Folding Paper: The Infinite Possibilities of Origami Educator Guide

January 31, 2014 – April 27, 2014

Description of Exhibit and What You Will See

This exhibit explores the rich tradition of paper folding worldwide, as well as the modern influence of origami on technology, math, science, and design. The exhibit has four main sections:

1.) History of Origami
2.) Animals and Angels: Representations of Real and Imagined Realms
3.) Angles and Abstractions: Geometric Forms and Conceptual Constructions
4.) Inspirational Origami: Impact on Science, Industry, Fashion and Beyond

Learning Goals

After reviewing the *Folding Paper* educator guide and visiting the exhibit, students should be able to:

- Understand the history of papermaking and the modern papermaking process.
- Recognize the different types of origami.
- Fold a piece of paper into a simple origami.
- Recognize how the art of origami intersects with science, industry, fashion, and math.

Museum Rules

Our goal is to provide a successful learning environment for all students. Clarifying expectations of appropriate behavior helps to create that environment. We ask that you share the following rules with your students:

- Walk in the museum. No running.
- Use indoor voices.
- Please: no food, drink, candy or gum in the galleries.
- Do not touch the artwork.

Folding Paper is curated by Meher McArthur with tour organized by the Japanese American National Museum, Los Angeles, and International Arts & Artists, Washington, DC. The exhibition was generously supported by the E. Rhodes & Leona B. Carpenter Foundation.

JAPANESE AMERICAN NATIONAL MUSEUM

INTERNATIONAL ARTS & ARTISTS

PEORIA RIVERFRONT MUSEUM

Featured Artists' Bios and Example of Work

United States

John Blackman (b.1955, American)
John Blackman's interest in origami originated as a child and has grown into a passion. His other pursuits are gardening, nature, and *Ikebana* (the Japanese art of flower arranging), all of which he merges with origami. Today Blackman mainly folds plant and flower forms, often turning them into Japanese-style arrangements.

Joel Cooper (b.1970, American)
In 2000, Joel Cooper encountered origami tessellation and was attracted immediately to its potential for complexity, savoring the pure mathematical regularity of tessellations. He soon combined the techniques of origami tessellation with his background in sculpture to create a new style of folding complex masks from single pieces of paper.

Brian Chan (b.1980, Chinese American)
Brian Chan studied origami avidly as a child. While pursuing a degree in mechanical engineering at MIT, a visit by Robert Lang in 2004 re-inspired him to take up folding seriously. Now an instructor at MIT and a freelance artist, Chan is considered one of the world's foremost origami folders. His eclectic range of complex origami forms includes insects, humans, and figures inspired by fantasy and the visual arts.

Erik Demaine and Martin Demaine (b. 1981 and 1942, Canadian-American)
Canadian-born Erik Demaine completed his Bachelor of Science degree by age 14 and his Ph.D. by age 20. His dissertation, a seminal work in the field of computational origami, received national awards and won him a MacArthur Fellowship. Since joining the MIT faculty in 2001, he has been the leading theoretician in computational origami, the study of what can be done with a folded sheet of paper, and he is exploring origami applications in architecture, robotics, and molecular biology. Artistically, he collaborates with his artist father, Martin Demaine, to create "curved-crease" sculptures and other unconventional origami works.

Christine Edison (b.1975, American)
Christine Edison is a teacher and paper folder based in Chicago, specializing in tessellations. Her work varies from intricately detailed tessellations to bold sculptural pieces.

Eric Gjerde (b.1978, Norwegian-American)
Eric Gjerde focuses on the geometric art of origami tessellations. He teaches, exhibits his works, and has written *Origami Tessellations: Awe-Inspiring Geometric Designs* to introduce readers to the incredible beauty and diversity of origami tessellations.

David Huffman (b.1925, American)
David Huffman was a pioneer in developing the mathematics of origami, including 3D polyhedral and curved forms. In contrast to traditional origami, which was primarily representational and used only straight folds, Huffman developed abstract and geometric structures based on curved folds.

Tom Hull (b.1969, American)
Tom Hull is the preeminent authority on the mathematics of paper folding. Hull's own research has developed some of the mathematical foundations of origami, and his historical analysis has uncovered previously neglected mathematical origami contributions by other scholars. His book, *Project Origami*, explains how origami can be used to teach math, and his origami works, which are mostly modular forms, display the intersection of mathematics and art.

Roy Iwaki (b.1935, Japanese-American)
Roy Iwaki was born in Los Angeles and was six years old when war broke out with Japan and he was sent with his mother and older siblings to the Manzanar Relocation Camp. After the war he enlisted in the Air Force and then went on to study architecture. Before starting his career, he visited Japan, and developed an admiration for Japanese art, including woodblock printing and origami. After two years as an architect, he relinquished that career to pursue his passion for working with his hands. Iwaki first created his origami masks in the late 1960s and was making these and other works of art until his death in 2010.

Goran Konjevod (b.1973, Croatian-American)
Goran Konjevod is a mathematician and theoretical computer scientist who originally practiced origami as a hobby. His pieces are mostly abstract shapes formed by tension in the paper when multiple layers are arranged according to their regular or irregular patterns. Their final forms are, in a sense, organically discovered rather than invented or designed. He also creates three-dimensional forms using multiple layers of thicker paper.

Daniel Kwan (b.1986, Chinese-American)
Daniel Kwan started folding origami at age five in Chinese school and avidly studied origami books by Tomoko Fuse and others. He has developed a specialty of using edge-based modules to weave together various polyhedra compounds (of which the two models in this exhibition are examples). As of 2008, he has expanded his focus in the origami world to include tessellations.

Michael G. LaFosse (b. 1957, American)
Michael G. LaFosse is internationally regarded as one of the world's top origami masters. LaFosse, a master paper-maker, and his partner, Richard Alexander, also create handmade origami paper, known worldwide under the name "Origamido® Paper," which they use for their own work and is also sought after by many other origami artists. A biologist by training, LaFosse skillfully uses the wet-folding technique and his own specially made papers to create dynamic representations of the natural world.

Robert J. Lang (b. 1961, American)
After 30 years of studying origami as his passion, Dr. Robert J. Lang gave up his day job as a laser physicist to focus on both the art and science of origami. He is now one of the most respected origami artists in the world and uses his background in science and mathematics to design complex and lifelike forms from uncut squares of paper. Although Lang uses mathematics (and even, on occasion, computer programs) in his work, he has developed many design techniques that require no more than a pencil and paper.

Linda Tomoko Mihara (b.1959, Japanese-American)
Linda Tomoko Mihara is best known for her work with folded cranes, in particular her three-dimensional origami sculptures. She is an expert in the *rokoan* technique, in which multiple cranes are folded from a single sheet of paper. This style was based on a series of two-dimensional works illustrated in the 18th century book *Hiden Senbazuru Orikata (Secret Folding Methods for One Thousand Cranes)*.

Jeannine Mosely (b.1953, American)
Jeannine Mosely is a graduate of MIT with a Ph.D. in electrical engineering and computer science, and has pursued a career in three-dimensional modeling. Best known for her Menger sponge, a cube measuring 1.5 meters (5 feet) on one side and made from 66,048 folded business cards, Mosely believes that folding origami structures is a way of giving life to a mathematical theorem or formula. Her recent origami work focuses on folding curved lines, both in modular forms and tessellations.

Jared Needle (b. 1987, American)
One of the younger artists featured in the exhibition, Jared Needle has been folding paper since he was a child and has recently begun exhibiting his own designs at national conventions and exhibitions. Many of his works are inspired by the world of fantasy and the supernatural, in particular the characters featured in anime and video games.

Bernie Peyton (b. 1950, American)
Bernie Peyton has a background in wildlife biology and spent many years conducting field research and conservation on endangered species, including spectacled bears in the Andes. Many of his origami pieces are sculptural in composition, relate to his work with wildlife, and feature elements made from folded paper mounted on structures to enhance their realism.

Florence Temko (b. 1921, American)
Florence Temko was born in the United Kingdom and was a pioneer in spreading origami throughout both the UK and the United States, where she later lived. A prolific author on the subject of origami, she was a strong influence on origami beginners, many of whom went on to become renowned artists. Several of her designs, such as a family of penguins, are among the most popular with young folders.

Arnold Tubis (b.1932, American)
Arnold Tubis taught physics at Purdue University for 40 years. Origami has been an avocation of his since the early 1960s and he has co-authored four books on the subject. Tubis has also published seven articles on the use of origami in mathematics education, and served as a consultant to the *InCreasing Math* (origami math) project of the *Dramatic Results Organization* that operates in the public schools of Long Beach and Compton, CA.

Monica Leigh Rodriguez (American)
Monica Leigh Rodriguez is a Los Angeles-based contemporary fashion designer. Her red silk satin organza evening gown was inspired by an origami crane and box.

United States/Isreal

Paul Jackson (b.1956, British)
After attending art school in London, Paul Jackson taught folding techniques, wrote books about paper art, and in the 1990s started exhibiting his origami. In 2000 he met Israeli artist Miri Golan and relocated to Israel, where he now teaches at art and design colleges. In contrast to the complex, detailed origami of many artists, Jackson's paper sculptures aspire to be simple, with forms that appear to have been "discovered" in the paper, rather than contrived from it.

United Kingdom

Kaori Kuribayashi and Zhong You
Kaori Kuribayashi and Zhong You both work at the University of Oxford in the UK. They have used origami for technological innovations. For example, they have created stent grafts made out of a titanium-nickel foil that uses origami folding. They have also used origami techniques and geometrical analysis to successfully develop a few concepts allowing thin-walled cylinders to be shortened to a small package by introducing folding patters on their surfaces.

Richard Sweeney (b.1984, British)
Combining hand-craft with computer-aided design and CNC (computer numerical control) manufacturing techniques, Richard Sweeney seeks to maintain an experimental, hands-on approach, utilizing the properties of often mundane materials, such as paper, to discover unique sculptural forms.

Polly Verity (b.1971, British)
Polly Verity sculpts in a wide range of media and performs as a member of an experimental electronic band called "I," playing purpose-built and modified instruments. Her paper sculptures explore patterns and shadows and are complex and varied, from organic crumple forms to elaborate tessellations, often including curved folds.

France

Vincent Floderer (b. 1961, French)
Vincent Floderer has moved away from conventional origami and has developed a whole new vocabulary of techniques, most famously crumpling. He also uses the techniques of dampening and stretching to create organic forms such as mushrooms and toadstools and multi-layered forms such as corals and sponges.

Eric Joisel (1956–2010, French)
Eric Joisel was widely regarded as one of the most talented origami artists in the world. Largely self-taught in origami principles, he combined design techniques like box-pleating, folding techniques such as wet-folding, and tools he seamlessly adapted from his sculptural background to create figures and animals that appear sculpted or molded rather than folded. He excelled at animals, whimsical fantasy figures such as dwarves and wizards, and masks, sometimes depicting the faces of fellow origami enthusiasts. Before he died, he was working on a group of meticulously costumed characters from the Com-media dell'Arte.

Nicolas Terry (b. 1974, French)
A psychotherapist with a background in engineering and molecular chemistry, Nicolas Terry discovered origami as a child and in 2002 started creating his own designs, beginning with a snail. Since then, he has designed numerous forms, mostly of animals, given presentations and exhibited internationally.

Germany

Heinz Strobl (b. 1946, German)
Heinz Strobl is known for his development of two types of modular origami using strips of paper. In *Knotology*, the strips are knotted into flat pentagons layered on one another, and woven and plaited to make models that, like his *Snapology* figures, are stable without the use of glue or tape. In *Snapology*, which he developed later, strips are folded into polygonal prisms (the units or modules) that are joined using a second set of strips that snap them together, creating geometric forms.

Switzerland

Sipho Mabona (b.1980, Swiss/South African)
Sipho Mabona has covered a great range of different origami styles, from very intricate, representational designs to abstract geometrical shapes. Recently, he created a number of thought provoking origami installations, bearing powerful social messages about environmental destruction and the dangers of consumerism. He also designed origami for the award-winning Asics corporate movie "Origami in the Pursuit of Perfection," which is featured in this exhibition.

Uruguay

Roman Diaz (b.1968, Uruguayan)
Roman Diaz was born in Montevideo, Uruguay, and lived in Argentina, Honduras, and Mozambique as a child. During his travels Diaz occasionally experimented with origami. He returned to Uruguay, completed his studies, and became a veterinarian. Fascinated by the possibilities of origami, he started designing his own models.

Japan

Satoshi Kamiya (b.1981, Japanese)
Satoshi Kamiya started folding paper at age two and began designing more sophisticated models at age 14. At age 17, he was invited onto a Japanese game show, Origami TV Champion, where he won the competition against artists twice his age, and proceeded to do so for the next three years straight. He has made hundreds of origami models, drawing inspiration from nature, Eastern and Western mythology, manga, and even video game characters.

Hideo Komatsu (b.1977, Japanese)
Hideo Komatsu is a member of the Japanese group *Tanteidan* (Origami Detectives) and has been very actively involved in their publication *Oru (Fold)*. In 1998, he was invited to be a guest folder at the Origami USA Convention, which took him overseas for the first time. His works, mostly elegantly stylized animal forms, have been featured in several international exhibitions.

Koshiro Hatori (b.1961, Japanese)
Koshiro Hatori is a professional translator and origami artist who has made significant contributions to the academic study of origami. His research has led to breakthroughs in the mathematics of origami as well as the history of this art form both in Japan and the West. His designs range from traditional origami to abstractions, crumpled forms to pleated sculptures.

Makoto Yamaguchi (b. 1944, Japanese)
In 1989, Makoto Yamaguchi opened Gallery Origami House in Tokyo, a venue that showcases the works of origami folders. Yamaguchi encourages young creators to improve their models and exchange ideas and techniques with origami enthusiasts overseas. He travels extensively teaching the art of origami, and his passion has led to involvement with origami associations around the world.

Miyuki Kawamura (b.1970, Japanese)
Miyuki Kawamura is a well-respected folder in Japan and is a board member of the Japan Origami Academic Society. Kawamura has a background in physics and specializes in modular origami. She has published several books about origami including *Polyhedron Origami for Beginners* in 2002 and has exhibited her work internationally.

Tomoko Fuse (b.1951, Japanese)
Tomoko Fuse is widely considered one of the world's preeminent modular origami artists and has designed many modular boxes and containers, polyhedra and other geometric objects, as well as *kusudama* (balls made by sewing or gluing together separate, usually flower-shaped, units), paper toys, and masks. Since the early 1980s she has published over 60 books in Japanese, Korean, and English.

Koryo Miura (Japanese)
Koryo Miura was a Japanese astrophysicist known for his invention of the "miura fold." The miura fold is a rigid fold that has been used to simulate large solar panel arrays for space satellites in the Japanese 1995 Space Flight Unit. It is an example of the practical importance of rigid origami, or treating hinges and rigid surfaces like the paper and creases in paper folding problems.

Akira Yoshizawa (b.1911, Japanese)
Akira Yoshizawa is widely considered the father of modern origami art. The son of a farmer, he devoted his life to his art, living in poverty as he perfected his craft and developed thousands of new designs. He pioneered the now widely used technique of "wet-folding," which allows for delicate sculptural modeling of organic forms. In 1954, he was propelled to prominence by his book, *Atarashi Origami Geijutsu (New Origami Art)*, which introduced a system of folding notation. The same year, he founded the International Origami Center in Tokyo and began holding origami exhibitions overseas, serving as a cultural ambassador for Japan. In his last decades Yoshizawa received worldwide recognition for his contributions; he wrote 17 more books on origami and in 1983 Emperor Hirohito awarded him the Order of the Rising Sun.

<u>Japan/USA</u>

Ruthie Kitagawa (b.1937, Japanese American)
Ruthie Kitagawa was raised in the Los Angeles area during the time when President Franklin D. Roosevelt signed Executive Order No. 9066, which authorized the incarceration of nearly 120,000 Japanese Americans across the greater West Coast during WWII, including Kitagawa and her family. She was actively involved in the Boys and Girls Club as a child, where she developed her love of crafts, and eventually, origami. Kitagawa regularly teaches classes at the Japanese American National Museum.

<u>Vietnam</u>

Hieu Tran Trung (b.1984, Vietnamese)
Hieu Tran Trung is a chemistry teacher living in Ho Chi Minh City, Vietnam. Tran recently joined a growing group of Vietnamese origami folders and his work has been featured in several international exhibitions. Fascinated by dinosaurs, he specializes in constructing complex skeletons of various types of dinosaurs from multiple sheets of paper.

<u>Vietnam/USA</u>

Giang Dinh (b.1966, Vietnamese-American)
Giang Dinh studied architecture in Vietnam and in the United States and currently lives in Virginia, where he works for an architectural firm. He started creating origami in 1998 and is now well known for his simple and elegant designs infused with a zen-like spirituality. Rather than crisp, sharp folds, which he compares to ink, he chooses soft folds, which are like pencil lines. He often works in plain white paper so that the viewer can concentrate on the pure form and shadow of the work. Many of his works are wet-folded and have the appearance of semi-abstract sculptures.

Brazil/Germany

Paulo Mulatinho (b.1956, Brazilian)
A native of Brazil, Paulo Mulatinho studied graphic and industrial design in Rio de Janeiro. He has been folding origami for over 20 years and has lived in Germany since 1985. Paulo Mulatinho is the founding president of Origami Germany. He has written several books about origami.

Belgium

Herman Van Goubergen (b.1961, Belgian)
Herman Van Goubergen is a computer programmer and his designs are known for their playful tromp l'oeil quality, as they are not always what they first appear to be. He creates new works infrequently, and each piece is scrupulously based on a novel origami concept that challenges conventional notions of folding. In all his projects Van Goubergen seeks to create a work that encapsulates and demonstrates the innovative concept he is exploring.

Poland

Krystyna and Wojtek Burczyk (b.1959 and 1960, Polish)
Krystyna Burczyk has taught mathematics for more than 20 years. In 1995 she began folding paper, exploring the relationship between origami and mathematics through the creation of geometric models. Her husband and artistic collaborator, Wojtek Burczyk, also started origami in 1995 and has a similar background in mathematics and computer science. Together they promote origami within their community, and participate in national and international origami exhibitions.

Israel

Miri Golan (b.1965, Israeli)
Miri Golan is probably best known for the educational work she does in Israel, using origami to unite people of different religious and cultural backgrounds. Her students often create garlands of origami cranes as a wish or prayer for a more peaceful world. Golan, who is married to English origami artist Paul Jackson, also creates conceptual pieces, such as *Two Books*, in which origami figures emerge from the pages of two sacred texts, the Torah and the Koran, and reach out to each other.

Italy

Andrea Russo (b.1981, Italian)
Andrea Russo has a background in law and a passion for art, which he expresses through his origami works. Rather than rely on traditional and conventional forms of origami, he prefers to create tessellations with geometric patterns and abstract sculptures using straight lines or curves, in an attempt to extract new forms and visual concepts. He has collaborated with designers and architects and has exhibited his work in museums and private galleries. Russo recently participated in a convention of Islamic Art, where he showcased paper tessellations that represented Islamic geometric patterns.

Russia

Victoria Serova (b.1969, Russian)
Victoria Serova is one of the few female origami folders to specialize in complex origami forms such as multi-legged insects and crustaceans. Her husband, Vladimir Serova, is also an origami artist, and together they have published several novels and exhibited their work in books and exhibitions throughout the world.

History of Paper

Antecedents of Paper

From the beginning of history, humans have found ways to record their lives and express their longings in graphic form. Before they used paper, humans recorded information on everything from walls of caves to marble slabs, clay tablets, shell, bone, wood, and even wax. However, as civilizations evolved, there was an obvious need for a lighter material that could be easily stored and transported. As a result, three fibrous materials with similar characteristics were developed independently in three locations around the globe: papyrus in the Mediterranean, pre-Columbian paper in America, and paper (as we know it today) in the Far East.

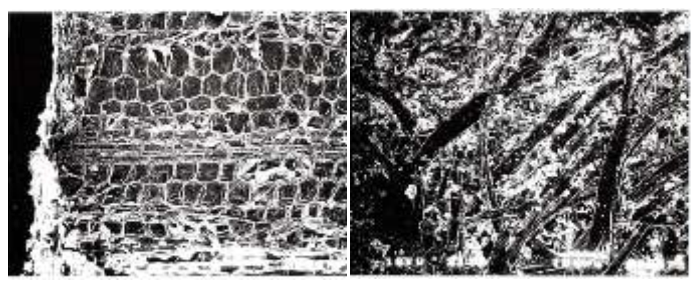
Paleolithic drawings in the Lascaux Caves of southwestern France.

Mesopotamian clay tablet.

Papyrus is a thin, paper-like material produced from the pith of the papyrus plant, *Cyperus papyrus*. The properties of papyrus allow its leaves to be worked to form continuous, broad, smooth surfaces that are very similar to paper. Layers of leaves were placed parallel to one another at right angles before being beaten to release a natural liquid that bound them together in a single sheet. To prepare the papyrus, its surface was polished using marble or agate. The Egyptians used it as early as 3200 B.C.E., and its use lasted until the 10th century, when paper production began to overtake papyrus.

Egyptian papyrus document.

The papyrus plant can reach a height of 18 feet.



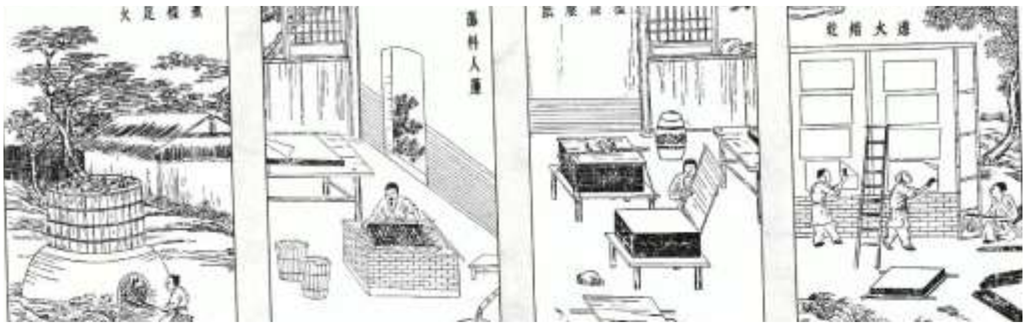
Scanning electron microscope image of paper pulp (right) versus papyrus (left).

Another antecedent of contemporary paper is Pre-Columbian paper. It is believed that the Incas of the South American Andes used indigenous plant fibers or bark to make a paper-like material similar to papyrus. Remains of some of this material, dating from around 2100 B.C.E., were discovered in excavations carried out in Peru. Pre-Columbian paper was made from a tree in the ficus family. The bark was removed in a single strip, left to soak for several days, and beaten on a flat trunk with another piece of wood until it became finely textured and elastic. Descendants of the Aztecs make a similar paper today, called *amate*. Amate paper, like its predecessor, is also made from the inner bark of a tree in the ficus family.

A painted amate rich in color and symbolism.

The Invention of Paper

In 105 C.E. the civil servant T'sai-Lun of China succeeded in creating the first paper in history by mixing plant fibers extracted from rags, fishing nets, mulberry-tree bark, nettle, and hemp. To make these papers, the plant fibers were softened in lime water and left to ferment before they were crushed and ground to pulp using hand mortars. The resulting paste was mixed with water. Then a strainer made of bamboo fibers or cloth was submerged in the mixture to gather the amount of pulp needed to make a sheet of paper. Next, the strainer was hung on the walls of an oven to dry in the sun. Once the sheet dried, it was peeled off the strainer and burnished with a smooth stone. To waterproof the pages, they were coated with solutions made from an alga or plant juices.



T'ien-kung k'aiwu, *Handmade Paper in China*, 1634. The four main phases of papermaking can be observed in this series of four illustrations : preparing the fiber, forming the sheet, pressing, and drying.

The Spread of Paper

Paper spread to the East from the Chinese province of Hunan through the Silk Road in the caravans of Persian and Assyrian merchants that reached as far as Central Asia. Paper spread through the Arab world when the Muslims prevailed over the Chinese in a battle near Samarkand (present day Uzbekistan). Among the Chinese prisoners taken were papermakers who revealed their secrets to the Muslims in exchange for preferential treatment. The spread of paper then moved westward via the Arabs, who set up paper mills in all of Asia Minor and North Africa. Paper reached Europe through the Islamic culture, and from Europe, it was exported to America. Paper was known throughout the world by the seventeenth century.

Map depicting the migration of paper from China across the globe.

The History of Origami

The word “origami” comes from the Japanese words *ori,* meaning “to fold,” and *kami*, meaning “paper.” Origami became possible with the invention of paper and was originally an art form only the rich could pursue, as paper was extremely expensive. The origin of origami is disputed, with independent paper folding traditions existing in both East Asia and Europe. No single person is credited with the invention of origami itself, rather masters of the craft have shaped its development over the centuries. However, the Japanese were the first to create a book on origami, called “Hiden Zenbazuru Orikata” or “Folding Methods for One Thousand Cranes,” published in 1797.

Japanese origami began sometime after Buddhist monks carried paper to Japan during the 6th Century. Originally, Japanese origami was used solely for religious purposes, due to the high price of paper. However, by the Heian period (794-1185), the use of origami became prevalent in the culture and was used in a variety of ceremonies. For example, the Japanese used origami butterflies during Shinto weddings to represent the bride and groom, and Samurai warriors are known to have exchanged gifts adorned with *noshi*, a good luck token made of folded strips of paper.

The modern growth of origami can be attributed to Akira Yoshizawa, a Japanese origamist credited for raising origami from a craft to a living art. Yoshizawa created a system to indicate how to fold origami, and the Yoshizawa-Randlett system is now used internationally.

Yoshizawa-Randlett System

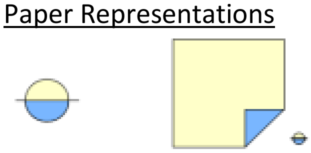
The Yoshizawa-Randlett System was originally created by Akira Yoshizawa and further perfected by Samuel Randlett and Robert Harbin. The Yoshizawa-Randlett system is a diagramming system used to describe the folds of origami models. While other books attempted to explain how to fold origami models, prior to the Yoshizawa-Randlett system, there was no systematic, universally accepted way to describe how to fold an origami piece. In 1954, Yoshizawa published a monograph entitled “Atarashi Origami Geijutsu,” or “New Origami Art,” detailing a system of dotted and dashed lines to represent mountain and valley folds, and other symbols such as the “inflate” and “round” symbols. Later on, Randlett and Harbin added a few symbols such as “rotate” and “zoom in,” and then adopted it as the standard. The Yoshizawa-Randlett System has become the accepted form for origami notation and is used throughout the international origami community today.

Origami Symbols

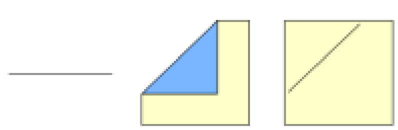
The two main types of origami symbols are lines and arrows. Arrows show how the paper is bent or moved, while lines show various types of edges:

- A thick line shows the edge of the paper.
- A dashed line shows a valley fold. The paper is folded in front of itself.
- A dashed and dotted line shows a mountain fold. The paper is folded behind itself, this is normally done by turning the paper over, folding a valley fold and then turning the paper back over again.
- A thin line shows where a previous fold has creased the paper.
- A dotted line shows a previous fold that’s hidden behind other paper, or sometimes shows a fold that’s not yet made.

<u>Paper Representations</u>



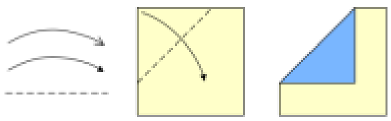
Side Color



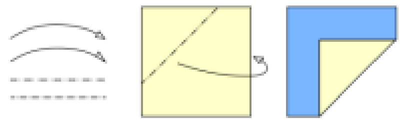
Crease

Invisible Line

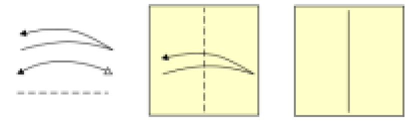
Operations



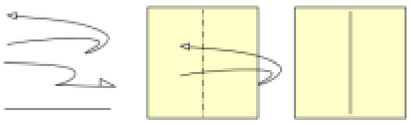
Valley Fold



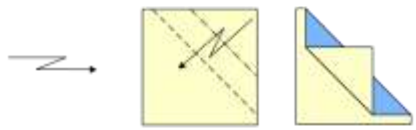
Mountain Fold



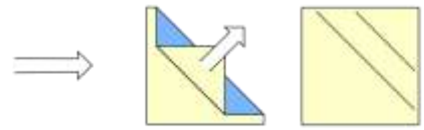
Fold and Unfold Valley



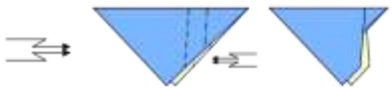
Fold and Unfold Mountain



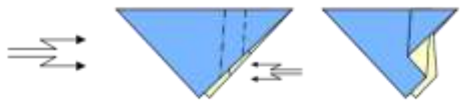
Pleat Fold



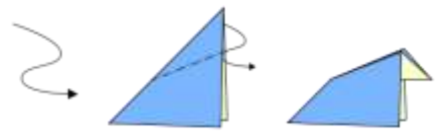
Pull



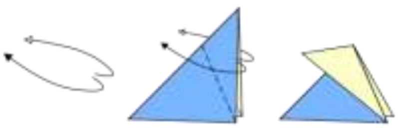
Inside Crimp Fold



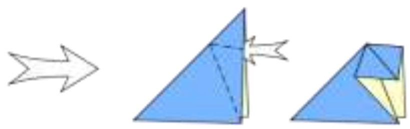
Outside Crimp Fold



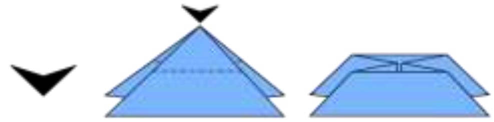
Inside Reverse Fold



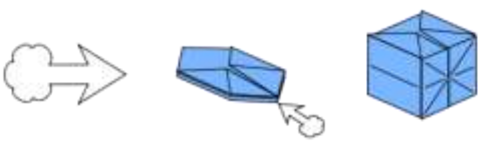
Outside Reverse Fold



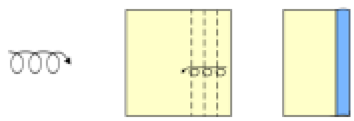
Open



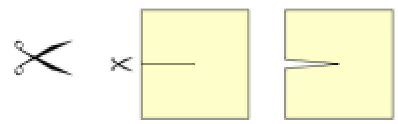
Sink



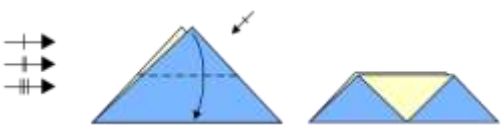
Inflate



Roll

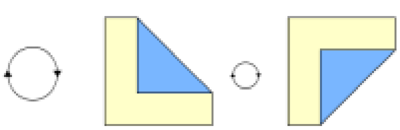


Cut

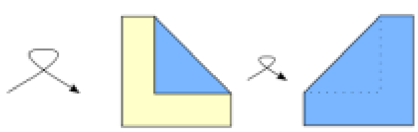


Repeat Action

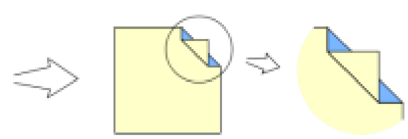
Views



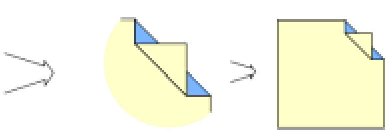
Rotate



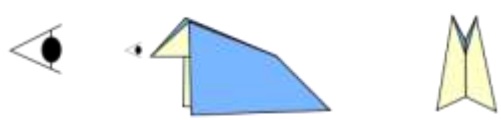
Turn Over



Zoom In



Zoom Out



View From Here

Types of Origami

Below are some of the principal types of origami:

Representational Origami – One or more sheets of paper folded into an animal, flower, or figure from the real or supernatural realm.

Geometric Origami – Includes *modular* origami and *origami tessellations*. In modular origami, multiple sheets of paper are folded into individual units and then assembled into a larger, more complex geometric structure. These structures, created using mathematical calculations, are held together by friction or tension. In origami tessellations, a pattern fills a plane with no overlaps or gaps, like decorative wall tiles, often created using pleats to connect together elements such as twist folds in a repeating fashion.

Action Origami – Refers to origami which requires inflation to complete, or, when complete, uses the kinetic energy of a person's hands, applied at a certain region on the model, to move another flap or limb.

Wet-Folding – A technique that involves slightly dampening the paper before making a fold. Wet-folding allows the paper to be manipulated more easily, resulting in finished origami models that have a rounder and more sculpted look. The wet-folding technique was pioneered by Akira Yoshizawa.

Pureland Origami – A type of "pure" origami, in which no cutting, decorating, or using of glue, tape, or scissors is allowed. Pureland origami allows only the use of simple mountain and valley folds.

Kirigami – In traditional origami, you fold paper. In Kirigami, you fold *and* cut paper. Cutting was often used in traditional Japanese origami, but modern innovations in techniques have made the use of cuts unnecessary. Most modern origami designers no longer consider models with cuts to be origami, and most contemporary books do not even mention cutting.

Origami is a constantly evolving art, with origami artists creating ever-changing techniques that bring the art form to new levels of complexity and innovation. While not mentioned above, other "fringe" types of origami include business card origami, candy wrapper origami, dollar bill origami, palm weaving, toilet paper origami, and fabric folding.

Inspirational Origami: Impact on Science, Industry, Fashion and Beyond

Origami, mathematics, science, and design are becoming increasingly interconnected. Origami is not only used today to explain and teach arithmetic and geometry, but computational origami employs algorithms and theory to solve complex problems. For example, Dr. Robert J. Lang is a scientist and mathematician who was approached by Lawrence Livermore National Laboratory to help develop their Eyeglass Telescope, which would be 40 times larger than the Hubble telescope. Dr. Lang used computational origami to determine how to fold the lens so that it could be launched compactly and then re-opened in space. The resulting design used an origami structure he called the "Umbrella" after its resemblance in the furled state to a collapsible umbrella. Other examples of the intersection of origami with other fields includes airbag logistics, cell phone design, architectural design, and even heart stents have their basis in origami principles.

The Modern Papermaking Process

1. ***Timber*** – The papermaking process begins with the raw material—timber! Timber is wood prepared for use in building and carpentry. Timber farmers have to plan ahead, as they produce a crop with harvest rotations that can approach 100 years in length, and their raw material is in high demand by various industries. Papermakers usually use only the parts of the tree that other commercial industries do not want, such as saw mill waste and forest thinnings.

2. ***De-Barker*** – Once the trees are harvested, their bark is removed from the logs by knife, drum, abrasion, or hydraulic barker. The stripped bark is then used for fuel or as soil enrichment.

3. ***Chipping Machine*** – Stripped logs are chipped into small pieces by steel wheels. The chips pass through vibrating screens, whereby both undersized chips and oversized chips are rejected. Accepted chips are then stored in huge bins ready for the next step in the papermaking process.

4. ***Chemical Pulping Process*** – Chips from the storage bins are fed into a digester to which caustic soda and sulphur have been added. The woodchips are then “cooked” to remove lignin, the binding material which holds the cellulose fibers together. Wood provides about 90% of the basis for pulp production, while about 10% originates from annual plants. The timber resources used to make wood pulp are referred to as “pulpwood.” Wood pulp comes from softwood trees such as spruce, pine, fir, larch, hemlock, and from hardwoods such as eucalyptus, aspen, and birch.

5. ***Mechanical Pulping Process*** – Mechanical pulping is an alternative to chemical pulping where debarked logs are forced between enormous, rotating steel discs with teeth that literally tear the wood apart. Unlike the chemical pulping process, the mechanical pulping process produces paper which will discolor, since the lignin is not removed. Lignin is sensitive to light and degrades, turning brown with exposure to sunlight. An example is newsprint paper.

6. ***Hydrapulper*** – The wood pulp is added to a hydrapulper, a circular tank containing water and an agitator which work together to further disintegrate the pulp into a thick porridge. When the process is complete, the pulp is discharged into large storage tanks.

7. ***Blend Chest*** – The pulp is then transferred to a blend chest where the final properties of the paper are obtained by adding just the right mix of chemicals and additives. Computers are used to accurately monitor the chemical balance and additives of the paper, to ensure the final product has the required characteristics.

8. ***Waste Paper*** – Once paper is no longer of use, it can be recycled to create new paper. Recycling plants collect the paper you discard in recycling bins and sort the paper into different grades. Paper not suitable for recycling is removed. Paper suitable for recycling is baled and taken to the paper mill. About 37% percent of the fiber used to make new paper products in the US came from recycled sources in 2011.

9. ***De-inking*** – Before waste paper can be recycled, the ink must be removed. The de-inking process begins with washing the waste paper in a pulper. The pulper contains lots of water and breaks down the waste paper into a pulp. Afterwards, the water is drained from the pulper through fine screens which allow the ink particles to escape without removing any paper pulp. Next, more water is added to the pulper, along with surfactant chemicals which make a sticky froth at the top of the pulp**.** Surfactants lower the surface tension between two liquids, or between a liquid and a solid. A “floatation” process begins, in which bubbles are blown through the pulp, “capturing” ink and bringing the ink particles to the foamy surface. The foam is then skimmed off the top of the pulp, the water drained, and the remaining pulp is ink-free!

10. ***Refining*** – The de-inking process renders the paper fibers in the pulp stiff and inflexible. Consequently, the pulp must go through a refining process in which pulp stock is pumped through a machine with revolving discs which fibrillate the paper. Fibrillation refers to the violent process of cutting, opening up, and de-clustering fibers in the pulp, in order to create a pliable end product.

11. ***Screening and Cleaning*** – Using rotating screens and centrifugal cleaners, small particles of dirt and grit are removed from the paper pulp. The screening and cleaning process is essential to remove undesirable materials from the final product.

12. ***Papermaking Machine*** – The papermaking machine is a sophisticated piece of machinery measuring the length of two football fields and running at speeds of up to 60 miles per hour! The first section of the machine is known as the "wet end," and is where the diluted stock first comes into contact with the paper machine. The pulp stock is placed into a flow box and then carefully distributed evenly over the whole width of the paper machine. The pulp stock then makes its way through the paper machine, undergoing drying and rolling, until it is finally collected onto a jumbo reel. The whole process is monitored carefully by computers in order to ensure proper moisture content, weight, and any other desired characteristics for the final batch.

13. ***Conversion and Printing*** – Large reels of finished paper must now be converted to the final product. Converters specialize in transforming reels and sheets of paper into a vast array of finished products, including printer paper, cartons, and stationary. The printing industry also converts paper and board, much of which reaches the consumer as newspapers, magazines, or books.

Key Vocabulary

Action origami – a type of origami which requires inflation to complete, or, when complete, uses kinetic energy of a person's hands to make a portion of the origami piece move.

Agitator – located inside the hydrapulper and responsible for disintegrating paper pulp into a thick porridge which will later be sent to a blend chest.

Amate – a type of paper made from the inner bark of a tree in the ficus family. It is made by the descendants of the Aztecs, the Otomi Indians of San Pablito, Mexico.

Blend chest – a holding tank where paper pulp, chemicals, and various additives are mixed before going to the paper machine.

Converters – transform reels and sheets of paper into a finalized paper product.

De-inking – the process of washing waste paper and removing the ink.

Fibrillation – the process of cutting, opening up, and de-clustering fibers in the pulp, in order to create a pliable end product.

Floatation – the process of blowing bubbles through the paper pulp during the de-inking process, “capturing” ink, and bringing the ink particles to the foamy surface of the paper pulp.

Flowbox – collecting box for dilute paper stock in papermaking machine.

Geometric origami – a type of origami that includes modular origami and origami tessellations.

Hydrapulper (or pulper) – circular tank containing water and an agitator which work together to disintegrate pulp into a thick porridge.

Hydraulic barker – a machine which removes bark from trees.

Irregular tessellation – tessellations made of curved shapes, not just polygons, and having a variety of appearances.

Kirigami – a disputed form of origami which involves paper cuts and folding.

Lignin – the binding material in wood which holds the cellulose fibers together.

Modular origami – a type of origami in which multiple sheets of paper are folded into individual units and then assembled into a larger, more complex geometric structure.

Noshi – a Japanese good luck token made of folded strips of paper, usually given by Samurai warriors.

Origami – the art of folding paper into decorative shapes and figures.

Origami tessellations - a type of origami in which a pattern fills a plane with no overlaps or gaps, like decorative wall tiles.

Paper machine –a sophisticated piece of machinery used to make paper. The first section of the machine is known as the “wet end,” and is where the diluted stock first comes into contact with the paper machine. The pulp stock then makes its way through the paper machine, undergoing drying and rolling, until it is finally collected onto a jumbo reel.

Papermaking – the manufacture of paper.

Papyrus – a thin, paper-like material produced from the pith of the plant, *Cyperus papyrus*, whose invention is credited to the ancient Egyptians.

Polygon – plane figure with at least three straight sides and angles, and typically five or more.

Pulpwood – the wood pulp of softwood trees such as spruce, pine, fir, larch, hemlock, and from hardwoods such as eucalyptus, aspen, and birch, which is used to make paper.

Pureland origami – a type of origami, in which no cutting, decorating, or using of glue, tape, or scissors is allowed.

Refining – process in which pulp stock is pumped through a machine, which fibrillates the paper, creating a pliable end product.

Regular polygon – two-dimensional shape with straight sides, such as a triangle, square, or octagon.

Representational origami – one or more sheets of paper folded into an animal, flower, or figure from the real or supernatural realm.

Semi-regular tessellation – a tessellation made of two or more regular polygons.

Steel wheel – a part of the wood chipping machine which takes the stripped logs and converts them into small chips of wood.

Surfactant – a substance that tends to reduce the surface tension of a liquid in which it is dissolved.

Tessellation – tiling of a plane using one or more geometric shapes, called tiles, with no overlaps or gaps.

Timber – wood prepared for use in building and carpentry.

Washing – the process of removing contaminants from waste paper and preparing it for the de-inking process.

Waste paper – the term used to describe paper that is already in existence, used and no longer of use, that can be recycled to create new paper.

Wet-folding – a technique that involves slightly dampening the paper before making a fold, allowing the paper to be manipulated more easily, and resulting in finished origami models that have a rounder and more sculpted look.

Class Project Ideas
Below are a sampling of pre- and post- visit project ideas to facilitate with your class in order to aid their understanding of the exhibit, the paper making process, and the artistry of the origami featured in the exhibit *Folding Paper*.

Pre-Visit Ideas

Tin Can Papermaking

Description:
Students will learn about the industrial papermaking process and try their hand at tin can papermaking. The tin can papermaking process is a handmade papermaking process which uses recycled paper to create new paper.

Materials:
2 Tin Cans (The diameter of your cans will determine the size of your paper. 26 oz coffee cans work great. Cut one end out of one can, and cut both ends out of the other.)
Hardware Cloth, 6" x 6" or larger (You can purchase hardware cloth at your local hardware store.)
Non-Metal Window Screen, 6" x 6" or larger (You can purchase non-metal window screen at your local hardware store.)
Cellulose Sponge
Paper Towels
Board for Pressing
Shallow Dish
Clothes Iron
Blender

The above supply list is good for 1-2 students, working in teams. Adjust the quantities depending on the size of your classroom.

Instructions:

1. Get a tin can with one end cut out. Set it on a level surface, open-end up.

2. Over the tin can's open end, place a 6"x 6" piece of hardware cloth.

3. Place a 6"x6" piece of non-metal window screen on top of the hardware cloth.

4. Place a tin can with both ends cut out over the window screen. If the cans are the same size, match their rims. You have set up a "pour" mold with which you can make handmade paper.

5. Tear up a piece of 7"x 7" waste or used paper into small pieces. Put the pieces into a blender. Add about 1 ½ cups of water.

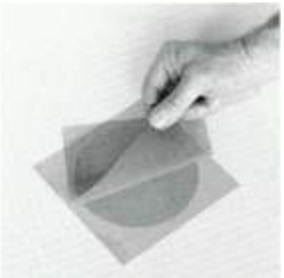
6. With the lid placed on top of the blender, run the blender for about 20-30 seconds. Pour half the blender's contents into each of two containers.

7. Add about a half-cup of water to each container.

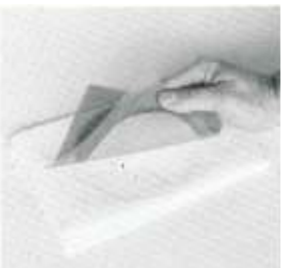
8. Take one container in each hand. Rapidly pour (not slowly, but dump) contents of both containers at the same time, into the top can. Pour from opposite sides so that streams from the two containers hit each other. Let all the water drain into the bottom can.

9. Raise the top can straight up and off. You should see your new sheet of paper on the window screen.

10. Lift the new sheet and window screen off the support screen, and place them on a flat surface. Place another 6"x 6" piece of window screen over the new sheet. Take a sponge and press it down on top of the window screen over the new sheet. Squeeze water from the sponge, and continue pressing and squeezing until the sponge removes little, or no more, water.



11. Peel off the top window screen, carefully starting at one corner.



12. Pick up the screen with the new sheet on it, and turn them over onto the towels, new sheet against the top of towel. Apply sponge as before (step 10), and apply pressure over entire sheet with as much force as possible.

13. Starting slowly at one corner, peel off the window screen, leaving the new sheet on the paper towel. (If the sheet rises with the screen, apply the sponge again with all the force you can, until the new sheet of paper remains on the paper towel.)

14. Place another paper towel on top of the new sheet. Take a flat piece of wood and press down hard on top of the dry towel. Remove the top wet towel and replace with a dry one. Repeat this process until little water is removed with additional dry towels.

15. Place the new sheet on an ironing board or other dry, clean surface that will not be harmed by heat. Iron new sheet dry. Move iron slowly but steadily so that all parts of the sheet dry at about the same rate. When the sheet is dry, it is complete!

Example:

Museum Connection:
Students should have some understanding of how paper is made, in order to better appreciate the origami artwork on display. Paper is a unique medium because is it highly pliable and can be manipulated into many different forms. The wet-folding technique has proven particularly influential in helping the art of origami to evolve from simplified folds to more sculptural creations. As you view the artwork on display, remind the students that although some of the origami pieces look like they are carved of stone, they are all actually made of paper.

Exploring the Different Types of Origami: Geometric Origami

Description:

Students will learn about the art of origami and come to realize that there are different forms of origami. The students will learn about "modular origami," a form of geometric origami in which multiple sheets of paper are folded into individual units and then assembled into a large, more complex geometric structure, without the use of glue or tape. The students will create an origami coaster using four sheets of paper.

Materials:

4 sheets of colorful paper, per student (Each piece of paper should be a different color.)

Instructions:

1. Have students fold a piece of origami paper in half, on the diagonal. It is important that students make strong creases.

2. Fold the paper in half again. Make sure the triangle forms a right angle.

3. Repeat steps one and two, until you have four right triangles with which to build your coaster.

4. Insert the two points of one triangular unit into the pocket of a 2nd triangular unit, as shown in the images at left.

5. Repeats step four by inserting a 2nd triangular unit into a 3rd triangular unit.

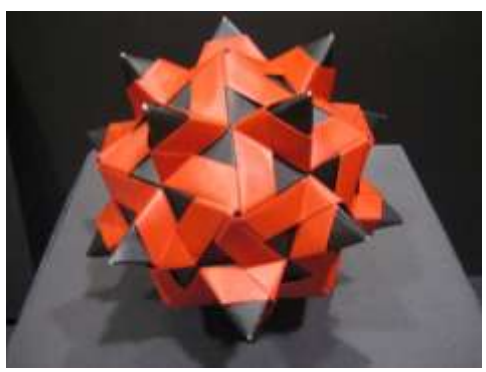
6. Repeat step four again, this time inserting a 3rd triangular unit into the 4th triangular unit.

7. Insert the two points of the 4th triangular unit into the 1st triangular unit.

8. Squeeze all four triangular pieces together so they are tight and make a coaster. Your modular origami piece is complete!

Museum Connection:
The origami coaster is a wonderful first modular origami piece for students to create, as it is fairly simple to assemble. However, modular origami pieces can be quite complex as evidenced by many of the examples on display in the *Folding Paper* exhibit. Daniel Kwan, for example, has an interlocking pentagonal prism on display, while Tom Hull has a paper icosidodecahedron and rhombic enneacontahedron on display.

Daniel Kwan interlocking pentagonal prism



Tom Hull icosidodecahdron

Tom Hull rhombic enneacontahedron

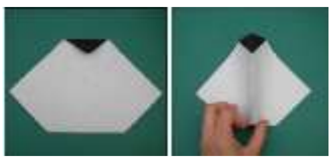
Exploring the Different Types of Origami: Representational Origami

Description:
Students will learn about the art of origami and come to realize that there are different forms of origami. The students will learn about "representational origami," a form of origami in which paper is folded into an animal, flower, or figure from the real or supernatural realm. The students will create an origami penguin, in the style of origami artist Florence Temko, using one sheet of origami paper.

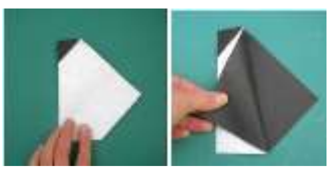
Materials:
1 sheet of origami paper (preferably black on one side, white on the other)

Instructions:

1. Fold a square piece of origami paper on the diagonal and then unfold so the white side of the paper is face up.

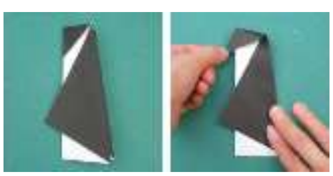


2. Fold the top corner down about 1 inch. Fold the bottom corner back about 2 inches. Fold the paper in half backward (mountain fold).



3. Once folded in half, bring the outer corner over beyond the edge, first on the front.

4. Repeat step three, except bring the outer corner beyond the edge, now on the back.



5. When both sides are folded, pull the head forward from the beak and flatten the back of the head.

Museum Connection:
Florence Temko designed the origami penguin above, and students can actually view her penguins in the *Folding Paper* exhibit! Temko is a British origami artist currently residing in California. She creates origami penguins in varying sizes, designed to be grouped together in small displays.

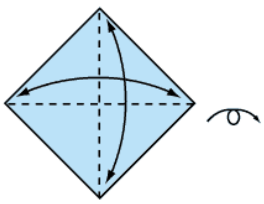
Post Visit Ideas

Sadako Sasaki's Origami Crane

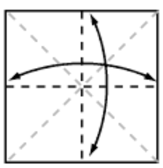
Description:
Students will learn the history of Sadako Sasaki, a Japanese girl who was two years old when the atomic bomb was dropped on August 6th, 1945 in Hiroshima, near her home. Sadako is remembered through the story of *Sadako and the Thousand Paper Cranes*, which chronicles her life with leukemia, a result of radiation exposure from the atomic bomb. To this day, Sadako serves as a symbol of innocent victims of war. After learning about Sadako, students will learn to make a paper crane. According to Japanese legend, a person who folds a thousand paper cranes can have a wish granted.

Materials:
Book, *Sadako and the Thousand Paper Cranes* by Eleanor Coerr
One sheet of origami paper, any color

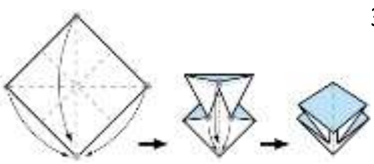
Instructions:



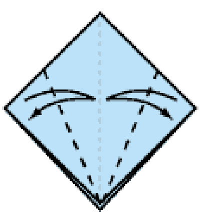
1. Start with a square piece of paper with the colored side up. Fold the top corner of the paper down to the bottom corner. Crease and open again. Then fold the paper in half sideways.



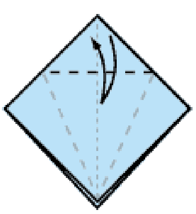
2. Turn the paper over to the white side. Fold the paper in half, crease well and open, and then fold again in the other direction.



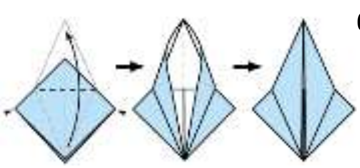
3. Using the creases you have made, bring the top three corners of the model down to the bottom corner. Flatten model.



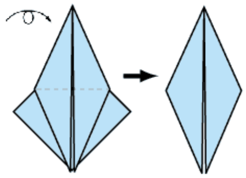
4. Fold top triangular flaps into the center and unfold.



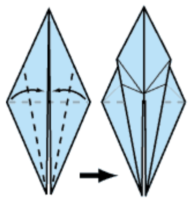
5. Fold top of model downwards, crease well, and unfold.



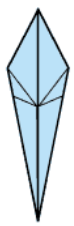
6. Open the uppermost flap of the model, bringing it upwards and pressing the sides of the model inwards at the same time. Flatten down, creasing well.



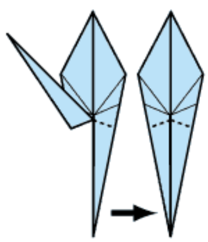
7. Turn the model over and repeat steps four through six on the other side.



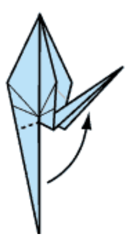
8. Fold the top flaps into the center.



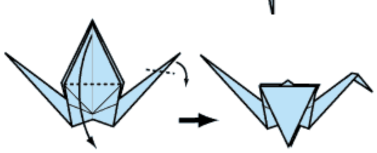
9. Repeat step eight on the other side, so that your model looks like the image at left.



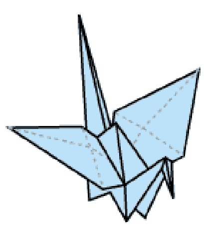
10. Fold both legs of the model up. Crease the legs well and then unfold them.



11. Inside reverse fold the legs of the crane along the creases you made in step ten.



12. Inside reverse fold one side to make a head, and then fold down the wings.



13. You now have a finished paper crane! Finish your lesson by reviewing the history of Sadako Sasaki. You may choose to have your students read Eleanor Coerr's *Sadako and the Thousand Paper Cranes*. Assemble your class' paper cranes in chains, just like Japanese students do at the "children's peace monument" in Hiroshima Peace Memorial Park, which commemorates Sadako Sasaki.

Museum Connection:
There are several origami cranes on display in the *Folding Paper* exhibit. Students can even see one of Sadako Sasaki's paper cranes! Some key crane-themed art pieces to view include:

- A reproduction of Japan's *Hiden Zenbazuru Orikata* (Secret Folding Methods for One Thousand Paper Cranes), the first written origami book.
- Sadako Sasaki's paper crane, made from a candy wrapper.
- Meher McArthur's photographs of a bronze statue of Sadako Sasaki holding an origami crane, located in Hiroshima Peace Memorial Park.

Children's Peace Monument in Hiroshima Peace Memorial Park, Japan


Sadako Sasaki is featured at the top of the monument.

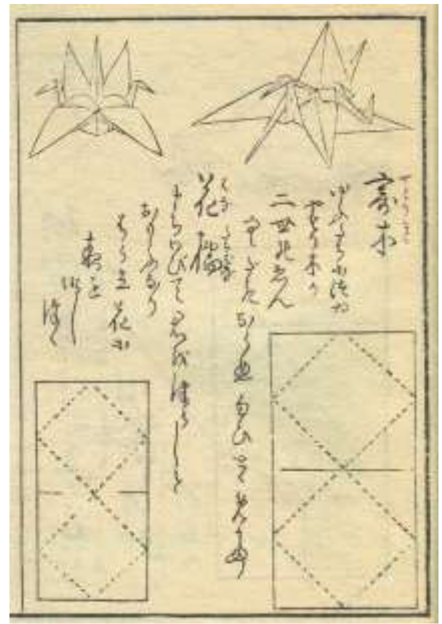


Image from *Hiden Zenbazuru Orikata,* the first written origami book

M.C. Escher Inspired Tessellations

Description:
A tessellation is the tiling of a plane using one or more geometric shapes, called tiles, with no overlaps and no gaps. Origami tessellation is the filling of a plane with a pattern, containing no overlaps or gaps, like decorative wall tiles, often created using pleats to connect together elements such as twist folds in a repeating fashion. Students will learn the difference between tessellations and origami tessellations, and put together a tessellation. Students will also learn about M.C. Escher, a Dutch graphic artist known for his mathematically inspired woodcuts, lithographs, and mezzotints.

Materials:
Examples of M.C. Escher tessellations (The following link has lots of examples: http://www.youtube.com/watch?v=njp6yexWbfw)
Scissors
Construction Paper
Cardstock Paper
Pencils
Glue Stick

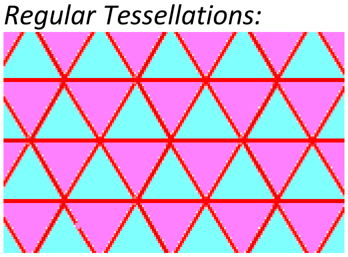
Instructions:

1. Explain to the students how a tessellation is made. A tessellation is created when a shape is repeated over and over again covering a plane without any gaps or overlaps. See the images under the "examples" section below, to get a visual for a few different tessellation designs.

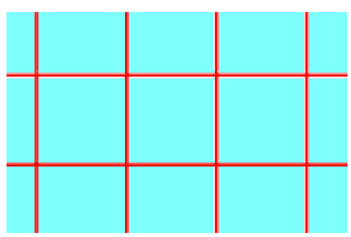
If you have access to a computer, have students practice making tessellations in this online tessellation creator: http://illuminations.nctm.org/Activity.aspx?id=3533

2. Quickly review regular, semi-regular, and irregular tessellations with your students. Regular tessellations are made using repeated regular polygons. (A regular polygon is a two-dimensional shape with straight sides, such as a triangle, square, or octagon.) There are only three regular tessellations: triangles, squares, and hexagons.

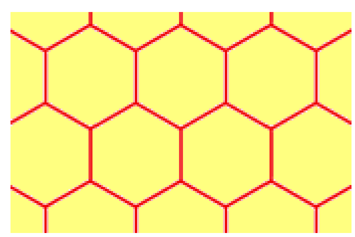
Regular Tessellations:



Triangle Tessellation



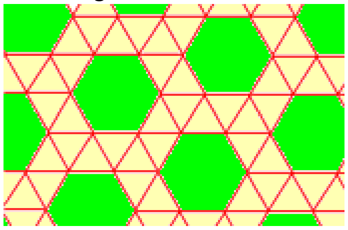
Square Tessellation

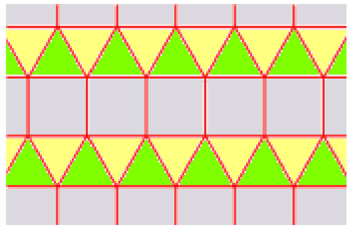


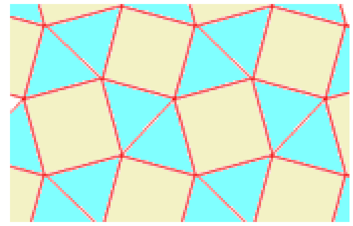
Hexagon Tessellation

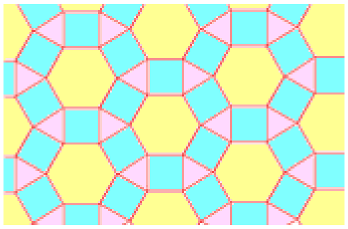
3. Semi-regular tessellations are made of two or more regular polygons. (A polygon is a plane figure with at least three straight sides and angles, and typically five or more.) The shape must be "closed," meaning all lines meet up. The pattern at each vertex must be the same. (A vertex is simply a "corner point.") There are only eight semi-regular tessellations.

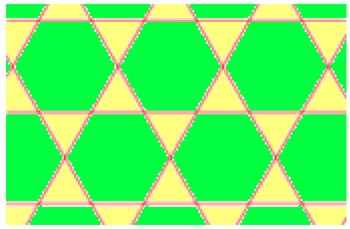
Semi-regular Tessellations:

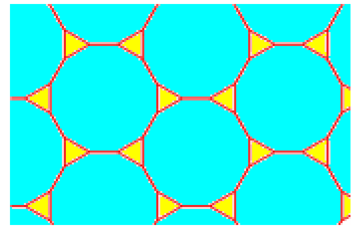


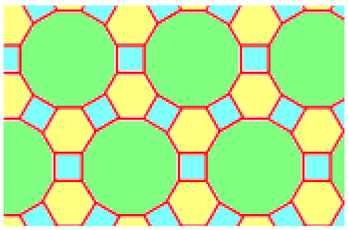


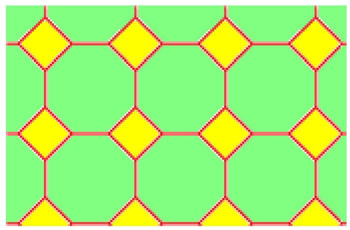






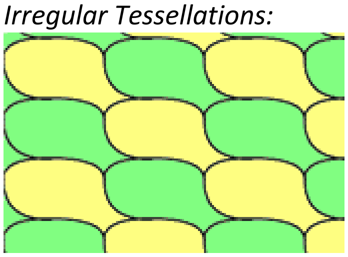




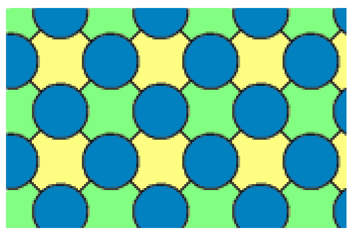


4. Irregular tessellations allow for curved shapes (not just polygons), and can have a variety of appearances:

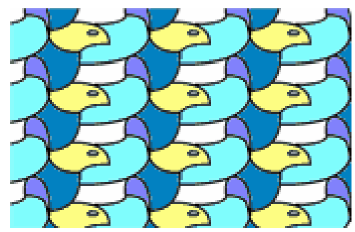
Irregular Tessellations:



Curvy Shapes Tessellation



Circle Tessellation



Eagle Tessellation

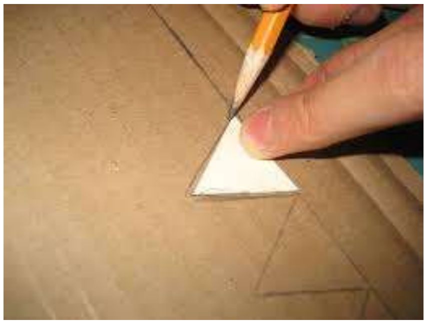
5. After getting a sense of what tessellations look like, and how they are made, show the students examples of irregular tessellations by the artist M.C. Escher. Escher was a Dutch graphic artist known for his mathematically inspired woodcuts, lithographs, and mezzotints. In his early years, he sketched landscapes and nature. His later works were inspired by mathematics and the Moorish sensibility for symmetry and geometric grids. Later on, he became obsessed with representing infinity on a two-dimensional plane (see image of "Circle Limit III"). Below are some examples of Escher's works. (You can view a gallery of Escher's work on his official webpage: http://www.mcescher.com/.)

Circle Limit III

Relativity

Pegasus

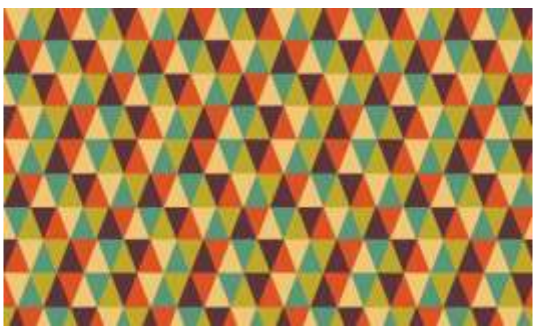
6. Now that the students have reviewed tessellations and tessellation art by M.C. Escher, it is time for them to try to make their own tessellation! Start easy by having students make tessellations using regular polygons. For instance, they can make a tessellation of equilateral triangles. Have students create a stencil of an equilateral triangle using cardstock paper. After creating the stencil, have the students trace and cut lots of triangles out of construction paper. Limit the students to 2-3 color triangles for their tessellation.

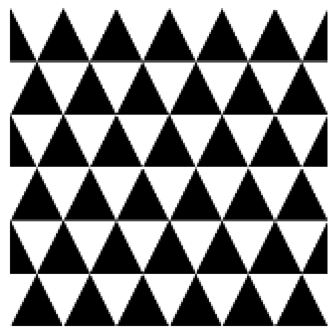


Create a triangle stencil using cardstock.

Trace and cut out lots of triangles of varying colors.

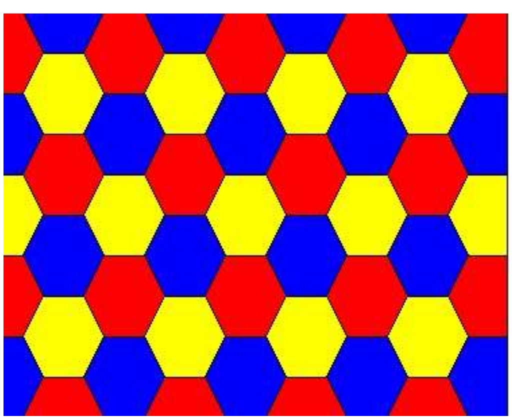
7. Have the students glue their equilateral triangles onto a sheet of construction paper, using a regular pattern and making sure that no space is left between the triangles. There final triangle tessellation might look something like the following examples:





8. For older students, have them create their own unique tessellation designs, for an extra challenge! The following two links may prove helpful in explaining to students how to create their own tessellating shapes:
    - http://www.wikihow.com/Make-a-Translation-Tessellation
    - http://est430wiki.wikispaces.com/Learning+to+create+a+Tessellation

Examples:



Museum Connection:
The above examples are of tessellations. Origami tessellations are similar to tessellations, but are three-dimensional. Have the students look for origami tessellations in the exhibit *Folding Paper*. Christine Edison, Eric Gjerde, and Chris Palmer, for example, all specialize in origami tessellations. Below, you can see an example of their work.


Christine Edison


Eric Gjerde


Chris Palmer

Resources

Recommended Books and DVDs:

Book	Description
Sadako and the Thousand Paper Cranes by Eleanor Coerr	Based on the true story of a young Japanese girl who contracts leukemia as a result of the atom bomb that was dropped on Hiroshima, the story follows Sadako as a healthy school girl through her long stay in the hospital. While in the hospital, Sadako begins folding paper cranes, as an old Japanese legend purports that if a sick person folds one thousand cranes, the gods will grant her wish and make her healthy again. Ages 8 – 12.
Papermaking for Kids: Simple Steps to Handcrafted Paper by Beth Wilkinson	A children's illustrated, step-by-step guide to making paper, Christmas decorations, bookmarks, and bowls. Ages 7 and up.
From Tree to Paper by Pam Marshall	A simple introductory book on the paper making process intended for new readers. The book starts with planting a tree and explains how the wood is cleaned and processed to become the paper we use in newspapers, books, and magazines. Ages 4 – 7.
The Complete Book of Papermaking by Josep Asuncion	A comprehensive guide to the history of paper and the process of making artistic, homemade paper. All the technical aspects are explained in detail, with special attention to fashioning a sheet of paper, step-by-step. The book details how to make ten projects, including a Palm Paper Album, a rustic notebook, an accordion book, and more! Ages 12 and up.
Tin Can Papermaking by Arnold Grummer	Can you really recycle waste paper into beautiful new art or decorative paper? Yes! This book goes through the process of creating recycled paper, using lots of different techniques such as the mottled surface technique and internal embedment technique. The book also details information about paper and recycling. Ages 12 to adult.

Absolute Beginner’s Origami by Nick Robinson	An origami guide for people who are intimidated by origami. The book includes step-by-step full-color photographs to guide readers into the basics of folding, through intermediate steps, and on to putting it all together to make real origami. Readers will also learn how to understand and read line drawings and how to choose the right paper for their project. Ages 12 and up.
The Origami Bible by Nick Robinson	Readers will learn the spectrum of skills needed for origami, from choosing the right paper to building 12-fold designs or 24-fold models. Ages 12 and up.
Easy Origami by John Montroll	A collection of origami projects for novice origami hobbyist, clearly illustrated and with easy-to-follow instructions. Subjects range from an ultra-simple hat, cup and pinwheel, to slightly more challenging designs such as a penguin, pelican, and piano. Ages 6 and up.
Between the Folds DVD	A fascinating PBS documentary about the science and art of origami. The DVD profiles brilliant artists, mathematicians, and scientists who are reinventing the ancient Japanese tradition of paper folding. With just one piece of paper, and without the use of glue, tape, or staples, these offbeat and provocative minds are creating unimaginably beautiful works of art and thought-provoking mathematical models. Run time: 60 minutes.

Recommended Websites:

Want to learn more about paper, origami, and origami artists? Explore the world of origami on-line!

Website URL	**Description**
http://www.youtube.com/watch?v=E4C3X26dxbM	A comprehensive and quick overview of the papermaking process, from selecting trees to convert into paper, to the industrial papermaking process. Intended audience: late elementary to adult. Run time: 13 minutes.
http://www.youtube.com/watch?v=7IP0Ch1Va44	A brief introduction to how paper is made, beginning with harvesting trees, to the industrial papermaking process, and ending with creating paper from recycled waste paper. Intended audience: pre-K to early elementary. Run time: 2 minutes.
http://individual.utoronto.ca/abdel_rahman/paper/fpmp.html	The full industrial papermaking process, presented by an actual paper factory—World Wide Paper.
http://users.stlcc.edu/nfuller/paper/	A brief history of paper and papermaking.
http://inventors.about.com/od/pstartinventions/a/papermaking.htm	A brief history of paper and papermaking.
https://origamiusa.org/	Origami USA is a national organization based in New York City. The website includes information about origami events around the world, and links to local and international origami societies. The website also offers easy origami diagrams,

	an origami store, and various publications.
http://www.origami-resource-center.com/	Information about the art of paper folding and links to diagrams, databases, book reviews, and ways to be a part of the paper folding community.
http://www.coolmath4kids.com/tesspag1.html	A brief overview of tessellations for kids.
http://www.mathsisfun.com/geometry/tessellation.html	A more comprehensive guide to tessellations for kids, including quiz questions.
http://www.artsandartists.org/exhibitions-foldingpaper.php	The official website for the *Folding Paper* exhibit, including an exhibit summary and images of artwork.

Academic Standards Supported by Exhibit

Illinois Learning Standards for Fine Arts:

Grade	**Learning Standard**	**Example of how to relate to exhibit**
Early Elementary	25.A.1d – Identify the elements of line, shape, space, color and texture; the principles of repetition and pattern; and the expressive qualities of mood, emotion and pictorial representation.	As you explore the different kinds of origami in the exhibit, help students notice and articulate the different shapes that make up the piece. Examine how the color of paper used affects the overall feeling of the origami. Explain to the students that origami is often made with repetitive folds in the paper.
Late Elementary	25.A.2d – Identify and describe the elements of 2- and 3-dimensional space, figure ground, value and form; the principles of rhythm, size, proportion and composition; and the expressive qualities of symbol and story.	As you explore the different kinds of origami in the exhibit, discuss the 3-dimensional quality of the artwork. Notice how you can observe the origami from all sides, and that the piece occupies physical space and is not flat. Compare and contrast like works in relation to size and proportion. For example, you will find both large and small paper cranes in the exhibit.
Early Elementary	26.A.1e – Identify media and tools and how to use them in a safe and responsible manner when painting, drawing, and constructing.	As you explore the different kinds of origami and artwork in the exhibit, have students guess what the piece is made of. For instance, they should recognize that the vast majority of the art on display (i.e. origami) is made of paper. Have students analyze any inherent risks in working with paper.
Late Elementary	26.A.2e – Describe the relationships among media, tools/technology and processes.	Discuss with the students how the art of origami impacts other industries such as science and fashion. Point out how origami has been used to help develop air bags or create space telescope lenses. Can the students find any other examples of the intersection of origami with other fields in the exhibit?
Middle/Junior High School	26.A.3e – Describe how the choices of tools/technologies and processes are used to create specific effects in the arts.	Examine the different kinds of origami on display. Help students to notice how the different origami techniques (e.g. wet-folding), produce a vastly different end-product than traditional origami alone. Can the students find any other origami processes in the exhibit which produce specific effects in the final origami?
Early Elementary	26.B.1d – Demonstrate knowledge and skills to create visual works of art using manipulation, eye-hand coordination,	In the exhibit, there will be an area where you can create your own origami. There will be instructions for origami of varying difficulty levels: easy, intermediate,

	building, and imagination.	and difficult. Students can use the instructions, or use their imagination to create their own original origami.
Late Elementary	26.B.2d – Demonstrate knowledge and skills to create works of visual art using problem solving, designing, sketching, and constructing.	In the exhibit, there will be an area where you can create your own origami. There will be instructions for origami of varying difficulty levels: easy, intermediate, and difficult. Students can use the instructions, or use their imagination to create their own original origami.
Middle/Junior High School	27.A.3a – Identify and describe careers and jobs in and among the arts and how they contribute to the world of work.	As you explore the different kinds of origami and artwork in the exhibit, discuss the different job roles involved in creating *Folding Paper*. Some examples of careers represented in the exhibit are origami artist, photographer, curator, exhibition technician, etc.
Late High School	27.A.5 – Analyze how careers in the arts are expanding based on new technologies and societal changes.	Origami artists used to be simply paper artists. However, more and more, origami is used to help develop new technologies and teach other subjects. For example, origami can be used to explain and teach arithmetic and geometry, and computational origami employs algorithms and theory to solve complex problems. Visit the section of the exhibit titled "Inspirational Origami: Impact on Science, Industry, Fashion and Beyond," to learn more.
Early High School	27.A.4b – Analyze how the arts are used to inform and persuade through traditional and contemporary art forms.	Explain to the students how the arts can convey powerful messages that move people to action and change. For example, Miri Golan's *Two Books*, has origami figures emerging from the pages of two sacred texts, the Torah and the Koran, reaching out to each other. Through her art, she is attempting to persuade the audience to create a more peaceful world in which people of different religious and cultural backgrounds are united.

Next Generation Science Standards

Grade	**Standard**	**Example of how to relate to exhibit**
K	K-ESS3-3 – Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.	Using the *Folding Paper* educator guide, conduct the "Tin Can Papermaking" pre-visit activity. Discuss the industrial papermaking process and the importance of reducing, reusing, and recycling paper. How can recycling paper help the environment?
K	K-2-ETS-1 – Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.	Using the *Folding Paper* educator guide, conduct the "Tin Can Papermaking" pre-visit activity. Discuss the industrial papermaking process and the importance of reducing, reusing, and recycling paper. Have students watch the following YouTube video: http://www.youtube.com/watch?v=7IP0Ch1Va44 Discuss how deforestation can be minimized through recycling.
4	4-ESS3-1 – Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.	Teach students about the industrial papermaking process. What natural resources are needed to make paper? Does the papermaking process present any dangers to the environment?

9-12	HS-ESS3-1 – Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.	Teach students about the industrial papermaking process. How has the availability of trees and water influenced human activity?
9-12	HS-ESS3-4 – Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	Review the industrial papermaking process. How has recycling affected the papermaking process? Has recycling helped to mitigate the effects of humans on the environment?

Common Core Standards

A. Mathematics

Grade	Standard	Example of how to relate to exhibit
K	CCSS.Math.Content.K.MD.A.1 – Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object.	As you explore the origami in *Folding Paper*, describe the measurable attributes of the works on display. For example, if you are viewing Robert Lang's *Soaring Red-Tailed Hawk*, you can describe the wingspan of the bird, the length of the body, and the approximate weight of the piece.
K	CCSS.Math.Content.K.MD.A.2 – Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference.	Compare and contrast Sadako Sasaki's origami crane with Ruthie Kitagawa's origami crane. Which crane is larger? Which crane is taller? Which crane required a larger piece of paper to make?
K	CCSS.Math.Content.K.G.A.3 – Identify shapes as two-dimensional (lying in a plane, "flat") or three dimensional ("solid").	Examine the origami on display in *Folding Paper*. Is the origami two-dimensional or three-dimensional? How can you tell?
1	CCSS.Math.Content.1.G.A.3 – Partition circles and rectangles into two and four equal shares, describe the shares using the words *halves, fourths,* and *quarters,* and use the phrases *half of, fourth of,* and *quarter of.* Describe the whole as two of, or four of the shares. Understand for these examples that decomposing into more equal shares creates smaller shares.	In the exhibit, there will be an area where you can create your own origami. Have students choose a set of instructions to follow. As students create their origami, describe their folds using mathematical terms. For example, you can tell students they are folding their paper in halves or fourths, depending on which origami they are creating.
2	CCSS.Math.Content.2.G.A.1 – Recognize and draw shapes having specified attributes, such as a given number of angles or a given number of equal faces. Identify triangles, quadrilaterals, pentagons, hexagons, and cubes.	As you explore the origami in the exhibit, have students analyze the component parts of the piece. For example, if you are viewing Tom Hull's *Hybrid Unit Icosidodecahedron*, you may notice it looks like the piece is made of lots of triangles. If you are viewing Tomoko Fuse's *Whirlpool Pattern 00810*, you may notice the piece looks comprised of many squares and rectangles.
8	CCSS.Math.Content.8.G.A.4 – Understand that a two-dimensional figure is similar to another if the second can be obtained from the first by a sequence of rotations, reflections, translations, and dilations; given two similar two-dimensional figures,	Using the *Folding Paper* educator guide, conduct the "M.C. Escher Inspired Tessellations" post-visit activity. Discuss how shapes that can be tessellated can be rotated, reflected, or translated without changing the structural integrity of the shape.

	describe a sequence that exhibits the similarity between them.	

B. English Language Arts Standards

Grade	Standard	Example of how to relate to exhibit
K	CCSS.ELA-Literacy.RL.K.1 – With prompting and support, ask and answer questions about key details in a text.	Explain to the students what an exhibit label is. Have the students choose a favorite artwork, and as a class, read the label out loud. What do we learn about the artwork or the artist from the information on the label?
K	CCSS.ELA-Literacy.RL.K.4 Ask and answer questions about unknown words in a text.	After reading the exhibit label, ask the students if there were any words that were unfamiliar to them. Explain what the words mean.
1	CCSS.ELA-Literacy.RL.1.1 – Ask and answer questions about key details in a text.	Explain to the students what an exhibit label is. Have the students choose a favorite artwork, and as a class, read the label out loud. What do we learn about the artwork or artist from the information on the label?
1	CCSS.ELA-Literacy.RL.1.2 – Retell stories, including key details, and demonstrate understanding of their central message or lesson.	After reading the label, ask students to paraphrase the label in their own words. What was the main message of the label? What does it teach us about the artist and his or her artwork?
1	CCSS.ELA-Literacy.RL.1.5 – Explain major differences between books that tell stories and books that give information, drawing on a wide reading of a range of text types.	Though a label is not a “book,” you can explain to the students that a label gives information about the artwork on display in a museum. Compare and contrast a museum label to a favorite childhood book.
2	CCSS.ELA-Literacy.RI.2.2 – Identify the main topic of a multiparagraph text as well as the focus of specific paragraphs within the text.	Explain to the students what an exhibit label is. Have the students choose a favorite artwork, and as a class, read the label out loud. What do we learn about the artwork or the artist from the information on the label? What specific information is revealed in the distinct paragraphs?
2	CCSS.ELA-Literacy.RI.2.5 – Know and use various text features (e.g., captions, bold print, subheadings, glossaries, indexes, electronic menus, icons) to locate key facts or information in a text efficiently.	After reading the exhibit label, identify text features which locate key facts. In particular, see if you can find the title of the artwork, name of the artist, year the artwork was made, and material of the artwork.
2	CCSS.ELA-Literacy.RI.2.6 Identify the main purpose of a text, including what the author wants to answer, explain, or describe.	After reading the exhibit label, determine the key points about the artwork or the artist.
3	CCSS.ELA-Literacy.RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.	After reading the exhibit label, ask questions regarding the label’s content in order to assess the students’ understanding.
4	CCSS.ELA-Literacy.RL.4.1 – Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.	Explain to the students what an exhibit label is. Have the students choose a favorite artwork, and as a class, read the label out loud. What do we learn about the artwork or artist from the information on the label?
4	CCSS.ELA-Literacy.RL.4.2 – Determine a theme of a story, drama, or poem from details in the text; summarize the text.	What is the main message of the exhibit label? Have students summarize the key points of the label and share with their peers.

5	CCSS.ELA-Literacy.RL.5.4 – Determine the meaning of words and phrases as they are used in a text, including figurative language such as metaphors and similes.	Have students read the exhibit labels and use context clues to figure out the meaning of key words and phrases. What does the text reveal about the artwork on display or the artist who created the work?

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