics Lab	•									•	•
Visit Resources	1 *Glass Forest #5*	•				•			•	•		
	2 Northwest Room	•	•							•		
	3 Sealife Room	•								•	•	
	4 Persian Ceiling								•	•	•	
	5 Mille Fiori	•							•		•	
	6 Float Boats, Ikebana, Drawings	•	•	•							•	
	7 Chandeliers	•							•	•	•	
	8 Macchia Forest	•		•					•		•	
	10 Glasshouse	•								•	•	
	11A Garden	•	•						•			
	11B Chandelier Walkway	•										
Post-Visit	Glass Reflections									•	•	
	Physical Science Extensions	•				•	•		•	•	•	•
	Life Science Extensions									•	•	•
	Earth/Space Science Extensions	•					•			•	•	•
	Engineering Extensions	•								•	•	•

Connections to NGSS Disciplinary Core Ideas: Life Science & Earth and Space Science

Disciplinary Core Ideas [Life Science (LS) & Earth/Space Science (ESS)]

		ESS1.B Earth and the Solar System	ESS1.C The History of Planet Earth	ESS2.A Earth's Materials and Systems	ESS3.A Natural Resources	ESS3.B Natural Hazards	ESS3.C Human Impacts on Earth Systems	LS1.A Structure and Function	LS1.B Growth and Development of Organisms	LS2.A Interdependent Relationships in Ecosystems	LS2.B Cycle of Matter Energy Transfer in Ecosystems	LS2.C Ecosystem Dynamics, Functioning, & Resilience	LS4.A Evidence of Common Ancestry & Diversity	LS4.B Natural Selection	LS4.C Adaptation	LS4.D Biodiversity and Humans
Pre-Visit	History of Glass Timeline		•		•											
	Properties of Glass			•	•											
	Engineering Design Process															
	Nature of Glass Glossary															
	Science Vocabulary Exercise															
	Glass Videos															
	Video Viewing Exercise															
	Glass in Your Environment Lab				•		•									
	Distinguishing Characteristics Lab												•			
Visit Resources	1 *Glass Forest #5*							•								
	2 Northwest Room				•											
	3 Sealife Room			•	•					•		•				
	4 Persian Ceiling															
	5 Mille Fiori				•					•				•		
	6 Float Boats, Ikebana, Drawings															
	7 Chandeliers															
	8 Macchia Forest															
	10 Glasshouse						•									
	11A Garden															
	11B Chandelier Walkway															
Post-Visit	Glass Reflections															
	Physical Science Extensions															
	Life Science Extensions							•	•	•	•	•			•	•
	Earth/Space Science Extensions	•		•	•	•	•									
	Engineering Extensions															