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CRITICAL REVIEW, ASSESSMENT AND INVESTIGATION OF ANCIENT TECHNOLOGY EVOLUTION OF DOOR LOCKING MECHANISMS IN S.E. MEDITERRANEAN

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ABSTRACT

Door locking is the mechanism for access, control and security that relies on a veiled knowledge of mechanics. However, as a symbol of power, authority, wealth and stature, it can reveal many cultural, economic and social practices and habits. The subject of ancient classical technology of door locking progress mechanisms is full of interest, and has received considerable attention during the last two centuries including recent years. However, it has not been until now the subject of many scholarly studies, that examine issues such as types, operational function and mechanism technology, access feature and security, and manufacturing based on recent archaeological data and findings. This paper attempts to present a comparative critical assessment and investigation of the mechanical and typological evaluation technology, mainly of the so-called Homeric, the simple and smart Hellenistic tumbler Laconian, in addition to the main advanced and elegant Roman door locking with spring mechanism. The paper shall address mainly the Hellenistic gap in material studies, according to recent archaeological records and findings. It suggests that door locking utilizing spring technology is Hellenistic and not Roman as it was believed. In addition the paper attempts to clarify and present some new aspects and suggestions to several misunderstandings about the locking system origin and the know-how of controlling the sliding horizontal bolt movement. These aspects will be critically discussed and clarified through 2D and 3D graphical reconstructions and models.

KEYWORDS: Homeric lock; Smart Hellenistic tumbler Laconian lock; Sliding deadbolt; 2D and 3D graphical reconstructions; Hellenistic Macedonian tombs doors ; One and two-handed operation mechanism

1. INTRODUCTION

In our everyday life, there is no common device than door locks. History of door locking, in fact, represent the history of mechanical security that goes back for several thousand years. Progress of door locking mechanisms progress is full of interest. However, the perception of its design, the action of locking a space to prevent accessibility from others, the cultural implications that it might hold, its dependence on a common social and religious practice, as also on criminological regulations dictate that, "some people have the right to control and restrict others' access to certain spaces or objects" (Gustafsson, 2005, 22).

Unlike other security barriers, locks are designed to be unlocked. From the perspective of the intended key-holder, this also suggests that "locks provide an access-control device that is premised on the notion of appropriate or authorized permission" (Kerr, 2010, 264). In the ancient world, social identity of the key-bearer was also understood as a symbol of status and power (Pace, 2014, 32).

Pace (2014, 108) concluded that "Such materials are more than just a physical barrier in the ancient world, but also serve as a socio-cultural identifier and a means of conveying personal wealth and affluence". On the other hand, locks are "as much technologies of permission as they are technologies of exclusion" (Ian Kerr, 2010, 265), in which "one ingenious detail became the key not only to mechanical locks, but to much of the technology as a whole "(http://www.historicallocks.com/en/site/hl/Locks-and-technology, 2011).

The advanced digital technology, however, has changed the role and manufacture of locking mechanism and keys to the point that, small plastic pieces, digital numbers and codes, within the computer chip inside "acts more effectively than a lock made from a hunk of metal with a key to open it"(Steele, 2013, 5). In theory as also in practice, any mechanical lock that is operated with a key can be picked (Bill, 2005, 297). Meanwhile all locks could be picked, Linus Yale clarified that there is un ultimate danger for any lock based on a key and keyhole to be picked, though the solution is using no key at all (Giedion, 1948, 61-62).

Generally, the origin of locks and keys, and their mechanisms remains ubiquitous in the archaeological records (Pace, 2014, 9). Although the archaeological evidence for early locks remains small, many books, book chapters and articles, have been written during the last two centuries.

Historically, from the beginning all locking mechanisms and keys were completely made of hard wood and strictly avoiding curves, especially those that appear in Mesopotamia and Egypt.

It seems that, wooden-key types arose early in most diverse cultures that relied upon wood as a basic material, and so far as for their main tools. The wooden locking devices were of grand implication; they were noticeably similar in their operational and functional approach. Actually, various specimens of the wooden-key types survived at many traditional door houses and structures in over large parts of the world, ecpecially in the Mediterranean region.

On the other hand, it is not so easy to confirm who inspired whom, in terms of door locking cultural influences, or whether the similarity can be seen as a case of analogous solutions to a common problem or need to all mankind. It seems that, the first simple devices of wooden locks and keys, were probably invented by many early civilizations at the same time. Generally, we can assume that cords and ropes were used to fasten doors, and the legend goes, a knotted cord became a common symbol of security in different early cultures.

According to Curtis and Ponting (Curtis and Ponting, 2013, 58) locks and keys made from bronze and iron were utilized after the Chalcolithic epoch. However, these do not match the Hellenistic locksmithing technology as shall be shown, nor the well established and advanced locksmithing technology found later on in the Roman period (Pace, 2014, 15).

Unfortunately, limited quantities of ancient metal locks and keys have survived from the ancient world, as they had decomposed over centuries. Fortunately, many bronze and iron locks and keys have survived from Classical, Hellenistic, and especially Roman and later times in the S. E. Mediterranean, showing the rapid locksmithing technology development and applications.

Nevertheless, a complete review of ancient technology of locking mechanism is well beyond the scope of this paper. Basically, we can classify two main mechanisms/systems for door locking; the simple indoor and outdoor locking mechanism. In the simple indoor locking mechanism, or the internal locking mechanism both locking and unlocking are obtained from inside the space.

In the outdoor locking mechanism, or the external lock mechanism, both locking and unlocking are obtained mainly from outside the space. Generally, the main difference between the indoor and outdoor locking appear in their functional approach. In the indoor mechanism there is a need for a person to be inside the space, which means that there is no need for a certain key. In the outdoor mechanism there is no need for a person to be inside the space, but there is need for a key.

The stages of utilizing the indoor lock represent the beginning of understanding that by using horizontal or vertical device movement, one can secure and control closing and opening the door shutters from inside the space. The final stage of this development patterned from this indoor locking achievement was the use of a wooden simple lock and key types.

2. INDOOR LOCKING MECHANISM: THE BARRED AND BOLTED

In the indoor locking of single or double doors or gates, the main locking device principle was the "barred and bolted". This device used to protect a space from intruders, whenever deemed necessary, as also at night. Locking a door from inside, though, with wooden bar (*mochlos*[1]), and later on rarely from metal, is the oldest sufficient and simplest locking mechanism principle. It might have been invented along with the door, and it is still in use until today **(Fig. 1a).**

However, little is known about the ancient metal bars; examples of iron bars were preserved in some early Hellenistic Macedonian tombs, within the marble doorways, as it is evident from Eurydice tomb (circa 340 BCE) at Vergina/*Aegae*- the old Macedonian capital- and Potidaeas tomb at Chalkidiki (end of the 4th century BCE). The width of those iron bars were about 5 cm.

Figure 1a A wooden bar hold a double gates together in a straight line (https://www.youtube.com/watch?v=fx-MuPKoal4, 2015).

Many alternatives of wooden barring were used; by means of a cross beam, either dropped into sockets or sliding in staples fixed on the door shutters. A bar could be also placed in two brackets attached to the door, or on both of its sides, then slides back and forth, or into a recess in the side wall. Other door shutters were latched on their interior face with a small pivoted wooden bolt, in which one end was dropped into a slot in the threshold. Plethora monuments from S.E.Mediterranean dated to the early and classical epochs, up till now still show threshold bolts traces, where holes in the sill correspond to the bolts in the valves.

In order to keep the beam in place, in the case of the sliding bar, an additional vertical bolt/ pin might have been dropped into a hole through the staple and bar together, which in turn required hinge pins/ bolts *(Pessulus)* (Winter, 1971, 261-2 , fig. 301-2, Damerji, 1987, 177-179 , fig. 63-66); one on top and one on bottom. This kind of primitive indoor locking were used by the Mesopotamians, Egyptians, Greeks, Romans and continued up till our recent days. In conclusion, the functional and mechanical principle approach of the main indoor mechanism was mainly utilized by means of controlling a horizontal device movement by:

1. One bar and two bolt-sockets set in the doorway posts *(emmochlion*), as shown in **Fig. 1.b,c**. One socket permits the bar in a hole, and the other one with vertical cut above the bolt-socket of the doorway post secure it.
2. Double bar; with two small horizontal bars/ bolt at the doorway posts, one for each shutter. The bar movement was controlled by a horizontal small bolt-pin at the two bar ends, or with U shape bolt socket at the same shutters, sometimes, with a small vertical hole for pin/ peg.

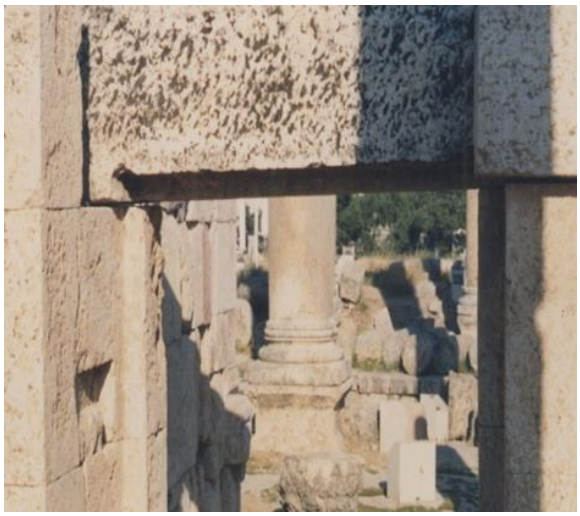


Figure 1b Bolt-sockets in the doorway posts for bar locking from ancient Roman Jerash.

In fact, several archaeological data and literature provide evidence for these simple wooden bars (*mochlos)* that were in use from the earliest stages of the indoor locking mechanisms. The constructions of such simple devices vary in size depending upon the span space that the lock is securing.

Though, large bar locks and bolt/pen as primitive key forms are required to secure larger beams and doorways; it appears that defensive structures relied on these simple methods of securing from unwanted entry as is evident by large numbers of ancient doorways' remains (Husselman, 1979, 40-41).

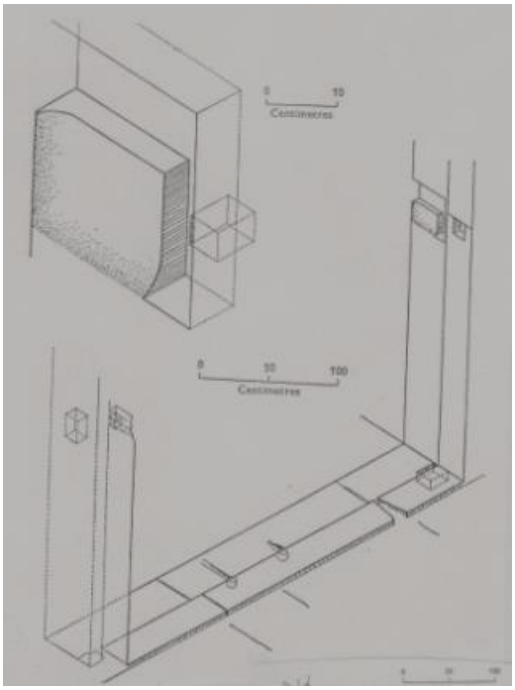


Figure 1c Bolt-sockets in the doorway posts for bar locking from Roman Ostia/ Horrea (Riekman, 1971, fig. 3).

Many traces for such locking mechanisms were found in various ancient door jambs' gates. Some examples were found at the Neo-Assyrian palaces[2], and at some huge gateways with wooden bars from the classical period at Telmissos in Pisidia (Winter, 1966, 135-7), and at the early Byzantine fortifications of Nikopolis, where the bar section in both cases reached up to 30 cm by 40 cm.

From the Roman period, plethora examples were found as at shops and door houses in Ostia (MacDonald, 1965, 122; Rickman, 1971, 33-5, fig. 4-6, 56, fig. 14), at the Roman agora in Thessaloniki and at shops from Roman Jerash in Jordan. Figure 1 (b, c), present examples of bolt-sockets for bars that are preserved in fine conditions at the doorways posts.

3. OUTDOOR LOCKING MECHANISM: THE BEGINNING OF CONTROLLING THE SLIDING HORIZONTAL MOVEMENT OF THE LOCK BOLT

In order to prevent access from the outside, and protect valuable objects or hinder somebody inside from leaving, a simple bar or bolt is inadequate; it has to be secured by a lock. The basic technological concept of the first outdoor locking system, though, was to provide access from outside to inside, and emerge in developing a smaller and more complex mechanism, fastened on the interior shutters' face, for controlling the bolt horizontal movement.

This was achieved by a small horizontal sliding wedged shape bolt that could be moved in both directions, by using a primitive key quite large and crude in design. These wedged shape bolts can be divided into two categories: mount and casing[3]. The key shape, though, should rely on general attributes that outlined its function, and reflected the details of the same lock body structure.

As an exception, however, to this system, are some interesting straightforward metal simple devices for only one use. These are found in many early Hellenistic marble doors at Macedonian tombs. They are preserved *in situ* at Phillip II tomb, Prince tomb, Romious and Bella tombs at Vergina (Haddad, 1995, 213). The locking device consists of a small vertical bolt-pin *(kataraktis),* with a small piece of rope *(chalstirion),* and bolt socket (*ballanodoki)* in the threshold. The functional approach of this "*chalstirion kataraktis*" device is shown in **Fig. 2.**

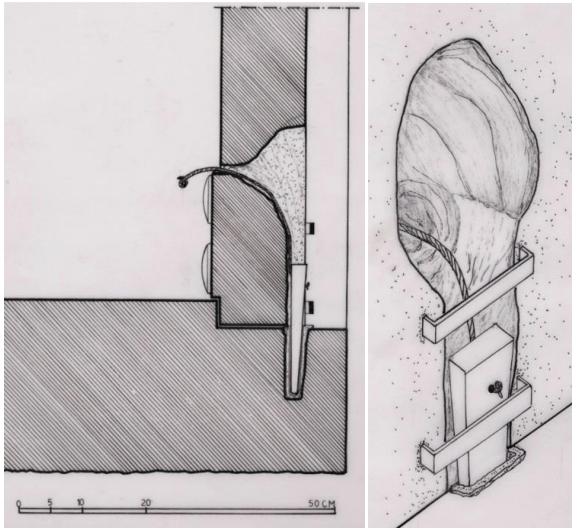


Figure 2 Illustration showing simple outdoor lock device for only one use found in situ in many Macedonian tombs with marble doors.

3.1. Outdoor Locking Mechanism by the so-Called "Homeric Lock"

Because locks are fragile and provide little security, typically they are placed on the interior surfaces of the door shutters. The first really well documented outdoor locking device mechanism found in both ancient text and archaeological sites, is the so-called "Homeric lock and key" or, as we here term it, "Bolt-rammer". It was confirmed accurately by Homer's *Odyssey* descriptions[4]. From some of Homer's verses, we can confirm its functional approach and its usage

in Greece at least since Homer times (eight century BCE).

Basically, Homeric locks do not have a casing, as such devices operate on few parts; the bolt, rope, and key (James and Thorpe, 1994, 468-469). More analytically, this earliest outdoor locking mechanism had a small wooden cross bolt mounted on two wooden brackets, or wooden latch at the interior shutter face of the doorway. To unlock it, a person from the outside through the keyhole *(kleithria)*, could control the bolt's horizontal movement and slide the bolt back to open position by using a very angular metal key of bronze or iron. In addition, a thin cord/rope or leather strap was attached under the bolt, passing through another hole in the shutter to slide the bolt from the outside. To lock the door shutters no more was required than pulling only at the cord/rope *(Stropheion)* or the leather strap, as shall be discussed and shown in Fig. 5.b,6.

The Homeric lock dimensions vary between 15 to 30 cm, meanwhile the key length varies between 20 to 40 cm **(Fig 3.a,b).** The disadvantage of this locking mechanism is that it can be locked much easily more than it can be opened. However, compared to the latter developed locks, it provides little security. From **fig 3.c** ,we can also note how the key hole position is so high in relation to the door shutters.

It should be also clarified that meanwhile the Homeric key was used to secure spaces from entry and access of persons from outside the door, however, any one inside the space could lock or unlock the bolt thus open the door without the need for the key.

Many data provides evidence for its usage from early times to present, especially at the traditional and vernacular openings at the Aegean Islands (Dawkins, 1902-3, 191-3). The Homeric style devices were also, till recently, still in use amongst some Ethiopian villages (James and Thorpe, 1994, 469)[5]

Its origin, goes back to ancient Egypt and Palestine (Dawkins, 1903-4, 102; James and Thorpe, 1994, 469). Parts of simple locks much akin to the Homeric functional approach were also retained to Khorsabad; these utilized beams set inside copper rings to shore up the door shutters and gateway doors, likely for indoor bar internal locking security (Curtis and Ponting, 2013, 56-57).

However, while locks and keys used in early Egyptian dynasties were mostly made from wood, the Homeric bent metal key might have developed from it. But, compared to the wooden key type, according to Giedion (1948,74), it never travelled very far, especially for the traditional and vernacular doorway shutters.

Figure 3 a) Second Homeric type Celtic angled bronze key (length 40.5 cm) from Artemis temple in Lusoi, Arcadia (5th century BCE). The original is at the Museum of Fine Arts in Boston (Sketch by the author). b) A temple servant carries a giant Homeric key on her shoulder form an Attic votive relief of the fifth century BCE (After Diels, 1914, 40. fig 19). c) Representation of a young priest woman opening the Treasury door with Homeric key on a classic (fifth century BCE) red-figure hydria (Diels , 1914, 43, plate VI).

Several Homeric keys, dated from the Classical and Hellenistic period were found at many Mediterranean sites (Diehls, 1914; Haddad 1995), as also some representations on vase paintings (Fig. 3 c) and at Attic tomb's reliefs (Fig. 3,b). The Homeric key as a straightforward mechanical device, in fact, had a symbolic religious origin (Miller, 1993, 68), as a votive key, where the housewives of ancient Greece offered it to enlist the help of the goddess Hera in the task of protecting their homes (Resco, 2009, http://www.tfahr.org/key.html).

3.1.1 Investigation of the Two Types of the Homeric Lock and Key

Based on the survived metals mainly keys and some bolts from different archaeological findings, we can confirm that there were two main types of the Homeric locks and keys. These two types can benefit the field methodology in archaeology.

The first type is with double bent side or the "bent pressure key". Such examples were found at Argos, at the urban Heraion and at Paestum (Fig. 4. a), and at the Acropolis of Bylazora, dated to end of the fifth century BCE (Fig. 4. b). In this type the key shape is resembling the human collarbone, which thus gained its name of key-bone or clavicle (Diehls, 1914, 46).

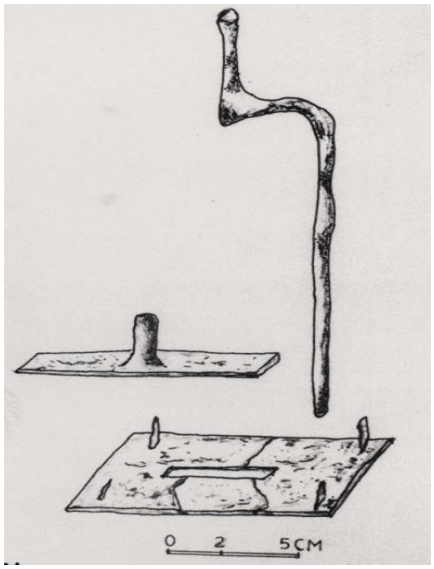
a *b*

Figure. 4. a) First type of double bent side votive keys from Paestum (Resco, http://www.tfahr.org/key.html, fig 8). b) First type of iron votive key discovered at Bylazora, (After Resco, 2009, http://www.tfahr.org/key.html, fig 1)

The second type is with one only bent side or the "straight pressure key" (Figures 3, 5). Its bends and long shafted crank bring to mind the handle of a car jack. Many examples were found at S.E. Mediterranean sites from this type; at the Heraion at Foce del Sele, dated to the end of the sixth century or the early fifth century BCE (Montuoro, 1965-66,183), and the well known **Celtic** key of the sanctuary of Artemis in Arcadia dated to the 5th century BCE (Fig. 3. a), where the priestesses carried such a long heavy key over their shoulders (Fig. 3.b).

It was used also at the classic period houses in Olynthus. Later on, it continued to be used in the Hellenistic period such as at Kallipolis, at Dodoni and at many Macedonian tombs at Thessaloniki and Dion (Fig. 5. a). It was also used in Roman and early Christian periods (Haddad, 1995, 215-17).

According to Resco, there is a slight variation between those angled two keys types in shape, that might indicate some chronological information; the bent pressure keys of the first type seem to begin to cease in use during the fifth century BCE, and was replaced by the straight pressure second key type (Resco, 2009, p.5, http://www.tfahr.org/key.html).



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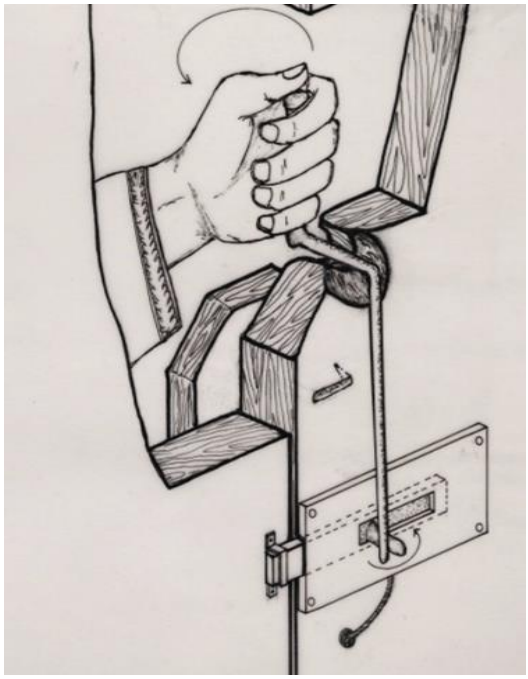


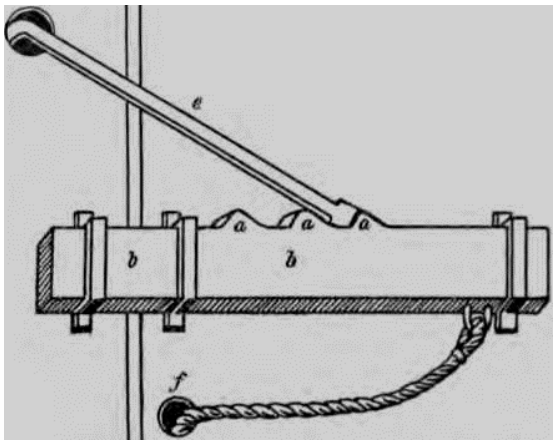
b

Figure 5 a) Second type Homeric lock and key from the wooden door of the Macedonian tomb II in Dion (After Haddad, 1995,plate 110, c). b) Haddad's proposed reconstruction of the second type Homeric Lock (After Haddad, 1995, plate 111).

3.2. Critical Assessment and Investigation of the Functional and Mechanism Approach of the Homeric Lock

The form, shape, dimensions and composition of a key are indicative of its functional mechanism and the level of simplicity or complexity of the lock size and manufacture. They also reveal the mentality behind the key's creators and craftsman. The key structural formation, though, can present and illustrate the crux for understanding and shaping the lock typology. This while "the form of a key always follows its function as each key is crafted for a specific lock"

(Pace, 2014, 7). Just the same can be said about the manufacture and form of the lock mechanism; it will at least pronounce the type of the key, if not the exact formation that is needed for any reconstruction endeavor.



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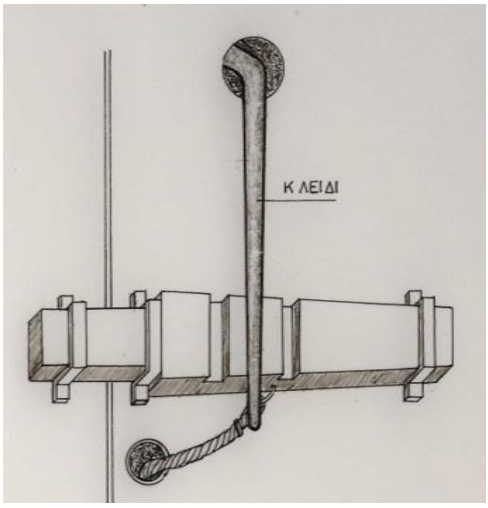


b

Figure 6 a) Brinkman and Diels (1924) proposed reconstruction of the second type wooden Homeric lock (Diels, 1924, 50, fig. 14)
b) Haddad's proposed reconstruction of the second type wooden Homeric Lock (After Haddad, 1995, plate 109, b).

As shown above, the Homeric lock as "bolt-rammer" has certain functional parts (see Fig. 5. a, b, 6). However, there is a debate and misunderstanding concerning some functional details of the mechanical operation of the way of shooting the bolt for both of the two types. Regarding the second type, Brinkmann (1900, 44), Diels in his work *Antike Technik* (1924, 40, 51; 1914, 136, Figs. 23, 24) and Neuburguer (1919, 339) were the firsts to put forward a reconstruction.

Resco (2009,http://www.tfahr.org/key.html, p.5) later on, in his article the votive key of Bylazora, followed also the same stream, based on the reconstructed model of Neuburguer (1919, 339). All of them in their reconstructions for this type (shown in Fig. 6.a) agreed and considered that:

1) The key hole and the bolt were placed at different shutters**.**

2) In order to displace the bolt, its upper surface is shaped with horizontal stops/bosses to be controlled by the straight pressure key.

3) The inserted key into the key hole put pressure on stops at the top of the bolt

On the other hand and according to Haddad's (1995, 216) reconstruction of the Homeric lock, which is based on recent archaeological discoveries from wooden and marble doors at early Hellenistic Macedonian tombs, and from a stone door tomb, dated from the early Christian period, he clarified and considered that:

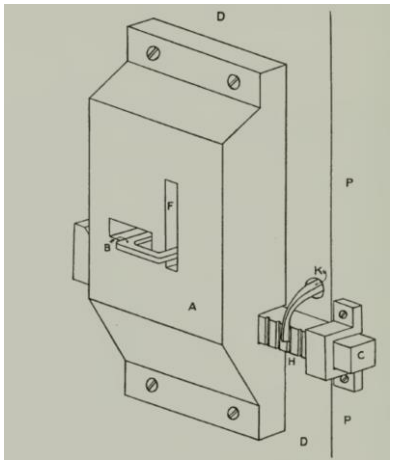
1) The key hole and the bolt should be situated at the same shutter**.**

2) Regarding to the bolt outline, he has suggested two feasible operation techniques for the bolt functional mechanism approach. More analytically:

The bolt outer surface is shaped by vertical grooves as shown in Fig. 6.b. One might assume that by proposing vertical grooves cutting at the bolt body, it is not so easy to carry out the needed operation. However, based on a unique preserved metal bolt found at an early Christian stone door tomb that has vertical grooves, and in which the key hole and metal bolt are also existing at the same shutter, we should accept that, most probably, this formation was also used at the wooden Homeric bolts. This assumption is also strengthened by some handcrafted traditional wooden door locks from Karpathos (Dawkins, 1902-3, 192-3, fig.8,9) (Fig. 7 a) as also from a recent publication (2012) at San Benedetto at Perillis, a traditional village in central Italy[6] (Fig. 7b). These vertical grooves, are similar to what can be seen in the mentioned example from the early Christian stone door tomb.

The second type bolt operation technique is based also on survived materials of both iron locks and keys that were found at some stone and wooden doors of early Macedonian tombs. In these doors the key hole and bolt are also found at the same shutter. These have a notched iron bolt encased in the lock case and consists of only one protrusion/ boss, as shown in Fig. 5.

These Macedonian Homeric metal bolt types, in addition to the wooden traditional examples, are actually a reproduction of the Homeric archetype bolt. Therefore, we should agree that, at least there were two alternatives for the formation of the Homeric bolt functional operation mechanism.



a

b

Figure 7 a) Wooden lock from Karpathos (Dawkins, BSA, X, 1902-3, 192-3, fig.8). b) Hand-crafted wooden door lock from the traditional village San Benedetto in Perillis, Italy (Soldati, 2012, https://www.youtube.com/watch?v=9zp2Xi5OnUM).

In comparison with the above discussed second key type, the Homeric first key type, the double bent lock or "bent pressure keys, unfortunately there are no archaeological data and findings that could enable us to comprehensively reconstruct how the bolt functioned. There are three totally different conceptual suggestions for the bolt mechanism operation.

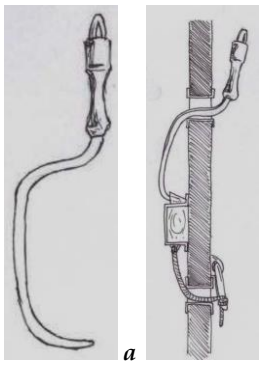
The first suggested simple mechanical appraoch for this type is the one shown in the second type, in which the bolt outer surface is shaped by vertical grooves as shown in Fig. 7.a.

Hwoever, Resco in the beginning, (https://www.youtube.com/watch?v=9zp2Xi5OnUM. 2009, p.4) had suggested that, the key whole and the bolt were placed at different shutters, while the key was inserted into the bolt orifices to press and move it, as shown in Fig. 8.

This suggestion is impractical and unreasonable, as it is extremely hard to be carried out. However, it is greatly reasonable that this type was functioned as later on (2013) suggested also by Resco[7].

In his new 3D graphical reconstruction and real model operational test, this time, he rightly considered that the key whole and the bolt have been placed at the same shutter. As shown in **Fig. 9**, the main wooden bolt body is curved by a quarter circle groove, so that the key could efficiently move the wooden bolt and open the shutter form the outside. Meanwhile the closing could be achieved just by means of a small rope/cord fastened beneath the surface of the bolt.

Finally, in comparison with the latter Laconian lock, the Homeric locking mechanism provides little security. However, the Homeric lock practice in some Macedonian tombs' doors, appear to be manufactured not only for practical reasons, but also for a symbolic sealing of the property, as well as an actual restriction of access to property.



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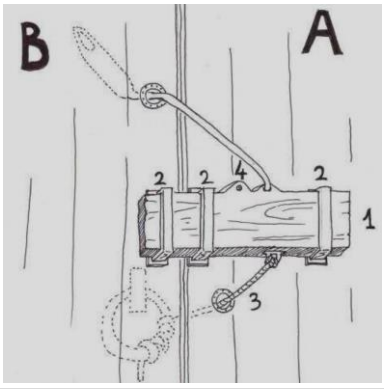

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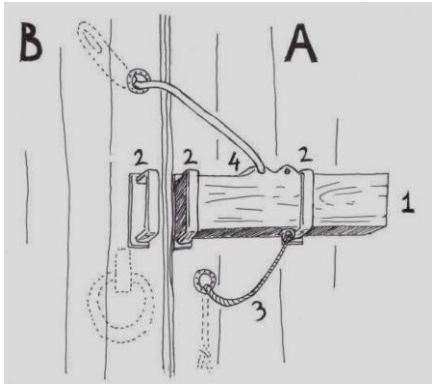


d

Figure 8. a) First type, diagram of a Bent Votive Key b) Section of a door with a bolt-lock prepared for this type of key. c) First type, diagram of the operation of this type of key before opening the bolt. d) First type, diagram after opening the lock (After Resco, 4-5, fig. 3, 7).

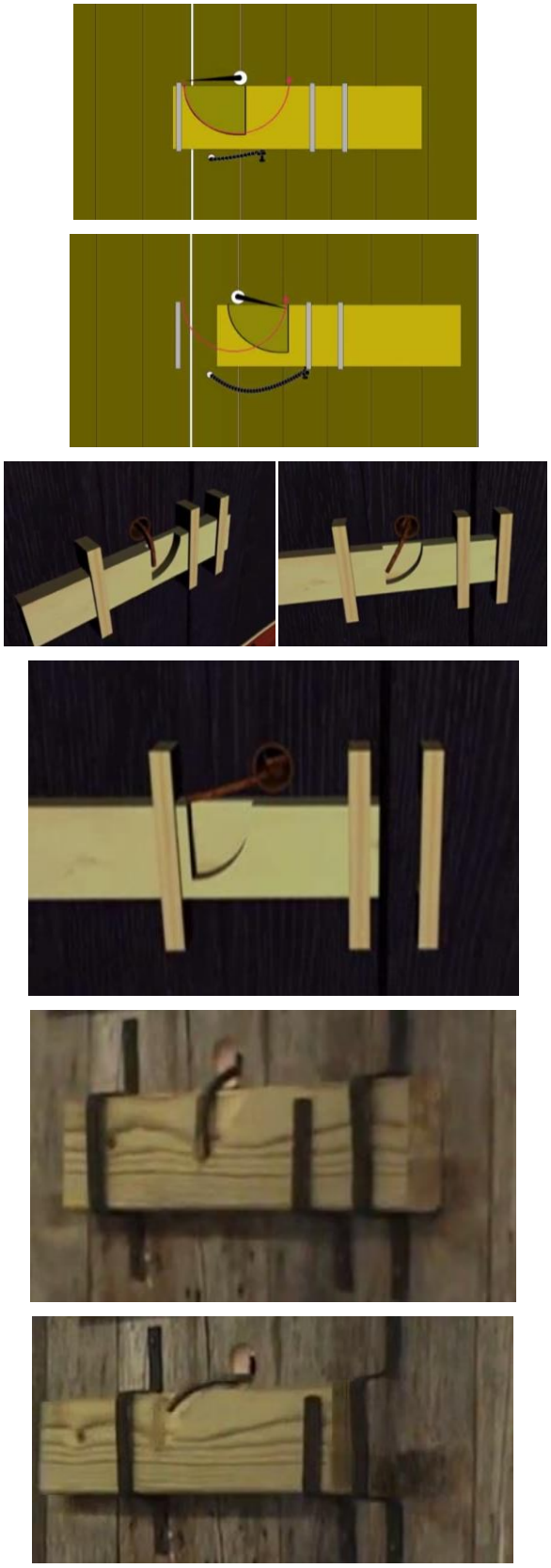


Figure 9 Different selected images from the video, showing the main stages of Resco reconstruction of the first type functional approach of Homeric lock (Resco, 2013, https://www.youtube.com/watch?v=GuHritO7Nww&noredirect=1).

It seems that whether the lock was functional, the symbolic nature of the thing also suggested a robber that the owner would protect the contents by any means. Nevertheless, we can assume that the function and responsibility of, and for, such Homeric locks and keys was more eternal.

4. OUTDOOR LOCKING MECHANISM: THE BEGINNING OF APPLYING OBSTRUCTIONS FOR OPERATING AND CONTROLLING THE LOCK SLIDING BOLT'S HORIZONTAL MOVEMENT

Given that the bolt types of the Homeric lock, do not operate on a complex system of prongs or levers since a simple key is needed for the operation (Pace , 2014, 17), and as a new door locking system had to be more robber resistant than the old, a different mechanical approach then was needed. So, the key's new function is now to control some obstructions' movement that held the bolt in place. This means that the key must be made first, to match these obstructions in the bolt body, and should reflect the exact formation of the key prongs arrangement (see Fig. 10).

This conception was achieved by the so called Laconian lock and key. In fact, the idea of the developed Laconian locking mechanism is more complicated in comparison with the Homeric one. It is also more practical and secure; here by means of obstructions in the same bolt to prevent the wrong key from entering and sliding the bolt.

According to Giedion, the origin of the Laconian lock, should be traceable to an archetype other than the simple bent metal key type of the so-called Homeric lock, and this new product was of a culture experienced in the working of metals (Giedion, 1948, 74). By the invention of this lock, actually, a new direction in the functional, mechanical approach and in the evolution of the history of outdoor locking mechanism was started.

4.1 The Simple Warded Laconian Lock Functional Mechanism in Classical Greece

Archaeological excavations of classical Greece have revealed many metal keys in a wide range of shapes and sizes for such a mechanism. The Laconian lock type was named after many finds in Laconia in the southern part of Peloponnesus in Greece, the well known Greek mining centre, where the metal industry flourished. From Laconia, it spread to the rest of the Hellenic world (Giedion, 1948,73) of classical Greece (Olynthus, ancient Kynouria) (Robinson, 1941, 507).

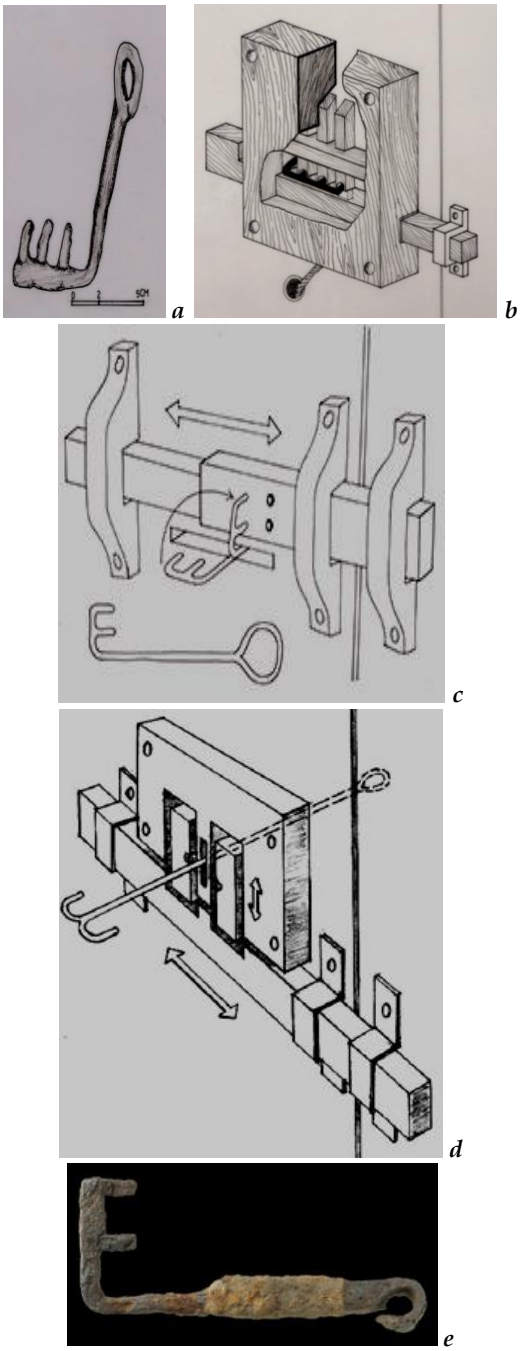


Figure 10 a) Iron Hellenistic plain Laconian key with three prongs from Thrace/Greece (After Haddad, 1995, plate 112, a). b) Haddad reconstruction of the simple wooden Laconian Lock (Option 1) (After haddad, 1995, plate 113). c) Hellenistic sliding bolt lock of wood with metal key (Option 2) (After http://www.historicallocks.com/en/site/hl/Other-locks/Locks-of-wood-and-iron/Sliding-bolt-locks/). Published 22 Jan 2008). d) Wooden pull lock with anchor-shaped metal key (After http://www.historicallocks.com/en/site/h/other-locks/19-keys-and-locks-from-imperial-rome/roman-door-locks/roman-door-locks---more-images-3/). e) One of the Roman keys which were discovered during excavations at Cambourne in Cambridge shire(https://www.flickr.com/photos/wessexarchaeology/311186507/in/album-72157619350562063/)

The use, however, of Laconian locks, is also maintained by *Aristophanes'*(445-385 BCE) women, as has been pointed out (Diehls, 1924, 46). The women complained that the bad men have locked and unlocked the door with the aid of a three-pronged/ "three-*gomphos*" key[8].

This indicates that how much the Laconian keys were distinguished having three prongs/teeth, and how much notably were common in Laconia (Fink, 1890, 22-31)[9]. According, however, to the archaeological finding of such keys the number of prongs varies between two to four.

Many such metal keys, dated to the early Hellenistic period, were found at Florina, at Olympia and at Thrace (Fig.10. a) (Haddad, 1995,218). This locking mechanism was also in use in the Roman period (Gaheis, 1930, 252) (Fig.10.e), and continued in the Viking age (8th–9th Century) (Steele, 2013, p.21, fig. 20-22) uptill the end of the 19th century in some Isles of Aegean Sea and Cyprus (Dawkins, BSA, X, 1902-3,190, fig.7-9).

The sliding bolt of these locks might come in different shapes, but all worked in more or less the same way. Based on the flat notched L- shaped key (Fig. 10. a, c, d, e), two main probable locking mechanism types can be suggested for its key/bolt operation. They came either in two-handed or one-handed operation design. However, we can add a third openning option, based on the operational mechanism of the Homeric lock, as already shown and disscused for the Wooden lock from Karpathos (Dawkins, 1902-3, 192-3) (see Fig 7.a).

In the one-handed operation, the opening and locking rests directly in the construction of the double bolt feature, in which the exterior part houses the interior one, and not on obstructions. To allow the bolt to be shot there were carved slots/holes, aligned in preselected positions with the key at the exterior face of a two parts' bolt body, as shown in Fig. 10.c.

Though, in the one-handed suggested type it was operated mainly by a metal key formed with two to three prongs. The key is inserted through a narrow slit hole in the door shutter, and matched up with analogous slots engraved at the same bolt body, allowing the bolt to be moved in either direction. The advantage of this one-handed operation, allows the user to insert directly the key into the lock bolt, then sliding the bolt out of position for entry. However, this suggested functional approach is akin with the Homeric bolt operation. This solution is also fragile; it is structurally weak, particularly when it is applied to small wooden size bolts.

The two-handed system operation is a tumbler lock type, depending on removing obstructions' access from the bolt. This locking mechanism relies on gravity to pull the ward tumblers down into posi-

tion. The mechanical principle here is by means of raising parallel pins/pegs/wards (fixed projections in a lock) on pivots as shown in Fig (10. b, d) mostly in encased bolt lock, to allow and control the bolt sliding horizontal movement. Here the key is inserted in the tumbler pins themselves, but they are falling independently of each other. However, with no key in the lock, all the wards stack cuts rest within the plug. The deadbolt was then pulled to the open position with the assistance of a rolling rope / cord attached to the bolt. Then by using the second hand to withdraw it from the door shutter (Fig. 10 b), analogous to the closing in the Homeric lock. Though, this locking system consists from a small horizontal bolt-pin *(Ballanos[10])*, bolt socket *(Ballanodoki)*, and metal key *(Ballanagra)* (Haddad, 1995, 207).

The two-handed tumbler locks, actually, required more dexterity, as the key have to be inserted into a certain position to lift the tumblers, and synchronously using the other hand to throw the bolt. However, in the examples of the Isles of Aegean Sea, these are off shoots of a worldwide dissemination as Dawkins points out; these are also found in a composite type, with two keys, one of which is used to ram the bolt; "a descendant of the Homeric lock"[11] (see Fig. 7.a).

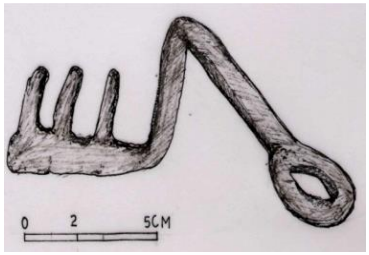
In conclusion, this mechanism body is the first patent for a pin tumbler lock housed within a casing. The disadvantages of this Laconian locking type appears in the opening and closing of the door, where two hands are needed. In comparison with the suggested first one-handed operation type, this type cannot be opened from inside the space. However, it can not be easily picked or opened without its key (see Fig. 10.b).

4.2. The Technological Change: The Smart One-Handed Operation Tumbler Hellenistic Laconian Lock Functional Mechanism

The typical Laconian lock key shape, of the second type, the two-handed lock, is slightly different from many examples that survived, dated mainly to the early Hellenistic and Roman periods (Fig. 11.a,b,c). In these examples, the bent L shaped key (Fig. 11, 12.a) is noticeably divided into three sections: the handle, the shank, and the bit. All these three sections play an integral role in the lock function. This new smart key, where its function is held primarily in the bit; if bitted to the wrong shank, and bit depth and height, it will not allow the lock to operate even with one pin in position.

The new structural formation of the smart Hellenistic Laconian key type (fig.11) is probably a post-Egyptian period achievement. Even it cannot be traced with certainty to classical Greece. Tangible evidence, till now, begins only within the early Hellenistic period. Findings from early Hellenistic Greece, especially from Macedonia at Florina, Peters, Vergina, Pella, and Aiani (Haddad, 1995, 219-20, plate 112), provide such strong evidence (Fig. 11.a).

From the Ptolemaic period similar metal keys were also found. Figure 11.b shows a key from the product of this technically advanced period flourishing under the Ptolemais[12]. Interestingly enough is that, such locks and keys of small sizes were used also for small boxes. Such locks and keys were found in Veroia in Macedonia/Greece in some rock-cut tombs dated to the second century BCE. The key length is only about 5cm and the bit is designed with double rows each with four prongs.



a

b

c

Figure 11 a) Iron Hellenistic smart Laconian key with 3 prongs from Florina/ Greece (After Haddad, 1995, plate 112, b). b) Iron Key from Ptolemaic period. From Lord Carnarvon's excavations at Drah abu'l Negga, Thebes. (http://www.wclca.net/keys.htm). c) Smart Roman Laconian massive iron key (5.2cm) from Ancient Rome, c. 1st - 3rd century AD. (http://www.ancientresource.com/images/roman/keys/roman-iron-key-ar2317.jpg)

Many Roman similar examples of this Hellenistic smart Laconian type for door keys were also found. One of those appealing keys is a Laconian Roman massive iron key from ancient Rome (c.1st - 3rd century AD) shown in Fig. 11.c. These keys sometimes are with more than three prongs in each row. They

are found with double or triple rows as shown in the example from Jerash in Jordan (Fig. 12a). They are also found in more developed forms at early Christian Delphi, Delos, Corinth, and Dodoni (Haddad, 1995, 219-220). In these examples, wards come in a variety of shapes and sizes to correspond with the small size keys.

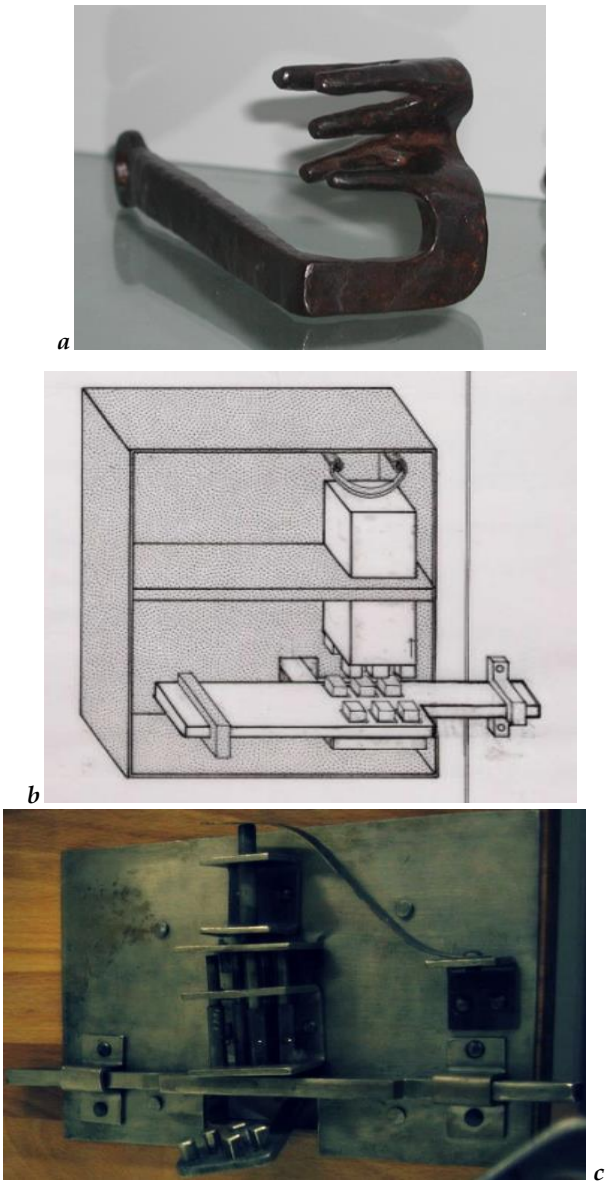


Figure 12 a) Roman smart Laconian from Jerash in Jordan. b) Haddad axonometric reconstruction of the smart Laconian Lock (After Haddad, 1995, plate 114). c) Recent reconstruction model of smart Laconian Lock smart Laconian Lock, (After https://museumsaskew.files.wordpress.com/2013/08/lock5.jpg).

As shown above, in the warded classical Laconian lock, it was first managed to take advantage from the technique of gravity falling pins/pegs to control and secure the movement of the bolt *(Ocheys)*. However, some times the fallen tumblers by gravity-fed, met with resistance in their channels; they may have not always fallen into the right position into the bolt. This problem based on the new structural formation of the smart Hellenistic key, this problem was solved by the addition of a spring to prevent this from occurring.

The spring was positioned in a way that makes it apply pressure to the tumblers. Meanwhile, in order to keep the deadbolt in locked or unlocked position, the pin/ward acting tumblers are weighted down by a flat hammered thin iron spring with a slight recurve shape, affixed to the top interior of the casing as shown in Fig. 12b, c, and Fig.13. We can, though, summarize the main advantages of the introduction of springs at the Laconian smart type as follows:

1- Under pressure from the spring, it applied resistance to the wards/pins' *(Pessulus*) tumblers, thus preventing them from being jammed in their recess. The spring guarantee that they are pushed back into position once the deadbolt is slid back into the jamb and the key is removed (Pace, 2014, 45-46). In this new position, thus, the plug is immovable, and the mechanism is always locked. Only when the proper key is inserted into the L-shaped keyhole of the lockplate, the key moves the tumblers to a position that frees the plug to turn. To lock it again the deadbolt is only pushed in, and the upper pins fall into the holes found in the bolt body by the force of the spring, and not only by their own weight.

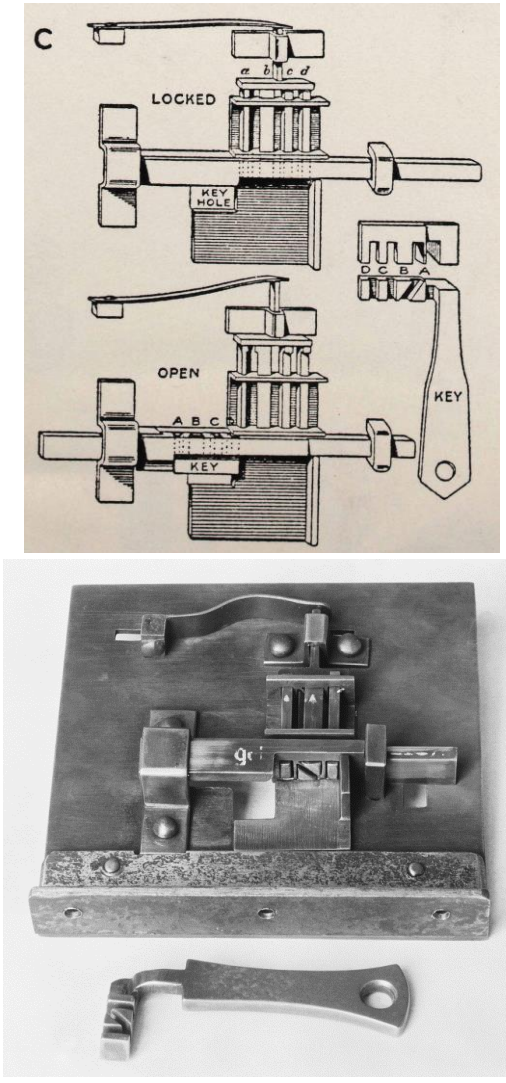
2- In the case of a variety of length, shaped and outline of the tumblers corresponding with the prongs for the key, the spring can easily manage and operate them. Each of these prongs corresponds with a complimentary tumbler pin in the locking mechanism.

Though now, there is no need for the rolling rope/cord, while opening and closing can be achieved by one hand only (Gaheis, 1930, 238-41). They are also operated by such keys that turned, screwed, and pushed (Figs. 12b, c, Fig. 13). Therefore, due to the new layout design arrangement of the smart warded pin-tumbler Laconian prongs, the lock is more secure and safer. However, here the keys have to be used by more complex movements.

In fact, with the appearance of the smart warded Laconian lock, the lock started to be transformed into a more reasonable functional outline, and with a more complex secure mechanism. This characteristic change in technology, utilizing the technology of springs in the smart Hellenistic tumbler, allowed the mechanism elements to work as one part of the casing. With this device, actually, we can notice how the sophistication of mechanics within the Hellenistic society was.

In conclusion, based on the archaeological findings up till now, it is clear that by the early Hellenis-

tic period door locks and keys of this type (10-15 cm by 5cm) started to utilize the ward tumbler spring technology. The spring technology palyed a major role in the determination of the evolution of the later Roman metal springs' locking mechanism with more elegant and smaller dimensions keys (4 to 5cm). Though, this locking mechanism spring type was not introduced by the Romans as it was believed, but by the early Hellenistic creative technicians.



a

b

Figure 13 a) Illustration showing the main parts of the Roman smart Laconian Lock, and the functional approach of opening and closing (After Gaheis, 1930, 239, fig. 115). b) The same Roman Tumbler Lock mod dated to the 1st-2nd Century ACE.(Reconstruction) Courtesy of the Deutsches Museum, Muenchen (After Pace, 2014, 55, Fig. 5).

Finally, meanwhile early Hellenistic locks technology is usually viewed as a non smart and unsecure, it should be considered as the critical intermediate stage of the spring technological change. This critical stage of the history of locking technology gave inspiration to the Roman innovators who quickly managed to improve and introduce more developed completely metals springs locks.

4.3 Critical Assessment and Investigation of the Origin of Tumbler Laconian Lock Debate

This section presents a critical review and assessment of the suppositions and debate regarding the time and place of the origin of the tumbler-pen Laconian lock, the so-called Egyptian lock, which was known in ancient Greece as the Laconian or *balanos* lock (Diels, 1920, 52-55).

One of the greatest challenges, however, is how to assess the findings of the related locks and keys' material that was published. We have to clarify that, as we rely mainly on key remains, it is not always easy to determine precisely the design for which the lock type was used. However, many findings and other indicators can shed light on this matter. It is hoped that this section shall illustrate the potential of such a line of inquiry and to provide a starting point for further discussion at a new level.

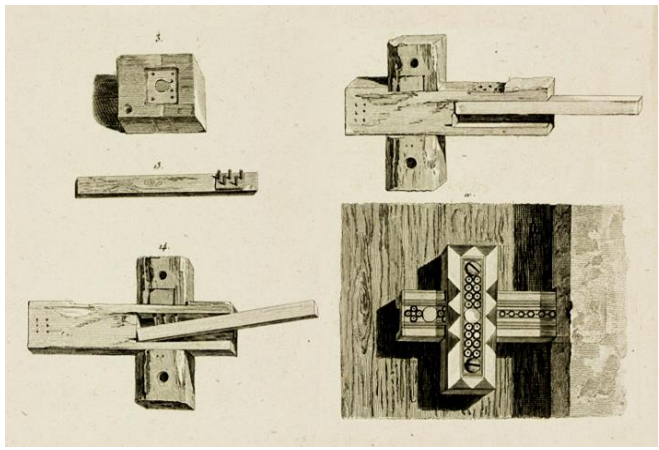


Figure 14 Illustration showing the so-called Egyptian lock parts and mechanism.

(After https://www.youtube.com/watch?v=lMh-KDe8b)

For long time it has been thought and claimed that this locking mechanism root, relied on the same pin tumbler principle, that had originated in ancient Egypt, and later on it had been transferred through Ionia and the Greek Isles (Fink, 1890, 28). For two centuries, however, many researchers and historians dealt with these lock types considered that, the oldest surviving mechanisms come from the region of ancient Egypt or even Mesopotamia. They believed that Mesopotamian lock utilized a known wooden technology that relied primarily on gravity to keep the tumbler pins down in locked position.

The so called Egyptian lock **(see Fig. 14)** though had been studied extensively, for its supposed Egyptian place of origin (Chubb, 1850, Chap. XIX; Hobbs and Dodd, 1853, 14-15; Holland and Hunt, 1853;

Flinders Petrie, 1917, 59-60; Hobbs, Fenby and Mallet, 1868; Husselman, 1979, 40-41; Kuhlmann, 1984, 658-661; James and Thorpe, 1994, 469; Wilkinson, 1994, 16, 112).

Diels (1924, 40, 51-52) [13] argued that analogies to the so-called *ballanos* lock, found in Egypt, as early as the time of Ramses II (1292-25 BCE) and mentioned that it still existed in China and Tibet. Pace (2014, 62) following Diels considered also that, with reference to the introduction of the so called Egyptian lock, he assumed that the keys' description found at Karanis with three separate prongs follow the form of the Egyptian keys. A number of these wooden keys at Karanis were described by Husselman (1979, 40-41, 54)[14]. Nevertheless, for over than 150 years it has been believed that the this type of key-based locks originated in ancient Egypt.

Consequently several recent articles attempted to present reflections on the origin problem of this locking mechanism in ancient Mesopotamia. Many historians and researchers, based on literature and inscriptions, insisted that such devices were prominent amongst Sumerian culture [15]. James and Thorpe (1994, 471), Curtis and Ponting (2013, 58) assumed that, the earliest evidence of wooden constructed as tumbler locks and keys come from Khorsabad at the palace of Sargon II. They believed that identical examples with this type also survived at Karanis[16].

Based on Sumerian and Akkadian phraseology of locking, both of Leichty (1987, 190-196) and Scurlock (1988, 421-433) agreed that, technically, ancient Mesopotamian locking mechanism was very simple. However, each one concluded that there was different sort of locking mechanism prevalent in the region. Scurlock (1988, 421-433) preferd a model of a cross-bar, fastened with a pin or peg.

Joining Leichty direction, Zettler (1987, 197-198), based on evidence derived from clay sealings found at Nippur, assumed that the most widespread technique for keeping doors shut, was a simple latch attached at the inside of the door shutter and fastened to a knob on the side of an adjacent wall.

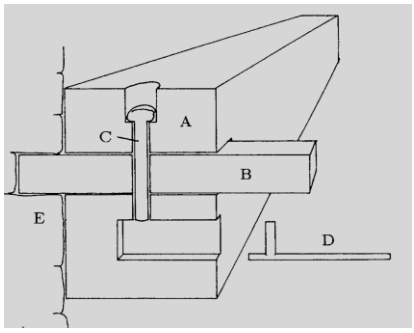
In fact, Leichty rejects completely the notion of Mesopotamian mechanically complicated mechanism of more than a latch. It should be also clarified, according to Potts (1990, 186) that neither Zettler, Leichty, nor Schurlock had any specialist's literature reference on early primitive and pre-modern locks.

On the other hand, a reconstruction of the Assyrian lock type (Fig. 15. a) has been suggested by Fuchs (1998, 97–107)[17]. He assumed that the mechanism of this lock closely resembles that of the so called Egyptian lock.

Potts (1990,189, Fig. A) rejecting the opinions of Leichty, Zettler and Scurlock, he proposed to use the so-called Egyptian lock (the so knwon *balanos* lock) as a model for the identification of the most important terms of the Mesopotamian lock. Based only on literature using terminology from different ages, he had suggested another also different reconstruction approach for the Mesopotamia lock mechanism[18] as shown in Fig 16.

Recently, Radner (2010, 270) based on authors of the nineteen century such as Layard, (1853, 596), and Bonomi, (1856, 170–1), where both of them had also compared the Mesopotaimian finds to the so called Egyptian Lock, had also assumed that locks and parts of locks from the Neo-Assyrian period have been found at the palaces of Nineveh, as also at Dur-Sarrukin (Khorsabad) and Kalhu.

Based on a copper object "with three longitudinal slots and a protruding knob" **(Fig.15.b),** that was identified as part of a lock[19], found from the Neo-Assyrian period from the Kalhu palace recent material review, Radner considered that this copper object is a lock's holding bar from part of a lock, that was used with three bolt-pins.



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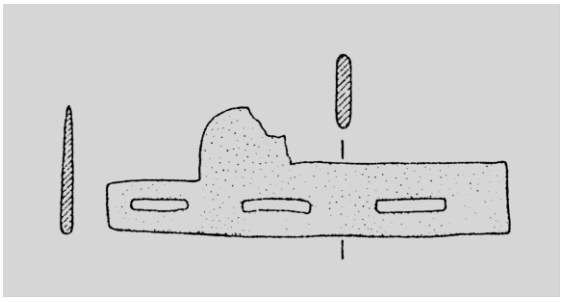


b

Figure 15 a) Fuchs suggested reconstruction of a Neo-Assyrian sikkatu lock (After Potts, 1990, 270, fig 1,2). b) Copper object with three longitudinal slots and a protruding knob, that was identified as part of a lock (length 11.4 cm, maximum height 3.5 cm) (After Potts, 1990, 270, fig. 1)

Finally, Schuyler Towne relying on the efforts mainly of Potts, Radner and other linguists, considered that, this is a strong evidence of the first tumbler key-based locks and of its invention in Mesopotamia between 2500 and 1800 BCE (http://schuylertowne.com/research/rethinking-the-origins-of-the-lock).

However, the hypothesis of the copper object with the three longitudinal slots is extremely weak, to be

used as for a three bolt-pins. Actually, the above mentioned assumptions, suggested reconstruction and beliefs, based mainly on comparing of the lexical field discussion with the so-called Egyptian lock, cannot be taken at a certain face value and as a convincing argument. This firstly because, the essential elements of the Mesopotamian lock are still in question; there is no any Mesopotaimian locking mechanism which have hitherto been published. Secondly there is no real archaeological evidence to support this argument, and thirdly their argument is based on the assumption of the so-called Egyptian lock assuming that the Greek, Hellenistic and Roman tumbler lock were originated in ancient Egypt.

On the other hand, even the passage of the locking tumbler technology through ancient Egypt or Mesopotamia into western Europe is not remarked upon by ancient historians. The "origin argument" can be only considered as more about perpetuation of misinformation of locks. In fact till now we do not know much about the Egyptian locks. The following selected descriptions show some examples of this perpetuation of misinformation of ancient locks. These are representing the main stream of the many examples to what and how many researchers have thought about this issue and discussed it.

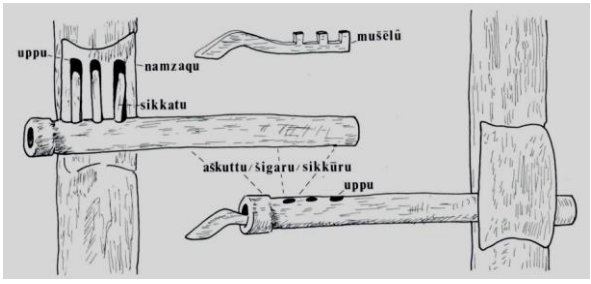


Figure 16 Potts suggested lock system in ancient Mesopotamia (After Potts, 1990. 189, Fig.A).

Flinders Petrie (1917) in his book *Tools and Weapons,* which is considered a good survey for locks of ancient Egypt, mentioned that "Another, and perhaps the earliest, type of lock, which has not yet been found in Egypt, is the "Homeric lock" (Brit. Mus. Greek and Roman Life, fig. 170). This has two tumblers, which are lifted by putting a key like W203, IXXII, through a vertical slot between them, and then turning it round to engage them and lift them. This type is usual in Roman and Saxon times, and still used in Norway and China (P.S.A.S. 11 June, 1883)"(Flinders Petrie, 1917, 59).

In fact, from the above description we can confirm that, we cannot be sure and rely on many lock researchers of the nineteenth and beginning of the twenty century. This description, firstly, is for a Laconian type key and not for Homeric. Secondly, the text actually states that this key type-which is Laconian- has not yet been found in Egypt until that date (1917). Thirdly, till that time, some researchers labeled this Laconian type as a Roman, which is not true as discussed and shown.

In another primary book, Chubb book (1850) entitled "*On the Construction of Locks and Keys*", which is considered to be one of the main references for most histories of locksmithing and ancient locks. Its early history and illustrations are repeated over and over in later books including its mistakes about the so called Egyptian lock. This scheme, unfortunately, was spread and reported also in many recent articles, books, and web sites articles and posts about the ancient technology of locks[20].

Thus using the incessant repetition by some lock historians has obscured what could be the truth about the origin of the first Pin-tumbler mechanical lock. In fact, Chubb suggested reconstructions of the so called Egyptian wooden locks are hypothetical as they lack of actual findings. Even less convincing are the questions of origin, which are also the more developed Laconian traddional locks' examples found on some of the Greek Isles (see Dawkings, 1902-03, 193-4, fig. 9, 10).

Damerji[21] (1987) on the other hand, in his dedicated book on Mesopotamian doors and gates, recorded fully the locking mechanisms in chapter three "The Door leaf and its mechanism". He clarified in details many misunderstanding issues of locking in the Mesopotamian door. No indication for tumbler locking was mentioned. Based, however, on different archaeological excavations findings, he explained that the vertical locking bolts/pegs were used for floor-barricading as a pivot post in the socket; they "are put into the holes separately or connected by a cross piece, meanwhile the inclined supporting beam is connected to the crosspiece".

In the meantime, we can find ancient references that confirm that such technology is attributed to a western origin, as Pliny's (23-79 CE) attribution of the invention of such devices is given to a *Hellene* (Pliny, 7.198). According to Pliny NH VII 198, *Theodoros* of Samos (6th-century BCE) discovered the *ballanos* system, a tradition which Diels (1920, 52) explained by noting Samos technological classiness and the occurrence of its relations with Egypt, subsequently, he was implicit that the Egyptian lock technology must have been borrowed. Diels (1897, 132) also showed that the *Ballanos,* which was identified as the vertical word/peg in pin tumbler Laconian lock was unknown in the Homeric times.

According to Giedion (1948, 71, 75) the excavations works till his well known work "*Mechanization takes command*" in 1948, did not reveal certain information that can assist and contribute to our understanding of much about the ancient Egyptian locking

mechanism and its development. Giedion, clarified that the earliest evidence for a tumbler lock in Egypt, is dated to the Hellenistic Ptolemaic period, which is a 5.5 inches (about 14 cm) iron key with four prongs (shown in Fig. 11.b) found at Drah abu'l Negga, Thebes by Howard Carter. He doubted even whether any tumbler locking mechanism originated in Egypt at all.

However, he assumed that "simply we should consider the uncertainty of its past which yields only ambiguous and uncertain interpretation", as there is no evidence to where this lock mechanism originated, in Babylonia, as had been suggested based on the Babylonian cylinder seals dating from the third millennium BCE (de Vries, et al, 1992, 32), or in Egypt as believed from the findings from Egypt (Ramsis II).

Klemm recently (2008) in his book Ancient Locks: The Evolutionary Development of the Lock and Key, in chapter I, the so-called Egyptian lock, challenged also this often repeated assertion that, the ancient Egyptians invented this type of pin tumbler lock. Klemm has researched the extant evidence and the Egyptian locks. His research looked into extensive references and proved the weakness of their evidence and logic. He argued convincingly that the first pin tumbler locks date to ancient Greek and Roman times, not to the Egyptians.

Though, it would then seem that, the Laconian type with its tumblers lined up one behind another and with its key, had originated outside Egypt and Mesopotamia. It also seems that the functional mechanism of the archetype of Egyptian wooden locks was not with pin tumblers, with anchor shaped keys to lift the tumbler pins, nor evolved to incorporate pegs that would be lifted in slots by a key.

Based on the critical examination of the historical evidence, combined with the proof of archaeological artifacts' findings records, locks built on the tumbler principle (the Laconian lock), probably, seems to have been used mostly in Greece from the fifth century BCE onward, and later on have been carried to Egypt in early Hellenistic times.

To conclude, it seems that the so called Egyptian type has been retrieved from the early Hellenistic Macedonian and Ptolemaic example as was above discussed and clarified.

Until now, however, these early Hellenistic smart spring Laconian keys are the earliest existing convincing examples, that might have emerged during the Hellenistic times. These examples suggest a more accurate debate about this type and when it had entered the world.

Finally, the history of the pin-tumbler cylinder lock, known as the "Yale lock[22]", is closely bound up with this creation of the Hellenistic smart Laconian type, and more clearly to the spring based latter plethora Roman examples of locks and keys. Yale's lock even could not have been derived from the simple classical Laconian lock. Actually, the smart Laconian key shape stems from the highly technical early Hellenistic examples found mainly in Macedonia and Ptolemaic Egypt.

5. THE ADVANCED ART OF THE ROMAN LOCK MECHANISMS: THE TECHNOLOGICAL CHANGE IN CONTROLLING BOTH OF HORIZONTAL BOLT AND VERTICAL WARD MOVEMENT BY METAL SPRINGS

Building on the Hellenistic locking mechanism tradition, the Roman kept the doorway closed by means of a bolt held fast by springs, but now with various forms of concealed pins that prevented the deadbolt being moved. In fact, the Roman period provides a number of the most vital locking mechanism technological changes.

The expansion of the Roman empire, combined with the extensive commerce activities led to a great demand for locks among the many wealthy merchants and politicians. Locks, thus became widely circulated, and the Roman technicians and engineers shaped creative and ingenious features that were to have been of great implication for the improvement of blacksmithing locking mechanics technology.

The Roman locksmith's mechanization creativity and change of material significantly reduced the cost of production, but also achieved strong protection against brute-force attacks. The Roman developed bolts, wards, lock cases and keys that worked all with metal springs. In fact, metal springs made of cold-hammered iron, making them very rugged, have been crucial to the design development and function of their locking mechanisms. Due to the reliability of metal locksmiths since metal workers became skillful in their craft; iron tumblers and deadbolts were then produced in various alterations and in small secured sizes within the protective hardware mechanisms (Pace, 2014, 43)[23].

Furthermore, the Roman lock designs were more reliable and easier to manage. They were capable to move forward the locking mechanism security, by: 1) creating more complicated interplay between tumbler and bolt. 2) providing the key and tumbler with slits and notches. 3) concealing the keyholes beneath ornamentation by making small sized keys. These keys were particularly favoured because they were portable.

In contrast to the smart Hellenistic Laconian key, the Roman made pegs of unequal lengths and shapes, so that the hidden pattern of the peg holes could not be easily copied. The Romans, actually, created the first keys in the modern sense, with elab-

orate and highly detailed ornamentation, which are with little modifications still in use.

In conclusion, the rotary sliding and pushing new locking mechanisms have given place completely to complex movements of the warded smart Hellenistic Laconian mechanisms. As a branch of the Roman advanced blacksmith's art, the skill and imagination of smiths were apparent in these locks. Table 1 shows a general comparison between the Hellenistic smart Laconian locks and Roman locks.

Table 1 Comparison between the Hellenistic smart Laconian locks and Roman spring Locks

Hellenistic Smart Laconia Lock	Roman Lock
Key hole L shape	*Key hole L and I shape*
Bulky key	*Small key*
Using springs to keep pressure on the tumbler pegs of the deadbolt	*Using springs in all types of locks mechanism*
Complex movement of the key	*More simple movement*
Less complicated	*More complicated*
Less elaborate ornamentation	*Elaborate and highly detailed ornamentation*
Wood Tumbler wards	*Metal Tumbler pins*
Need skill for the operation	*No skill is needed*
The ward number is 2-4 in one to two rows	*More than 4 and in double and triple rows layout*

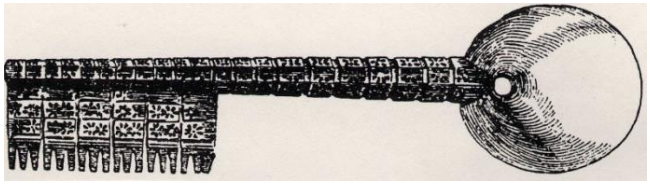
The following is a brief overview of the two main locking types that were in large use in the Roman period.

5.1 Roman Sliding Bolt Locks Using Rotary Keys

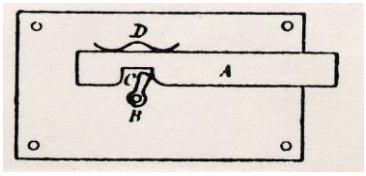
In locks such as the turning or rotary key when inserted merely slides along the springs to compress them and then drives the shackle outwards. Sliding Roman bolt locks and rotary keys came in different shapes and sizes, but all worked in more or less the same way. The functional mechanism principle is based on the key bit that acts directly, without any intermediary on the metal spring-loaded deadbolt. Through a narrow slit in the door, the metal complex shape teeth key directly acts with its winged end on the bolt, perpendicularly to the key hole. With only one movement (right or left) of the key, it was easy to control the movement of the bolt (Fig. 17).

Thus, compressing the springs, so the shackle can be pulled out, by twisting the key one moves the bolt that lock or unlock the door shutters. However, rotary keys were also used in warded locking mechanisms. They were contemporary with pin tumbler locks and keys.

Diels (1924, 56) believed that the origin of the Roman spring rotary key lock was Greek**.** According to Pace (2014, 38), these were likely introduced to the Near East in the 1st century BCE. However, there is no archaeological evidence before the Roman period for such rotary keys. These were probably first invented and developed by the Romans. Many such high-quality keys and locks have been numerously found among the Roman remains.



a



b

Figure 17 a) Turning rotary key discovered in Pompeii with rich decoration (Diels, 1924, 56, fig. 21). b) Schematic illustration showing the direct movement of the bolt (A) by the key rotary (C) and the metal spring (D), (Diels, 1924, 56, fig. 21).

The rotary keys found in Pompeii have hollow stems, turning on a key post, from which the oldest one discovered bring rich decoration (Fig. 17.a). From early Christian and Byzantine period and later on, this type will be the main lock and key. Plethora fine examples from the early Christian and Byzantine periods were found at Athens and especially at Corinth (Haddad, 1995, 223).

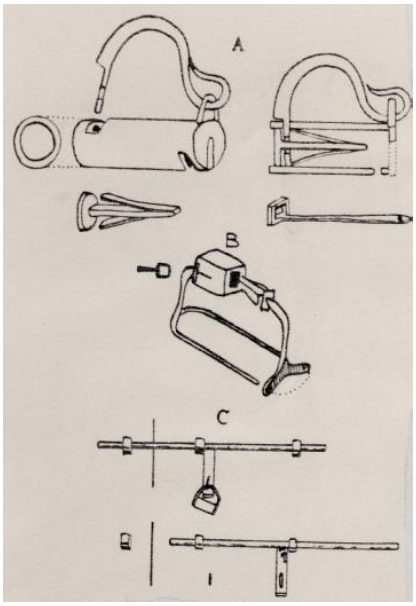
5.2 The Outdoor/ Indoor Roman Hang Lock/ Padlock and Push-Key

Another further Roman creative development of the spring locking mechanism was the hang lock/ padlock or the Luchetto (Gaheis, 1930, 258, fig. 122-23). This is a key-operated door lock developed and has three main parts: a plug and the cylinder that surrounds it, a latch or bolt, and a key (Fig 18). However, meanwhile the Romans are credited with the padlock invention, there is also evidence that the Chinese may have independently invented it before or about the same time.

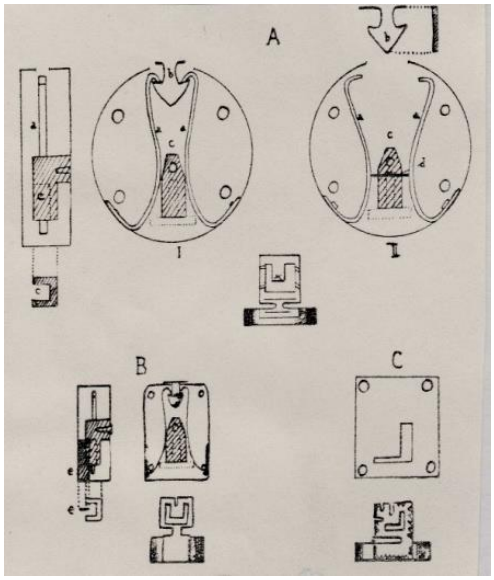
The padlock key is of simple construction; the bolt kept in locked position by protrusion of a spring or springs, which were compacted by the key, thus, allowing it to move back. The opening in the key compresses springs to free the bolt. The exterior of such locks were in keeping with the interior.

As a result many beautiful specimens with delicate forging, open work and fine traceries were pro-

duced over much of the world (http://www.locks.ru/germ/informat/schlagehistory.htm).



a



b

Figure 18 a) Illustration showing the main parts of the Roman handled padlock and its functional approach. b) Roman lock with protective casing. (After Gaheis, 1930, 258, fig. 122-23, 260, fig.124)

The padlocks main advantages can be summarized as follows: they are usually small, hardy, cheaper than a door lock and convenient to use; they could be carried and used where necessary, as they don't need much space.

Their main disadvantages are that they have limited life spans, particularly when they are used outdoors. They also require some kind of fittings on the door or the object to be locked (http://www.historicallocks.com/en/site/hl/Padlocks/).

These were more used for chests, rather than doors. As "mobile seals" (Tomtlund, 1978,13), they prevented access to spaces that for some reasons could not be locked with standard fixed locks.

On the other hand, a padlocking conceptual design approach means that, there are certain measures to deal with for whoever breaks the lock, but conversely, to whom who takes responsibility for the items that are locked up (Gustafsson, 2005, 22)[24].

At least from the third century AD and later on, the use of hang locks/ padlock at the external door surface was in major application (Gaheis, 1930, 258). Figure 18 a, b shows steel ward springs and locks with protective casing (Gaheis, 1930, 260, fig.124).

In the north of Europe, plethora metal padlocks have been found since the late Roman period (Gustafsson, 2005, 19). Many such Keys were also found in grave sites throughout Scandinavia, and in the Viking settlements at the British Isles and beyond (Steele, 2013, 5). It also continued to be used by the manufacturers very well from the 17th century up to the 19th century (Gustafsson, 2005, 22)[25]. In fact, the straightforward principle in this particular type is the basis of many padlocks with wide diversity of design and different sizes and shapes over much of the world.

6. SUMMARY AND CONCLUDING REMARKS

The study of security material culture represented by door locks and keys used in various cultures can reveal many of their social habits. They provide the basis for many conclusions about the wider social context for many aspects of the ancient world. Generally, keys with their locks held a remarkable degree as symbols of power, authority, wealth and stature.

Ancient locks and keys with their design and functional mechanism have been influenced and continue significantly shaping how people think about security and the need to protect property, as also access to security technology in the everyday life. They also reflect the technological achievements of these cultures. Until our digital age, basically, this technology relied on controlling the horizontal movement of a deadbolt with different approaches.

Generally, in contrast with the large survived number of keys, very little material survived material of both the external and internal parts of the lock bodies.

However, to discuss the locking material more accurately and effectively, as many of their terms and names have overlapping meanings, one of the foremost needs is a standard illustrated terminology of ancient technology description and categorization of systems of locking mechanism.

In addition, by utilizing the achievements of the digital technology, three dimensional experimental

models should be developed thus allowing for more accurate real-world locking mechanism reconstructions.

It has been shown that the lock and key devices, in which opening the shutters is obtained from the outside, firstly appears to rely on the functional approach of the so–called Homeric types, then continued by the evolution of the locking system of the simple Laconian type, then by the smart Hellenistic Laconian lock, and finally with the new forms of the spring Roman ward, such as the rotary and padlock locks and keys. The function of the keys of the Laconian tumbler lock types is to apply pressure to gravity fed tumblers (as at the two-hand tumbler Laconian), or spring (as at the one-hand smart Hellenistic and Roman Laconian), to allow for an appropriate pressure against the tumblers.

The continuous improvements of the locking mechanisms which had been made to their operation design appeared to be rapidly solving many of their problems. The main concept of the outdoor system of locks can be summarized by developing different approaches for controlling the deadbolt horizontal movement. This was achieved by the first really outdoor locking system by the types of Homeric keys. Meanwhile the Homeric lock kept its shape without any evolution, however, it opened new horizons for door locking mechanism technology developments.

The critical review, assessment and investigation, based on the available material, has shown that a clear evolution of the Laconian tumbler locks and keys have been used and developed from at least the early Hellenistic period. This period is characterized by a high degree of technology-sharing between cultures and regions.

Later on, the Hellenistic locking technology influenced the Roman lock and key technology, which in its turn influenced the following periods. The main changes were essentially more to their aesthetic attributes and typological variations.

However, we owe a debt of gratitude to the Hellenistic engineers, who designed and produced a somehow secured functional locking mechanism. Two of the most important innovations of the Hellenistic locks were the spring loaded bolt and the use of encased wards. We can assume that already the Hellenistic engineers and technicians testified to a progression of a spring tumbler technology of the one handed operation, situated on the interior door shutter, meanwhile the engineers and technicians of the Roman Empire testified to a progression of the one handed operation technology, situated even on the exterior door shutters. None of all of those locks would have worked without springs. This assumption contradicts with most of the cited related research and bibliography about this particular Hellenistic lock type.

On the other hand, it is difficult to establish precedence for the one hand tumbler smart lock and key as an early Hellenistic invention, as the principle idea of one pin-tumbler device of gate bars *(mochlos)* might have been used in different and dissimilar forms before; as in Mesopotamia, Egypt and even classical Greece. However, if new data from mainly archaeological findings, continue to show an established frame of use of the smart Laconian Hellenistic one hand tumbler locks, then the invention should be undoubtedly attributed to the early Hellenistic engineers.

Till now, however, we can confirm that, the turning point in the formation of the locking mechanism system is found only according to the metal smart warded pin tumbler Laconian keys dated to the early Hellenistic period. It was perfectly developed and obviously industrialized by the Roman engineers *"Mechaniki"*. However, spring tumbler locks typify the most utilized lock in the Roman period, and shape the main base for the technological change beyond this period.

This progression, however, is truly fascinating. The Romans translated the Hellenistic traditions into terms of an elaborated mechanical and industrial production. In fact, the Roman locksmith's mechanization creativity made the lock more elegant and secure. These Roman achievments were later on used wiledly by the early Christian and Byzantine community until at least the nineteenth century, and survived up until our present days at some traditional and vernacular different Mediterenian societies.

Finally, the first real locking mechanical production industry started by the Romans, can be considered as ultimate solution of many locks' problems; among the manufactured schemes there are the pin tumbler locks, rotary locks, padlocks and cylinder tumbler locks. We can assume that the Roman smith keys and locks' technology were the main one used until the appearance of electric locks and electronic security; the difference is in the way the key works.

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FOOTNOTES

[1] The main ancient Greek terminology mentioned in this research is after the modern term. As an example (*mochlos)* means bar. For discussion and interpretation of this terminology see Haddad, 1995, 203-6.

[2] According to Radner (Radner, 2010, 269-270), the Palace in Kalhu, where Esarhaddon, King of Assyria (680–669 BCE) had an elaborate gateway whose inner and outer door could be locked. However, as in the Assyrian palaces, the in-door locking mechanism, the barred and bolted as an internal lock, were also installed at some exterior gates of the palace; they may also have been deemed functional in order to lock up the women's quarters or rooms housing guests. However, in the palace quarters and rooms that required to shut in something or somebody (treasury, storage rooms, armouries, libraries, prison cells and the living quarters), without the possibility of opening the door from the inside, external locks were used.

[3] According to Pace (2014, 40), the mount incorporates the elements of structure that linked the components to an object or entryway, while the casting housed the internal components that interacted directly with the key in operation. These were often exposed when installed on the interior of a doorway.

[4] Homer's *Odyssey* descriptions as follows: *"when Penelope unlocks the door of the chamber in which Odysseus' bow is stored, 'and took the well-bent key in her strong hand, a goodly key of bronze, whereon was a handle of ivory ... anon she quickly loosed the strap from the handle of the door, and thrust in the key, and with a straight aim shot back the bolts"(*Homer, *Odyssey*, xxi, Butcher and Lang transl, 2011. http://www.vub.ac.be/SOCO/tesa/teaching/ReaderB/Giedionmechanization.pdf). In another translation for Homer we can also find *"…she climbed the high stairway to her chamber, and took the bent key in her strong hand, a goodly key of bronze, and on it was a handle of ivory...."(*Homer. Odyssey. Translated by A. T. Murray. XXI. 5-7, http://www.tfahr.org/KEY_notes.html). *"…she [Penelope] quickly loosed the thong from the handle and thrust in*

the key, and with sure aim shot back the bolt…and quickly they (the leaves of the door) flew open before her…".(Homer. *Odyssey*. XXI. 46-50. http://www.tfahr.org/KEY_notes.html).

[5] According to Pace (2014, 18), they are analogous to the Homeric mechanism system and consist of hollowed cylinders attached to ropes and inserted through a key hole; the cylinder would be forced against the interior deadbolt to push it out of a locked position upon pulling the rope.

[6] Based on the recently published in a four minutes video by Soldati, on Apr. 22, 2012 https://www.youtube.com/watch?v=9zp2Xi5OnUM.

[7] With reference of the votive iron key found at Bylazora, in his work, "Re-Creating an Ancient Lock and Key Mechanism", and throughout a 14-minutes video, published on Oct 1, 2013, he described his new proposed reconstruction https://www.youtube.com/watch?v=GuHritO7Nww&noredirect=1.

[8] *Aristophanes, 420. "Our husbands now carry little Spartan keys on their persons, made with three teeth and full of malice and spite*"

[9] Fink, 1890, 22-31, investigates in detail the Laconian lock.

[10] *Ballanoi*: acorns. The term *ballanos* was used in Aristophanes' time. see Fink,1890, 28, and Haddad, 1995.

[11] Dawkins, BSA, X, 1902-3,190-195. There is also found a composite type, with two keys, one of which is used to ram the bolt: 'a descendant of the Homeric lock.'

[12] It also might have survived on stucco-painted wooden tablet, that reveals a crouching figure wielding a three-tined key from Egypt dated between the Ptolemaic and Roman periods (Pace, 2014, Fig. 9).

[13] Diels(1924, 40, 51-52) noted that in *Women at the Thesmophoria* 421, Aristophanes had the women express their annoyance at the introduction of keys with three prongs.

[14] These surviving versions of Karanis have linear prongs of various shapes and heights to correspond with the appropriate lock. The key and the operator's arm are placed through a port in the door and the bit of the key is inserted into a hollowed-out recess, or shaft, within the bolt (Husselman , 1979, 40-41, 54).

[15] They argued that similar parts and concepts were used in the construction of ancient shaft keys and locks, which are described as using pins and deadbolts to secure the devices, accessible via shaft, and the anatomy of the key has a bit to manipulate the lock (Salonen, 1961, 75-78).

[16] They assumed that these first locks were designed to obfuscate any attempt to open a passage, save by possession of the appropriate key, while the position of these Karanis locks on the doorways and passages do not appear at a designated height. However, locks seem to have been installed, in many cases, at the base of the door, whereas in other cases have been installed around waist-level (Pace, 2014, 11).

[17] Fuchs (1998, 97–107) suggestion for the locking mechanism consists of a heavy transverse bar. In order to lock the gate a smaller holding bar, is pushed through the appropriate hole in the transverse bar. The holding bar is in turn kept in place with the help of one or several bolt-pins. In order to open the lock, with the help of a primitive key, the bolt-pins have to be removed from the holding bar.

[18] Potts (1990, 189-90) assumed that the essential elements of the Mesopotamian lock were the bolt; the assembly, or lock proper, the pins; and the key. He clarified that "The pins were lodged in hollows within the assembly, down from which they dropped, passing through holes in the bolt which kept the door from opening. To open the door, a toothed key was inserted into the hollow bolt, and lifted so as to push the pins up into the lock assembly, thereby allowing the bolt to be removed".

[19] Radner (2010, 270) state that "More recently, David and Joan Oates identified a metal find from the Review Palace (ekal ma!arti = 'Fort Shalmaneser') at Kalhu as part of a lock. They describe the piece as 'a thin rectangular copper object with three longitudinal slots and a protruding knob' (Fig. 1). I would like to identify this object as the lock's holding bar, to be used with three bolt-pins."

[20] Such as (Blaze, 2003, 26) as also http://www.historicallocks.com/en/site/hl/Other-locks/ and http://www.ehow.com/facts_5579225_history-door-locks.html, see also http://www.locks.ru/germ/informat/schlagehistory.htm, http://www.smith.edu/hsc/museum/ancient_inventions/hsc09b.htm

[21] Damerji (1987, 178, fig. 66) also clarified that the metal rod cylinders that have been suggested for bolts (length 12 cm and1.5 cm in diameter) is "somewhat more than the thickness of a door leaf, and the bending at the lower end is to make a secure attachment by gripping the back of the door leaf" p. 172. Fig 60.

[22] "Pin-tumbler cylinder lock is the technical name for Linus Yale's lock, but outside of specialists nobody calls it thus", Giedion, 1948, 55, note 4 . http://www.vub.ac.be/SOCO/tesa/teaching/ReaderB/Giedionmechanization.pdf

[23] However, judging from the complicated and elaborated arrangement of the survived ward-bits of their keys, one might suggest that they have been elaborately contrived. The shape of the prongs correspond with the recess for the tumbler pins, ensuring the security of the lock if the key is not cast several times in a mold and is uniquely made (Pace, 2014, 58).

[24] According to Gustafsson (2005, 22), such locks are merely symbolical and the same lock is not so important, but the action of sealing that matters

[25] See also http://www.historicallocks.com/en/site/hl/Other-locks/19-Keys-and-locks-from-Imperial-Rome/Roman-door-locks/Roman-door-locks---more-images-2/ A metal turnkey lock, showing the key with bolt and steel spring.