BOOK ONE: THE BASICS

The Fundamentals of Locks, Safes, and Security

PART A: General Principles

General Introduction To Locks and Keys

LOCKS, SAFES, AND SECURITY provides detailed information on the construction, theory, bypass, and analyses of modern locking mechanisms and security containers. The scope of this beginning chapter shall be to present a summary and chronology of major technical achievements of locking mechanisms during the past four thousand years. Particular emphasis will be placed upon developments since the beginning of the nineteenth century.

The historical development of **safes, combination locks, and lock picking** are topics presented elsewhere, but not covered in this chapter. Detailed relevant historical developments for each type of locking system are provided at the beginning of the chapter describing that mechanism.

Lock makers have demonstrated tremendous intellectual energy, cleverness, and skill for over forty centuries. These craftsmen would continually improve upon designs, playing a never-ending game of "security chess" with their opponents; the burglar. As each new feature was designed into a lock to frustrate methods of bypass, a resourceful locksmith, engineer, or criminal, in order to circumvent the last innovation, would develop new techniques.

It is difficult to fathom the problems presented by early security needs. Consider living thousands of years ago as a wealthy landholder, merchant, or banker. You have land holdings and have amassed many possessions of great value. Perhaps you are a merchant, jeweler, or moneylender. How do you protect your valuables, your castle, and your family from robbers and thieves? In the beginning, there were no vaults, electronic alarm systems,

safe-deposit boxes, high security locks, or other devices that could guarantee security. Extremely inefficient yet effective, the hired watchmen together with constant vigil provided the only real security to protect your possessions from the thieves and robbers of the day.

At some point, the local blacksmith is consulted, and asked if there is a way to provide better security through fortified enclosures and secret fasteners or locks. So, the blacksmith sets to work on the problem, apparently in many different parts of the world simultaneously. Such a demand for security was experienced that a special guild would emerge for those who dealt with such problems: locksmiths.

Remember, there is no machine shop, no security industry, nor any high security locks or enclosures. The only materials are wood, brass, bronze, and iron. There are no factories, sophisticated metallurgy, or machinery to make the small and intricate components found in modern locks.

There was essentially nothing to draw from in the blacksmith's experience to solve the problem of protecting people and their assets. There is no history of technological developments. It is the beginning.

So how did we arrive at the end of the twentieth century with such an array of simple to highly sophisticated and secure locking devices and enclosures designed to protect people and their assets. Assets, as defined in our modern world, now include information, perhaps of such a sensitive and valuable nature that improper or unauthorized disclosure or acquisition could literally result in the destruction of the planet.

Chapter 1, then, traces the slow evolution of the lock through four thousand years to present state-of-the-art designs. The organization of the chapter attempts to present the logical steps that must have occurred in the development process.

LSS+ CD/ROM presents an in-depth overview of the history of locks, offering an extensive collection of photographs of both ancient and modern devices. In order to provide the reader with the rich history and perspective of the development of the modern lock, the author has revised two major works of the nineteenth century that are considered the source reference works on the subject of locks, safes, and security.

Fire and Thief-proof Depositories and Locks and Keys, was written by George Price in 1850. This is one of the most comprehensive and authoritative works on locks and safes, providing a chronicle of innovations and developments in locks and safes from their inception.

Locks and Safes: The Construction of Locks was written by Alfred C. Hobbs and edited by Charles Tomlinson in 1868. This book provides another chronicle of the technology of early locking devices, and traces the conceptual changes in design as relates to security. Interestingly, both of these individuals were American lawyers. Mr. Hobbs is credited with having been the first person to bypass the Bramah lock, produced in London. This feat, as will be described subsequently, set the stage for a race for higher security and new designs in locking mechanisms at the Great Exhibition of 1851 in London. That race continues today.

CHAPTER ONE: HISTORY

The Lock: Four Thousand Years of Technology

"And the key of the House of David
will I lay upon His Shoulder."
-Isaiah, CH. XXII, V. 22

Master Exhibit Summary

1_1.0 Introduction

Apparently the need for greater security was felt in a number of societies at about the same time. Around 2000 B.C., evidence can be found that man began to construct the primitive locking devices that would lay the groundwork for forty centuries of development, culminating in today's sophisticated technology.

1_1.1 Original References to Locks and Keys

It is unknown when the original mechanism that could fairly be described as a lock was really created. It appears that the first reference to locks was noted by **Joseph Bonomi(1)** in Ninevah and its Palaces. This described one of the frescos discovered in the ancient biblical city of Ninevah that showed a picture of a lock. The fresco was painted by an Egyptian artist, which provided evidence of dating to that era. The remains of an actual lock, corresponding to the fresco, were found in the ruins of a sumptuous palace near Ninevah. It is believed that this is

the oldest lock in existence.

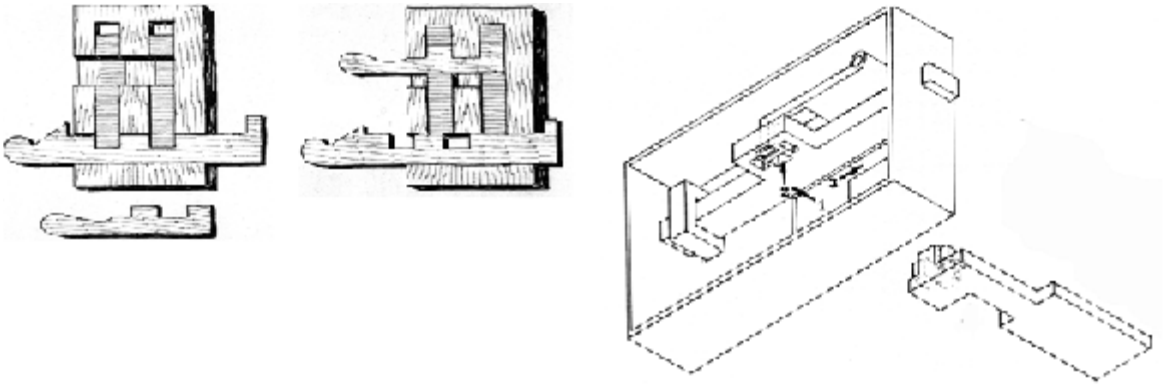
The reference in Bonomi's book described a lock as having secured the gate of an apartment in one of the palaces near Ninevah. He wrote that **"the gate was fastened by a large wooden lock, the wooden key with iron pegs at one end to lift the iron pins in the lock, being so much as a man can carry."** He described the length of the key as ranging from a foot to two feet. The reference clearly described the Egyptian pin tumbler lock.

There are a number of references to locks and keys in the Bible, leaving no doubt that the lock as we understand the concept today, has existed for at least forty centuries.

1_1.2 The First Fasteners and Locks: Greek and Egyptian

It is logical to believe that primitive man's treasures were initially buried or hidden in caves, hollow trunks of trees, or other physical locations that could be easily created or exploited. Once doors or other solid surfaces were employed to secure a perimeter, the next obvious step would have been the capability of locking the door in place. In the beginning, of course, there were no latches as we understand the term today. It appears that the Greeks, who developed crude wooden fastening devices on the inside face of the door, conceived the initial concept of using bars and boltwork. These bolts were lifted from the outside by a cord passing through a hole in the door; later a crude key was utilized.

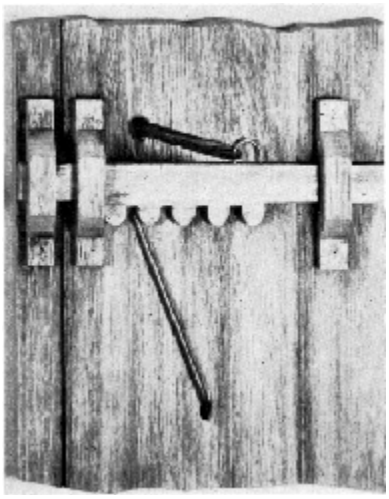
Realizing that one of the drawbacks of the Egyptian lock was its vulnerability to attack, the Greeks placed their locks on the inside of the door but provided access to the mechanism from the outside through a keyhole. Although it is unknown whether the Greeks took these ideas from the Romans, they are credited with the concept of interior locking mechanisms, operable from either side of the door.



They utilized a massive bolt with a large sickle-shaped key. It had a semi-circular blade, measuring a foot or more in diameter, and a long handle that tapered to a blunt point. The Greek "keys" would often be inlaid with precious metals, for locks were utilized by the wealthy. The major problem with the Greek design was that there were very few different key patterns available. Thus, there was little security against bypass through the use of primitive "skeleton keys." The only possible variations (or differs) were those of curvature and length of the key.

1_1.3 The Greek Influence

The development of the Greek and Egyptian door locks appear to have occurred at about the same time. Interestingly, Greeks are credited with making simple bolt-locking mechanisms available to the middle class, while the Egyptian pin tumbler locks were affordable only by the wealthy. In the days of Homer, doors were tied shut with intricately knotted ropes. They were so cleverly laced that only the owner could find the correct method of unknotting them. Moreover, the superstitious beliefs of the times insured that no one would dare to tamper with the ropes, lest a curse fall upon them and their families. Ropes, of course, gave way to a number of different configurations involving the use of a beam of wood mounted to the door.



Some evidence suggests that the first mechanical barring of a door was by a cross-beam that was dropped into sockets or by sliding staples affixed to the door. It is theorized that a vertical pin was probably dropped into a slide to secure the beam. If the beam were to be placed on the outside of the door, then the locking pin would have to be hidden, yet retained and accessible through a hole in the beam or staple. In order to make the lock function from outside, the cross-beam was shortened into a long bolt which was made hollow to allow the pin to be reached. To move the bolt, a **key** was fashioned that had pegs matching the hidden pins within the bolt.

A variation of this early lock was a configuration wherein the pins were reached by holes in the staple, not through the bolt. This design was very popular and was utilized in different parts of the world, including Scandinavia, the Faro Islands, Africa, and the Balkan states. There was a principal difference between the Greek and Egyptian lock. In the Greek mechanism, the key moved pins into position to allow release of the bolt, which then was moved back by hand. In the Egyptian lock, the key actually was used to withdraw the bolt.

The next improvement was mounting the bolt on the inside surface of the door. Keys appear to have been sickle-shaped pieces of iron, apparently put through a hole in the door and used to push or pull a retaining pin.

The final "primitive" style lock also placed the bolt on the inside surface of the door, but with the addition of a **spring** that would spread against the sides of a staple. The key would

compress the spring to open the lock; the bolt could then be withdrawn.

The Greeks are credited with the concept of interior bolt mechanisms accessible through a keyhole. It is interesting and curious that they never applied their intellectual abilities to the design of locks, as did the Egyptians and Romans, in spite of the great academic, political, and scientific achievements of Athens.

1_1.4 The Original Egyptian Pin Tumbler Design

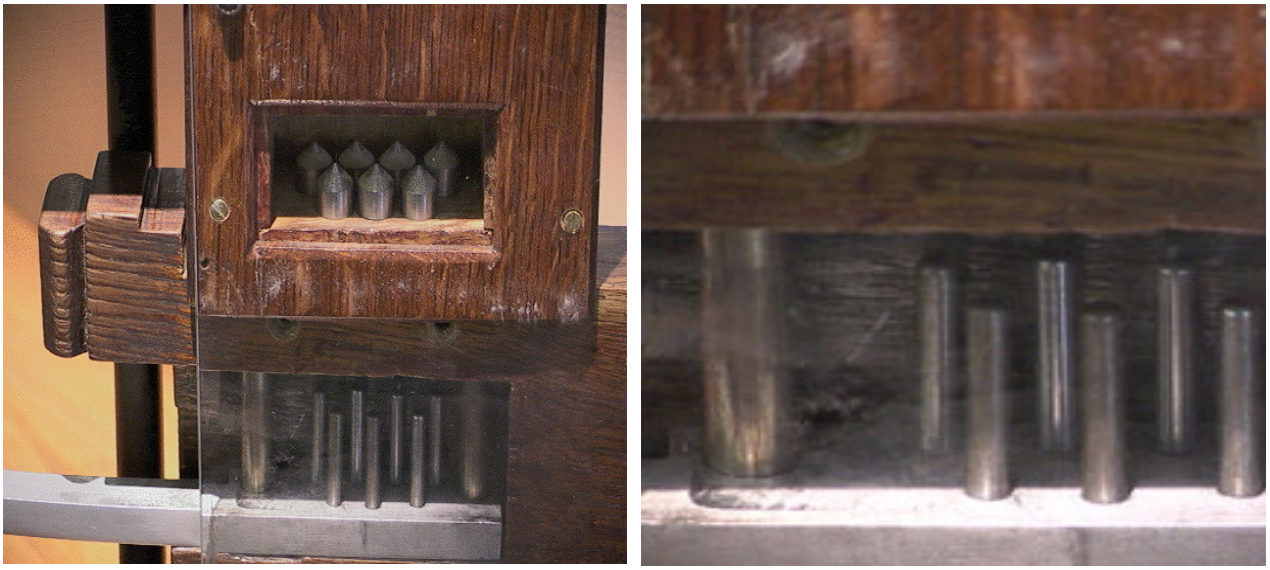
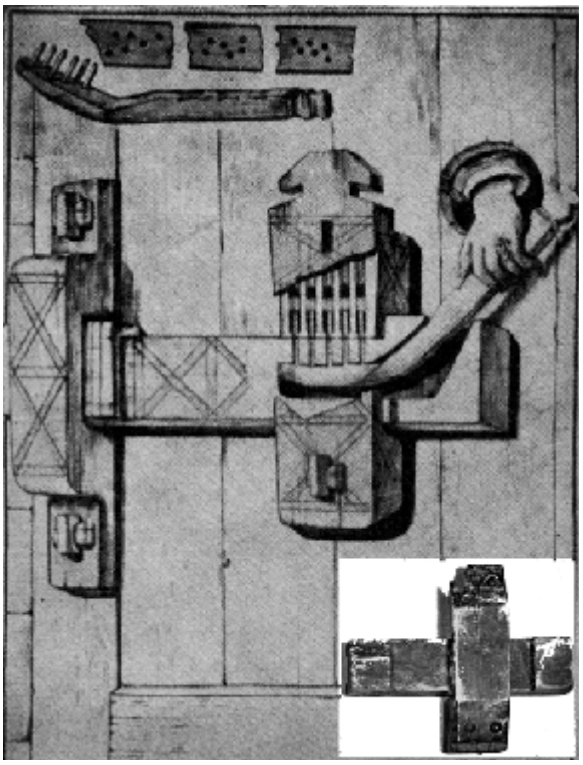


Figure LSS+101. A mock-up of the original Egyptian lock, produced by the British Museum, London. This replica shows the interaction of the protruding pegs with the internal pins.

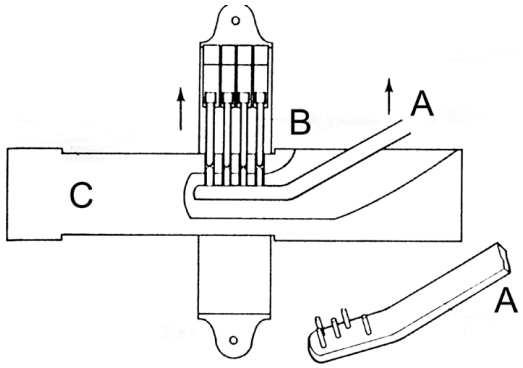
The Egyptian craftsmen are responsible for conceiving one of the principles upon which all modern lock designs are based; the pin tumbler. Their invention would ultimately lead Linus Yale to perfecting and patenting the modern version of that mechanism.

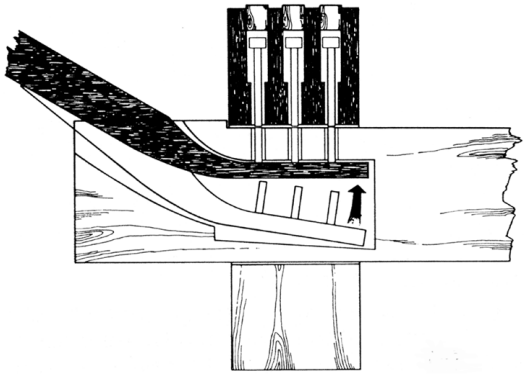
The real genius of the Egyptians was in conceiving **double-acting detainers** that had to be lifted to the correct level in order to create a **shear line** to allow the lock to operate. Their clever innovation set the stage for the development of every mechanical locking mechanism in existence today.

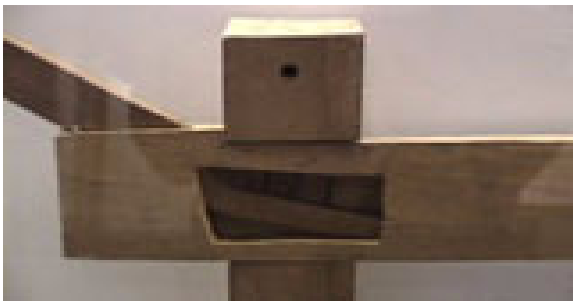


Yale would base his lock design upon this principle, with the further refinement that the detainers or pin tumblers could not be lifted too high or too low: they would have to be raised precisely to the correct height.

The Egyptian lock was attached to the outside surface of the door. First made of wood, later models were constructed of brass and iron and ornamented with inlaid pearls, gold, and silver. The locks measured two to three feet in length. The mechanism was housed in a rectangular container into which the bolt would slide. Inside this hollow container was placed several irregularly shaped wooden pegs or pins, usually numbering from three to seven. They were arranged in random patterns and were set to move up and down. When in the locked position, the pins rested half in the bolt and half within the main lock housing.







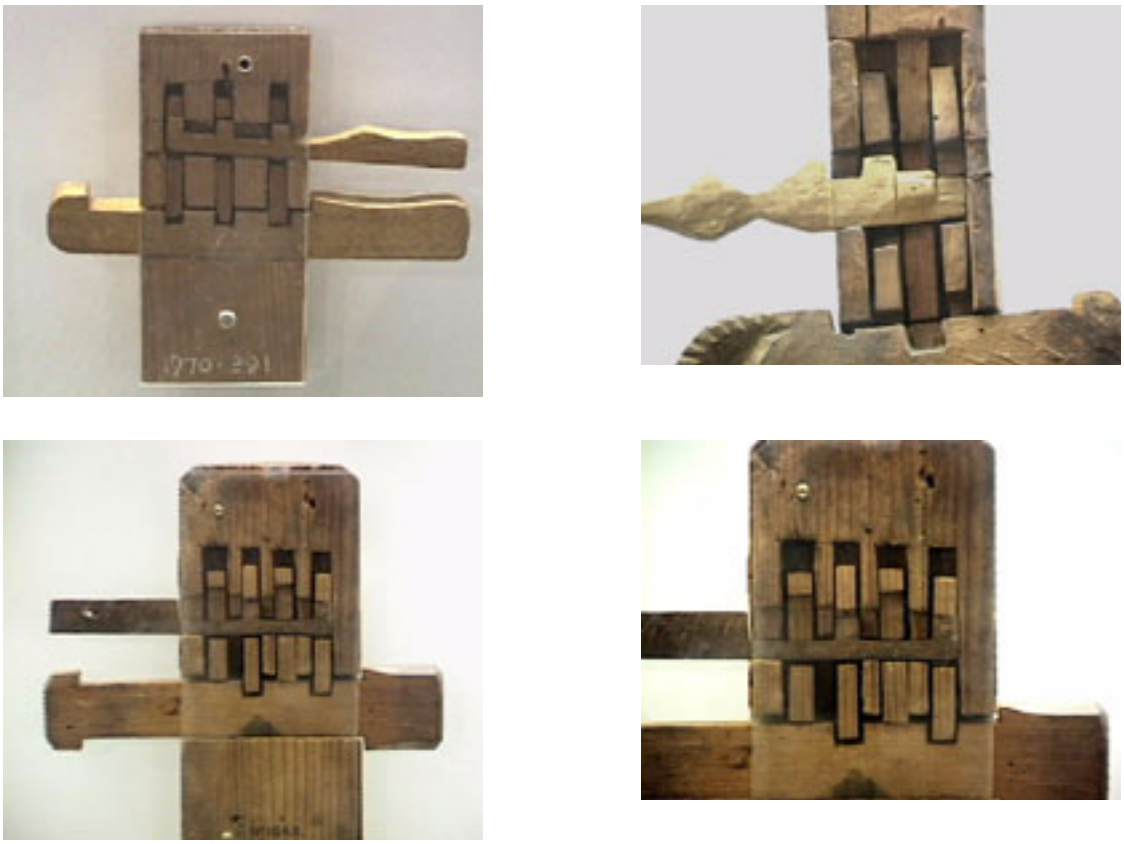
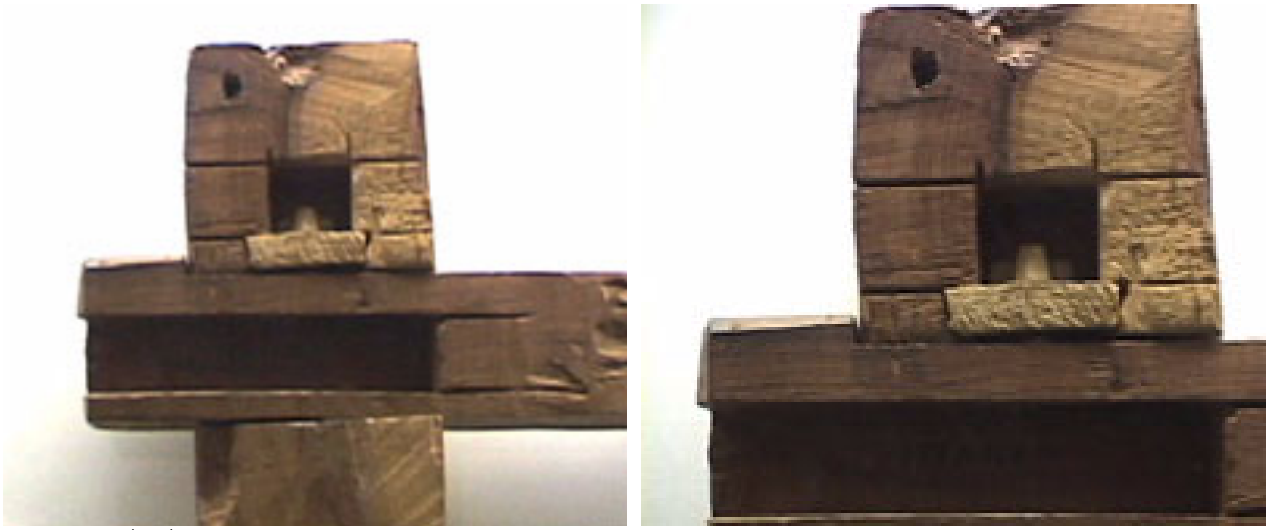


Figure LSS+102. Examples of different approaches to the original Egyptian pin tumbler design. These locks have been gathered from different countries, and demonstrate that the idea of using pins or pegs to secure a moving bolt or locking piece was not unique to any one society, although the Egyptians are credited with the initial concept. These exhibits are on display at the Science Museum in London.



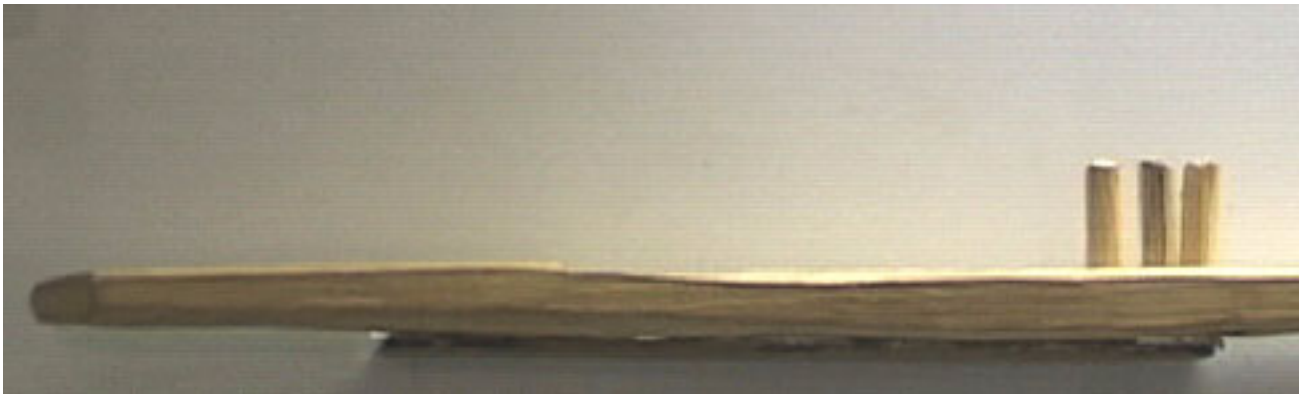


Figure LSS+103. An example of a pin tumbler lock found in North Africa during the last century.

The key for the Egyptian lock was also two to three feet in length and had wooden pegs inset in a vertical position at one end. These pegs were placed on the key to match the pin positions inside the lock. The function of the internal pins was to hold the bolt solid in the lock housing. Keys came to represent a sign of spiritual and temporal power. They symbolized man's ability to gain access to those things he considered to be of greatest significance.

The pin tumbler concept was widely imitated, and even to this day similar locks are occasionally dug up in places as remote from each other as ancient Assyria, Scotland, Japan, and America. Apparently the skill and techniques of the ancient lock makers, as well as the fundamental soundness in design, survived the fall of great empires and even time itself.

1_1.5 Early Roman Locks

The craftsmen of the ancient Roman Empire are credited with a number of major advancements in the development of the lock. Recognizing basic defects in earlier devices, they took the best of the Greek and Egyptian designs to produce sophisticated locks, as well as the revolutionary **warded** design. They also popularized padlocks, originally developed by the Chinese. The Roman artisans were familiar with working in metals; thus they dispensed with large bolts and keys. They recognized that smaller keyholes made locks more difficult to pick. Their keyholes were mounted on the interior surface of the door and were operated with a key from

the outside. Although keys for the Greek and Egyptian locks were quite cumbersome, the Roman counterpart was small, ornate, and intricate.

Evidence of the sophistication of Roman lock design can be found in the ruins of the ancient city of Pompeii which was engulfed by the volcano Vesuvius in 64 A.D. One of the significant finds in the ashes of Pompeii was the discovery that keys were required to rotate within locks **less than 360°** to actuate the bolt. Thus, it appears that the Romans were the first to introduce a **spring-loaded bolt** into their locking mechanism, thereby eliminating the problems encountered in gravity-locking devices.

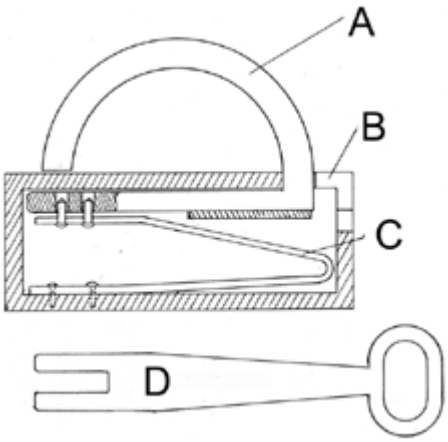
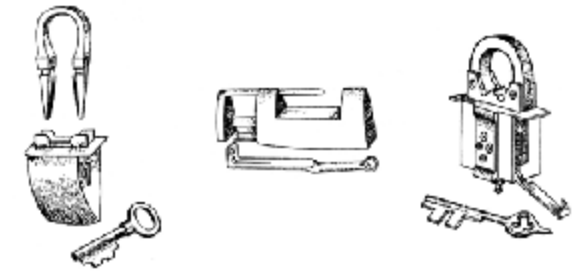


Figure LSS+104. An example of a seventeenth century Persian padlock.

1_1.5.1 Roman Padlocks

Padlocks are the logical extension of fixed mechanisms and provide a connecting link between primitive devices and the beginnings of the development of the modern lock.



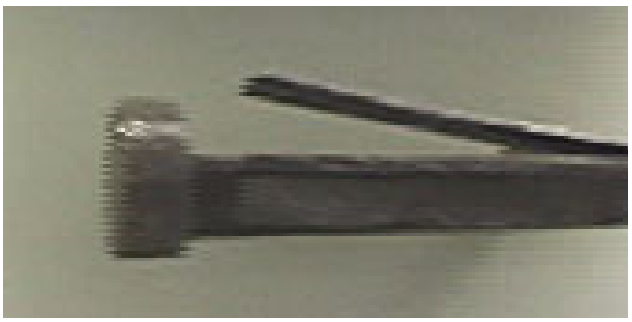


Figure LSS+105. Examples of early Roman and African padlocks.

Figure LSS+106. An example of an early European padlock.

Although the Chinese and Near East peoples developed the padlock, the Romans are credited with having popularized it. They made it a practical device, even going so far as to produce the key as a part of a finger ring for convenience in carrying by the owner. The fact that the Romans had no pockets in their togas may have inspired their locksmiths to devise keys that were small and inconspicuous.

1_1.5.2 Warded Locks

Figure LSS+107. An early warded lock, showing the obstructions to rotation of the key.

Figure LSS+108. This mock-up of a warded lock demonstrates its principle of operation. The key is allowed to rotate the bolt only when the obstructions are cleared. This and the following illustration were produced by the Science Museum, London.

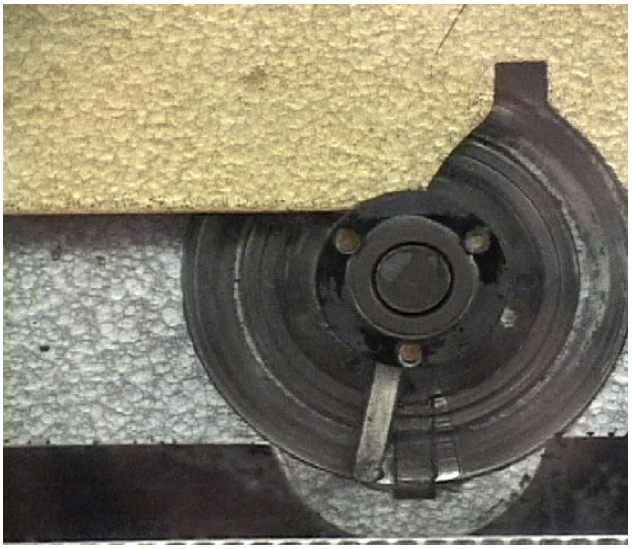


Figure LSS+108 This working model of a warded lock shows the circular wards and how they interact with a key.

While Roman artisans knew that their locks provided greater security, they continued to seek refinements in the mechanisms to frustrate the conventional forms of bypass. The answer came in

the form of **wards** that were incorporated within the lock design. The origin of the warded lock is obscure. It is likely to have been invented by the Etruscans in northern Italy, although recent evidence indicates that the Greeks also knew of the concept. Regardless of its origin, the warded mechanism was perfected by Roman artisans and was to remain the most popular design until the middle of the nineteenth century. It is still found in wide use today.

Wards were a logical extension of the primitive alteration of the shape of a key to frustrate entry into a lock. Some ingenious lock maker discovered that he could place a series of obstructions in the path of a turning key and thus make the lock secure. Only the correct key with the same spaces on its body could pass the obstructions. Thus, the essential principle of the warded lock was to provide one or more internal obstructions to block entrance and rotation of all but the correct key. The incorporation of wards added a completely new dimension to security against picking and led the way for the production of many different shapes and sizes of locks.

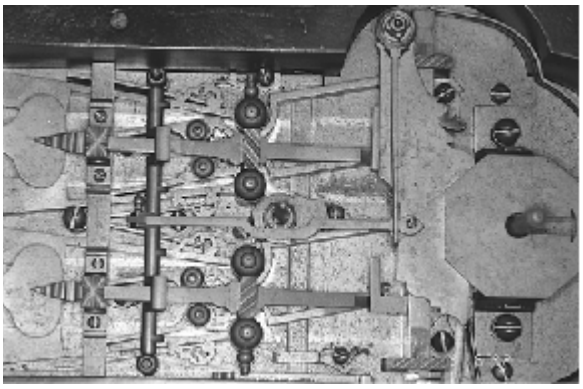
Craftsmen continued to improve upon the mechanism, making the keyway and ward pattern more intricate. Then, when this was not enough, they began to use multiple locks for greater security. As an example, it was reported that in 1415, Queen Isabelle of Bavaria called her locksmith to secure the apartment where the ladies-in-waiting were quartered. The doors were fitted with locks that required five different keys to gain access.

1_1.6 Lock Design during the Middle Ages and Renaissance

The Middle Ages followed the fall of the Roman Empire. While scientific achievements were few, locksmithing flourished during this period in history. Warded locks were now not only complex mechanisms but became works of art. Prestige and respect was accorded those with the most intricate locks.

Figure LSS+109. This is a warded lock that was produced between the fifteenth and eighteenth century. Note that multiple keys were required.

These were the days of castles and knights, of robber barons, and of monasteries containing books and manuscripts of great learning from ancient days. Security took on new and more urgent dimensions.



The warded lock had been designed to perfection, and yet it was not secure enough. The demand for more security increased to match the accumulation of wealth. The late eighteenth century produced the next significant refinement of locking mechanisms: the **lever** concept.

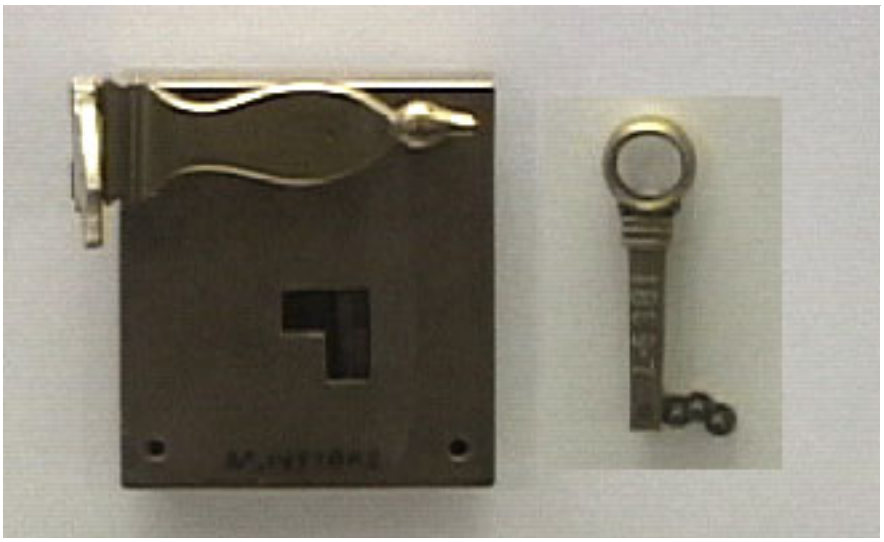


Figure LSS+110. This replica is made from a lock preserved in Pompeii after the eruption of Mt. Vesuvius in in A.D. 79. It closes with a hasp.

Figure LSS+111. Early warded door lock.

Endnotes

1 (Popup - HISTORICAL REFERENCE TO LOCKS)

There is an excellent treatment of the history of the first locks in the George Price book contained within this Infobase.