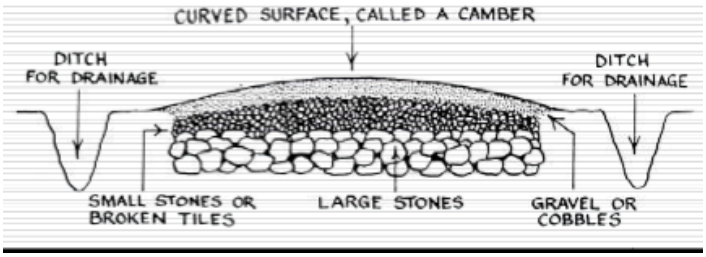
Nomen _____ Dies _____

Engineering Achievements of Ancient Rome

In this lesson, we will be exploring some of the significant achievements of Rome through excerpts from the History Channel documentary *Engineering an Empire: Rome*, as well as passages from various readings below. After reading the passages below and viewing the documentary excerpts, answer the questions that follow.

The Roman Road System

Roman engineers used an instrument called a ***Groma***. It was a pair of boards fastened together into a cross shape, operating much like today's plumb line. Lines with weights were hung from each corner so that they could get a straight line by lining up the weights with a pole a hundred meters or so away.



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Once the road had been planned the Roman soldiers cleared the land on both sides of the road to prevent **ambushes**. They also dug two ditches on either side of the road to act as drains. The earth from these ditches was piled into the center and rammed down. Stones were then gathered from the local area and laid down in different layers until they formed a hard surface that could take the weight of heavy carts. The surface of a Roman road was shaped into a **camber** so that rainwater would run off into the ditches.

1. What is the *Via Appia* and how long was it?

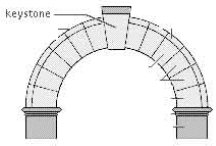
2. What are the markers that make a Roman city?

3. What was the "secret weapon" of Roman engineers that enabled them to grow bigger and stronger buildings faster than any other civilization?

4. List as many reasons as you can why the Roman army built roads.

5. Why was the surface of a Roman road curved rather than flat?

The Roman Arch



Although the **arch** was not invented by the Romans (the Sumerians were the first to invent the arch, and the Etruscans applied it in their architecture), the Romans did develop its use to its full potential. The arch was made by using a variety of materials, such as brick, stone, and **concrete** – a new building material made from lime, sand, and water, along with stones, rock, or pottery. This mixture was then combined with volcanic ash to delay drying time.

The arch revolutionized architecture in the ancient world by permitting far greater spans. Arches were built around a temporary wooden framework that held each stone in place until the keystone was laid in the center. The keystone evenly distributed weight down each side of the arch, allowing builders to stack additional stones above it.

Arches are an improvement upon building a straight wall in a variety of means, both in terms of their efficiency and in terms of their strength. The arch takes much less material to build, and are very strong at supporting structures such as roofs and aqueducts.

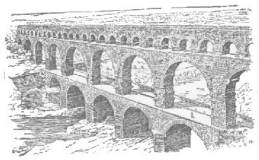
The arch became a basic feature in Roman architecture, seen in the **arcades** of the Colosseum and the expansive property of the **aqueducts**, as the arch could span a long distance with great stability due to the balance of **compression** and **tension** of its structure. The arch was also the basis of other structural forms. By extending the arch, it became a **barrel vault**. By intersecting two barrel vaults perpendicularly, a cross or **groin vault** occurred. By rotating the arch 360 degrees on its axis, a **dome** is formed.

1. Which Roman structures use the arch?

2. What are the benefits of using an arch in construction?

3. The stone laid in the center of the arch is referred to as the "keystone." Using a dictionary, provide another, non-architectural definition of "keystone."

The Roman Aqueduct System



Water is the lifeblood of any civilization. Without an abundant water source, Rome could not have existed. Ten great **aqueducts** with a total length of five hundred kilometers brought enough water for the million inhabitants to use an average of 200 million gallons of water a day each. Most of the water was used in public baths, for the ordinary citizens, and in the private baths of the rich. The water supply and drainage did not go to the upper floors of the houses so dirty water (and waste!) was emptied into the street. The water mains or *aqueducts* (*Aque* = water, *Duct* = carry) were often many miles long and originated from clean water sources far away from the towns.

The Roman aqueducts were designed on the simple principal that water seeks it lowest level; therefore, water flowed down a slope from one area to the next. However, the practice of building an aqueduct is a complicated undertaking. The Romans engineered their aqueducts to approach each city on a gradual

declining angle, or **gradient**, that was just several inches every 100 feet. To maintain the water's precise descent through high mountains, engineers dug perfectly angled tunnels through them. When the pipelines reached low valleys, they were elevated on stonewalled bridges held up by arches spanning the valleys.

Pont du Gard, the aqueduct serving Nîmes, France, is one of the best surviving examples of Roman aqueduct construction. Constructed entirely without **mortar** in 3 levels (w/ a road at the bottom level and the water conduit at the top), it was 160 feet high and stretched 300 yards across the Gardon River. It was part of an aqueduct that delivered 44 million gallons of water daily over a 31-mile distance from the spring at which it originated to Nîmes at a slope of 54 inches per mile.

1. How many aqueduct lines fed into Rome? How many gallons a day did the aqueducts transport? How many people did the aqueducts serve in Rome?

2. How do aqueducts operate?

3. Why were arches used in the building of aqueducts?

The Colosseum

A large numbers of Romans enjoyed watching events such as gladiator fights. This gave rise to the construction of the circular **arena** to hold all the spectators while allowing for direct sight of the action. The Colosseum, while not the only arena built in ancient Rome, was the largest and is certainly the most well known today.

The Colosseum was ordered by Vespasian and completed in 80 CE under Titus. The Colosseum is set at the southeast end of **the Forum**, and was the largest permanent arena, or **amphitheater** built in Rome. (Others were built, though they were temporary ones made from wood.) An amphitheater means "double theatre." It is an elliptical shape, and is approximately 615 by 510 feet in diameter. It stands approximately 160 feet high, and has four floors. The first three floors on the façade have eighty arches with columns in the **Doric**, **Ionic**, and **Corinthian** order (respectively). The top floor had consoles that supported posts onto which awnings would be stretched to shield the audience from sun and rain.

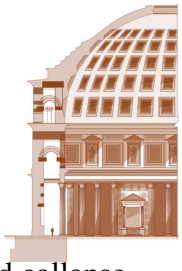
The Colosseum supported up to 50,000 people, and admission was free. Each class or group had different sections to sit in the amphitheatre and up to 80 different entrances to enter from, as reflected in the ticket needed for admission and the numbered archways to enter. The Colosseum set a new standard for amphitheater design. It contained an intricate network of corridors and staircases that quickly shuffled capacity crowds in and out in record time. The complex was designed not only to control the crowds, but also to keep them comfortable. It had 110 drinking fountains and two restrooms large enough to accommodate the capacity crowd.

1. What materials were used to build the Colosseum?

2. Describe some of the Colosseum's features that are shared with sports arenas today.

3. What kinds of entertainment could be seen at the Colosseum?

The Pantheon



The Pantheon – a temple dedicated to all of the gods – was the most amazing structure ever built by the Romans because of its **rotunda**, a huge interior space capped by a magnificent dome ceiling. At its center, the concrete dome rises nearly 150 feet and spans exactly the same length across without any support from columns or buttresses. Its dome remained the largest unsupported concrete span in the world for 18 centuries.

Before Hadrian's engineers could start pouring the dome's concrete ceiling, they needed to figure out how to direct its weight away from its center; otherwise, when they removed the wooden framework holding the ceiling in place, 3,000 tons of concrete would collapse under its own weight.

The dome of the Pantheon was formed by using **concrete**. To reduce the weight as well as to accentuate the design, **coffers** were used, creating a honeycomb pattern made by inserting wooden plates into the concrete and removing them once the concrete was dry. An **oculus**, or eye, of 30 feet in diameter allows light to filter in. The oculus is the only source of light; it is said to symbolize the sun.

1. What purpose did the Pantheon serve?

2. Why is the dome of the Pantheon so remarkable?

3. What techniques and architectural features did Roman engineers use to ensure the dome could stand?

4. What was the purpose of the oculus?

Sources: 1) Uhlig, Susan. "The Artistic Influence of Italy." West European Studies. 2005 – 2006. Indiana University. 04 Feb. 2007.
2) Rome: Engineering an Empire. 2005 – 2006. The History Channel. 04 Feb. 2007