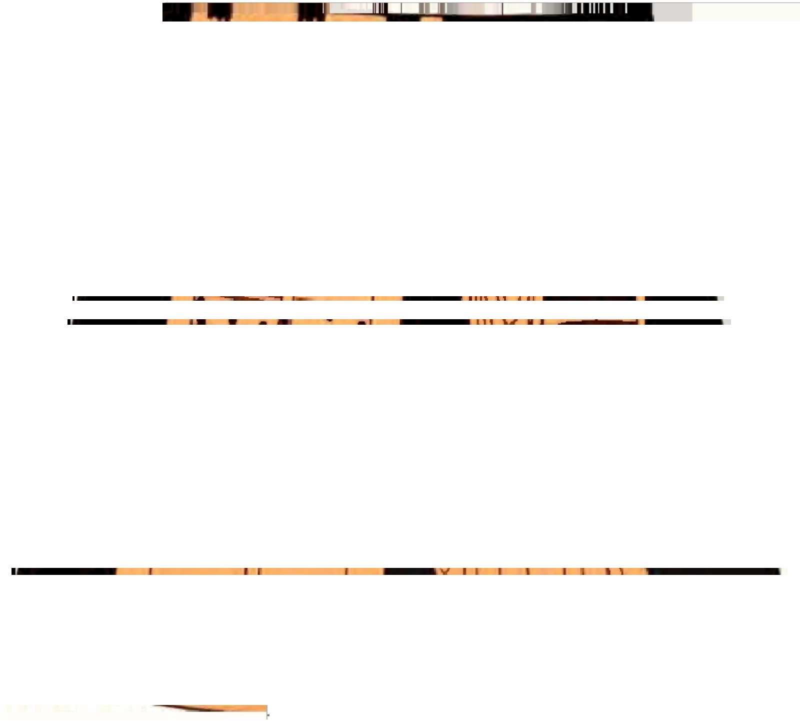

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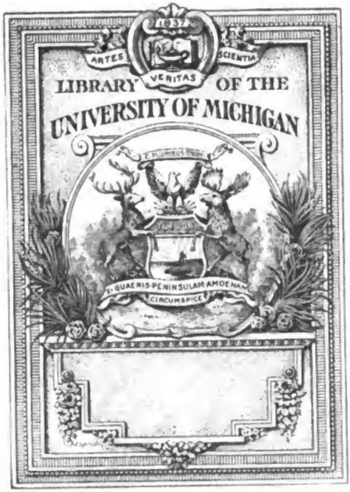
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SIX LECTURES BY

HERMANN DIELS

WITH 5o FIGURES AND 9 TABLES

PUBLISHER B. G.TEUBNER . LEIPZIG AND BERLIN
I9f4

RIC HARD SCHO E NE

DEDICATED IN

HONOUR

VOR\VORT

The present booklet summarises six lectures on the broad field of ancient technology that I have given in various places at different times. The Salzburg university lectures H-V deal with individual subjects of ancient technology that are still of interest today, the last one deals with the incunabula of chemistry, one of which h a s only recently come to light, and finally the first one, which introduced the Marburg Philological Assembly i 9i 3, gives a broad overview of the mutual relationship between technology and \ science in antiquity.

With the exception of the first, which appeared at the beginning of this year in a different place but with the same publisher as the present booklet, I did not respond to the many requests for publication that were sent to me by the audience and publishers immediately after the lectures were held, because I did not want to publish anything isolated. In this summary, however, in which I have added and rounded off a few things and added some explanatory illustrations and notes, but otherwise have not changed anything in the form of the presentation, the whole thing may well be more like the first one.

I wanted to use selected examples to show a wider audience that antiquity, even in its technical endeavours, is much more closely linked to the modern world than the intervening period of the Middle Ages, but at the same time I wanted to expose the countless threads that partly visibly and partly invisibly connect these two worlds, the old and the new. The

The battle of modern technology and natural science against antiquity, which raged through the last century and still oppresses many a narrow-minded brow, was based on a regrettable mutual ignorance and half-image of the two warring parties. The humanists, caught up in unclear idealism, knew too little about the real world of antiquity to understand its connection with today's realities, and their opponents, in turn, wanted to know nothing about the ancient hemisphere of our European culture, because they were naturally even less able to appreciate the realism of antiquity than the humanists and because they shunned its formalism and idealism, which the latter alone appreciated.

Today's classical philologists, who belong to the most hated species of modern mankind, a true *adtüm generi's hum'itn',* do not return this hatred at all. For they know that aversion based on ignorance disappears of its own accord as soon as better knowledge arrives. For the most part, they have familiarised themselves with the realities of ancient culture as well as with its immortal beauty of form and its ideal world of thought. They have taken it upon themselves to patiently introduce modern man, who has been enthusiastic about the wonders of technology since childhood, to the often small and ineffective beginnings of technical thought, in order to show him that the ingenuity and the power of ideas of the ancient and especially of the bright technicians is no less than that of the modern millennial artists. It is a long way from the idea of the aeroplane, as embodied by the Hellenic imagination in the mythical archetype of the wonder-creating Technite Daedalus, to the completed creation of Count Zeppelin! But anyone who knows the history of technology knows that without the imaginative forethought and testing experiments of the ancient artists and hand-and craftsmen and without the scanty remnants of their technical literature, which have survived the dullness of the Middle Ages and have been mutilated many times over, we would not have reached the pinnacle of industrial and technical culture of which today's world is so proud. We stand high - who would doubt it - but we stand on the shoulders of countless ancestors and above all on the shoulders of the Hellenic thinkers and artists who loved the gods. So this booklet, like the Ephesian sage of old, invites unbiased readers, especially from the circle of educated youth, to enter the smoke-blackened workshop where the flame of the **hearth** blazes: *Intraite; mern et hic di' sunt!*

Berlin, Easter i 9 i 4.

HeexAnn Dyers.

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SCIENCE AND TECHNOLOGY AMONG THE HELLENES ')

The main purpose of the German Philological Assembly is to bring together men of research and teaching in order to show them vividly how theory and practice must be combined if the common goal of our youth education is to be achieved, to fill the future generation with the spirit of ¥truth, which must prevail equally in science and art, in religion and morality, if we really want to lead our culture further and higher.

Since teaching and life, invention and application, scholarly \knowledge and pedagogical art are more closely linked than usual in these festive days, it does not seem inappropriate at the beginning of this conference to use the image of Greek culture, which can probably still be presented as paradigmatic in our philologists' meetings, to show the beneficial influence through which science and practice mutually fertilise each other. I am not thinking primarily of school science and school practice, although I will also touch on these important relationships at the end, but I am considering the whole field of science and "techniques, without, however, overlooking the infinite diversity of the two.

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i) Lecture delivered at the opening session of the Maiburger Philologen-tnges cci 3o September i 9 i 3. A bgedrocLt in the Aber JaArt. /. d. 4-/. Aliert. i 9 i q. I. Dept. z3. Vol. S, i - i y.

It would be wicked to attempt to speak in superficial poly- maths about things which presuppose a certain understanding of the subject, and to substitute witty generalities for an insight into the details, without which there c a n b e no vague knowledge. I shall therefore t r e a t the subject with deliberate incompleteness, by throwing individual highlights on certain areas and stages of development which are closer to my particular studies and can serve as instructive examples. Among the ancient civilised peoples, Hellenism emerged so late that most of the technical inventions used in war and peace had long been made and spread everywhere. The hunter peoples had long since invented spears, bows and arrows, agriculture had long since taught them to build wagons and ploughs, robbing and trading shields had long since sailed the vast seas before the Hellenes entered history. For as highly significant as this golden age of pre-Hellenic history proves to be, even in technical terms, neither this culture itself nor the poetic glorification that Homeric poetry later devoted to this heroic age has anything to do with the Hellenic economy. At most, one senses in the self-confident, free tone that the heroic epic strikes towards God and the world, the autonomous master spirit t h a t made the Greek a philosopher, a man of the \"science zne' Z§o- 2#r. Furthermore, in the unifying urge with which Homer brings together and artistically depicts the political and religious particularities of the various Greek tribes, one senses something of the rationalist drive for unification and generalisation.

generalisation that Greek natural science displayed from its earliest beginnings. In Hesiod's Muse, even this semi-philosophical urge for systematisation has already partially congealed into external schematism.

Rather, we turn our attention to the venerable incunabula of Greek science, which the dying lonia in the 6th century B.C. considered to be the most expensive of all centuries. century as the world's most precious legacy. At the top of the list is the 6lilesian T h al es, whom legend portrays sometimes as a stargazer oblivious to the world, who falls into the well during his nocturnal observations of the heavens, sometimes as a calculating merchant who cleverly knows how to exploit the oil boom. Serious history, however, knows him as a technician. The oldest witness to mention him, Xenophanes, marvelled at his astronomical skill, which enabled him to predict solar eclipses. But Herodotus, who has handed down to us the most accurate, albeit chronologically misaligned, account of this triumph of astronomy, indicates clearly enough to the initiated ') that it was not scientific insight into the movement of the stars that had enabled the Milesian to make his prediction, but an empirically tested method, presumably developed by the Chaldeans.

') 1 7i -i- s '°M°N- -°w-s- -5i jNrsc 0°15t° ^f'1'i°'°c oai "ixvi upoqyöpavai $atr#oi ovpor apoifijiteop fri "vrov so0ro", He se' tq rel éyé "rro g pte "#ol;i}. Thnles Lannte eon the Chsldäern found
formula found by the Celdeans, according to which the events are repeated in a cycle of i 8 years i i days (the days are not equal). Since he was able to observe the great eclipse of the 8 suns that occurred on i 8 h4ni 6o3 in Egypt, he was able to calculate that after 6o3 d- r 8 years, i.e. a little more than i 8 May 58$, but before the end of the Jv'awrép (i.e. more precisely the Sornmenol- sbtium according to the plausible etymology of C. Brugaisnn, Idg. Forscb.
XV 8y), i.e. before A blxoF of June 98 j ai- eclipse would take place. At present, the eclipse will take place on z 2nd ff ai di---- J-b'--. The right
Jahr war den antiken Chronologen, wahrscheinlich aus Xanthos, bekannt. S. meine *Vorsokratiker* **1 A 5 (I³ 7, 21).**

leaned probability theory. In the field of astronomy, therefore, he was probably not a man of science but a technician, albeit one who knew and could do more than his fellow countrymen and the neighbouring barbarians. At least the rumour persisted until Herodotus' time that he had been consulted by Kroisos before the battle of the Halys to divert the river.') The historian, of course, confuses this story and has the Lydian army move across the Halys on the usual route. \If he is right, the legend in the 5th century must have attributed such hydraulic engineering skills to the famous astronomer. In fact, we now know that Xerxes had the famous bridges over the Helles- pont, which withstood the river and the storm better than those previously built by the Egyptian and Phoenician engineers, built by H a rp a1os -), who has probably been rightly identified with the astronomer who must have lived between Cleostratus of Tenedos and J\le- ton, i.e. between the second half of the 6th and the second half of the 5th century. He made a name for himself by improving the Octaéteris of Cleostratus. Since Babylonian astronomy was deeply

Since Babylonian astronomy knew neither the eight-year nor the nineteen-year cycle until well into the ö- J -*.
y. century, as a genuine Hellenic observation.

---

t) Herod. I y5.

*) Heiod. +'< 3¥ D'- -'- of the °°gehenren T-ne *-h Herodotus

3) Wrrr-IJ *Alexand- ill 8,* 8 (.Ebb. d. Brr1. .¥h. i 9ot p. 8), sx'n Rehm, Pnuly -N. R. - Eric. VII : o i rind Giunel , C'fironñoyi II 386 uimrsehen.
S. onten p. z6 -.

) Boll, Wtu-icé/uu¢ if. "itre-t. If ??réñ'dcy (A'uZtur *d.* Gc¢rwu-. IH 3, sonderabdr.) p. s/ .

Table I.

Fragment eines Steckkalenders aus Milet (109 v. Chr.).

Umschrift:

Linke Spalte

• ἐν τοξ]ότηι ὁ ἥλιος
• ὠρίων] ἑῷος δύνει καὶ προ-
κύων ἑ]ῷος δύνει
• κύων ἑ]ῷος δύνει
• τοξό]της ἄρχεται ἑῷος ἐ-
πιτέ]λλων καὶ περσεὺς ὅ-
λος ἑ]ῷος δύνει
• •
• σκ]ορπίου τὸ κέντρον ἐπι-
τέ]λλει ἑῷιον
• •
• τ]όξευμα ἑῷιον ἐπιτέλλει
• ἰχ]θὺς ὁ νότιος ἄρχεται ἀκρό-
ν]υχος δύνειν
• ἀε]τὸς ἑῷος ἐπιτέλλει
• δίδυμ]οι μεσοῦσι δυόμε-
νοι]

Rechte (mittlere) Spalte

ἐν τοῖς αὐτοῖς
• •
Λ
• ἐν ὑδροχόωι ὁ ἥλιος
• [λέων] ἑῷος ἄρχεται δύνων
καὶ λύρα δύνει
• •
• ὄρνις ἀκρόνυχος ἄρχεται δύνων
• • • • • • • • •
• ἀνδρομέδα ἄρχεται ἑῴα ἐπι-
τέλλειν
• •
• ὑδροχόος μεσοῖ ἀνατέλλων
• ἵππος ἑῷος ἄρχεται ἐπι-
τέλλειν
•
• κένταυρος ὅλος ἑῷος δύνει
• ὕδρος ὅλος ἑῷος δύνει
• κῆτος ἄρχεται ἀκρόνυχον
δύνειν
× • οἰστὸς δύνει, ζεφύρων ὥ-
ρα συνεχῶν
• • • •
• ὄρνις ὅλος ἀκρόνυχος δύνει
ἀρκτοῦρος] ἀκρόνυχος ἐπι-
τέλλει]

which the Ionian astronomers endeavoured to give more and more scientific certainty and practical usefulness. How practically these ancient calendars were organised can be seen from the fragments of two
"Steckka1ender- , Greek anpaaJp "sa(Tafell), which were found during the German excavations in Miletus ten years ago.') They were made according to the hluster of Meton i. J. 43 BC in Athens, to which reference is made. By inserting bronze plaques with the names of the months and day numbers
By inserting bronze plates with the names of the months and day numbers of the variable civil calendar into the holes on the side or between the lines of the perpetual star calendar engraved in ßlarmor, a convenient means had been found to link the unchanging solar year, the rising and setting of the stars and the associated weather indications with the city's official calendar. There is no doubt that, although not the specimens found, the whole set-up in Miletus w a s ancient and closely linked to the studies of the Milesian astronomers.

Since the Milesian school of the Thales seems to have been continued by Cleostratus on Tenedos, who had built his observatory on the opposite mountain Ida (i y 30 m) $, perhaps Harpalos, who rectified his calendar, also belongs to this series. It was then understood how a technician living in Tenedos, who had observed the difficult tidal conditions in the Dardanelles from close up (Ionian astronomy, after all, served the practical astronomy of Thales and Cleostratus), had been able to make his own observations.

---

1) Diel* and Rehm, *Poropegmeei frogmeeite aus filet, Bert. 'Si'tz.-Ber-* i9o , 9z ff. Cf. Deesau ibid. p. z66.

a) Pi'rz. l- 8, o note ; II - i 9y.

3) Zheopbr. De sign. (f *rt. II - i 9y, 8).

The great work of Harpalos (who regarded the Black Sea as his domain) was able to construct his bridge with better success than the foreign engineers.

But Harpalos' marvellous work is not alone. Even before **Xerxes**, Ionian engineers had a c h i e v e d similar feats. In his youth, Herodotus saw an image in the temple of Hera at Samos depicting the reed bridge built for Darius across the Bosporus near Byzantium during his campaign against the Scythians. He reports that'): "Da- reios was very pleased about the bridge construction and gave the architect Mand ro k1es from Samos gifts over and over again. From these gifts, Mandrocles donated a picture as a votive offering, which depicted the bridging of the Bosporus and King Darius on his throne and his army as it crossed over. This image, which he donated to the Temple of Hera, bore the following inscription:

'He who recently gave the brigade over the Bosporos floods,
ätandrokles dedicated the image in honour of Hera.
For himself he won the wreath, for the Saints world fame, And the
finished work was praised by the king."

This Sami engineer, w h o secured immortality through his dedication, is a compatriot and contemporary of Pythagoras, who had, of course, already left his homeland at the time. If Heraclitus the Ephesian, who probably got to know him mainly through t h e philosopher's \virus in Samos, criticises him precisely because of his polymathy, then he must have made a name for himself in his homeland not only through his number theory and his theory of the transmigration of souls. Rather, we may assume that this eminent mathematician (like Thales, Anaximander and the

1) IV 87. 88. 2) *Vors.* 12 B 40.

other astronomers of the time) was also an outstanding practitioner, skilled in many fields, who owed his inspiration and education to the then unusually high technical culture of his native island. Herodotus considered the temple of Hera in Samos to be one of the first buildings in the world. Wiegand's new excavations have revealed the admirable beauty of the old temple, which was destroyed after the fall of Polycrates.) Whether the scheme is designed according to the hexagram, which Odilo Wol8 recently tried to prove as the norm of ancient temples, or according to the triangular calculation that Rob. Reinhardt tested on the Theseion in Athens and on the temple of Aphaia in Agina, the experts may decide.^) But the simple proportions that \Viegand has established also show that the architect, be it Th eodo ro s or R h o i- ko s, thought through his ground plan mathematically. The other \Vunder- work of Samos praised by Herodotus, the water conduit of Eup a1in os -), also rediscovered by German research, which was led through the Kastro mountain rising above Samos by means of a kilometre-long tunnel from the spring on the other side of the mountain into the city (Fig. i, p. 8), goes even further.) What particularly interests us about this work is the question of how the tunnel, which was drilled from both sides at the same time, was scientifically prepared, i.e. how

---

i) Wiegend, I. Zurich t üéer dii Auigraé. iw *Somoc* (déA. 'f. &m/. Ai. i 9 i i) p. i9.

3) R. Reinhardt, We Nz zfßmäQi@4-c@ *dyy-* . ZfauRny/ I. der Z e- *erst n per in Athm,* Stnttg. i 9o3. Cf. J. Durvi, z. x. rer". *D. Ar'hytytieyi* and Zug.- Uer-in-, t9i z No. ez p. i9o ff. ; No. z3 p. zoo ff.

¢) m 6o.

j) Fabri*ius, mAm. i/irr. IX (i 88d} p. i65 ff.

line through the centre of the mountain. It is highly unlikely that Megara itself, which at that time had long since fallen into decline, could have achieved this great geodetic feat. Of course, neither the mainland nor Sa- wios, but Mi let became the actual starting point for the scientific movement, without which even Pytha- goras is inconceivable. I do not go as far as Haeckel, who recently recognised only three great philosophers (apart from himself) in world history at the ßfonist congress in Düsseldorf '): Ananimander and Anaximenes of J\4i1et and, thirdly, Wilhelm Ostwald of Riga. It is also clear to me that neither Pythagoras nor Heraclitus would be conceivable without Ana's brilliant intuition. But this extraordinary man was no parlour scholar. He grew up in the fresh sea air of Miletus, whose overseas trade policy also prompted him to intervene practically. He led the colonisation of Apollonia on the Pontus, he gave his compatriots the first map of the world for orientation, which was then extended by Hecataeus and remained authoritative for a long time, and he also drew up a celestial chart for the orientation of ships at night. After such directly practical achievements, one understands why the Milesians erected a statue in honour of their fellow citizen (Fig. 3), the remains of which were found during the German excavations and have now been given a place of honour in the Berlin J\Museum.*)

In these practical activities alone, Anaxander only continued the work of Thales. He went far beyond him with his philosophical and astronomical speculations. Not a sensually recognisable

i) Report of the '2 "ä,t-f. fiu=drrfiau in. Sept. iq i 3.

2) The testimonies about Anezimandroe are / Ari. i - i -z i .

The universe is not based on the primordial spirt, but on the infinite, which is in eternal motion, in changing formation and regression. Our earth and the cosmos that unites it is only a temporary special case of the creation of the infinite. Before us, after us, next to us, countless worlds will be separated from the "Wziipor. But no matter how much these separations are labelled with the stamp of destruction, like everything earthly, they still carry the traces of the higher, eternal origin in their order of well-being. The Hellene defines beauty as the right proportion of proportions. Thus Anaximander understood the regular movement of the stars, whose circular orbits he had first deduced from his astronomical observations, as a harmony of the spheres, which he illustrated by the symmetrically ordered distances between these celestial orbits. The ancient sacred trinity and its multiples played a mysterious role in this. For Anaximander, the earth itself is still a flat cylinder at the centre of the movement.

Abb. 3. Erhaltener Unterteil der Anaximandros in Milet errichteten Ehrenbildsäule. (6. Jahrhundert.)

centre of movement. Its height is in the ratio of 1 : 3 to its width. Three celestial spheres orbit it: the circle of the stars, the circle of the moon and the circle of the sun, the distances between which, it seems, are assumed to be 9, i 8 and z y earth diameters. As childish as these numbers must appear to a more advanced science, the basic idea of a harmony of our world system that can be expressed in numbers was correct. Anyone who considers Anaximander's theory of the spheres is reminded of Schiller's words, with which he describes the awakening of Hellenic science in the "Kiinstlern-'

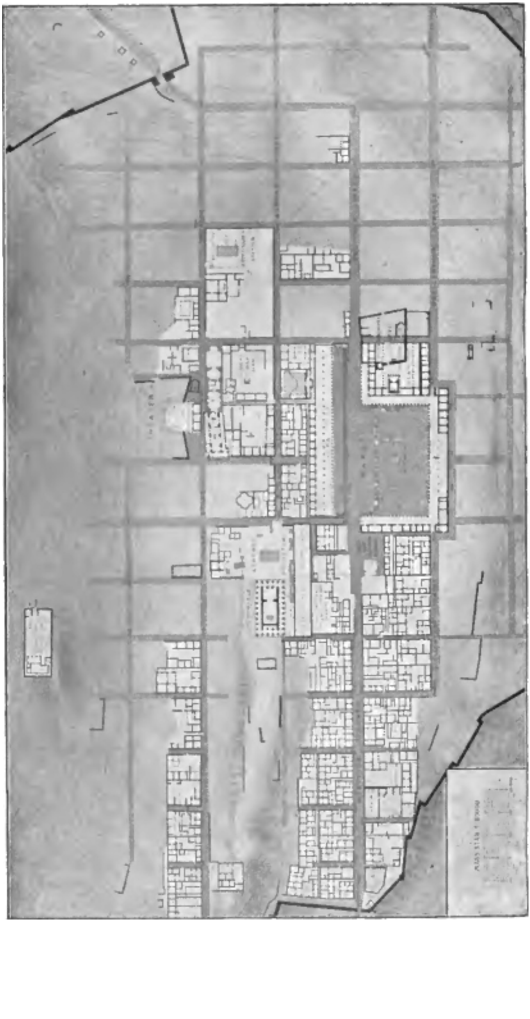
feie In self-contained, youthful joy
Leiht er den Sphären seine Harmonie,
Und preiset er das Weltgebäude,

Certainly, it is symmetry that Plato repeatedly cites as the hallmark of beauty and \truth. \ The pZcp" is what determines the orbits of the sun and no less the boundaries of human and cosmic life at H e ra k1it. It is the proportion, the lo- gos, that sets the unbridgeable limits to the oscillating alternation of coming into being and passing away. \While Heraclitus in this recognition of the mathematical law proves to be a disciple of Anaxander, Pythagoras, through his exact observations, e.g. of musical intervals, and through his progress in actual mathematics and celestial science, was even more closely associated with the Milesian school. Unfortunately, it is difficult to separate the individual aspects of his personal activity from the extraordinary fame of the Italic school he founded. As a result of the success of this school, the opinion that the entire physical and spiritual life of man could be understood as a temple of arithmetic with numbers spread widely in the 5th century. Arithmetic, the ra/in, took hold of humanity, and the battle with the irrational was taken up across the board. The most outstanding minds rack their brains on

i) See my essay Üéer Anasintnndcri Les riss lm Fredi" /. Crcrc/t. *d. Phitos*. 2t (i89y) p. zz8-a3 y.

z) Pbileb. 6q E. S. Treodelenbiirg, N/ei'ir *Schr.* II 3 i 6 ff. , Knlkinann, $3 Winckelmannsprogr., Berl. i 893 p. if.

Plate TI.



the squaring of the circle, everything is to be organised with a straightedge and ruler, everything is to be measured by numbers. The paroxysm of rationalism mainly affected technology. I will content myself with recalling two examples from the second half of the century of the Enlightenment: Hippodamus of Miletus and Polykleitos of Argos.

H ip pod am os, Anaximander's compatriot, also devoted himself to ancient natural science '), but he became known as an architect in the grand style. Pericles, who loved the modern rationalists, commissioned him to design a new plan of Piraeus. Intersecting streets at right angles, orientated towards the cardinal points, were intended to serve both mathematical regularity and hygiene. He also redesigned Thurioi and Rhodes in this way. His system continued to prevail in all new layouts in the following century. Alenandreia and above all Priene, which we have excavated and whose plan (Plate II) was designed in the 4th century and imposed on the opposing nature with unprecedented force, bear witness to the lingering influence of Hippodamus, whose Italian foundation was probably not without influence on the boring building scheme as s e e n i n the Roman camp plan and Pompeii.)

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i) Hesych. s. 9.'Jaaotoipov rfp$atç remit him persoipolăyoç. S. hers. I-293 c. 27.

IV i) p. i a i. That the technique of agrimcnsorcn is originally griocbiscb is proved by the Heuptinstruø:rent, the grants or d-ruaia cu, whose derivation from y"'iìpe (better from yud'poeœ) h a s now been satisfactorily clarified by the Etruscans. W. Schulze, her? S.-2fm. i9o5 ß . yo9. Tbalin, Z-oufy- *IP'. R.-Eric. Al* yi8, y. The presentation by O. ălüller, dler -Oi 3 is confirmed in aßeui \9essential ibre. The only question is whether this Greek mathematics in Itelia goes back to Hippodamus himself or to his predecessors (cv. mediated by Pythsgoras) Ygl. Beloch, Cam- pa rim ' 67. z3O. 3¢5 Pl. IJ. VIII. The Etruscan feast of Hnrzabotte (Uriaio, Aï'una- . one. I 4*9 ff. zș8 TaT. I. V} is qicbt ãltcr aJs Too.

Of course, the master builder did not lack contradiction. Aristophanes mocked him in the "Birds under the J\laske of Meton armed with a ruler, "whom Hellas and Ko- lonos know -'). But Hippoda- mos' ambition went further. He not only drew up city plans, but also state constitutions in which the usual three figures once again occupy a dominant position. Three tribes: farmers, craftsmen, warriors; three types of land ownership: state land, temple land, private land; three types of lawsuit: Jurisdictional action, action for damages, ltlord action; three types of judgement: conviction, acquittal, both with motivation. Of course, this triangular formulation has remained on paper.)

At that time, the misuse of the mathematical \mniscience played an even more disastrous role in sculpture. This finest flowering of Hellenic art was also infested by the ßleltau of arithmetical rationalism. The visual artist should now also work scientifically. The one who demanded this was one of the most outstanding artists, the Argive P oly k let, whose \verke still delights the eye of the art lover. But like Leonardo, Dürer and many more recent masters, he began to ponder. And as a result of his pondering, he published a book in the effervescent style that artists love. It bore the ornate name *K--üv* Lineal -)1 The details of this theory of art are no longer known.

i) Arist. * C- 99°.

z) A last outgrowth of this Pytbagorean Stsatsaiathenetics are Plato's laws. S. Zeller. Z-fi. *d.* Er. Ha 956 f.

3) Puro. i - 29d c. 28 records the small fragments of this writing

q) Despite the uiiihsame measurements A. KalLmanne in the 53rd Winckd- mannsprogr. {29it *Proportionmi des "eszchts i'n dv gr. h "um i j.* Cf. such Kn1k- sad NarAgzforienri fPer,t hernosgeg. v. N. Voß p. $. If, according to Diodoro8

Plate III.

Polyklets Kanon. Der Doryphoros. Neapel.
Nach Brunn, Denkmäler.
Verlag F. Bruckmann, A.-G., München.

also here in the normal proportions of the face and the rest of the body the sacred trinity and next to it the decas is favoured. Fortunately, the artist did not adhere strictly to his system in his Doryphoros (panel HI), which he set up as an example of his theory, and the art of the ą. Century art deliberately set itself in opposition to this pseudo-science. Lysippus demanded a modern symmetry that had to take into account not the reality but the appearance of reality.')

But the symmetry of the Polykletic canon, which was so ill-suited to the representation of man, has been permanently preserved in another technique, where it was in fact more appropriate, in the construction of ancient guns. The mechanic Ph ilon), the oldest surviving writer on artillery, begins his instruction with the somewhat obscure guiding principle of the Polykletic Canon: sò ió aapd *yixqbv* did cells" 'ipiPpar yfi'zsni, i.e. øThe beauty of the work is the result of many numbers". He is saying that many interdependent numerical relationships determine the important proportions of a work. Through a slight oversight (nøp'i pixpd") it can happen that

1 98, 5 if. the priority of the Poly-Cletian canonical idea, like so many other Hellenic things, is traced back to Egypt, in that the same artists Telecles and Theodorus, the sons of Rhoikoe, would have learnt the same thing there in Egypt, and since the Egyptian ù (odul- measure is given there exactly, we now know that this is all the falsification of Hecateius of Abdera, who sought to return the entire Hellenic culture to Egypt. What is not clear to me is the context of the Byznntine canon (9 head lengths, tripartition of the face from the hume: stitn, nose, kim) in the 'lśppqusfe c§ç ṭ'oypaøizjç. S. G. Schâfer, fi' flu déucà *d.* 3/a/erri you 2frrør Othe tTrier 18$ 5) p. 8z.

fi Pbn. XXXIV 6' * tmetriò am 'li// enfitziine msfodiif move *intactaque ratione quadratas veterum staturas permutando, volgoque diceba ab illis factos quales essent homines, a se quales viderentur esse.*

2) Mech. Synt. IV S. 50, 6 Thevenot.

the completion (sö ei) is not achieved. A small i"eh1er at the beginning destroys the whole as the work progresses. Proportion thus presupposes a basic measure which, in correctly graduated multiplications, symmetrically shapes the entire pictorial work. So it is, Philon continues, with the guns. A small mistake at the beginning is avenged by the incorrectness of the whole work.

The standard measure that the ancient engineers used as a basis for the construction of throwing machines consisted of the calibre,
i.e. the diameter of the hole in which the elastic cocking nerves run, through which the gun is cocked and earthed, i.e. fired. The size of the entire gun and the tensioning force of the strands must therefore be built according to the weight of the stone ball or arrow that is to be fired. According to Philon, the Atexan engineers had found the best formula for determining the size of the calibre:

i.e. the diameter of the cocking hole must be as many dactyls (t) as the cubic root of the number of Attic mines (u) multiplied by too many, which the stone ball weighs, to which the tenth part of this amount must then be added. All parts of the throwing machine are then added to this unit of measurement.

Philon looks down somewhat disparagingly on the ancient engineers from the height of Alexandrian technology, which in the invention of the polybolon, the ancient Mitrailleuse, by Dionysius of Alexandreia ') created a marvellous work of precision mechanics. But it is not doubtful that the mathematical principle of construction goes back to the old masters of artillery,

1) See the 5th lecture on this and the chapter on ancient guns.

who around the year 4oo deol older Dion ys i os built the first war-capable artillery and thus contributed to the great successes of the ingenious prince. It is thanks to his scientific and technical insight and his ruthless vigour that Sicily and Italy did not become Carthaginian at that time. Philistus '), as an eyewitness, gave a vivid account of Dionys' artillery activity in his historical work, and Diodorus -) has preserved this report, presumably transmitted by Timaeus. It shows the feverish exertion of all available intellectual and financial resources to bring the army and fleet up to the highest standard. He had two new types, the tetrerene and the penterene, built instead of the trenches, but above all he induced the engineers, whom he called in from all sides and honoured brilliantly, to construct new guns in which the principle of the old hand bow was developed into gigantic machines.-During the siege of Motye on the west coast of Sicily (39 B.C.), the newly built guns were used for the first time on the beach batteries, which completely repulsed Himilko's huge attacking fleet.

Where did the mechanics who created this terrible new control centre come from? Sicily itself, and Syracuse in particular, was already under attack towards the end of the s century.

r) Fr. 34 tF. H. G. I i88). z) Diodorus 2t IV¢ i if.

j) Dlod z. a O. § @z *et y&Q z6 eerow,1rn$v riQ#9q xez& zo0-

z40't*- +fp fiv" cö roy at*'qypévs*'. Ephoros mentions in Plut. Per. ty, Ephorus mentions new "machines" which the Clazomenian Artemon had supplied to Pericles at a meeting of 6airios. Diodorus XM z8, 3 only mentions rams, which were considered to be a Carthaginian invention and had been in use for a long time, as well as the sight-shedder (zpto@ tat ylÄvo). The innovations of Artemon may well refer to the latter

This is shown by the marvellous coins of Euainetus and his contemporaries, who place their names next to the image of the gods with self-confidence - at a high level of artistic and technical perfection. But these new artillery tasks involved something else. As we have seen, the construction of these machines required a profound mathematical education, which had to be combined with technical training. Thus we think of the Pythagorean sect'), above all of the famous contemporary A r c hyt as from Tarentum, who was also in contact with Dionys himself. He had emerged from the school of the Pythagoreans and combined epoch-making mathematical research with the most successful practical work for the benefit of his native city. He was a strategist at the head of the state seven times and, as Aristoxenos testifies, he never suffered defeat. He was the first mathematician to develop the science of mechanics in particular -) and who also dealt with mechanical problems in practice. It is said -) that, as a great childhood friend, he invented a rattle and constructed a flying pigeon that could flap its wings and fly upwards by means of a hidden pneumatic mechanism. It goes without saying that such a mathematical and technical genius as a strategist also p u t his talent at the service of his fatherland. Unfortunately, however, we have only a generalised account of this.-) Archytas' homeland and his affiliation with the Pythagorean League alone remind us of a

i) modor mentions XIV ii, 3 among the ingenues appointed by ellen Selten also so'F9 it 'Jzvlfap.

z) Diog. VHI 8s (-or*. 35 A i ; 1- 3zz, s i).

3) Diog- a. a. 0. S- 83 (pre*. 1 3zz, z3).

4) Aristot. Pol. 0 8. Gell. K i z, 8 (Vor*. 35 A io. ii ; l - 3z5, i8 ff.).

) Vitt. VH Praef. i q u. p. 2t note i.

other mechanic Zopy r os, who must be placed in a closer relationship to the innovations of Dionys through a new construction of the so-called Gastraphetes, which is connected with his name.

The bow had been known in Greece since time immemorial, and archers played a role in all battles, even if they were not considered the most glorious weapon. With the bow, the elasticity of the bow arm combines with the 'rier string to shoot the arrow. But the stronger the bow and string become, the more difficult it is for the human hand to tension them.) This led to the invention of the crossbow, which holds the arrow between the bow and the catapult. However, they did not stop there, but constructed a crossbow-like rifle under the name paaspngfs9p (literally belly shooter), which used the strength of the whole body for tension and allowed smooth aiming and firing. Next Friday in the Saalburg you will see a model of this weapon, as described by Heron and reconstructed by Major General Dr Schwamm, and you will be able to see for yourself that the step from this belly gun to the various types of throwing rifles that you will also see there is only a small one. Heron, who follows the development from the hand bow to the large artillery in the introduction to his theory of artillery construction, also gives Gastraphetes this slit. Now the Alexandrian war writer Bi- ton) gives us two somewhat complicated models of this gun, which allowed arrows to be fired from ö-y feet and were cocked with a reel, although the name ynaspa-

i) Cf. Heron, Belopoiihe 5 (Poliorcet. 8. 2$, 8 Weichei) ; K6chly n. **Rüstow, *Kriegsschriftsst.* I 205 ff.**

z) Polioic. P. 6 t ß. Which.

qfr5- żiemeri s rsprúozlkAen Star e szeb I mat. The grò-
ßrr.e Mrfieii win ais Gear -ò y pay
çńz,;.' The ma- .lünellen h "erbesserungm of this
handmai e will be i by Biol debt Partner Zopyros rn-
-g ž e. 'en, *dec* sowoÒi fn Milet tie worked for Cnmã-e.
Yt'eiøi own in ó- i Pydiagoreerhatalogue of the Iambli- r.h'o
who w a s b o r n at the beginning of Aristonenos, in
Zopyros acs Tarentum, who must have lived at the latest
around the line of 4 Jażirk, that this Lar-'rLsmn 'n red
fiondesbrother of Arch3 with the mechanic of the
Gastra- phet i- Should not his Yerbessermig of the handgun
with the gro8arúgem. Dionys' artitleristic activity of the time
î- Finally: does not such a connection with the
inatheuiatiscb-Pythagorean style bring to its simplest form
the overly famous knowledge of ancient jewellery
technology recorded by Ptlilon, Vitruvius and Heron?

No one preached the Pythagorean view of the omnipotence and immortality of number and its fundamental importance for exact science more urgently than Phi 1o1aos, the first Pythagorean of the strict school, of whom there were textbooks. øThe nature of number", says Fr. i i, "is knowledge-giving, guiding and teaching for anyone in any matter that is doubtful or unknown to him." This Pythagorean, whom we know only as an almost mystical theorist, must also have put his mathematical knowledge to practical use.

I) A. s. 0. p. 6 . The notion that old 24sæcn are carried on without meaning is repeated in the Eutbytonon and Pelintonon, which only make sense for the ordinary and mythical Bogeu, not for the Køtnpulte.

z) Vit. Pytb. z6y (U-rz. I - 3ąq, 3 i).

technically utilised. For he is named at the head of the great masters who knew how to combine theory and practice like Archimedes.')

For the followers of Pythagoras, the power of number seemed to manifest itself most clearly in the \Velt of tones. At a time when ancient Hellenic music was already dying out, Philolaos wrote down the discoveries of Pythagoras and his pupils about the physical-mathematical basis of the tonal system. The harmony of the intervals became for them the most direct testimony to the invisible cosmic harmony and symmetry. An undoubtedly genuine question of Archytas derives from the three proportions of Łlusik, the arithmetical, geometrical and harmonic, the entire mathematical theory of proportions, which is the foundation of pre-Euclidean geometry.$

This theory of harmony is now also evident in the first physician of whom there were books, A1kma io n of Kroton, who is connected with the oldest school of Pytliagoras by virtue of his home country and who dedicated his book to three of the master's pupils. His teaching culminated in the proposition that health is the symmetry of the conditional qualities of warm, cold, dry, moist, sweet, bitter etc. and that illness therefore signifies the disturbance of this harmony.

t) Vìtrov I i , i y. Theophyhiet. ep. y 3 (Clique P. G. i z6 col. ą93

2) According to Vitruvius 1 I , 8, the artilleryman, who had to monitor the even tensioning of the catapults with the tensioners, was also required to have a uniform education so that he could determine and analyse the uniformity of the tensioning by the sound that the tensioned strings make when they are struck.

3) Aët. P lz*. V 3o, i (Voi s. i B : I - i 36).

The method of comprehending and mastering the J\human's relationship with the number seven can be found in the Hippocratic writing pDe hebdo- madibus'), which in its mathematical tendency is vividly reminiscent of Flow's theory) of the "course of life° according to the rhythm of z8 and 23, which has made such a strong impression on the human rationalism of modern J\medicine. So if the medicine of the

5th century medicine, following the Pythagorean model, pursued the Hebdomad theory to the point of adventure, when Empedocles and the Sicilian medical school that depended on him brought the Pythagorean tetraktys to dominate humoral pathology for thousands of years, we see here again how mathematical rationalism gradually took hold of the whole of technology from the Pythagoreans.

For according to the ancient view, medicine is also a sZ2vp and the physician a d§pvorpyd9.-) This view also explains the unusual extension that even the Hippocratic I§rpefn granted t o the sometimes quite artificial surgical ßlmachines in the dislocation of limbs.-)

On the other hand, since the beginning of the 5th century, this technique has been closely linked to the progress of science and philosophy.

\science and philosophy. The H ip p o- cratic corpus is characterised by the most diverse attempts at

i) Roscher, défi. fer 3'Icäs. ' ri. d. IP. z8 n. (Leipzig i 9i i) and *äexe., Die Tip9kr. Schn fi von der Slebenzahl,* Paderborn *i 9 i 3.*

z) Wilb. Ftieß, *Der* dé/au/ dr* réms. Nrundfr ng sur ezaé/rn dii'- Bad ir. Leipzig i 9o6.

3) Hipp. De prisc. medic. l (p. I , fi7 K%le w.) 'e0ate pol r4ßp 6@'cc

) Cf. the texts printed in the z. volume of the Kühleweinsc hen Hi ppokretes edition ; Faust, *Dy* "tnrAitiomrntfs 'ié oa£i@uü mcdicis af rrpo- zi?ürnrm arfi oru "i fuza/orum ofAiéifii, Greifsw. Dlss. fig i z.

to utilise older and newer systems medically. Pythagoras, Empedocles, Anaxagoras, Diogenes of Apollonia, even the Eleatics are consulted to support or refute the fantastic systems of these physicians. Of course, there is also no shortage of nouveau riche minds,

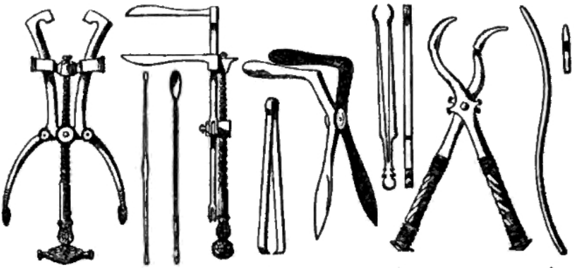


Abb. 4. Chirurgische Instrumente aus Pompeji.
Aus: Overbeck, Pompeji. 3. Aufl. Leipzig, W. Engelmann 1875. S. 413.

a (*a'*) speculum matricis. *b* Sonde. *c* Löffelchen. *d* Pinzette. *e* speculum ani. Zwischen *e* und *f* feine Pinzette. *g* gebogene Zange zur Entfernung von Knochensplittern. *h* Katheter.

who, like the honest author of "De prisca medicina", fight the "new-fangled medicine most vehemently"). But it would be going too far in this context to trace this connection between medical technique and philosophy, which formed the closest alliance in Galen, through all the centuries. I will only mention one thing here. The teripathist S trato n, who links Aristotle and Democritus, Athens and Alexandreia, is also the philosopher who, through his seemingly modern experimental physics, equally inspired doctors and physicians.

i) Hipp. De pr. med. r (S. z, t Kühlew.) 6ié mm 5}fous air ju fysyrs a ichanics of his time.') The great physician Era- sistratos based his physiology on Straton's fu'rror cnom, and the mechanics Ctesibios, Philon and later Heron produced their mechanical works of art according to the basic principles of modern peripatetic experimental physics. The extent to which hlechanics in turn accommodated ancient science can be seen in the wonderfully crafted medical instruments (Fig. , p. z 31, which have been preserved in abundance from antiquity.§ At that time, precision mechanics produced a pocket water clock with which Herophilos, one of the most important physicians of all time, m e a s u r e d the temperature of his patients.)

The astronomical science of the time also brought Alexandrian mechanics to extraordinary heights. The construction of the astrolabe, which made stargazing so much easier, played a major role in the scientific discoveries of the greatest ancient astronomer Hipparchus.-) The astonishingly high level of technology at the time also made it possible to measure time.

i) S. my Abh. On fes 9fiys. *System of the Sffatoei, Beef. Si'tz.-Ber.* 1893 p. i or ff.

z) blilne, Surd called Zwiruai air in J rccé 'ind Coiaan Z'i rin, Aber- cen i o . v. Tö 1 throat ü'tÄneun and cAirur isröe Zfe6ef uAres6. #eKow* /w'^XY (t9M) BeM. ry lL

3) bfa*cell. De pulsibns c. i i, 'd. H. s'i"-- (a 'i'r Fest lhr. i9oy) P. 63. blax Schmidt, NufwrAisr. &zitr. II (Leipzig i 9 i z) p. 3. io i. Am **Schluß Z. 265 ergänze ich ἐκπλήρωσιν ⟨τοῦ χρόνου⟩ und 266 πυκνότερον ⟨ἢ βραδύτερον⟩.**

) Among the a n t i q u i t i e s recovered from the seabed at Antikytliera, which make up a mnptreic of the National Museum in Athens, a small btonzeaes instrument in a wooden case, the Redindis in Svoronos, *Das* Aiär'ter W'zfiönn/muim "i (Athens i 9o3) Tef. K, *II r an* astrolnb. This is not certain, as the heavily oxidised parts and their inscriptions are very damaged. But from the original (not from the illustrations given above), one can **admire** the technique of the movement, which rivalled the precision of our chronographs.

refined and improved considerably. The crude method of measuring the hours of the day according to the length of the shadow gave way to water measurement with the klepsydra as early as the 5th century. In ą ., alarm clocks were already being built with it, as according to Aristoxenos Plato is said to have constructed such a night clock (rvxztptrór dipożóytov) with pneumatics.') From this time onwards, Mpa began to take on the meaning of "hour", which is probably first found in Aristotle's Homeric Problems. Since then, astronomers have only been able to determine time more precisely. The clockworks described several times by the ancients -), which even took into account the shift in the length of the hours according to the seasons, probably show the high point

i) Athens. S. i by c. A ristoxenos, who was mentioned immediately before Plato's mention, seems to be the cewbrsniann for this news, which has nothing unbelievable about it if one thinks of similar udptp ya of A rchytas (see p. i 8 Arm. ,). About the tehnical s. nan seh "idt, mf "r"'itor. 2i, "r. Il 58. g8, which freely explains T'neumatik üee Apparøleø aicbt (fgagsoocog čtg *km q* §q#iZq tiA cò JprretT4i-ei cà òpMayo" taò sob Gtnioç). The pneu- matic prinnip, which is reminiscent of the tanbe of Arch ytas, is ensured by comparing the Atb. with the \Vssser organ. Cf. Heron, Pneøm. z (I i 9* i . W. àchaildt). A tiiititãriscbe Wăchteruht describes Aeneas Tacticus zz, zș (p. 55, 9yy H. Scböne) , s. Bilfinger, *Zyi'tmrssm* dcr and. ÿd/- Arr (Stuttg. Prog. i 866) p. 8, which also deals with the iVeckerubt of Plston aa- itself s. 9 F. "Plato aiaß aich the ScblnF like the Behtirde the litigating parties the time by a besümrotes Wagserqøantum øø and gnb dev G eFaß a device, uonacb with the AblauF of the Wes- sels a sound was produced, which awakened him from sleep and gave him the Mògticbi*cit gen-üb r, to 8tinen nocturnal studies curückuzukehren." As Atbenaeue says, this precept must have been constructed according to the principle of the Jgøøøt. orgel lot nè9 sğ ćteet2tø@ About dø9 Scbatten. melt speaks Bilfinger op. cit. p. i o if.

•) Bilfinger, enti+ *Stand n "áhłung* (Stuitg. Progr. i 883) p. . "p" Examination of this hourly division in ĄØ ggiechiscben iterstur tmṭt p¢$t seit der Zeit Alexanders auf." Max Schmidt, *Kulturhist. Beitr.* II 44; Aristot. Fr. 161 (ed. Rose S. 129, 16 ff., Lips. 1886). In der Ἀθην. πολ. 30, 6 heißt ὥρα allgemein „Zeit", „Termin".

3) S. Bilfinger, *Zeitmesser* S. 23 ff.; Max Schmidt a. a. O. und S. 105.

the scientifically organised technology of the Hellenes. In Rome in i 39 P. Cornelius Scipio Nasica Cor- culum as censor set up a water clock in a public square.') Similarly, about a century later An- dronikos Kyrrhestes erected the "Tower of the Winds" in Athens (plate lV), in which a sundial w a s installed on the outside and a water clock on the inside.)

It is astonishing that the interest of antiquity in Glen's technical inventions and in the personality of the inventors outside of l-'ach science is quite low. The glamour that increasingly surrounds technicians in the Renaissance and modern times is almost entirely absent from antiquity, if one disregards medicine and military technology. And even in these fields it has happened that great names have disappeared without trace, as happened to the aforementioned builder of the bridge of Xerxes, whose name was only revealed to us recently by a scrap of paper preserved by chance. The writing on it contains, among other things, a table of the most interesting things in the shortest form from the good Alexandrian period. These *Mterculi Alexandrini*, as I have christened them -), list the most famous J\ painters, sculptors, architects and, before the chapter on the seven wonders of the world, a heptas of famous 6mechanics (rafel \'). Of these seven in the 2nd pre

i) Varro in Plin. N. h. VII z i$ and Censor. D. d. a. z3, J.

z) Vatro, De r. r. III i y , Vrtr. 1 6, .t ff.

3) Abh. d. Berl. Ak. igot. The accompanying illustration shows the relevant column.

8th column of the Latereoli. It reads in transcription: äfq2avtzof. ' Eacapirqt

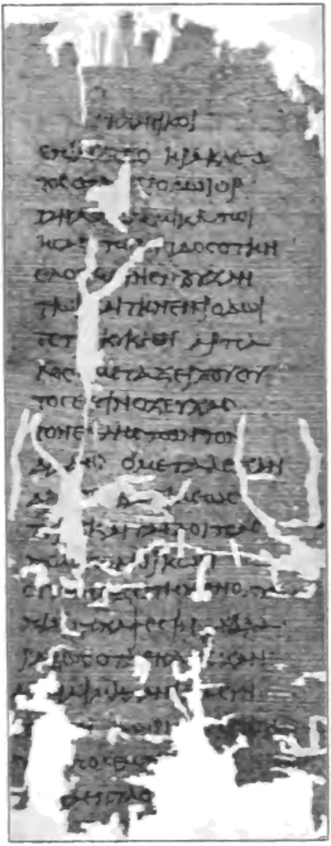
ὁ μετὰ Ξέρξου· οὗτός ἐστιν ὁ ζεύξας τὸν Ἑλλήσποντον. Διάδης ὁ μετ' Ἀλεξάνδρου τοῦ βασιλέως Τύρον καὶ τὰς λοιπὰς πόλεις πολιορκῶν ο Στύππαξ ὁ τὴν ἐν Ὀλυμπίαι ἱππάφεσιν ο Ἀβδαράξως ὁ τὰ ἐν Ἀλεξαν-

θ[αύματα.

Turm der Winde in Athen.

Auf der Spitze des Daches drehte sich ein bronzener Triton, der je nach dem Winde seinen Stab über einen der acht unter dem Gesimse abgebildeten Hauptwinde ausstreckte.

Plate V.



Laterculi Alexandrini. Achte Kolumne.

Four of the four celebrities of the technique recognised in the Christian era are completely unknown to us, and we know only very superficial things about the other three. Among the latter I emphasise D iad es, of whom Paulys Reallenikon said in the first edition: "Named by Vitruvius among those who had written about machines, but otherwise completely unknown to us. The new edition (published in 9o5) adds from the war writers that Diades is a pupil of Polyeidos, who built Philip's siege guns, and that he himself took part in Alexander's campaigns. From the Laterculi we first learn that Diades was the chief engineer of the memorable siege of Tyre, about which historians have pages and pages to report. The details of the back-and-forth battle are carefully described, and the name of the soldier who first scaled the wall is inscribed in the tablets of history. But the historians know nothing of the engineer who led this and all other sieges of Alexander's cities, who wrote a textbook on his art in which his inventions were described: the mobile siege towers, innovative rams, drop bridges and other war machines. They simply disregarded the 'fechnite', as did the whole of antiquity.

i) See the text in the previous note.

z) E.g. Arrian. Also. IT i 6- zq.

3) \'itr. X 13, 3 *Di'adrs* icri@fii iert es/cndi/ ir tNveniirzc /urrrrz so- nnig zur e/iiirn 'f ?se/ufai in csercifu rircen erre ze/cf'af raefcrea /cr't'ro "i e/ usrm'fra/-m 'nac/itüam , gua of eurem Alana jede Ironztmz *r.see posset, eti'am carv um d olitorem, quem* iiorn *mm gruem oppcIIunt. nof* m'nw u/eéo/ur arirZe wérefafe, m@ ro/töiiez zrri@fm rc/'@uJ. Y'-olgen blaß- angaben fiir die Türme und sndcre seiner Konstruktionen. Athen. 2tIech. 8. i o, io Wescher (p. i6, i R. Schneider) öiä4y9 Pty o4v e$rö9 gr,viv **ἐν τῷ Μηχανικῷ αὐτοῦ συγγράμματι εὑρηκέναι τούς τε φορητοὺς πύργους καὶ τὸ λεγόμενον τρύπανον καὶ τὸν κόρακα καὶ τὴν ἐπιβάθραν· ἐχρᾶτο δὲ καὶ τῷ ὑποτρόχῳ κριῷ. Folgt die Beschreibung im einzelnen. S. Schneider** a. t. O. p. 5y ff.

Only one name is an exception: A r ch i m ed es of Syracuse. His life, his death, his main works are known to every schoolboy and his sayings pIäIppxn'- and "pdf got aa QO mal zvuo cd> yav" are in the Büchmann.
\Venn Heiberg, the biographer and editor of the Archi- medes, emphasises') that he was the only ß4athematician that the non-scientific literature had taken care of, this is correct. At most, Archytas could be added for Horace's sake. But if he sees the reason for this extraordinary fame in his activity at the siege of Syracuse, then this needs to be supplemented, as the example of this Diades teaches us. For over a hundred years, the Syracusans showed so little concern for their famous compatriot that it took Cicero to show the local §rtkci@i his completely overgrown and forgotten tomb monument. The interest that the Romans and Roman history took in their stubborn adversary also prompted the later Greeks to commemorate the man of genius and to preserve his writings. Archimedes represents the combination of theoretical and practical talent in the most ideal way. His life and his writings still fill us with admiration and sympathy today.

Introduced to scientific astronomy by his father, the astronomer Pheidias, he not only made astronomical observations, e.g. on the length of the year, at an early age, but also created an ornate, \Vasser-

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i) In Gercke - Nordens 2fi*?. i* the A/irrtumrm. II- 39 . The same scholar has a popular account in A rcbenholda iPeh/t II (i9o9) p. i6 i ff. to which I refer for the following. Whether Archi- medes was an administrator of King Hieron (PluC 6Iarc. i ¢, y at'yyevjt rat 'ppm) is doubtful. When Th. Gomperz, fe?fenica H 3oz summarises the two expressions *in court titles, he attributes this to Plutarch elne sterke Flüchägkeit. ;Oean the one title excludes the other.

power-driven planetarium, which proved how he could put his theoretical knowledge into mechanical practice. His practical sense was also put to use in other ways. The astronomer's computational needs found an obstacle in the small number series that comprised the Greek numeral system. Thus, in the "Arenarius", he presented a new method for reliably classifying and labelling infinite series of digits. The invention of the Archimedean screw and the pulley blocks, which enabled him to launch Hieron's giant ship, probably also belong to his youthful period. His intensive preoccupation with mechanical problems encouraged him to solve important mathematical problems with the help of mechanics in his work "Methoden1ehre der mechanischen Lehr- sätze"), dedicated to Eratosthenes and rediscovered by Heiberg seven years ago. However, he only regarded this ßlethod as a preliminary observation. In his later writings, he provided exact proofs of the most important theorems. But what is admirable in that work is the boldness with which, following in the footsteps of Archytas, he went on to mechanically analyse mathematics.

fgodo9 found and published by Heiberg , Mr. KLII zq3. Now in Heiberg's edition

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of Archimedes (i 9 i 3) II z y with lntein upper setinog. German translation he gave (with Zeuthen) Bibl. Math. 111th inst. VH t*9°7) p. 3 z z ff.

z) Arcb ytes 35 A 1q (Kors. I- 3z6, i o). Archimedes, however, names as 8only Deaioknt and Eudoxos as his predecessors. Abrr the latter is a pupil of Archyine (Diog. VIII 86 Theory of oscillations: Theo ",uiyru. S. 6i, i i Hiller - Arcbyt. htm. 3 B i , l- 33z, 9 iT. w Platon Tim. iS. 6y B). xn- the relations of the Deaiocritus to the Pytbagorean bfathe- matics are known, if not fa0able in detail. Cf. Eur . II- i i , 3q g. Very important is the date in Plut. blerc. i cyv yöp 't yaaxpévqv zaérqc itat ntpi jqzov épyoui ny" (Con-

and handles the concept of the infinite, which ancient mechanics fearfully avoids, in a very modern way.
\ way of dealing with it. His work on statics also seems to fall into this first period.

The second period of his work was, it seems, devoted purely to mathematical activity, the results of which are summarised in the main work "On Spheres and Cylinders". After he had brought these theoretical investigations to a conclusion with the book "Von den Konolden und Sphärotden" (On cones and spheres), he elaborated on his earlier discovery of specific gravity, made during his examination of Hieron's forged crown, in the fundamental work "Über die schwimmenden-'. I briefly mention his fine elaborations on the number a, about which a more precise calculation has recently come to light, and on the spiral, work which was then continued by Apollonios, the master of conic sections.

The evening of his life shows us the old man again as a mechanic. He has returned to the love of his youth and is now working tirelessly in the defence of Syracuse in the service of his fatherland. We now see him

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struittion of the dpy "va, i.e. war mascbines) ;f,etarso plv utytf+ et ntpl BA io § o# xot 'Jg $äcen crecxfl1oc cey r y1 "g"vg@ (ü. b. Mecbarut') y¢e-
/z¢cg/op, xe) loycxgr xot yge/sy'x§y 6xo4'/§*eG eöc e5cogo0wo nto/1#-
are 6c' o7d@rd'> xot épyo-c "6v copo/¢*yjzoru+' éw*g¢/6os rey, uy r8

μένων ἀναγκαῖον εἰς ὀργανικὰς ἐξῆγον ἀμφότεροι κατασκευάς, μεσογρά-

dt fZtissv {yor'iuyar nal dissrfvaso wptp atso6p, A9 dwoln'uzep nv1 dtog0ifpovrop zé yz'oprseiap dy "0öv , Aah sd*v 'töoipissv with veqr&r duo4ifp "ditoGdqp Int sl "faPysi rat rpos2expfvqp a4Tip "G aé'@ai

sé'v asparuerfdo'n rs2v&r J}'cyéeci Cf. Synipos. VIIt z, i , y p. y i 8 F.

eager to organise defence measures against the attacks of the Romans. \The Romans organised defence measures against attacks by the Romans, building turrets, drilling the enemy ships into the ground with "'ighty beams or hook-shaped cranes or lifting them into the air and smashing them against the sulky cliffs of Syracuse. Eventually it got to the point that as soon as a rope or a pole appeared above the city wall, a panic-stricken terror gripped the Romans and älarcellus was almost brought to x'er-doubt. The late reports about the famous burning mirrors with which Archimedes had set fire to the enemy ships are, of course, not confirmed by the authoritative sources Polybios, Livy and Plutarch). His last word, when the Roman soldier attacked him after the conquest: "Gelt foréarr rir- *culas myas* - is worthy of the great scholar. Cicero wrote of him that he possessed more genius than seemed compatible with human nature 3, and Heiberg called him "the most brilliant mathematician of antiquity and equal to the greatest of modern times".) In fact, I would only have to place etxea Gauss, the great mathematician, astronomer, physicist, the discoverer of the ßmethod of the smallest quanta, the inventor of the heliotrope and the needle telegraph, alongside him.

What confronts us with these great men: the

i) Antheniios, the builder of the Sophieakircbe and great admirer of the Archl- m,d" h,or,iv6 (Weermzoo, P zdoxogr. i z, zo P) uod BuPoo r practically proved that an effect, as it is told by the later traditionuag , was achieved by a combination of concave mirrorsa Nano . Cf. Berthelot, Journa? drr *Savatits* i 899 p. 2$3. On the question, which concerns only the source crlti¥, not the technique, see Herbert, Q aeir. JrcAimcd. Haun. S. q i : H. Thlerech Päaroz p. 93 F. On forgeries in Archimedes' name a. Vortr. V g. End.

2) De rep. 1 2 2 ¢fus him *i'lla Si'cula ingencc", quam vi'dzretur natura hu-* /crre ¢u/uitt , iüdiceéam /wiie.

3) Gercke-Nordea, Ei° - ++' 394-

The fruitful combination of theory and practice is important for science in general. Only where scientific research remains in league with real life can the great advances of culture be achieved. Technology cannot do without science, and conversely, pure speculation in science, if it is not touched again and again by the fresh breath of life, becomes sterile and dies. Vitruvius, who lived at a time when the scientific sense was already threatening to die out, says the following at the beginning of his work as a warning to his younger colleagues: "The master builders, who without science strove only for mechanical skill, have never been able to gain decisive influence through their work. Conversely, those architects who relied solely on arithmetic and science seem to have chased after the shadow, not reality. Only those who thoroughly acquire theory and practice have the full armour to achieve the goal they have set for themselves with general recognition."

Even today, the words of the old practitioner are still worth their weight in gold. The high level of our culture today is only guaranteed by the intimate interpenetration of science and technology. Foreign countries recognise that Germany owes most of its upswing to this healthy combination of theory and practice. For schools, both lower and higher, this results in the task of awakening in young people a cosmopolitan outlook and practical skills combined with knowledge and scientific insight.

This is the Archimedean point of our pedagogy,

1) I 1, 2. Vgl. unten S. 59 Anm. 1.

which is also an art, the first and most important in the state.') The sentence that the historical overview of ancient conditions has taught us, that empiricism and theory must go hand in hand, also applies to this 'rechnik. Nowadays, when the technique of teaching is at a high level and the teacher threatens to become a virtuoso of a purely formalistic art, it is necessary to remember that the constant connection with science is indispensable for him if the youth is to be properly educated f o r the tasks of our time.

Here, too, I would like to briefly recall an ancient analogue to the \Warning at the end of the book, the example of Greek philosophy, which first exercised the **ci2rq** of higher education professionally. Their \Yirken, which dispensed with the exploration of truth and hammered ready-made templates into the pupils' heads, clearly shows where a merely formal technique leads the youth educator. \Woe betide the teacher of youth who no longer wants to keep pace with the progress of science and considers external drill to be a sufficient form of intellectual education, woe betide the educational artist who, in philistine self-restraint, does not try to get closer to the truth himself every day and lead the youth closer to the \truth! In this tireless search for truth, may ri "ion , rler victoriously overcome the #dvnraop aerdzf" § of the sophistical virtuoses, shine before us as a role model 1 May practice and theory, art and science, thought and action always remain in harmony, as they did with him, and may everything be in the service of the one goddess to whom we dedicate our lives, the \Truth[

i) Cf. Pqlaton, Legg. I 6J4 A B def syv aaidciau pqdape0 dup*i{*i",

z) A. a. O. p. 6qq A.

II

ANTIQUE DOORS AND CASTLES ')

In wider circles, antiquity is still regarded as the creator of outstanding works of literature and art; the foundations of science have also been gratefully traced back to the inspiration of classical antiquity, and the great philosophers of the Hellenes are almost still among the current forces of modern culture. Only technology is usually ignored. The age of steam, electricity and the aeroplane looks back with a smile on the ancient world's cool beginnings in this field.

In fact, technology was not as central to ancient civilisation as it is today. This is due to the completely different social conditions. Society in ancient Greece, as in ancient Rome, was aristocratic. The technician as such did not belong to the leading circles of the ancient world. The most democratic states of antiquity were socially more aristocratic than the most aristocratic states of the modern world.

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i) Lectures II-V were given at the Hocbschulicnrsen in 8alnbnrg Sept. i 9 i z. The literature on this subject is listed in Hugo Blümner, Aäm. Z-rivat'tfter/u'rirr (I. Aliillerc Zfand6ucfi IV z, s), Munich i 9 i i , p. a i *. T*h have treated these fmgs in *"Parmenides"* gr. u. PfzrA, Berlin 189 y, pp. i i y ff. In addition Fairbanks *PhilosophIcal* Reiten411 *#¢3 ,-* D. Sey- mour, Zier in /Ar Aa nwic age (N. York i9oy) i 9 ; Brinkmann, Sitn.-Ber. *der* A/t'rtumrgei. Z-rui Ja XXI (l 9oo) p. z9y if.; Pemice, J'ifiré. *d.* arm. 7rz't. l 904 (XIX) p. i 5 ff. About neugr. Balanos locks DawLins, d'tn "a? o/ i3r with. *School* az dzAem IX i go ff.

This aristocracy rested on the institution of slavery, regardless of whether the state was administered monarchically or democratically. Even factories, where they were owned by aristocrats, were managed and operated by slaves. But where a slave can be maintained for ten pennies a day, there is no need to invent machines to replace human labour. Thus, the introduction of technical innovations still encounters the greatest difficulties today in China, a country with an immense lack of human labour, because the ßmachines threaten to make cheap labour unviable, while America, on the other hand, is trying to remedy the lack of cheap human labour by a huge increase in technical inventions.

Despite these circumstances, antiquity was not lacking in great technical achievements, but these have become less well known because antiquity as a whole took little interest in such things and our age, which is so highly developed in this field, is only now beginning to warm to these incunabula again historically. Students have long since overtaken the old teachers in this field. Our appreciation can be all the more unprejudiced and just when we see how arduous and slow the progress is that mankind was able to make in the exploitation of the forces of nature in ancient times, although the all-round gifted Greeks also successfully turned their eminent acumen to these cultural works from time immemorial.

I will begin with the oldest Greek period, with the Homeric world. For even though the astonished

Although the culture of Greece in the second millennium, the so-called Mycenaean culture, h a s been brought back to us by the astonishing excavations of Schliemann and his successors, it is questionable whether the bearers of this culture were already Hellenes in the later sense, and how far this Aegean culture developed independently of the older cultural centres of Asia and Egypt. \What even the legends of this Hellenic prehistory h a v e to say about technology, e.g. about the construction of the labyrinth, the successful flight of Daedalus and the crash of the aviator Icarus, we can l e a v e that to one side.

So let me take you back to the h o me r ic \Ve lt and show you how the doors of houses were constructed and sensibly locked in the 8th century BC, when the Iliad and Odyssey were written.

We open the first book of the Odyssey. Tele- mach had spoken courageously to the free men for the first time. They went home at night. The young prince walks across the palace courtyard to his bower. Eurykleia, the faithful arbiter, shines her torch across the dark courtyard. He opens the door (i, ¢56), enters the bedchamber, sits down on the bed and takes off his chiton, i.e. his shirt, which he hands to the old servant to hang up next to the bed. Now it continues (v. 44 '):

Hereupon she went out end cogged the door by the silver handgri$
Quietly, and with a run closed the bolt.

As we can see from the foregoing, we have to imagine a double door. The closing of one wing is not thought to be self-evident. Perhaps only one sash w a s opened. \What such a door generally looked like has been revealed by the ancient excavations of both the Mycenaean palaces and the Mycenaean palaces.

and later buildings have clearly taught us. You must completely disregard our door constructions: Hinges in which the tiir rotates do not exist in ancient Greece. Instead, the two door leaves are embedded in round spars, which the Greeks call axles (dtoprp) because they look exactly like the axles of a chariot. As you can see, the word and the technique of \Yagenbau is conveyed to modern times by the U'riechen. Even Hesiodos, the Boeotian farmer, who wrote not much later than the poet of the Odyssey, does not describe more precisely the "hundred pieces of wood which, in his opinion, were needed to build a chariot '), but he does specify the size of the axle and the wheel components.-) The "axles also play a role in Solon's legislation, insofar as there were four recessed panels around a vertical central axle on which his laws were written.-) We now have such bogies set up in museums and railway station halls for similar purposes. Homer calls these bogies 0'ttpof -), whereas the philosopher Parmenides, the Eleatic who lived around s, they are really called d§orip, namely ;ro2J2a1uor, i.e. richly plated with ore. They are in an ornamental bronze shoe and turn

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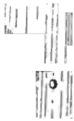
2) Jffirie and Z'ud c g z 6{o "a inzon6t9 . I set up the frame so that the wood reaches the two axles of the four-wheeled carriage. Then he holds each axle j '/, i"uß (2, i z m) , which is sufficient. l3nß the cart of the I4esiod cier has wheels, correctly notes Wall z, arms *of the* 2f/u-fci
XIV (1912) 226, der auch die Ungenauigkeit der sonstigen Maß-
zogsbco (very uogconuvs Vc 6ähoi* fe, na'üws *u wheel pedph rie) rictüig
aus dem primitiven Stande der Wagnerei aufgeklärt hat.

3) About the establishment of the Solonian uip}ftip and @o "tp s. \Vilamowitz, ***Aristoteles u. Athen*** **I 45. Die antiken Stellen gesammelt von Sandys**

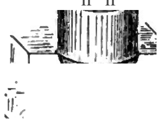
) Related to 8'iipo , originally "door walkers", i.e. posts , rr'it with which the door opens and closes.



This shoe is placed in a pan that is also lined with bronze. Many such pans and door shoes were found during the excavations (Fig. 5). At the top, this doorpost (pivot beam, axle) is now stuck in a hole in the stone p"""""" tiirfiillings. Thus (similar to >^-^ '-* ^-- "'-^- our wardrobes) the right and °"" "" " the left sash opens and closes in the corners at the top and bottom by leaning the door panels against the slightly protruding edge of the lower and upper sill, so that the F1uge1 can turn outwards but not inwards.

As the wood tends to shrink over time, it will often have happened that the animal wings are no longer exactly fixed in the pans and could be thrown out in the event of a knock. In addition, it is more difficult for such beams to turn with the whole round at the bottom than when the whole weight of the door leaf is balanced on one point. For this reason, in the 0th century, door shoes were fitted with a pointed peg at the bottom which engages in a hole in the pan (fig. 6). This is how the axones of Solon were set up, as we have been told, as was the heavenly door described by Parmenides.')

li "ll



\Yow, however, was the door itself closed? Homer says (Onl. i , qq i f.): ^""' g' r*,} ,.''''

She pulled the silver handle
the rope and closed the latch with the strap.

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i) Solon's axons rotate in cones (s "Ataue , i.e. azn ä d a § , att. zrdito'e "R eibezahn--) according to Et. m. i i i , q 6 u. 5qy, 6o. Parm. r, zo speaks of the cones (yöp9'oi) provided with "needles" (arpörai i.e. S{'itzen).

We would not understand this if we did not know the oldest Greek key, the so-called Te mpe 1- sc h1ü ss e1, and if we did not have an old vase-painting which showed us this key and the Homeric strap in the act of closing. Thus I succeeded in reconstructing .'the Homeric door system from these two elements in the year i 89d) Let us first look at the key. The priestesses pCegen to preserve the oldest Homeric form of the key, since in religion everything from ancient times tends to be faithfully preserved. This key was considerably larger and heavier than any now in use, so that it is usually shouldered (fig. 8, 9, p. So).

By a fortunate coincidence, the key of a highly famous sanctuary, the Temple of Artemis in Lusoi in Arcadia, which was uncovered at the end of the last century, has been preserved. } The inscription, whose features point to the 5th century BC, testifies to its origin. (fig. y, p. So.) The numerous depictions of bowl-carrying servants on Attic vases (fig. 8) and gravestones (fig. 9) are consistent with this. Indeed, an exact depiction of her key has even been found on a tombstone placed in the tenth century BC for the Polias priestess Habryllis (fig. i o), which, in addition to the sacred priest's armband (left), has a leather strap wrapped around the key's knee on the right, the use of which will become clear later.

How old the use of this key is is shown by the linguistic observation that the rounded, S-shaped

J) In "Parmenides" tNote i op. cit.), W. K6hler, Krcdi*. /. Ar?igiö on'. VIII (*9°5) *** >-

z) Published by me 3ie.-2trr. 'f. &m/. ai. i 9o8, p. zy. The inscription reads: zfl9 'Jpsitzisot c8t Zv Jodaoi t.

3) J. er. II zi69. Köhler, z*. 3zir/. IK 3o i.

Abb. 7. Schlüssel des Artemistempels zu Lusoi (Arkadien). 5. Jahrh. v. Chr.

Abb. 8. Vase der Petersburger Eremitage. Mon. ined. VI. VII Taf. 71.

Abb. 9. Attisches Grabrelief. Conze att. Grabrelief n. 812. W. Spemann, Berlin.

Abb. 10. Tempelschlüssel der Habryllis. Conze att. Grabrelief 1796—1799. Tafel 385.

Abb. 7.

Abb. 11. Clavicula sinistra, facies anterior hominis.

Abb. 8.

Abb. 10.

Abb. 9.

The shape of this instrument, as shown by the key of Lusoi and as it is also sometimes found on vase representations, gave rise to the naming of the human clavicle after it. This name (zlqfp) already appears frequently in the Iliad. An illustration of this bone (Fig. i i, p. So) will help us t o understand this attribution.

Having thus learnt the key, we can turn to Homer with a better understanding.

We hear how this poet has his Penelope, who is fetching Odysseus' bow, open the door (i i, 5 ff.):

She then hurried to the raised staircase of the \Vohnon¢
And gripped the well-curved key firmly with her hand: it was a rather bent and ivory handle.

You see, Penelope is grasping a bent, bronze key with an ivory handle for easy handling. This is our temple key. Now the description continues (z I, 4' 1:

Ah *e ooo came to the Kxmmez em r, de gotGc6e Furiüo,
She approached the cot elcbene shaft. The master had
Strictly in accordance with the rules of the art and the standard, Had carpentered the posts in and t h e shimmering doors.
Eileuds loosened the strap from the ring of the gate, inserted the key and pushed the bolts from the door with a purposeful push. Dg the door yielded, like a toothed bull roars and blomiger Am , so brought the shining mügel,
When they hit the key, and quickly came apart.

So she first removes the strap from the ring, inserts the key into the keyhole and pushes back the bolts of the door, which let out a loud roar as a result of the contact with the key

The most vivid explanation of this process, which Homer describes in loving detail, is provided by an old Berlin vase painting (plate VI), which Fink first published.

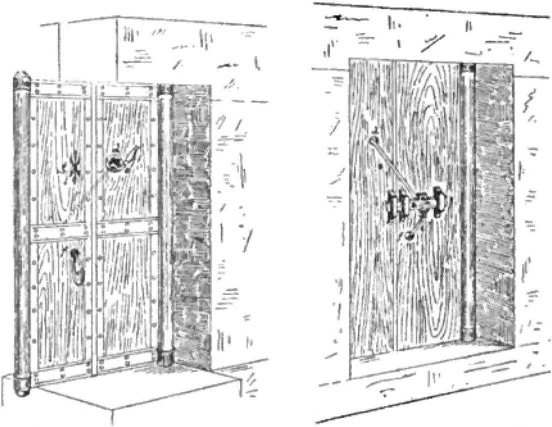

Abb. 12. Homerische Türe von außen. Abb. 13. Homerische Türe von innen.
a Aufsatz. *b* Riegel. *c* Riemen. *e* Schlüssel. *f* Riemenloch. *g* Griff.

but had explained incorrectly.') The correct interpretation is obvious if one tries to determine what is hidden behind the door from the process on the front.

Whoever holds the long, heavy slice in the lower grip like this little eel's hand is trying to thrust with it as with a lance. This explains what Homer says: i. "griff

t) *The Herschlu ff among the Greeks and Romans,* Regensburg i 89o. The reproduction of the Berlin vase painting is based on a painting by Prof. J. Tsehermah v. Seysenegg before the original. Wooden models of the Lomeran door based on my reconstruction can be found in the Berlin Antiquarium and in the Institute of Ancient Studies at Berlin University. Several similar models were also on d i s p l a y at the German University Exhibition in Berlin (Friedricbstr. i z6) *from* February *ii to* April i 9 i .

Plate VI.

Girl with the key o p e n i n g the treasury.
Red-figured hydria of the Berl. M uieum 238 z.

firmly with the hand" (2cipl aa rfc) with which the key must be handled, z. "with a sure push" (dere ctrpaxopJioj). It therefore pushes the twisted key from above through the round hole edged with ßletall, and e so that the longer part of the key m e e t s the bolt on the inside, while the handle remains on the outside.

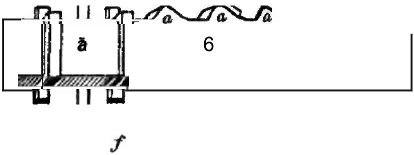

Abb. 14. Riegel (*b*) mit dreifachem Höcker (*a*) nach Brinkmann (S. 44).

remains outside. Of course, the bolt must also be able to withstand the strong impact (after all, according to the poet, there is a real bull's roar). be shod with ore. In order for the key to hit the right spot, some specimens have a wider rim at the bottom. This is the case with the key of the Athenian priestess Habryllis, which I have already mentioned (fig. io, p. o). The servant in our picture is now pushing the key against a latch on the back and thereby pushing it back. The door o p e n s .

The two illustrations (i 2 and i 3, 'p. j 2) schematically show the Homeric double door: once from the outside, after the key has struck the centre bolt through the upper hole; then in the second illustration it is shown in the locked state, before the key engages the upper hump of the bolt (attachment) from above and pushes it back to the right so far that the latch on the top of the door is pushed back.

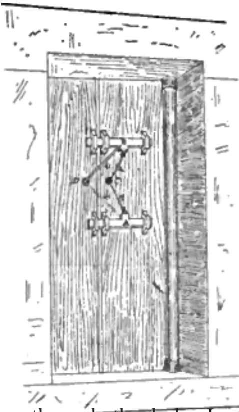

Abb. 15. Doppelverschluß der homerischen Tür.

left door leaf becomes free and this F1uge1 springs open

According to a modification of this system devised by Prof Brinkmann in Bonn, the latch can be fitted with two or more cusps at the top instead of one (Fig. i 4, p. 3). This can considerably increase the room for manoeuvre that the latch has to move back.') Once the door has been opened by pushing the latch back, it can be closed again in the simplest way in the world, namely by pulling the strap at the bottom of the latch through the hole.

through the hole. In this system, the key and the strap are therefore the same as opening and closing. This is why the priestess Habryllis carries the key with the corresponding strap. Because in temples that could not always be guarded, it was advisable not to leave the strap in place but to take it home with the key.

Homer says that Penelope pushed back the strap 1 (ß25"#). So there seems to have been at least one other latch. For the bow is described in

1) Brinkmann, *Sits.-Ber.d. Altertumsges. Prussia* XXI (1900) 299 legt Gewicht auf das Imperfektum ἀνέκοπτεν, das auch durch Annahme zweier Riegel eine ausreichende Erklärung nicht erhalte. Aber wenn seine Rekonstruktion des Riegels auch richtig sein mag und sich mit dem Impertum trefflich verträgt, zwei l sind doch nötig wegen des Plurals , der neben dem sonst nicht ungewöhnlichen Singular (z. B. Ω 566) seine reale Bedeutung haben muß.

the treasury, which must have been fitted with several bolts, as in our case. The above sketch (Fig. i 5, p. 44) may illustrate how one could imagine the opening of two bolts *(A* and ff} fixed at the top and bottom from the one keyhole *D*.

\But is the lock completely safe from thieves? No. That is why Penelope did not just pull the door of her treasure chamber with the strap and thereby push the bolt into the cramp, but also knotted the strap to the ring. Homer teaches us what this means in another passage of the Odyssey (8, ¢58). The Queen of the Phaeacians gives Odysseus a chest with a lid to store his gifts. \We can imagine her holding the Alüdchen on the Berlin Hydria in her left arm (panel VI):

> But Atete brought the marvellous chest to the Frerndling
> Jetnt from the chamber and placed in it many beautiful gifts, gold and
> garments, so honoured by the Phaacian princes Then she herself added
> a cloak and a magnificent shirt, And now she spoke to him aofievingly
> apt words:
> Now sift for the cover yourself, and nimbly tie the knot, So that no one robs
> you, sobsld you call on the journey home
> In the black cable of lovely slums un@angen!

You see, this is a magic knot that only the divine sufferer knows how to tie and untie. For he learnt it from the sorceress Kirke. It says immediately

> But as this the divine sufferer Odysseus,
> He put the lid on and then quickly twisted the knot many times back
> and f o r t h , as the sorceress Kirke taught him.

Unfortunately, the innocent state of J\humanity did not last long, where people w e r e kept from locked treasure houses by magic knots.') So they invented

1) On the form of the ancient knots, see Wolters, *Zu gri'ychischen jenen* (\Vürzb. T'rogr. I goi) S. y P.; ders., 6odrn *Hand* Ano/z'n ob dmu/¥fi¥, -4r¥1*

an artificial lock, the key of which i s called "1ak on i- se he r Sc hl ü ss e1-. In the Thesmophoriazusen, Aristophanes amusingly describes the women's annoyance that they could no longer snack in the pantry because the lords locked it with malicious secret locks with three prongs.') The system of these la-

• e

Fig. i6 **Fig.** i8 Abh r y.
Jscobi scho J\'models of hoicoroou balaooiscbloiners.

The conical key is old and did not appear in Greece. Such locks can be found in Egypt as early as the time of Ramses H. (i z 9 z- i 2 25). and they are still in use here and there in the Orient as well as here and there in many variations.

The simplest system is the following -): We have a two- or three-pronged key N, which is either inserted into the bolt A (fig. i ö) or into the housing d a b er (fig. i y)

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f. 2i-e?igi . VIII Supplement, p. 1 ff. ; v. Bissing, figjp/ürfir lno/maaiu/c/tr, ibid. p. s 3 ff. ; Heckenbach , N warf vincu/ü (Dieterich-Wünscb , Er/i-gioiiigc ch. PrrmrÄr IX 3) i oq $.

L#n0ri*' 6r*Q, *etCg Cyorre yo giovy.

2) The toe-uniicn are made after the delicate i\torlellen constructed by the late Geh. R. Jacobi in Homburg. Examples in wood and more complicated ones in iron are always on display and for sale in the Saalburg Museum. A similar Balsnos lock still in use in Thera is a gift from Mr Hiller von Giirtringen in the apparatus of the Bertin Institute o f Antiquities.

is inserted. In the former case, it is lifted by a small amount so that the prongs push the small blocks (j$dlnpoi, i.e. acorns) *B* above it, which engage in the bolt from the upper housing, upwards out of the bolt, thereby cancelling the lock of the bolt. By inserting the prongs into the holes previously occupied by the blocks, the bolt can be released from the lock by turning the key to the right. the second system (Fig. i y), which operates above the bolt, is similar. Insert the key N into the housing, lift the blocks *B* (Fig. i 8) so high that their lower part engaging in / is lifted (this condition i s shown in the illustration). This cancels the blocking of the latch N located underneath. It can now be easily pulled out at its end protruding to the right.

So that you can see how this Balanos lock works on the door itself, I show you here the view of a double door located in today's village of Politiko on Cyprus'), in which the old system, which has been faithfully preserved through the millennia, appears in a small variant (Plate **VII,** also the diagram Fig. i 9, p. 4)

On the right is the lock, above which is the ring for closing, in the locked state. The key has been removed and placed between the latch and the latch toggle, which prevents it from coming out too far (the indistinct bar between the ring and the lock is a scale). If the lock is now to be opened, the key *S* (Fig. i 9, p. 48) with three teeth is inserted into the keyhole and the Balanos blocks (fi) inside are lifted out of the toothing of the bolt N, which is then locked.

i) I owe the photograph of this door to Mr Wilh. Dörpfelä (Inititntephotogr. Cypern n. y9 Athens).

can be pushed back to the left as far as the *P* post.

The use of the 'dakonian' clasps and the associated balanos system in Greece and its colonies can only be traced back with certainty to the beginning of the 5th century BC.

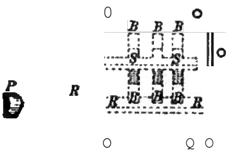


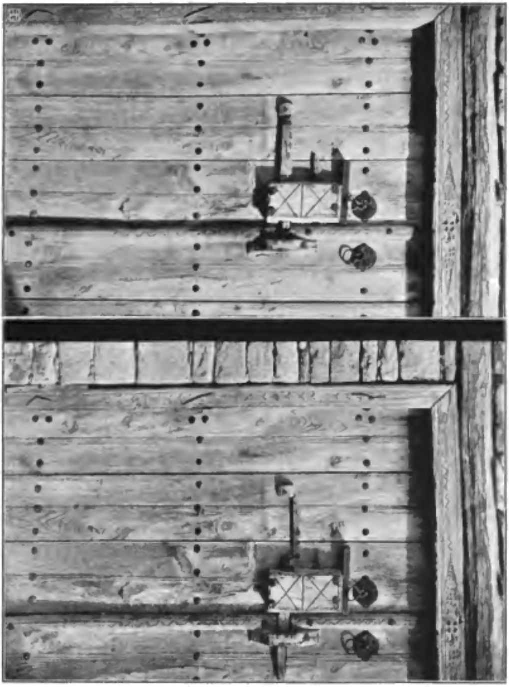
Abb. 19. Kyprisches Schloß mit der inneren Einrichtung.
S Schlüssel im Begriff, die Balanos klötzchen aus dem Riegel zu heben
^'-a-* ---^ *-=-^*-^-^ ^--
lanosklötzchen, unten noch im Riegel festsitzend. *P* Pflock zur Hemmung
o''

5th cent. century. Only when Aristophanes a. a. 0. calls these modern keys "home keys" (aRidfa xpoas") and in one of the most recent parts of the Iliad') the Thalamos of Hera is described, which her son Hephaestus is given with a
home castle (xl9rdt epvnry), which no other god was able to open, it is probable that the otherwise very modern poet of this episode alludes to this secret art as Parmenides in ''' '''''''' ''' ''o- his description of the celestial tiire.')

There may well be something to Pliny's report that Theodorus of Samos invented the key (only the laconic one can be meant). For, as mentioned earlier, this island was at the forefront of Hellenic technology in Polycrates' time, and the lively relations with Egypt make it not improbable that intelligent technicians from there brought a system to their homeland, the advantages of which are still used today in the more sophisticated locks of security cabinets.
locks of security cabinets.

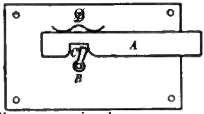
1) In der Διὸς ἀπάτη Ξ 165 ff. 2) 1,16 βαλανωτὸν ὀχῆα.
3) N. hist. VII 198. 4) S. 7 ff.

Offen



Verschlossen

Tür in Politiko (Cypern). Balanoverschluß.



Of course, our usual locks today are spring locks. The design of such a lock can be easily recognised by a schematic diagram.

tical sketch (Fig. z o). The use.'.. u"a"'" nos unit. key ø pÿq ending in a tube, 'r use see *it is placed on the mandrel &. The
-" " ○ *^-

"beard" of the key plays around this fixed point *B,* and by turning the spring-loaded bolt A from right to left when it i s turned, it pushes itself

back into the lock and thus opens the lock. This "double lock" is " already known to the Romans.

have been found belong to this system. Some of them are artistically crafted pieces, such as the Pompeian door key (Fig. i i). I have previously attempted to trace the origin of this convenient fastener back to Hellenic antiquity from the door locks and latches that appear on Attic vases.') This post-eis is not entirely certain, given the incorrectness of the vase painters when it comes to such details. We will therefore have to wait until test-dated artefacts confirm this hypothesis. But be that as it may, one will get the impression from what has been said that ancient technology did not work skilfully and successfully to secure property and gave modern times many a fruitful stimulus in this area too.

Abb. 21. Pompejanischer Türschlüssel.

1) *Parmenides* S. 145 ff.

WATER METER, AUTOMATON, TAXIMETER

Most x of you will be familiar with the water ski in the nearby park of Hellbrunn '), but only a few will know that it was built in the (Hellbrunn) Park.

However, few will know that these technical marvels, popular in (-)7and i 8th)ahrh.

The author's physical-mechanical works are almost the only remnant of ancient, scientifically founded technology to have survived to the Arabs and to us. This author is called H e r o n of Alexandria. He probably lived in the 2nd century A.D.$ and is particularly valuable to us because, in addition to a few small inventions of his own, he copied verbatim a great treasure of ancient physics and technology, which h a s stimulated and fertilised our modern mechanics in many ways since the Renaissance.^)

i) The imperial Hellbrunn Palace, 5 km south of Salzburg, was inherited by Archbishop Marcus Sitticas i 6 i 3 and the palace w a s furnished with large vases (a mechanical theatre with i 5 figures and an organ, Neptune's grotto with two birds), which still attract a large number of visitors today.

z) The views of more recent researchers dwindled between ioo before Christ (Msrün, Hultscb, Titte1, R. Meyer) and zoo after Christ (Hommer-Jensen, *N. $ahrb.*
/. d. *Bl. Ali.* XX V i 3 ff. which recently *[Hrrm.* XL V III zz ff.) even *Vi z* 3oo a. Chr.). In contrast, R. 6leyer, De Zferoarz setzte, Leipzig i 9o5. He concludes p. 39 *Heraeiem negue a tte secumdi onte CX r. n. saecuJi y'ai'*te n//eram nep "e neu/fo Dorf ¢ r i "ium a. für. 'i. ioerufum *tnedium* /oruüfie. In contrast, again .'Y. A. Bjornbo, may. #Ai?ot. fffirA. i 9oy, sp. 3z i ff. I adhere to the later dating (2nd century A.D.) first advocated by me and assumed by Carry de A'aux, Tx nery, H e i - berg and others, although a definite result h a s not yet been obtained. Literature in Tittel Art. *Heron i* ri Pauly-W. *R.-Esv. Bl* 11 99°

3) Heron's here mainly in consideration liotum pne umatica and

His name is associated in the school curriculum with the so-called He ronsb all, in which water is made to flow out by compressed air.') The principle has already been applied in the fire pump ') invented by Ctesibius. A more modern form is the siphon and the steam trap.

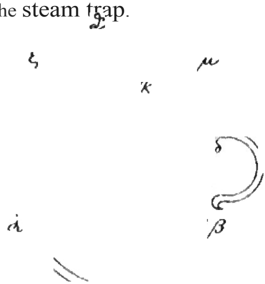


Abb. 22. Herons Dampfkugel.

form is the siphon and the perfume syringe.

Heron's steam engine 1 (Aeolipile)), the seed of the modern steam engine, became more important in the following period. The schematic drawings in our Heron manuscripts, which date back to ancient times, are difficult for the uninitiated to understand.

uninitiated a "

") They look like this (Fig. z z).

The two views of the steam engine, which \Vi1helm Schmidt himself added to his text, seem more comprehensible to us -) (Fig. z5 and 4. p. s°. sel

The water contained in the lower boiler nyd# is

Automata are available in an excellent edition by Wilhelm Schmidt, Heronis Oprra I mit Supplement (Leipzig, Teubner 1899), sor, in *'elcher dein nach den Hgg. gorgf ältig rekonstruierten griechischen Tezte eine deutsche Ü bersetaung und die modemisieiten Abbilduligen der gr. Unfortunately, one of the scholars who was inspired by me to write this work died as a result of revision after finishing Mechanics and Catoptrics (Heronis opp. II i , Leipzig i goo). II Schoene and J. L. Hciberg continued the edition (III, IV).

i) Heron, Pneumatik c. i 5 (I, p. z43 Schmidt). Cf. t3 (22 i).

z) Cf. Hammer-Jensen, W. Jo/tr6. /. d. 1'/. dt. XXV (i 910) -t I §-

3) The expression oco/i@'?a, which comes from \'itruv 1 6, z, actually means-

q) W. Schmidt, Einf . zu s. lleron 1, p. XLV, fig. 55 b.

3) p. z 3o and z3 i , fig. ; and 53 a.

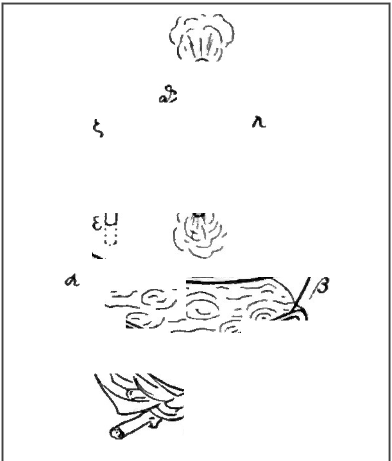


Fig. a3. -teeoa DmJ-gel coscorn.

is heated. The vapour rises in the tube f§q and penetrates into the ball Px, which rotates around q and 1 and has two hook-shaped curved outlet pipes whose ends are bent in opposite directions. The escaping vapour pushes against the surrounding air and therefore drives the easily movable sphere Px. in the opposite direction to the vapour atom, which causes it to b e noted quickly.

In order to demonstrate the old experiment to you here, I will use a p-i-curved glass tube, which is inflated spherically in the centre') and suspended from a wire on either side of the sphere so that it can rotate easily around its axis (Fig. z5). If I now fill the ball with a little \water and heat it carefully, the vapour flows out on both sides and the tubes rotate faster and faster the more the heating and vapour development takes place.

Burger & Go., Berlin N , Chansscestr. 8, which produced these two nI uster

Even simpler is the small one-armed apparatus devised b y an English scholar, Sir George Greenhill') and which I am also showing you here (Fig. z6). Although these small experiments clearly demonstrate the effect of steam power, there was still a long way to go before the invention of the steam engine.

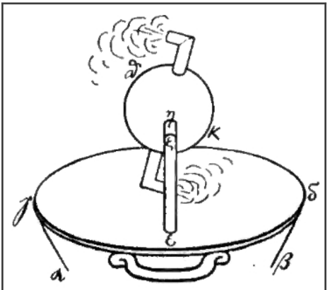


Abb. 24. Herons Dampfkugel von der Seite.

steam engine was still a long way off.-) Heron's time was more focussed on playfulness than on practical goals

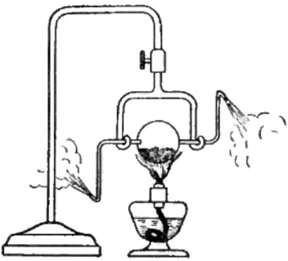


Abb. 25. Zweiarmige Dampfkugel.

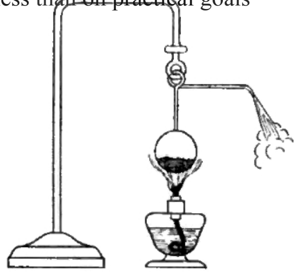


Abb. 26. Einarmige Dampfkugel.

1) Er war früher Professor der Mathematik an der Artillerieschule von Woolich. ie Kenntnis seines zi Herm. I owe d Amandns ier, der ihn s. Z. erticben A pparatee Hetm barer Aufhänger diente ihm dabei der obere Teil eines gewöhnlichen Taschenuhrschlüssel Schwarz dsl der A kadea e vorffirte a you , der an einen Ha er angeschraubt wurde.

2) Doch ist zu bemerken, daß der von Heron, Pneum. II 34 und Athen. (*iliarium*) eine Feuerei , mit den modernen Systemen von Cornwall, Galloway und Field bemer-

His presentation of physical problems is reminiscent of the way in which physics was practised in the curiosity cabinets of the high lords of the i j and i 8th centuries. Nevertheless, an application of the Heronian steam engine experiment for practical purposes shows an invention published by Giovanni Branca, who was employed from i hi6 on as architect of the Santa Casa in Loretto'), i öz9. He directs the outflowing steam onto a paddle wheel (Fig. z y), through which a small stamping plant is to be put into operation by means of several transmissions. I have not been able to ascertain whether the plan was actually realised. In any case, this invention initially had no further consequences for the technology.

A large part of Heron's work also boils down to of his automata. The writing that deals with these

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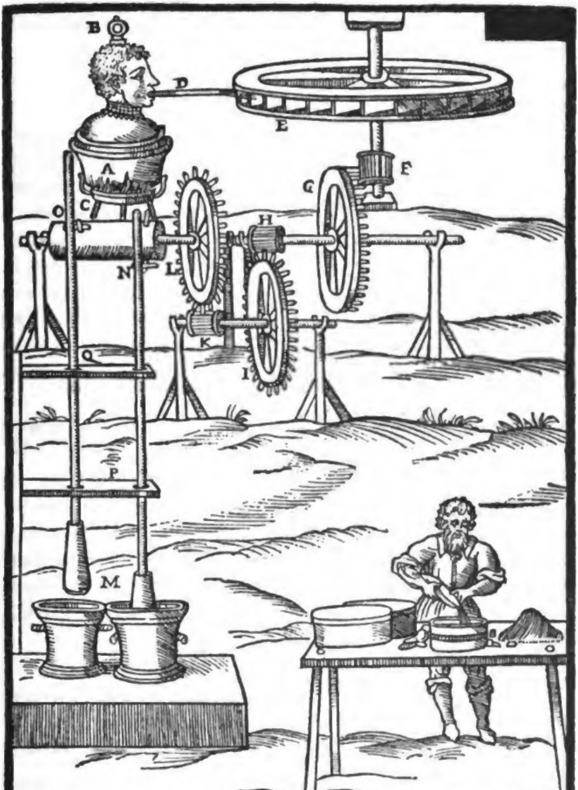
offers analogies worth considering. Cf. W. Schmidt, *Zur Gesch. des Das pfesseln i'm Altertua-, Dibliotheco math.* III. Folge (i 9oz) 33y ff. Furthermore, from O. v. Lippmann (A6A. u. /Ör/rrige li zoi) has also shown that the pot ("Digestor") invented by Papin i 68y is already described by Philu- menos, an archetype of the 3rd century AD, for the preparation of tisanes. The author rightly notes that this doctor c a n only be considered as a compiler. The invention is nlgo older.

J) His book has the title : je H/acAt*e. 1'oZp'fte rieoT'o rt li mOJfG *ortiflcia* des *fore eßetti inornz'i'gIi'osi'tanto Sp(rItaIi' quanta di Animale 0 pe-* rufii'nr ori?Aiia fJ é e / ?üsJme /gure ron /r 'firAtaroZtenr a rifi'- via fi ersr *in Ihng no molgore et lattnu,* Ro "ia f 6z9. - (Royal Bibl. Og 8698. zt-). The Latin explanation reads: Fig. z 5 *ad turidendum* m'if<rn*r Qm /ortkiida sie s?vrr i d cash miraö /i cioforr i mt/ a/tad r/ naht re u/ mzfa/ff ***cum suo trunco signato per A aqua pleno per foramen B posito supra accensos carbones in foco C, ut non possit in alium locum expirare quam in os D. ita violentum spiritum emittet, ut vertens rotam E et suum rochettum*** (Sabrzd) ü#vAm üf in rrom VsnAug G n swg ror4rno V'aor-f xe fa* / p "ue rocAef/o N mewr/ talk Z regt ci?*fro im9eraßie (friit pens *see) per z/o//m'f/ öuoßw ¢iiZ his W. 0. iii ,rtsii /u/r mrnf s T'. Q. gene iivi?rm ir e.rfoffzn/rs iuprn voia raz/o/ft 2Z iun'fu'Hur ¢uftu nfiaeyr "ia- /rrJar neceiitiofz. Since the vapour-blowing head sus Heron, Pnenmat. II 3¢ (I 30d, fig. y8 e Schmidt) stnmmt (similar "Püstriehe'- des i 5. Jahrh. bei Feldbaus, Vertritt p. 8 q ff.) as the motif of steam operation, i t is cc questionable whether this projefi t ever progressed beyond the paper stage.



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The purpose of this project, which is concerned with the delicate artworks of ancient mechanics, is theatrical or popular-religious performances. In this "automaton theatre", for example, an apparatus is described to conjure up a Bacchus festival in miniature for the spectators,) another performs an ancient drama by Nauplio in five acts, all of whose characters were automatically set in motion one after the other by gears and ropes.) Palamedes, the son of Nauplios, had been stoned to death by the Hellenes in the camp of Troy. Nauplios' father therefore took revenge on the Hellenic Greeks by erecting a false beacon in the night at the southern tip of Euboea. The Greek ships all perished at the dangerous promontory of Caphereus. Athena hurls the thunderbolt against Ajax.

The automaton theatre now presented the drama in the following five acts:

i. Act I: Twelve Greeks work on the ships to launch them. All kinds of craftsmen work in the background: sawing, hammering, drilling etc., similar to the Hellbrunn automata, except that this ancient Greek automaton theatre is not driven by water power but by strong weights that set the wheels and machines in motion with snaps.

2. Act: Launching of the ships.

3. Act: Voyage of the ships. Dolphins dive up and down next to the ships.

4. Act: Storm. Nauplios erects the false beacon.

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i) fftpt a6iopnzoaoiqttz§9 (i.e. Beaver the Kunet of the prefabrication of Automstea) Heron I 338- 33 ed. AV. Schmidt.

z) Ibid. c. i3 p. 3 * .

3) Ibid. c. z -3o p. ¢z3 ff. In addition W. Schmidt Zfw- v. Riet. (Sooder-abdr. sus W. 9Wré. . f. +f. er. i89§ p. zwo ff.), Leipzig i899, p. i z¡ R.Scboeoe, #s*r#d.sr ./v^V (8go) yj.

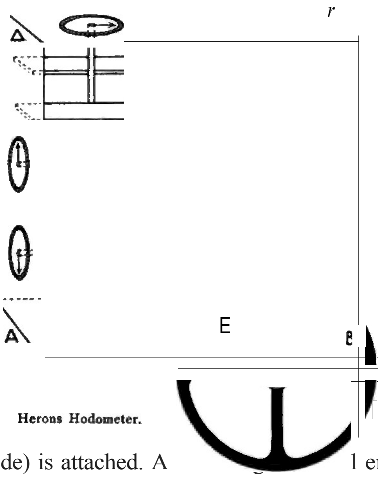
5. Act: Shipwreck. Ajan swims towards the land. There 'ñ-appears on top of the theatre machine (just like in the old Attic theatre) the goddess Athena, who hurls the thunderbolt at him. The thunder machine produces the obligatory thunderstorm noise. Ajax disappears into the water, where a prospectus slides forward and covers the swimmer.

In the past, these theatre automata were often imitated in the mechanical theatres of fairgrounds. Nowadays, only a few of Heron's automata, e.g. "the chirping birds" and the like, are still in practical use. Two of Heron's devices, however, have recently taken on an unusual significance for the trade: the tax machine and the vending machine.

Heron calls the tax am ete r (taximetre) the h o- d o m et er (waymarker). His description') reads like this in free translation:

w ith the help of the h od o m et er we can measure distances travelled in the country without h a v i n g to use the measuring chain or the measuring rod. Instead, we sit comfortably in the carriage and measure the distance travelled simply by turning the wheels. The machine is constructed in this way (Fig. z8, p. 58): You build a box *ABΓd.* A wheel 2f Z with eight spokes is placed on the bottom of the box, which rotates parallel to the bottom of the box around an axle that is embedded in a false bottom at the top. The box is cut out at the point where the spoked wheel runs in such a way that a vertical pin can engage in the spokes of the wheel from below, which is connected to the hub of the large balance.

I) Heron's Dioptia 3 (Lf, p. z9z ed. H. Sctioene); daze e. Wilamowitz, Zcseòwfi I z6z (eæendlerter Texł and Abbildiing).



Herons Hodometer.

wheel is connected so that when the wheel is turned once, it hits one of the eight horizontal spokes once and pushes it away, so that the second, third spoke, etc., moves forward to the cut-out.

A cylinder with a screw thread (screw without end) is attached to the upward-facing axis of the spoke wheel. de) is attached. A l engages in this thread and is attached to a transverse axle. This again has a thread that drives a second horizontal gear wheel; its axle with screw drives a third gear wheel, this drives a fourth system and so on at will. The more cogwheels and threads we attach, the more miles we can measure in the \vermeter.

Now the ßlechanism works as follows: Each turn of the thread advances the cogwheel by one tooth. When the rotating wheel of the carriage has completed one revolution, the pin of the hub turns one of the eight cogs. If the next gear wheel now has 3o teeth, the adjoining second worm thread marks an e' revolution when 8>< 3o million revolutions of the carriage wheel h a v e been completed. The next gear wheel then shows

2ĄOJwCjO-}2OOLI - rotations of the balance wheel. If this now has a peri- phery of to gr. cubits - i 5 gr. feet, the total sum gives y 2oo>< i 5 ft, i.e. i o8 ooo feet. Since 6oo feet make up a Greek stadium, the distance travelled is i 8o stadia.

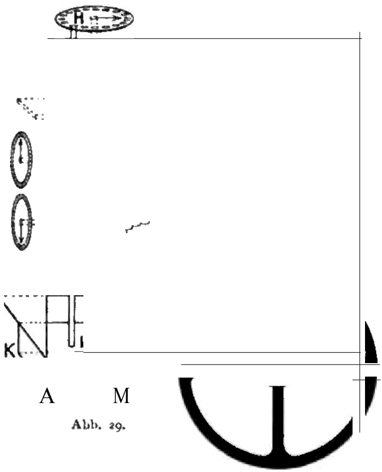


Abb. 29.

In order to make these numbers of revolutions recognisable from the outside, the round axes are used. the round axles of the gears extend outwards and end in a square shape. These ends have pointers that run through a graduated circle from which you can read the position of the individual gears and thus determine the distance more precisely. This is similar to our electricity meters.

A slightly different hodometer is described by the Roman arehitect Vitruvius X 9, i -ą '), who worked on similar mechanical devices to Heron in Latin, based on Alexandrian models. In particular, he provides information about the inventions of Ctesibius, the inventor of the fire engine. Vitruvius' hodometer (fig. z9) is otherwise constructed in the same way as Heron's. Only the last cogwheel, the revolutions of which determine the

i) He lived under Augustus. See above p. 3z.

To show the total distance travelled, a number of holes have been drilled in a circle, approximately the number of miles that can be travelled in a day. These holes are filled with balls which lie loosely between this wheel and the cover of the housing, which is located a short distance below it. Now, after travelling one mile, the hole f:f of the gearwheel runs over a corresponding hole in the housing, which, like the holes in the gearwheel circle, allows the ball to pass through. A channel Of opens into this hole, through which the ball is conveyed downwards out of the gearwheel and falls into an iron drawer 2ffi Uf under the hodometer box. This allows the other passengers to hear the mile travelled each time. At the end of the journey, you pull out the brazen drawer and count the balls: so many balls, so many miles. As you can see from the plan, Vitruvius' apparatus is not as elegant and scientifically accurate as Heron's \Vegmesser, but it is practical, it is Roman I

It is interesting that Vitruvius (R 9, 5-y) tells us what Heron omitted, that this hodometer can also be used in navigation. Ships, whether oars or sails, are fitted on the side with show-wheels of a certain dimension, like our wheeled steamships). The movement of the ship sets the wheels in motion and these mark the number of miles travelled.

Despite all recent attempts, this system has so far superseded the cumbersome and unreliable logging system of our ships, which was invented i 52 y by the engraver Humphray Cole.

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i) The idea of using Rsder to move ships had already emerged at the end of the Altertuuis (certainly after earlier writings) in Anonyuius De rebuo belIi*ie S. so ed. R. Schneider (Berl. i 9o8), which is discussed in more detail in the 3rd lecture

The way-metre has not yet been superseded by the way-finder, but it has prevailed for an age. Even Leonardo da Vinci, following Vitruvius, drew two sketches of Weginesserii.') The modern taximeter is also m o d e l l e d exactly on the principle of the ancient hodometer. The only difference is that the rotation of the rear wheel is not transmitted directly to the device, but through a pneumatic hose line to the coachman's seat. Finally, from Heron's series of machines, I'd like to mention the vending machine, which has become the model for our chocolate and ticket vending machines). In ancient times, this machine stood in front of the temples to allow holy water to trickle down onto the hands of pious temple visitors in exchange for a copper coin. Heron informs us that the clever Egyptian priests devised this combination of holy water basin (azpipp "ps§piop) and offering stick ('fnt'pd#) and t h a t the Alexandrian mechanics set up this apparatus. He describes his automaton as follows (Fig. 30, p. 6z): hlan takes an offering box *H B 'ä*, which has a slit o on the upper plate. Inside is a vessel Zi18A filled with water. At the bottom is a can *A,* which is connected to the outlet pipe *AM*. Behind the water vessel there is a vertical rod NJ in the sacrificial stock, around the upper hooked end of which there is a hook.

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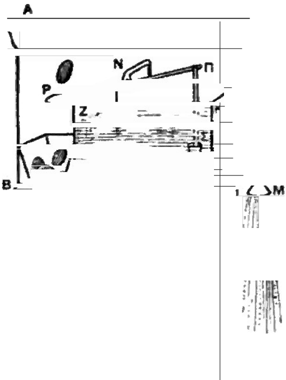
i) Cod. Atlantic. F. i R. (riech Feldhaus, Mnnarfo drr Z'erA'tiler, Jenn '9 ' 3- p. i i 5 f.)-

s) Heron, Pneumal. T z i (1 i io ff. Sch midt). Heron leaves the choice for the form of the autouiats between eioeai *SSonderen* (Krug sum Spen- den) or a Z'Acsizurpz (OpferLasten). For the sake of clarity, I have chosen the latter form for the drawing. A stone ZbeaFslln (she of Heronis*he) dedicated to Egyptian gods (Ssrapig, Isis, A nubis) was found on Thera in the 3rd century BC. Stift. f. elf. znzz. Xxl (i896) sky. I. G. 2tH 3 n. ¢3 (p. iog).



Uormig bent end of the ¥vage beam *PM* balanced. One leg of the balance beam has a small plate f- which, when at rest, is parallel to the right lid or the bottom of the sacrificial box; however, if the plate is weighted down by a small weight or a copper coin, it lowers and, of course, the other leg of the balance beam rises accordingly at IT. A rod fTfi hangs from this, which engages in the can *A* with a cover at the bottom and the outlet tubesd MJ

ess.,". ii""'. wwo "o""t in a state of rest.

''''o ' 'o'''

lHowever, the coin is inserted through the

If, on the other hand, the coin is inserted through the slot a at the top, it falls onto the plate P, presses it down and slides down the now lowered plate into the offering box. The lowering of the balance beam on the other side lifts the right leg of it and thus the rod fffi; the closure of the can *A* o p e n s and the water flows through the tube df *o u t* of the vessel0 *Z f-fOK*. In between, after the coin has fallen, the \vage bar snaps back into its old position, the rod f7fi closes the outlet pipe again and the game can begin anew. The sexton opens the offering box from time to time, takes out the copper pieces (Heron takes a piece of l'iinfdrachma, which is a little more than a

Lot [r y,8o g] as a standard piece) and refills it with fresh holy water.

The inventor of this ancient temple miracle would certainly never have dreamed that his idea would have transformed the entire modern retail trade. It is not known whether the modern inventor of vending machines ') used Heron directly. But since the book has had a direct and even more indirect influence on the whole of modern mechanics, a connection is probably possible, probably in England, where classical education is even more the mark of the educated man than elsewhere and a modern English translation, which was produced by the collaboration of a philologist and a mechanical engineer, has spread the ancient ideas more than here.

i) P. Evcritt io Loaüoé, who i 88$ üie cratea YcrkaaFsautomatea 1oa-

2) B. &oodcroft, Zñ/ ynzuenz¥*cc a/ hero a/ d/czc-zdno *from* Me ori- g-ina/ greek zronz/otcz/ onz/ carted, LoAdoa y8§ y. Dcs book is dedicated to Priozea Albert ge uqd aic°ht obne Verdieast. YgI. &. SchToidt, Hero, Sap-

IV

ANCIENT TELEGRAPHY

The desire to make one's will known to people at a distance certainly played a major role in the invention of writing, which was lost in the grey prehistory of the Sumerians and their successors, the Babylonians and Assyrians, as well as the Egyptians.') The rulers of the modern era also had a developed, unfortunately still undeciphered script. The notion that the ancient Greeks knew no writing has proved to be false in view of the discoveries of the last age of mankind. Even the common Greek script, which the ancients themselves called the Phoenician script because it was actually borrowed from the Phoenicians, was already in use in the 9th cent, Homer's time, and so we now look at the famous passage in the Iliad \, where King Proitos gives Bellerophon a letter from Urias to his brother-in-law, the Lycian king Lobates, with different eyes. 'Signs of deadly meaning carved in folded tablets' he gave him to Asia and commanded him to bring them to the related ruler.

As this writing tablet with the secret order to murder the chief bearer was not to be visible to Bellerophon himself, it had to consist of a wooden double tablet, as was customary throughout antiquity, with the two leaves attached together on one side and the other on the other.

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i) The Leöechen writings of the period collected by A. J. Evcni, *Scripta Minoa, the written documents of Minoan Crete with special reference to the archives of Knossos* I, Oxford 1909.

plate VI11.

Das tanagräische Mädchen mit dem Diptychon.
(Sammlung Saburoff.)

Diels: Antike Technik

The other, however, was sealed with a load and seal, whether it was a bent piece of birch bark with the signs carved inside, as was probably customary in ancient times, or one of the later common double panels made of wood with a hollowed-out surface into which wax was poured and into which the signs were then carved with a stylus. Such apdiptych is held by the ornamental Tana graffiti woman (panel VIIT), who may be .'pondering the letter written on it by her beloved) Whatever the form of the letter to Urias described by Homer may have been, it shows us the oldest type of secret epistle.

Another system of secret messages w a s officially used by various Greek states such as Sparta and Ithaca, the s k ytal e, which must have been generally known in Greece as early as the beginning of the yth century BC. It must have been generally known in Greece as early as the beginning of the y th century BC, because Archilochos already used the word in a figurative sense around 65o. This scytale consisted of two round sticks of completely identical design, one of which was kept in the archive, while the other was given to the official with whom one wanted to exchange dispatches. The dispatch itself was written on a strip of leather wrapped spirally around the stick. If you pulled it off, the writing would be shapeless and illegible to the uninitiated. But the distant official wrapped the leather strip around his scytale. Then the letters arranged themselves in the original rows again and the official realised the meaning.

You see here two cylindrical, equally thick sticks of wood, which have exactly the same diameter l - 7 cm)

) FuRväogkt, So=mf-ny Sd-ro (Bwho l88j D, TJ.86. YlGtwe Oscstellaageo points oacb Birt, 2/"<4re//< in d'v 6 "w/, Lpc. goy, S. so I .

have.') I now wrap this white io cm wide leather strip diagonally upwards onto one shaft (x t 'rdlr) so that the edges a r e close together. On this I write in ink a Greek text in the large ancient letterforms in the direction of the longitudinal axis across the wrapped rod. You can see for yourself that this tent is legible. Now I unwind the strap, and even the most ingenious philosopher can do nothing with the remnants of the letters that now appear on it. But now I wrap this strap over the twin rod. Immediately the spirals close tightly together again and the connection between the words appears as clearly as on the original stick. That is the secret of the Skytale!

Over time, more and more methods of producing secret messages were invented in Greece. An old military writer, who wrote a book about the cities around the middle of the ¢th century. Aeneas Tacticus, an ancient military writer who wrote a book on the siege of cities around the middle of the ¢th century, considers this subject, which naturally plays a major role in sieges, to be so important that he devotes a large chapter (c. 3 i) to it. There he enumerates i6 different systems of secret epistles and chi8res, from

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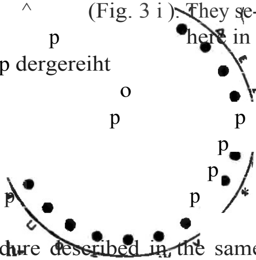
i) The two woods I showed were two halves of an equally round stick, which I had cut in the pencil. Everything depends on the uniform diameter. With a rod, you t. B. Birt, op. cit. (from note), p. zyq, which tapers at the top and bottom, the experiment would be visibly successful, as one would have to produce completely identical holes and the beginning of the v'icltelning would have to be precisely determined, which is not necessary if the thickness of the cylinders is the same. The main points are practised by SkytMc Tod OG. N. A.XXIIq,6P; Plut.Lys. Iq. Ygl. Riup, Nac/iri?Atcnu'cieu frz Wkrr/ums (Lpz- i 9i 3) 3 i 3 ff., who also refutes Birti's assumption. leb also notes that leather is better suited for this purpose than papyrua (Plutarch), since it has little durability, especially in such thin strips, and could be less easily concealed from uninvited persons or enemies when wrapped in a kniioel.

some of which are still in use today. Thus
z. For example, the first method of producing the secret message in any book by dotting the relevant letters is still used today by secretly engaged couples. One sends Schiller's poems to one's beloved, and the dotted t illustrate letters can be any -
p o p ^ (Fig. 3 i). They se- of a poem *p '
p here in a
give arieinan- -p dergereiht hülzerne
den "p o small disc
secret meaning. , p p p 2 j holes on the
Very refined p edge and
is that of Ae-"$ p some holes
neas in the same - p p also in
the



The procedure described in the same chapter p °
", " The position of the holes with the book gp", ,
ßlittellöcher gives the letter wheel'), which D-- D-r---s-
-- beginning of the edge at a small hole "' "' "' ""
holes. This is because the first hole at the edge represents the first letter d, which determines the order of the remaining z3 letters that follow to the right around the periphery. Now pull a thread through the holes that correspond to the letters of the despatches to be sent by inserting the thread into one of the centre holes when the same letter appears several times in succession and then leading it back into the same peripheral hole. It is intended to pick up the thread each time a word comes to an end. Now the recipient, who is aware of the meaning of the holes, only needs to put the thread back and write down the letters, starting from

i) Aeneas 3i, z i , p. 88, i $z6 ed. R. Schone.

right to left, i.e. upside down, and marking the ends of the words with dashes. If the wheel is unwound, the despatch is clear.

Among the other J\methods of cipher writing, Aeneas also admonishes the pun k tie re ys te m, in which the vowels are indicated by dots, so that a has one dot and o seven dots. This script is reminiscent of the Phoenicians, Jews and Arabs, who did not indicate the vowels in their writing, or only by strokes or dots, and perhaps borrowed it from the Orient. The despatch that Aeneas communicates refers to the younger Dionys and his general Herakleidas.') In Sicily, the Phoenician influence was very close. This system was quite widespread in the Middle Ages, before the sophisticated cipher systems of modern diplomacy were put into circulation from Venice.

One of the most practical methods during sieges and in warfare in general, to send dispatches from one place to another, is not mentioned by Aeneas, namely the letter post.) And yet it also e x i s t e d in Greece in his time. The beautiful legend of the dove that Noah sends out of the ark is an indication that trian used these clever animals to send messages in the Orient at an early stage. The comedian Pherecrates (fr. 33) attests to the pigeon post in Greece in the 5th century BC, and we hear of an Aeginetan Taurosthenes of the same period who r e p o r t e d his victory at Olympia to his homeland on the same day by means of the pigeon.

i) I have treated the Stetle in the das. d. & rz. m. i 9 i 3 (We 6ni-, rpauag des d/fo3oZi) p. z9 -. I myself have noted the continued effect of this cipher on the Middle Ages.

2) Cf. H. Fischl, fiü &rfr/tauéc im d/ter/um und im 3fi/fcfa/trr, SchWeinfun i 9o9 (Gymn.-Progreaim).

The Romans used pigeon post for victories in races and sieges (hlutina q3 BC), and the Arabs later developed this fast mail, which was probably always used in the Orient. In Roman times and later from the 5th to the 5th century there were regular pigeon posts in the Near East and Egypt.

However, all of this is not aseparate technology, i.e. telegraphy. This begins and ends with radio telegraphy. Of course, the sparks used in ancient telegraphy were not electric waves, as they are now emitted by wireless telegraphy, but the sparks of fire that shone from flaming sticks of wood or torches into the night from control room to control room. Homer already mentions the fire signals that the inhabitants of a surrounded city send out at night'), the post-Homeric epic of the Nostos tells of the false fire signal of Nauplios -), from which one may infer the establishment of such lighthouses or fire guards on the islands and cliffs of the Aegean Sea. Palamedes, the son of Nauplios, is regarded by the ancients as the inventor of fire signalling. Herodotus (9, 3) mentions that after the battle of Salamis, Mardonios hoped to bring the news of the capture of Athens by Persian troops to the fleeing king Xerxes by means of the fire post (avpao).

by fire mail (avpaoiat) across the islands (tid to}usr) to Asia. From this it is clear that such facilities existed at least in Asia.

i) Illas i 8, z i i (avpaoij. Cf, on the following H. Flcchl, fcra- sjfrecA- und *M'eldmuysfm* im A/ter2um, Schweinfurt I 9O$ (Gyinn.-Progrtmm); Riepl, Wae trirö/ rien p. Pty if. s) see above p. 56.

3) naher hnt c. Fries (ant' iii i s9. iv i i y) "ohi with Re*bt air Feiicrpost on Babylonian institutions indicated in the $fisql0texts.

Fig. ye. geue rgost in the Agaaoemnoa doc Aiscb ylos.

In the Persian War such fires were waiting, as Herodotus (y, i 8z) mentions, that the Hellenes at the Artemision on the northern tip of Euboea received fire dispatches from the opposite island of Skiathos, that two Greek ships had been taken by the Persians (aapd

The clearest description of the fire mail in Greece in the 5th century can be found in the drama Agamemnon by Aeschylus (q58 BC). It is inconceivable that the poet would have invented such things if such fire telegraphy had not been established there at least at some time (fig. 3z). The chorus leader asks Clytemnestra when Troy fell. The Piirstin replies:

In tonight's night geechch's, who gave this Tsg.

Chorus fugue*.

And which god ran with such speed?

Hephaestus, who from Ida sent bright light! The
I'euerpost gave Loh' to Lotte further hie
To uoe. The I d a sent her to Hermasberg
To Le m n o s. And the A t h os b c r g, the site of Zeus, 1'iahiri
dgnn for the third on the blazing beacon.
Then the \Yander torch stretched out huge
And leaping as if to scissor the wide 2rIeer Enteandte the sun-
bright torchlight lake
To the heights of E u boi a s , where Zfsiiistos stands guard.
The one who smells a foul, sleepy smell,
No, he hurries to post these flames. So he reports
them to the guards across the E u r i po ss and up.
The fiery f<ho: eurres heather Entßaoiniten them
tohsuf, a blazing signal. Then the flashing £'-ackel
drew unshadowed light across the plain deg A so po
s , where
\Vie full moon it ignited the newly inflamed fire on K i t hii
r oa s rock face.
The mountain's ever-lofty hat did not hinder the sound
of the messenger who had been cut off in December:
Quickly over the go r g o pisse e threw
It continued its glow of flames to the mountain And drove
the fire to the fire service there too.

It gives wood in the surface. The Lotte beats like a
celestial cäole and envelops the gold of S ar on in
fire gluC
Now leaping over its cliffs, it quickly hits the
neighbouring mountain as the last post

So who the order of my faekeßauFersebar,
So let the Flemmenboticliaft rwrh from hand to hand: The first
as the last has part in the bridge.
This is the burgcchsft and the Pfsnd of the joy mail,
The hmm me voo Tros *mnd:e mGo GmmahL

As grandiose and poetic as this oldest spark is, which carries the message of Troy's victory from Mount Ida across the island of Lemnos to Mount Athos, then southwards via Euboia to Boeotia and Kithairon, then from there across the Isthmus (Aigiplankton, i.e. Mount Geissberg) to Spitsbergen. i.e. Geissberg) to the Spider Mountain (Arachnaion) near Epidauros and finally to the castle of Mycenae, it can hardly be taken as a literal truth. •s . even i 8o km, which are found in this telegraph system, could not possibly be signalled with fire signals. In reality, some intermediate stations would still have to be switched on. Nevertheless, we can assume that none of these stations was chosen without reference to existing or previously existing signalling equipment.

But this radio telegraphy has a major shortcoming. You can only send a pre-arranged message. And even though it may have been possible to send a more precise message by agreeing on certain signals, as in the case reported by Herodotus, telegraphy in our sense was possible with the one-

i) Riep **.O. S.;*.

torch mail. In a fragment preserved in Polybios'), the aforementioned Tactics Aeneas now reports on an ingenious device that could be called a water e1egr aph e . He describes it thus (Fig. 33): "\If you want to have urgent ßlit messages sent to you by fire signals, you must two sounding vessels of equal width and depth. The depth must be about three cubits (i' m), the width one cubit ((4')cm). Then cut pieces of cork that are slightly narrower than the mouths of the two clay cylinders.
the clay cylinders. Attach rods to the corks which have partial lines cut into them at intervals of three inches (5.3 cm). This delimits z§ fields on each rod. The best-known and most common incidents in the event of war are written in these fields. E.g. inscription of the i. field: 'lt.eiter sind ins f.and ein-fallen*, z. 'Schweres Fußvolk- usw.; 3. 'Leicht-bewaffnete' etc.; furthermore ships, provisions, until the most probable events that can be calculated in advance are shown in the 4 fields.

Abb. 33. Wasser-telegraph.

The two sticks must of course be divided and labelled in exactly the same way. Then the two clay cylinders must be provided with drainage holes at the bottom, which of course must both have the same diameter and the same position. Now plug the holes, fill them with water to the brim and place the corks with the labelled rods on top to act as a seal. Now the devices are ready for telegraphing. One remains at the sending station, the other is handed over to the receiving station.

If one of the pre-recorded incidents occurs, a flare signal is first given at the sending station at night. The receiving station signals that it is ready with a corresponding flare signal. The flares are therefore both high at this moment. Now the sending station lowers the flare. This is the agreed signal that the hole in the clay cylinder is to be opened and the water slowly drained. As soon as the receiving station has noticed the lowering of the torch on the other side, the stopper is pulled out of the vessel on this side. Here, too, the water flows out just as slowly as over there. As the \water level1 of the two vessels now sinks evenly, the two cork floats also sink evenly and the rods dip into the vessels in the same way. When the inscription on the message is level with the edge of the vessel, the feeding station raises the torch again. This signal means: plug the hole 1 The receiving station then immediately checks which inscription is visible above the rim. This r e p r e s e n t s the transmitted despatch."

rolybius' criticism of this ingenious system is that the number of possible cases is too limited and, above all, that no more precise figures can be given. One would not only want to know that horsemen had fallen into the country, but also how many.

I now suspect that these justified expositions may well apply to the apparatus described by Aeneas'), but not to the original invention. For since it can be calculated from the dimensions given that just 24 fields are to be divided, I suspect that the inventor intended to produce an alphabetical telegraph.

i) In this I a g r e e with Riepl, p. 68.

z 4 letters.') Not z¢ occurrences, but all possible messages should be telegraphed through the z4 letter fields. Admittedly, this was somewhat cumbersome. Because if the letters were not in a row, an agreed signal had to b e used to command a fresh fill for each letter. But even if each letter was telegraphed individually with a fill, 2o letters could easily be communicated in an hour, i.e. a whole night's worth of messages could be transmitted.

Aeneas speaks only of night signals. It is obvious, however, that these devices could also be used during the day with flag signals. But of course, this dispatching was somewhat tedious and required the utmost care on the part of the crews. A practical blilitarian, like Aeneas or his predecessor, from whom he borrowed this system, made the apparatus more manageable for normal practice by means of the ready-made inscriptions on the zq fields. The origin of this shorter hlethode can be traced back an age via Aeneas. Aeneas wrote between

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i) I do not wish to deny that another origin of the division into the 2q fields has recently occurred to me. The water clocks constructed in the Alexandrian period from K tesibios onwards are e q u i p p e d with a line provided with a float, which dips to different depths into the flowing water. P. Schmidt, A'wfn rfiüt. &citr. 11 (Lps. i9 i z) qy ff. Since Heron (I 6 cd. W. Schmidt) describes an apparatus that works day and night (tt24H}prpot), there will also have been such water clocks in ancient times that were set up for zq hours and suitable for astronomical observations, in which the ruler divided into zq fields indicates the hours when the water sinks. There is nothing to prevent the astronomers of the 5th century B.C. from assuming the existence of such simple devices, even though they a r e not reported. A srabic \Verk by Seham al Din (} i 9) contains descriptions and illustrations of such water clocks, as does the "Archimedes" treated by C. de Vauz.
"Archimedes" treated by C. de Vauz. Cf. Eilh. Wiedeaiann , &irr. s. '7csrA. d. Woiurm. III z57,
XII z i 5 tEr1. i 9o and i 9oy , Sie.- der. #. erf. sis. Vol. 37 and 39).

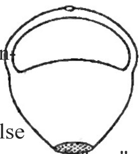
The shorter system, however, dates from the time of Dionys the Elder, who ruled Sicily from¢ io-3öy, and o r i g i n a t e s from the Carthaginians.

A later military writer Polyainos (h, i ö) reports that during the war with Dionys the Carthaginians h a d two equally sized (glass) weapons, which were fitted with rings running around the vessels. These rings were labelled with various commands, e.g. "warships approach", or "cargo ships*, or "money missing" or "machines". The Carthaginians kept one water clock in Sicily and sent the other to Ifiarthago. Now torch signals, similar to the devices described earlier, were used to regulate the outflow of water and the stopping at a certain ring

However, it should be noted that it is not p o s s i b l e to send signals directly from Sicily with flares over a distance of 5 kilometres. An intermediate station (such as the island of Kossyra) would therefore have to be used. But even then the distance is still too great. Perhaps the apparatus was not in operation between Africa and Sicily, but between individual locations on Sicily. The 'wass e ru h r en'), which are used here in this Carthaginian system instead of the clay cylinders, w e r e also common in Greece at that time. The Greek name is Klepsydra "water stealer" because water could be drawn unnoticed from below from a cistern or well trough through a hole or fine sieve that forms the bottom of a bulbous vessel. The vessel

i) Uber die aotikea Klepsydre" uad ibre E'ormea is\ maß zzocb z'icbt *has come to a conclusion. The latest literature can be found there. 2- 25g (co Emp. fr. too) gives ten, xr". z/i*t.i 89q, 339, Pott-r, z - -- -rcsz-/o,rrr -- i 89g, p. 8.

The top of the vessel ended in a narrow neck or a hollow hericle, the fine opening of which could be held shut with the thumb (Fig. 3¢). These water clocks were now calibrated to a certain quantity of water and used in court. As long as the water clock was running, the accuser and the accused were allowed to speak. \If witnesses were heard, the thumb was held on the water
water meter and thus the outflow was inhibited, because this 're il of the trial was of course not credited to the parties'). We do not know whether this water clock was also used for boiling eggs like our similarly equipped egg clocks,



but we do know that one of the most important doctors of the alexan-Athenian period, Herophilus, had a pocket water clock with the patients in order to check the pulse after the watch had run out g", g "q q" q" """; q "g control.-)

I have mentioned the hypothetical a lp h a b e t i c telegraph with the s 4 fields, I have mentioned the c a r rih ag i c Klepsydratelegraph, I have finally mentioned the A en ea s water apparatus, which appears to be a compromise of the two previous systems. Now I must show what the golden age of ancient technology added to these inventions. Fortunately, the famous historian and strategist Polyb ios (i o, 5) has given us an invention made by the Alexandrian engineers K le o x e n os and De m ok1e it os.

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i) ti about the measurement of the Rcdezcit by the Klepsydra s. Br. wedge, dn=ym** Mr -ntü (Staßbug igoQ S.z§OR; bfAx Schmid, hußurün.

z) As Max Schmidt wants (op. cit. p. 25 F.). 3) See above p. z .

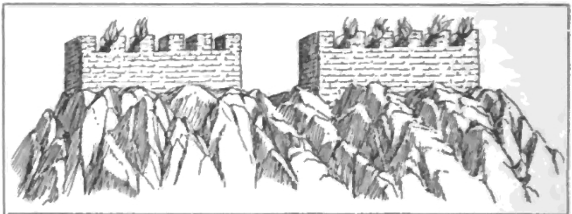

Abb. 35. Packeltelegraph des Polybios.

The signalling telegraph, which he himself improved, is described in detail (Fig. 3$). The sending and receiving stations are only equipped for night service. Two tinned walls are erected at a suitable distance from each station. Each of these walls has five holes two feet apart in which flares can be laid out and signalled to the station. Furthermore, each station has a cipher key containing the 24 letters of the alphabet in the following arrangement:

Board I " - s
" II *t* - -
" IH 2 - o
" IV ri - v
' v W i P <-

Now it is telegraphed like this. lis, for example, t h e following de- pesche: "Kreter ioo deserted."

First the letter N is despatched.

is on the second panel. So on the left wall, which is intended for the boards, zz-two torches are placed in the gaps. The receiving station notes this. Then fiinf torches are placed on the right wall. This is because N is the fifth letter of the second board. The right wall indicates the order of the individual letters within one of the five groups signalled by the left wall.

The receiving station therefore notes panel II, letter 5, i.e. Zv". This continues with A, ü, F, A, N and so on. This system clearly contains the seeds of our modern telegraphy. It is doubtful to what extent Polybios and his Alexandrian predecessors were influenced by the signalling system of the z4 letters that I have reconstructed. Perhaps, like so many such ideas, that ancient invention had fallen into oblivion because it did not penetrate into practice.')

It is easy to see that this system is very complicated, and Polybios himself anticipates this objection. But, he says, ordinary reading is also quite complicated at first, until y o u get used to it.

It has been calculated t h a t the above despatch "ioo Cretans deserted- i y3 torches, and that this could be done in half an hour. This time could certainly be reduced considerably with sufficient manpower.') But even if we assume the maximum, this time expenditure was by no means the reason why Polybios' system d i d not become established in practice. Rather, the main reason is the

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i) Riepl p. 93: "What Polybios describes here is nothing other than the essence of our modern telegraphy. Kleoxenoa and Demokleitos are the inventors of 'relegvcphy, Polybios deserves the credit for its first improvement, although we do not know what it consisted of. All (?) predecessors of Polybios, and for the most part forgiven ones, had contented themselves with conveying at best about half a dozen foreseen and pre-arranged 2'1itmessagesii by signs, Polybios was able with his method of signs to convey any, even unforeseen, event, fact. Instruction or any association of ideas, which can be expressed through speech and writing, can be transmitted at any distance."

z) S. Riepl op. cit. p. io5 against Pacbtler , *Dex* Z'c/cgra¢frrrn #rrr ellen Ué/io, Innsbruck i 86y (Feldiiircher Progr.).

short range of flare signalling. Due to irradiation, the individual flares can only be clearly separated from each other at about zooo feet. An improvement to this system could therefore be achieved by using only one flare, as Fischl') suggests, and by raising and lowering the flare behind the wall to give first two and then five signals in succession. But then, in order to avoid confusion, the pace would have to be slowed down considerably.

In any case, in ancient times these optical

optical yelegraphs required a large number of intermediate stations. If we take the distance between the stations to be one kilometre, which is already a lot, more than ioo stations were needed for a distance from Vienna to Semmering. So the invention had no practical success. The improvement of the Polybian apparatus by an unnamed Roman, which is reported by Julius Africanus (it is similar in principle to Fischl's proposal), w a s apparently not put into practice either.

A German Ve ge l i n von Clärberg, *aul'ie prae/ectus* in Nassau, devised a similar system in iö59, presumably based on the Polybian, but he used the telescope, which had already been invented at the time, and set up the system for daily service. Ve ge t i us, a writer of the Roman period, mentions (de re militari Hl 5) very briefly a telegraphy by means of beams that were raised or lowered on "towers".

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1) S. 69 Anm. 1.

z) In the J@dsof c. JJ. The authenticity of the enserpt is disputed. However, it is based on good 9 sources.

3) For more details see Pachtler and Riepl a. a. 0. r i z.

be lowered. This system was then further developed in more recent times Claude Chapp e presented his invention of the optical telegraph to the National Convention on 2 March i y9z, and the first practicable telegraph line w a s set up from Paris to the border at Lille in i y93. zo stations were switched on, each character taking six minutes to transmit. This and similar systems w e r e also set up in Germany at the beginning of the last century. An optical line Ber- lin-Cologne-Trier w a s opened as late as i 832. But the inventions of the Germans Söinmering i 8o8, Gauss and Weber in 1833 and Steinheil i 83y made possible the e le c t r i c t e I egr aphi e, which adopted the alphabetical system from antiquity, but replaced the torches with the electric spark.

The following report in the Frankfurter Zeitung ') shows that the old optical telegraph system is nevertheless indispensable:

"The large battle spaces that we can expect in the future due to the increased firing effect of the \Yaffen, require a reliable connection between the leader and the troops. The technical aids available for this purpose, such as wire telegraphy, telephones and radio telegraphy, can fail or become unusable at times and places under the influence of the enemy, the terrain and the weather. For this reason, optical links are also used, which are characterised by the fact that they are independent of the intermediate terrain and are less exposed to the influence of the enemy. They therefore enable above all

i) z6. Aug. i 9 i 2, No. z36, p. z (H 2rforgenbl.) : 2fJn new t¢fiscfies ***Si'gnalgeral.***

traffic over impassable terrain. However, if such aids are to serve as a substitute for wire connections or radio telegraphy, they must be very powerful. The "indicators" introduced for group use are sufficient for short distances and under favourable conditions, but for longer distances a signalling device is required which enables reliable communication even at long range. Heliographs are dependent on the position of the sun and the \Vetter and can only be used when the sun is shining. Optical s i g n ala p pa r a t e s w i t h c o n s t i t u t i o n a l l i g h t are also dependent on the size and strength of the light source, but are more reliable. 1'irma Zeiß has now produced a very powerful apparatus which is characterised by an extremely intense light source, so that a range of x'on z 5 kilometres can be achieved during the day and y5 kilometres at night, and the signs can be easily seen with the naked eye under medium light conditions. The peculiarity of the apparatus is that the light source is obtained by heating an incandescent body located on the burner of the lamp with an acetylene oxygen lamp....

A very simple diaphragm device mounted inside the lamp between the light source and the concave mirror, which i s connected to a flasher switch, is used for drawing. Precise adjustment of the apparatus to the remote station is made possible by a separate prismatic telescope."

V
THE ANCIENT ARTILLERY

We are informed about the achievements of artillery in antiquity partly by ancient historians and partly by the ancient engineers whose works have come down to us. The most important of these are the mechanics Philon and Heron, whose texts, although illustrated, are still very difficult to understand. Knowledge of language and expertise must go hand in hand. In order to reconstruct these ancient guns, philologists and officers joined forces three times in the last century, and it was finally possible to produce practical models that show what these ancient war machines could do. The first pair to unite for this work was the philologist K öc hly and the artillery officer R üsto w, who published .'the Greek war writers with German translations i 853- i 855) As a first start, this achievement was commendable, but both had worked far too quickly and with inadequate aids, so that the book produced by the joint work of the two scholars is now quite outdated. An attempt at reconstruction, which they practically presented to the Heidelberg Philological Assembly in 86d, was not particularly favourable. Then N ap o1eon III took matters into his own hands. His excellent work on Caesar also led him to

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i) H. Köcbly and \Y. Rüstow, Er. 1ri'g**cfir/tt/-f/cr. Gr. and German I. u. i. z, Leipzig i853 - i8$5.

the ancient artillery. He commissioned the Alsatian philologist We sch e r') and General de R effy e to edit the ancient texts and reconstruct the models of the guns. Unfortunately, the two, who were very headstrong, did not work well together. As a result, the large gun models that are still on display today in the St Germain Museum are little more than modern fantasy constructions. Finally, a philological casar expert, m y late friend Rudolf S ch ne i de r, and a Saxon officer, the current Major General Dr Schwamm in Bautzen, joined forces, and the result is the reconstruction of the most important antique guns, which was supported by the Prussian House of Representatives and the Society for Lorraine History in Metz with very significant sums. As early as i 9o4, the German Emperor, who was keenly interested in this question, was shown three \throwing machines in ßletz, which are similar in effect to the ancient reports and in any case represent the best reconstruction of ancient artillery to date. These original Schramme guns are in the Saalburg Museum in Homburg and smaller models of them in the Berlin Armoury.§

1) C. Welcher, *Poliorcdtique des Hrecs, Pont 1 86 y.*

z) The more recent literature, to which reference should be made here once and for all, is as follows: E. Scbrcmin, I. JoZré. 'f. 6'zi. /. /o/Ar. J 'zrä. Bsnd XVI (i 9o¢) i ff. ; II. B. XVOI (i 9o6) zy6 if. , III. B. XXI (i 9o9) 86 ff. R. Scbnei der,
/uAré. f. N'i. /. For which. Crc*cä. XVII (i 9o5) z8¢ ff, Aäm. Pen. XX (i 9o$) i66 If., XXI (i 906) I§3 ff. nnony mi d. reé. ée//. /ié. ed. R. Schneider, Berl. r 9o8 ; "gl. *N. 'f'ahrb. f. kl. Att.* XXV, I (i 9io) 3zy ff. Ders.: nrz,yfrr,e *gys fi'ttrIri7Iers,* Berl. t9 i o , Pauly -W issowa , *R.-Eric.* VH (i 9o9) i z9y If. He re-edited the texts with the antique illustrations and published "' rrecö. *Poli'orketiker"* iii d. déA. d. ' äi/. ' zr. d. ffhz., J/ti?.- A. Nf. N. F. X i (i 9o8),
XI i (i 9o8), XH$ (i 9 i z). Th. Beck in C. Matschoß, Acer. s. p'*ca.
der *Technik u. Industrie* III (1911) 163 ff. Feldhaus, *Technik* S. 384 ff. S. auch das unten S. 91 Anm. 1 erwähnte Werk von Max Schmidt.

No remains of ancient guns have been found, which is natural since they were mainly constructed of wood.') But we do know their projectiles, the cannons. 2tIan has found many of them. The most interesting are the pieces found by Schulten) during his excavation in Numantia in Spain, which flew into the city during the heroic defence of this city against the younger Scipio in i 33 BC. They are made of sandstone and weigh between three and ten pounds. Arrowheads have also been found, which were used to reconstruct the darts fired with the cannons. Then Greek and Roman reliefs, e.g. from the Pergamon Altar and Trajan's Column, manuscript illustrations and, above all, the very detailed descriptions of historians and poliorketics (war writers) helped to make a more accurate replica of the guns possible.

In the past, the invention of artillery was attributed to the Jews, because the book Chronicles II zö, i 5 says of King Uzziah (8th century BC): "He made grins in Jeru- salem.) They came to the towers and hlauerecken to shoot with arrows and large stones." This report in the Bible alone is implausible. The author lived around the year 3oo B.C. and transferred the conditions of the Hellenistic era to the prehistoric era.

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i) However, during the excavations in the sltcn Emporion on the Spanish east coast in the Siiden of the Pyrenees, remains of the iron frame of a Roman catepulta (ca. i. century BC) seem to have been found. Cf. W. Berthel, Nr'iné/. *Z.* t9 i , No. i i 8, z. Morgenbl.

z) Schuften, Au grub. in Nunr'iritid, 9aAr6. d. *D.* Fred. J lit. 190s, Beibl. I i 6. 3 , i 9o9, Bcibl. TV 93.

3) n4tü 5ar/e*J Luther translates incorrectly: made *breast* '*honour* inzi- lit/i. Rather, war machines are commonL The Wott artillery Lommt of poor as In enieur of iii rium middle-aged. - Steaehine .

time. In reality, as Diodorus') credibly reports, artillery was invented around the year¢oo v. The ingenious and energetic prince to whom we owe this innovation is Dionys the Elder, who brought in the best engineers from all over Greece and Italy.

from all over Greece and Italy to construct guns suitable for attack and defence.')

Abb. 36. Römisch-gallische Jagdarmbrust mit Köcher. Von einem Grab-

The ancient cannons have "ert '" uns" developed from the primitive weapon of mankind, the bow, whose invention dates back to the oldest times.

Q Homer also describes the famous horned bow of Pan- daros in the Iliad -), and the archer Heracles is the national hero of the Hellenes. We know from the Odyssey what strength it took to draw the strong bows of such heroes. In order to make it possible for ordinary mortals to draw and shoot stronger bows, the crossbow, which you will recognise from the simple construction of our boys' toys, was initially used. Such a crossbow was certainly used in Roman times, but probably also earlier in Greece as a transition from the bow to more complicated rifles. We ourselves are only familiar with the ancient crossbow from two reliefs found in the neighbourhood of Le Puy in France.

i) i , qz. z) S. above p. ry $.

3) Schaumberg, &"grn and &ogmcfiütcr éri dm Grierfirn, Erf. This. Nuremberg is'° t*-'*-' bne illustrations). q) q, red ff.

$) Neel sagtio ia Dsr-mbcrg-sagt'o,p z, "n "oir, des an'tpyzz, l jg8, Fig. g6 . The ezate l'lonuzocat, ücza üiese Abbildoog eataozazaea is - ea shall good time &agebözeß -, is a Cippus , üer eiaem jTger aabekaoatea

Construction quite similar to our boys' toy. You can see a hollowed-out channel in the centre, into which the arrow is placed. The string, which is attached to a strong wooden or metal bow, is pulled over this channel and then released from below by pulling back the bowstring. Since the string runs under the crossbow shaft as shown in the illustration, it was probably also slotted at the side like our boys' crossbows, so that the string was pulled between the upper and lower **layers** of the shaft up to the breech and then, after the arrow was loaded, was released all the more securely in the gap. The Greek war writers do not tell us anything about this simple device because, as is probably the case with the two French reliefs, it w a s generally the equipment of hunters, not warriors. Instead, they refer to a more powerful rifle that bears the name "pG astrap h ete s"). Like the crossbow, this "belly rifle" is equipped with a bow, string and firing channel. However, the more powerful bow arm cannot b e cocked with the hands. Instead, a special tensioning mechanism must be used. The Greeks constructed the shooting channel in such a way that it formed a dovetail groove (fig. 32, p. 88),

Nsmeng is erected. The device suspended behind the crossbow is the corresponding quiver. The second depicts a J-ger himself with crossbow and

The crossbow (orcuéaffüto) is first used by Vegetiusg H i 3 treiben der ma ruh fun

S*glio understands the asopsfdte , which Archimedes turned to at the siege of Syrslrus (Poly b. Vul y, 6), from such crossbows. Likewise the irer¢iönci minorrs mentioned by Seilenos at Scipio's siege of Carthsgene (21o BC). Liv. 26, 49, 3 (cf. $y, 6).

i) Cf. above p. i 9. A partly differing reconstruction of Gastra-phetes is given by Prof. Th. Beck (in the work III i6 mentioned on p. 8 note z) with an anecdotal figure. I adhere to Scbreaim's reconstruction.

Abb. 37.
Schwalbenschwanznute.

Abb. 38.
Schwalbenschwanzfeder.

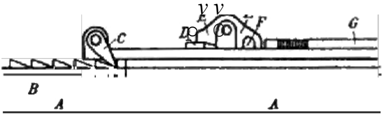


Abb. 39. Einzelheiten des Gastraphetes (Seitenansicht).
AA Schaft der Armbrust. B eiserne Zahnstange. C Sperrklinke. D Abzug. E Sperrfinger. F Sehne (vom Finger E gespannt). G Pfeil.

and a second bar (dovetail spring) now grips into this groove,
Fig. 38) so that the upper moulding could be easily slid back and forth on the lower one (Fig. 39). Al- so a kind of
"slide" or
"runner . \When you want to load this belly gun, you push the slide forwards. An iron finger is attached to its rear end, which grips the bowstring of the crossbow in the centre (Fig. So). If you now push the crossbow with the protruding end of the sled onto the dode, the other end comes to rest against the belly.

to stand. By pushing with the belly and the whole body, the sled rises again, the string is tensioned and can be locked in this position by a locking mechanism.

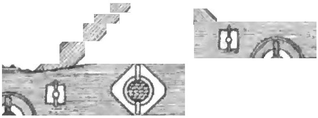
and can b e held in this position by a pawl.

(Fig.) (#) (top)
›anner (Gastraphetes).
Nach Heron.

Now place the cocked arm on a support, place the arrow in the groove behind the iron finger at the top, aim and then shoot by pushing the finger, which holds the string, by pulling back a side **bar,** the so-called trigger. The string immediately whizzes loose and s e n d s the arrow flying in front of it.

From this construction of the belly gun, which was further improved and strengthened by Z o py r os from Tarentum (presumably at the beginning of the ¢ rst century), the actual artillery, the c atap u 1t e s (x "i "fJz "i, r "f "pu/far, *ballistae)*, now developed*.)* They have various names, such as Grad- e uthyt ona (arrow guns) or pa l int o n a (stone ball guns).-) Before I move on to these colourful constructions I would like to

Fig. p. Onayc
(Riesenschleuder). Xo
Seitenansicht.



I would first like to remember a machine that developed from the ancient sling, just as the catapult developed from the bow.

In Roman antiquity, this eldritch sling is called O na ge r, i.e. wild ass. The ancients fabled that the wild donkey would hurl stones behind it with its hooves when it was pursued. The purpose of this giant sledge was to hurl large stones against the walls or to d r i v e the besiegers from the battlements.

Imagine a large sledge whose two runners are firmly connected to each other. In the centre, tendons (so-called tension nerves) are often pulled back and forth between the two runners (Fig. q i). This forms an elastic cord into which a strong wooden arm like

i) Cf. above p. zo. z) For the names see p. zo note t.

a gag is inserted into it. This arm usually protrudes obliquely into the air. However, if you bend it downwards, it will tighten the tension nerves strongly, and they will try to turn the arm back into its old position with all their might. With the large machine, such

II force is required to pull the arm downwards so that you have to use a t'inde to turn it (Fig. 4z). Is now

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the arm is strong bent back, then a belt is created which bends it into

" ai's ,' s,"""¢ a''' o "t-r a'''eii ai" u'ti a-.

this ready-made position. A sling with a stone ball is now attached to the top of the arm. Now, on the command "Go", the bar in front of the arm is pulled away with a string, the arm returns to its original position and strikes against a solid support, the stone rushes out of the sling and hits its target in a high arc. Schramm's reconstruction of the onager shoots a four-pound ball 3oo metres. It can be assumed that the ancient projectiles were much more powerful. The historian Ammian, who was himself a military man, says that this gun should not be placed on hard bricks or stones.

Because the recoil was so strong that it would completely tear apart the base. So you have to put it on grass or gravel.

Now we come to the actual cannons, of which I can show you a Heine model here (Fig. 43)- ') The essential power of this cannon lies, in the case of the Onager, in the torsion of the nerve bundles. Two of these bundles are mounted in civilian housings to the right and left of the firing channel. However, the tension arms are not horizontal as with t h e onager, but vertical rechC In each of these

Abb. j. Æzloœeoo(Kegeg;ctaw)
Nach Philon, Heron, Vitruv.

Each of these two bundles is fitted with a solid wooden toggle, and the ends of these two wooden arms are connected by a strong bowstring or string. A sledge with fingers moves along the shooting channel,

i) I owe the transfer of the m o d e l , which was made b y a primary school student at the Princ - Heinrichs-Gymnasium in Berlin-Scboneberg, t o Prof. Dr Max Schmidt in Berlin, who in a Æea?útùcficn fńrrrsta- ma/Zir MI (Lpz. i goi) p. i 5o If. some Greek texts relating to warfare have been reprinted in full and p. 36 If. an introduction to the g escbulzaeses of antiquity has been given.

which is cocked from behind with a crank. If the tendon is tightened by the gripping finger, the tension of the two tendon bundles is increased. The tension is also protected here by a pawl. Now place a bullet (Palintonon) or an arrow (Euthy- tonon) in front of the string, depending on the design. hlan releases the finger holding the string by pushing the latch aside. he shot is fired and the bullet flies between the two nerve bundles towards the target. By raising and lowering, turning to the right and left, you can aim precisely.

The firing tests that Major General Schwamm achieved with his original gun are as follows. His stone gun (Palintonon) shot 3cio metres with a one-pound lead ball, his arrow gun shot 3 yo metres with an 88 em long arrow. These arrows pierced an iron-shod shield 3 cm thick in such a way that the arrow penetrated half its length, thus disabling the shield-bearer.

The animal sinews have colossal strength, but they are known to be a very sensitive hygrometer. The elasticity therefore leaves much to be desired over time and especially in damp weather. This is why the Alexandrian engineers made sure that by turning the bushings in which the tensioning bundles are located in opposite directions at the top and bottom, retensioning is possible, as in the tuning of stringed instruments and pianos.') However, as Philon notes,

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i) It seems unavoidable, when the strings are turned round to the right and centre, to ensure that they cannot return to their old position. For this reason, Beck, op. cit. p. i68, suggested that the edge of the bushes should be provided with lower locking teeth that would interfere with the teeth located in the groove of the "peritreton (strand holder). 7In fact, it is easy to slide backwards in the case of small 8tooths that cannot be adopted exactly. Only I saw with

this tensioning also has its disadvantages. Therefore
£e1 he tried new constructions which should avoid the disadvantages of the usual catapults. He invented a catapult in which the chord strands could be tensioned at will by means of wedges inserted into the tensioning bars on the right and left. He also invented the so-called E rz sp an ne r ($eJxd-oror), in which the elasticity of hammered bronze springs is used to tension the i3ogen arms. These ingenious constructions were also modelled by Schramm. But they do not seem to have caught on in antiquity. The elasticity of bronze is difficult to produce and seems to promise even less durability than the usual animal sinews.

There is a very interesting description of an invention in Philon, which combines the principle of the mitrailleuse or machine gun with the ancient torsion gunC Mr Schramm has also reconstructed this p o1y bo1on (ßlehrlader), which was invented by Dio- nysius of Alenandreia (Fig. 44. p. 94). And as complicated as the invention seems, it proved itself
it proved itself in the reconstruction.

The gun is cocked as usual until the finger grips the string and cocks it. The same turn of the crank which now causes the cocking and, connected to the trigger by a chain without end, causes the automatic release of the finger, simultaneously causes a new arrow to be inserted each time after the shot. (See the diagram in Fig. 43, p. 94 below.)

The shooting tests conducted by Major General Schramm on j. October i 9 i 3 at the Saalburg with the original gun showed that the guns, which had been turned with a powerful spanner, held perfectly steady, and the builder confirmed that the re-cocked guns had not yet been turned back. This is why the ancient descriptions do not contain any devices to stop the re-cocked guns.

Above the arrow
The arrow groove is covered by a funnel in which any
"
number of arrows
From this funnel
•
funnel an arrow falls into a roller rotating below it, the a
p" "" " """ "" p ""
longitudinal groove
into

into which the arrow just fits. Now the roller rotates, and the arrow rotates with it and now comes to rest over the arrow groove in the slot. The arrow falls down into the chute, the emptied cylinder rotates upwards again and while the new arrow is shot as a result of the crank rotation, the cylinder picks up another arrow from the top of the funnel. So this polybolon, which is operated by one man, actually works like a mitrailleuse. Major General Schwamm emphasises the accuracy of the gun, which of course could only be effective at shorter distances.

All of these ingenious inventions are based on the

elasticity of animal tendons, hair or metal feathers. Our artillery, however, is based on the compression of gases.

p

Of which the age-

(Schematische Seitenansicht.)

*

at least one

had an idea. Because in ancient times people also shot with rifles. Today we call such a rifle a
\Vi nd bü chs e.') Philon describes an invention of the C te si- b i o s (3rd century BC), which he calls aër oto n on (air cock). The ingenious Alexandrian engineer constructed two carefully crafted cans in which pistons went up and down. The bow arms of the catapults were pressed against these pistons, which were forcibly pushed into the cans, in such a way that the tension of the string pressed the pistons down in the cans. If the tension was released when the string snapped free, the compressed air naturally drove the pistons out. The arms were pushed back to the opposite side and the shot could b e fired.

As ingenious as this invention is, Schramm's reconstruction has shown that it is practically only effective if the pressure of the rifles is regulated by an air pump. This is probably not seen in Alter- turn.

So the air tensioner is probably one of the many attempts that only existed on paper, although Philon claims to have seen the positive effect. Ę The ingenious inventors of Hellenic and Hellenistic antiquity were Greeks, who were always stronger in theory than in practice. And the practical Romans added almost nothing in this field and forgot a lot. The only author to be mentioned here, the Anonyrnus *De reàus órí*?iččii, did in the time of Justinian, based on old, forgotten models, write a

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) her Æ, modeoeGezcicMe der Aiodbucheevg1.O. vLippmann, Ferrr. v. v4d*. II zip: Feldhxus, ZzrÆni S. øo] uod 4$4

He made a series of fantastic proposals for war and naval affairs, but it is not clear that he had much luck with his contemporaries and descendants.')

It was not until the i 2nd century that technology began to revive.

Man learnt to feel with nature again and to use its powers. Around this time, Western mankind once again endeavoured to wrest the secrets of nature, partly based on ancient Greek recipe collections: to distil alcohol \, to produce gunpowder, to discover spectacles and binoculars, to construct diving suits, self-propelled vehicles, ships with ß4machine propulsion and the aeroplane. All this can be found in the book je *serrctis* n¡deriéui by the remarkable Franciscan monk Roger Baco (i z 14 to ' °94) describes it more or less clearly. -) Of course, here too, as later with Leonardo da Vinci, most of the

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i) Again al'drnek of the Frubeniana by R. Schneider (Berl. i9o8). The view of this researcher that the book is a fictionalisation of 's- J-*'*- --i. has not been able to prevail. I follow in the above approach R. Neher, *Dcr* A'tp tJ mus *De* Aréus Arf/i?ü, Tüb. i 9 i i .

z) Cf. H. Diels, *Die Entdrck- ng des Atkohoh, Abh. der Bert. AG. i 9 i y,* //,i/.-A,?/. Cl. 3 ; v. Lippmann, &cJir. a. -cic t. d. J/1ofiofi, *Chemikrz-Zrii.* i 9 r 3 No. i z9, p. 13i 3 ; No. i 3z, p. i 3q6 ; No. i 33, p. i 358 ; No. i 38, p. 1 i 9, p. p36 ; no. i 39, p. i z8.

3) Opera ined. ed. Brewer (Lond. i 8$9) de seeret. c. , p. 53z ff. e. 6. On the i-'lugmogcbine ibid. c. t, p. 53 j : 7tr "t /oswnt /rri iwtrumcrita i'o/riri'fi; t'f account ir'frat Ja *medi'o* Jwtruinr "fJ rrro/vcns oft@o'f rrigrnium machine), ecr guck old arfiJciö?i?rr com§"ri?ae orrrm vr 'érrrrrrf ab mc- 'do az'i* vofantéf. He says about theee inventions last: 2/abc autcm ***facta sunt antiquitus, et nostris temporibus facta sunt, ut certum est, nisi*** sig i "y /rumrzttuin vo/ariifi; 9usR mon midt, ecr Mom *rm *q'ui' z idisse$* fog novJ, sr'/ sa/'irir lem, per hoc nrt{/7nü" rzcogi?uzu'f rz§/rrrr, cognosco. As fantastic as many of his lt4iracula, which are partly honoured in Arabic 9uellen, may seem, most of them are really at least theoretical constructions of Hoger Baco and other inventive geniuses of the time.

had only been theoretically and in part fantastically devised, not experimentally tested and practically realised. However, the problems had been posed anew and the inventive power of J\people, which had lain dormant for over a thousand years, had been greatly stimulated. The invention of gunpowder was the turning point for artillery.

This invention is shrouded in darkness, like most of the technological achievements that emerged towards the end of the J\Middle Ages. For the scientifically illiterate mankind of those dark times regarded all those uncanny things with horror and was inclined to make short work of the inventors, whom they mistrusted as magicians. Some of the artillery innovations were also zealously guarded state secrets, as we know from the preparation of Greek fire in Byzantium, which can be regarded as the forerunner of gunpowder.[1]) At the siege of Constantinople in 6y3 n. C., the architect K a1 1inikos from Heliopolis had successfully u s e d Greek fire. It is not easy to imagine the composition of this explosive and its application from the hints given by historians. However, a recipe by Marcus Graecus, of which a Latin translation of the i c. century has been preserved, reads as follows:

p i part rosin, i 'leil
sulphur,
h parts saltpetre

finely powdered, to be dissolved in linseed or laurel oil, then placed in a tube or hollowed-out wooden shaft and dried.

1) Berthelot, Lrz comQ*itii "*s *incendi ai res* fuw fautipu£fZ e/ au moyen *âge, Revue des deux mondes* 106 (1891) 786 ff.; *Chimie au moyen âge* I 93 ff. Romocki, t7cicA. d. *Es f lasiystoffe I* (Ber1. i 89d) p.*$ H,*

to be found. It flies immediately in any direction and destroys everything with its fire."')

The recipe no. i 3 given there takes us even closer to the composition of the powder: "Flying fire *(iğnii* vn/nóifis) is produced in the following second way: Niinm i part sulphur, z parts lime or willow charcoal, ö parts saltpetre, all finely powdered in a marble mortar. Then you can make a rocket or a thunderbolt with it. The rocket must be long and the powder m u s t be firmly crushed. The thunderclap, on the other hand, must b e short and thick and only half-filled. The two ends must be well tied with iron wire." If you now read the description that Leo (probably the Isaurian, 2 i y-- 7 4) gives in his Tactics of the fire trier, which has a s i pho n (i.e. a tube) at the bow for firing. (i.e. a tube) for firing against the enemy ships, his words that the "prepared* (Greek) fire with thunder and ranch, which precedes the fire, is launched from the tubes Ę, indicate that it is a matter of explosive propellants, which are fired and launched like rockets.

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r) Marcue Gr., Ziòer return n. i z (Berthelot, 6'fiíiø. an mega Age z) 1

(Migne 1oy, I oo8) ¥ò JB8tooa voe tfip pfTt poprĄp Not æp-

I. 108), 13 (I, 109).

zà nolčøixà alotn): the un versländliehe Lessrt ape rcípov labe ich nach dem Vorgang der lat. 4 "fberset*nng (/umu ignite) in reoaúpov gebessert. The Monac. gr. i q 3 has confirmed this assumption by changing from erstet Hgnd

without deleting pal. The vulgar redaiction of Monac. gt. q 3z also reads iihnßeh: oror zà 6ztve6ehv nip, yyouv tò lap rpäy,

μετὰ βροντῆς καὶ καπνοῦ τῶν προπύρων πεμπόμενον. Diese Lesung bethus draws the epithet on §povri)ç rind snavoiì in the same way, but renders kgum dae Echte. I owe the readings of the õlünchner Hss. to Heisenberg's kindness.

According to this description, it cannot be doubted (sql. Berthelot, *Ctumie an moyen äge* 1 98) that saltpetre as an exploding component in to hurl fire that is difficult to extinguish at the enemy fleet. Similarly, the hand siphons Jzipoafgoetp), which are mentioned there in c. 56, can be understood as smaller exploding fireworks to be hurled at the enemy's face') Roger Baco, who wrote his famous *F pi'stoln dü secrztis operi'bus arti's et naturae et de nullitat" m'igi"ie* to Bishop William of Paris around the year r zöo, also draws on such sources. Here he first describes in

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Greek. But this was kept secret, for it is incompatible with Leo's report to assume that, in addition to naphtha, sulphur and unsoluble lime, which are found in water (already known in Alexandrian times, see Berthelot s. a. 0. 9$), were related (v. Lippmann, N6fi. u. ffir/r, I i 3 t ff.)- For how should the hand-siphons, which the Greek fire hurls in the face of the enemies, be used? For how are the hand-held siphons, which hurl the Greek fire into the face of the enemy, to obtain the necessary water to ignite the kafka ? How, moreover, are they to be provided with the fire extinguishers that are deemed necessary for spraying the fire? However, the expressions "lustful fire" in Theophanes, Chionogr. 1 396, r 3. q99, i i de Boor (éypés sep), which he uses alongside spp 'P"- patsdv (396, z9), set P'c1ä "aiov (3 4, i3), a=tva "sév sep (o3, zo) for the gritchian fire, lead to the v etrrintion that, in addition to that explosive propelling sati, which is *similar* to the later powder, a liquid (either oil as in the first recipe mentioned above or naphtha) was fired, which ignited in the explosion

und unlöschbares Feuer auf die Schiffe und Soldaten der Gegner schleuderte.

I refer to such an apparatus in the oldest illustration of a gun in Walther von Hile iete (Christchurch-Bibl. Oxford) sus the J ' 3z6, which Feldhaus, Technik 09, fig. zy i depicts. The bulbous container is fitted with a spike so that it adheres to the wood of the bosque gate. Wiedeizisnn, *Betty.* VI (Erl. i9o6) p. 38, 5z.

The illustration sketched on the left of this page shows how the Arab's *(1td'adfooj)* hand-held moiser probably evolved, which an Arab author of the r q. c. Scbems-Edd. century Scbems-Eddin Mohammed describes it (}similar to a. a. 0. I r8 r). The bolt, which is pressed onto the firmly plugged wooden tube (which must be as wide as it is deep), whereupon the ignition of the firing rod takes place (probably through an ignition hole), is by no means a pro-

&e etgertbc6e Kaoooc cgisüc¥eh hzbco.

sixth chapter *de ce perimciitis tiii'rabi'Ii "biis,* like a small £nger-thick prepared JYIasse in the air could produce thunder and lightning stronger ale a thunderstorm.')

He then revealed the secret of his thunder powder in the c. i i by recommending saltpetre and gunpowder and, as a third ingredient, anagrammatically hidden cofilene powder for the production of thunder and lightningla) But the knowledge of saltpetre and its explosive power was by no means sufficient to discover the iiother cannon. It was a matter of taming the explosive force of that mixture and utilising it as the driving force of a projectile. We owe this significant progress neither to the Arabs, whose claims are certainly unfounded -), nor to the Chinese -), but to the Germans, who were regarded by both Byzantines and Italians as the inventors of the new "barbaric" technology -) *< 4- and i (s) century, the Germans exclusively possess a

t) p. 536 ed. Prewer Sam toni vz/ur /'mirrua Esprit Jeri cz carwca-*tiones in aere, immo maiori horrore quam illa quae fiunt per naturam. Nam modica materia adaptata, scilicet ad quantitatem unius pollicis, sonum facit horribilem et corruscationem ostendit vehementem.*

z) p. 35 i Br. Romocki l.c. 1 93, the reading of which, however, does not quite agree either with the prints or with the l'Iannshript mentioned by Brewer.

j) Roœocki Iy8 A.

p homocWljg|T W. F. AWyers yowr- °/r*-NowwfDno sont e/ lhr Z-ogaf diüctii S-r. 1869 - i 8yo (N. S. VI), Shengbni i 8y i , p. 76 ff. In contrast, G. 8cblegel, P ouni- Maa Arcfi*rs hour Scrum d fZfu'f- 'fe fAi-*quiet ... 'fe f'Asir ari?nZaf Str. M, vol. III ti 9oz) p. i IT. O. v. Lippmann, AéA. u. Kortr. I iq9 ff ; II z8 ff.

$) Interesting is the report of the contemporary L.aoniLos Challtondyles de reb. Ture. V, p. 231 ff. Bonn about Miirad II's futile belsgcrong of

antike Etfindoog , swan believe that they were explored by the Germans and from dori had quickly spread the earth (et per cqit-

pfyq"). The driveLrafi, which hurl stone hail, is formed doteb the pul-*er (hears p): z59 di nörc'o9 sä efrpoy ü2sr ser diivapi i' ßr9poxi er xcl dere Jsqzij rvpirq.

artillery literature, and German gunsmiths play the leading role in all countries.') The legend of Bert- hold Schwarz as the inventor of powder or the cannon cannot, of course, be fixed in historical terms. Only this much is certain: in the course of the i 4th and i 5th centuries, the new artillery weapon spread through Europe and Asia with uncanny speed, so that the cities of Germany and Italy were already equipped with cannons in the first half of the 4th century. Around the middle of this century Petrarea raged against this new "plague", which some attributed to Archimedes.§ At the beginning of the following century under the powerful Emperor Yung-1 (*4°3 to '4>5) the cannon already penetrated into China, and Ber- lin currently possesses in the Museum of Ethnology (No. (no. ¢ö), a bronze cannon (fig. ¢ö) 35.j cm long (calibre i6 mm) with an ignition hole and mounted on a pole, which according to the authentic inscription dates from i 4z I.3

i) Rf. Jshns, '7rscs. d. N'ui-gm. I (i 889) zz $.

z) Petmrcc iei dialogue *De* rcmrdiù -iri *rane /orZiinu 1 99 (ed. Ba- sil. l5 @ foI., p. 8) Nr. Naéro maràrim et Gufùtuz iùnumzrm. 2i-. 3fJru "i *nisi et glandes aeneas, quae flammis iniectis horrisono tonitru iaciuntur. Non erat satis de coelo tonantis ira Dei immortalis, homuncio, nisi (o crudelitas iuncta superbiae) de terra etiam torruisset; „non imitabile fulmen", ut Maro* [Aen. VI 590] *ait, humana rabies imitata est, et quod e nubibus mitti solet ligneo quidem, sed tartareo mittitur instrumento, quod ab Archimede inventum quidam putant eo tempore, quo Marcellus Syracusas obsidebat. Verum ille hoc, ut suorum civium libertatem tueretur, excogitavit, patriaeque excidium vel averteret vel afferret* [l. *differret*], *quo vos, ut liberos populos vel iugo vel excidio prematis, utimini. Erat haec pestis nuper rara, ut cum ingenti miraculo cerneretur, nunc ut rerum pessimarum do-*cifzs Toni animi, ita commu'iit ezf et an um Hund/i6zt d rittii ormorum. The passage is also interesting because, among other things, it attests that Pettarca still keine Metallgeschütze, sondern nur hölzerne kennt. Über Archimedes s. S. 104.

3) Feldhaus, *Zeitschr. f. hist. Waffenkunde* IV 8 (1907) S. 256. Photographic reproduction of the pieces in thea. Verf. Z'cchnik (I-pz.- Brtl. i 9 i q) p. z , fig. s8 i.

It is the oldest dated control centre of this type that has survived.

Once cannons loaded with powder had replaced crossbows and cumbersome lever-action guns, which had almost completely replaced the ancient torsion guns in the Middle Ages'), all other constructions gradually disappeared. all other designs gradually disappeared;

p and even the cannon supposedly invented by Archimedes

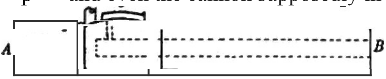

Abb. 46. Chinesische Stangenbüchse von 1421. *AB* Rohr. *A* Öffnung zum Einstecken der Stange. *B* Öff-

--ng d-c S--I-. c zd-dpfa--- =i' za-ai--s " --

Durchm.), ursprünglich mit Deckel geschützt.

invented by Archimedes, of which perhaps Petrarca already had an obscure idea.

te, ohne ihre Konstruktion zu kennen [2]), die Leonardo da Vinci genauer beschreibt, hat den Siegeslauf der Pulvergeschütze nicht aufhalten können. Da sich an die Beschreibung Leonardos eine interessante Streitfrage knüpft, will ich zum Schluß Ihnen diese Erfindung, die selbst im Zeitalter des Dampfes noch nicht zu praktischer Anwendung hat führen können, vorführen. Der geniale Maler und Techniker gibt in seinem in Spiegelschrift verfaßten und mit Zeichnungen und Skizzen versehenen technischen Manuskripten (B f. 33) den „*Arcitronito*“ des Archimedes in drei andeutenden Skizzen wieder (Abb. 47).[3])

Dieser „Urdonnerer“ besteht aus einem langen Kanonenrohr, das, wie die oberste Zeichnung verdeutlicht, zu einem Drittel in einem Feuerkasten steckt und dort glühend

i) Rud. Schneider, Uni drA//crfr In 3fiitc?ufrmz, BerL i 9 io.

z) See above p. ioi note z.

3) S. Feldbaus, *Leonozda* der Techniker uwf firJndcr (Jena i9i 3)
On the chronology of these mss. see Feldhaus, 2'rcänté p. 6ss. The
Padsai ßIs B szmmt ao- t§88-§

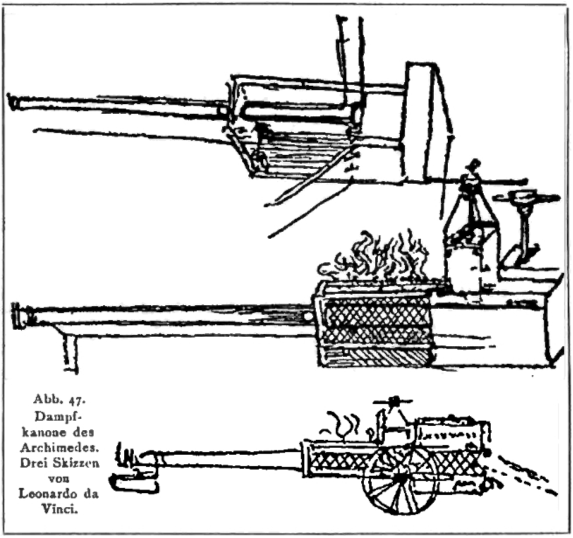

Abb. 47.
Dampf-
kanone des
Archimedes.
Drei Skizzen
von
Leonardo da
Vinci.

is made, as shown in the second sketch. There is a water boiler above the right end of the gun barrel. When the screw labelled *d* (mirror writing on the middle sketch) is unscrewed, the water flows into the smooth part of the gun barrel and suddenly turns into steam, forcibly dragging the x'or1 lying ball out of the barrel. The cannon, it says at the end, t h r e w a ball weighing one talent six stadia.)

While Matsehoß, the historian of the technik'), had no hesitation in crediting the most famous engineer of antiquity with this 'first steam engine', others have serious doubts about this honourable name. As far as we know, antiquity never used the power of steam, although it had been tested on a small scale, for larger machines and especially never for the construction of guns. If Archimedes had used such guns at the famous siege of Syracuse (z i z BC), history would certainly have reported it.

Feldhaus therefore explains the l'lamen "Archimedes" as the epithet of an engineer of more recent times, from whom Leonardo had borrowed this invention.-) But this explanation also fails. For apart from Petrarch, whose allusion I have given above, the ß-measurement according to talent and stages points with certainty to Greek antiquity.

The correct solution is found in the observation that a series of obvious l"forgeries can be traced under the name of Architriedes among the Arabs.-) The name of the Syracusan scholar and technician, highly famous in the Orient and Occident, automatically provoked the Arabian literary world, which was all too inclined to naive forgery, into making insinuations. The alchemical and florilegic literature of the Arabs is full of ancient and antique names that lack any real background. Aristotle, the intellectual master of the Middle Ages, gave rise to a wealth of pseudepigrapha. Thus the assumption becomes obvious

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i) i' ezcA ic t/c *der Dompfmascbi'ne* (Berl. i 9o9) p. z6. He surmises, that Leoosrdo Goe cos *urtoreoe lT d: Ardümudcs must beoutz 6zbcn.

2) So heißt z. B. Jacopo Mariano (um 1440) *Archimede*.

j) S. Oleibergio ßrcheoholdi "fHflo2¥"IK i8G uod obeo S Aom. v that an ingenious mind among the Arabian physicists (there is no lack of such) wanted to give confidence and further dissemination to his invention under the famous name of Archimedes, whose fame was established at all times by the defence of Syracuse. And this supposition becomes almost a certainty when we see how Leonardo states in the same passage (B f. 96) that Archimedes had invented a machine for hurling incendiaries (i.e. pots or copper shells filled with incendiary substances) and pitch at the enemy fleet. He had found in Spanish history books that Archimedes had used these rocket engines in the battles of the Spanish against the "ZmgJrsi' in the battles of the Spanish. In particular, he had supported *Cliderides*, the king of the *"Clradnstri",* with his findings.') This Spanish fable with the Greek-sounding l'lamen leads to Moorish-Arabic tradition. For this is exactly how the Arab alchemists played with the ancient names. Perhaps a scholar familiar with Spanish-Arabic literature will be able to t r a c k down Leonardo's original, if it has survived.

So even if the modern development of warfare is not directly linked to the Hellenic tradition, there is still evidence of an imperceptible transition from the old to the new, from the Greek fire originating in the ancient tradition to the modern firearms. If, as is probable, the Germans took the decisive steps in the development of the new weapons, they proved here, as so often, to be the torchbearers who knew how to fan the almost extinguished sparks of antiquity into a bright flame. Of course, at the time when the new

i) Libri , *Historie* dc* *Sci'encrs* mail. eu /ta/ic I * (H:ille i 863) p. 36.

The invention of the ancient chivalry changed and destroyed it from the ground up, and many romantically inclined souls looked at the barbaric work of the devil. In addition to Petrarch, whose urn of condemnation I mentioned earlier, Ariosto's lament, which he loosely interwove with the story of his hero Roland, is particularly significant. He fights with the Frisian king Cimosco, who has invaded Holland and fights against him in vain with his two cubit-long fire pipes. After his victory, Roland receives the cannon as booty. However, he throws it into the deep on the high seas so that the "obsolete barrel" can no longer cause mischief and dishonour knightly virtue.)

Nevertheless, the machine later rises again height):

XI zz Ans hondert Klnßer tieFen hfeeresgruften
'*Vermoabte* drum dev TeuFels Zauberœacht
Die hößisclie òlnsehine doch zu luften:
It will first be given to the Germans. T o
i n s t igate the ousters ranches with it, Uod,
always intent on our mischief, Damon refined
their spirits:
Thus became mshlich sic dea Werkee Meietere.
z3 Italian, Frenkreicb rind die Länder slle
Learned this grey art with host:
Here they melt earth metals in the furnace,
Which may then be set in hollow moulds;
There they bend iron, as in every case,
Small or large, the ball fits into the hole.
....-
Give, poor warrior, all your weapons
To the scbmieóe bia to éeia gutcs Scbwert!
You must get used to the birches now,
No one will ever reward you again!

1) Orlando furioso IX 28. 29. 90. 91. Hier heißt es: *O maledetto, o minoso ordigno Che fabricato nel tartareo fondo Fosti per man di Bel-*

2) XI 22 ff.

z5 How dost thou wander ner entrance at the
gates O thou eerruchte, dniuaie Teufelskunst?
Through you ' 'eder fame lost
The RiRwe6re became the Count Duozl

Soft souls still join in the lamentations of the ancient Italians that those terrible means of war of modern artillery a r e an invention of Satan, without considering that they serve no less for protection than for defence. But anyone who sees in these perfections of war technology proof of the anti-cultural mission of the German genius may well be reminded of inventors such as Gutenberg, who r e a l i s e d the vague idea of the great Poseidonius of movable type printing conveyed by Cicero, to Copernicus and Kepler, who turned the Somnia Pythagorea about the cosmos into a \truth, to so many other ¥founders of mankind that Germany provided in the later centuries. Every true German prefers to fight the spiritual wars that these men forged. However, if one day, mischievous neighbours, who want to hinder our material and spiritual progress, should start the fight with other \Ya1fen, they will also f i n d us equipped here. What was the highest glory for Archimedes, to have defended his fatherland with the best \Yehr and Warte, will not be a disgrace to the German Archimedesl

i) Poseidonius as Cicero's source I have in the 2f/rmrnfum (Leipzig i® s9)

VI

ANCIENT CHEMISTRY')

While in the last century chemistry has probably also risen in our fatherland to become an important, indeed the most important \science for the theory of world view as well as for the practice of world history, in antiquity it hides in a mysterious obscurity. At first glance, both the name and the cause appear to be equally unknown. Only the tombs of Egypt, which have been opened for a hundred years, and the research into sources by philologists and chemists, who have also turned their attention to this occult field with ever-increasing energy, are beginning to throw some light into the darkness.

In the past, the astrologer Firmicus Maternus, who wrote his astrological handbook around 53ö II. Chr., was regarded as the first to speak of chemistry.-) hlan read a passage in the 3rd book which deals with the influence of the tdonde in the house of Sa- turn and promised *sni'enfi "nm alclii'tniae* to those born under this constellation. Since the old scholars knew that alchemy was a form first created by the Arabs, they read rßimi'rr and claimed that this was in the Hss. of Firmicus. The latest, only reliable edition of this strange writer)

i) From a lecture at the Archlologisehen Gesellschaft zu Berlin at . 2-f$rz i 9 i 3 expanded. Cf. iPec/icaicAr. /. i?. Z-äi/et. i 9 i3, io}o.

t) Ygl. H. Kopp, &ctfr. z. Jesrö. d. G'/iemii (Braunschweig i 869) p- 44 ff.

3) lulii Firmici 6fatemi matheseos libri VIII ed. Kroll, Skutsch, Ziegler. z Bde., Leipzig i ß97. is i i. Cf. on the large gap filled by the filling ibid. I i 89, 8.

has shown that the whole passage is a cheeky interpolation of the first edition, which appeared in Venice at the end of the i 5th century.

Thus, essentially only Zosimos of Panopolis in Egypt, one of the main exponents of alchemy in the . a.d. century, remains as a witness for the word chemistry. To a Yidi legend about the origin of the art of separation, to be mentioned later, he adds the remark that the first book of this kind came from the prophet Chemes and that this is where chemistry got its name.') The attempts to derive the word from the Egyptian'), according to which it is supposed to denote either Egypt (as the black earth) or the black earth, which is the original state of mankind.

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i) Zosimoc b. Synccll. zj, I i Dind. Jerry one e'frr*äv rpd'z9 a'rp'i- Xt#q9]

atpl so4ssr she zs$sißv. tndRae di zaérqs cqr $f tov Zqpt0
5- *Xfitzov* - dpov), Iz0es rel zf2vy Xqpcfe italcfrai. According to Bertbelot, S/iii=ii an muyrn äg-e II 23o, the Syriac text (ca. 5th-6th century) reads: Os o /Zr Brrr /ic're Cfi z m a (ioumou2 et r'ezt d
?d Due ff rfi is the Jinummj a reyn tun nem. Only the Tezt bites much more literally: *"Si'e* were /c*cnd the Se tr/lm the f tumu and fi*crz'ou will g-znoiinr you Mario." The Syrian thus reads **Upov** and Avpefa. Cedrcnus seems to have read the form Xqpn as the title of the original chemical book p. 6z9, 8 BekL. (z. J. 3 i 5 AD) sésc 'tal d "gp rq$ t i # v zq 9
ἐκ τῶν τῆς Χεἱμης τεχνῶν εὐφυὴς ὢν ταῖς ἀπάταις ὀφθαλμοπλανῆσαι ὑπεδείκνυεν ἀργυροπράταις καὶ ἑτέροις χεῖρας καὶ πόδας ἀνδριάντων καὶ ἕτερα εἴδη χρυσᾶ λέγων θησαυρὸν εὑρηκέναι καὶ πολλοὺς ἀπατήσας εἰς
ntyfar yv "yec. $Jjiqt is the name of the Heros Eponyaioe of Chemistry in Olym- piodor, the com- mon of Zoelmos, Berthelot-Ruelle, Alcbeai. gr. 8 , i z (see below p. i i 6 nnm. z). In other places in the Zoairnos the name is K4p§q 169, 9,£ y2, I y, ds e en Xfpqp I8z, 18¡ fi83, 22 {Vor. Nüpqp Here

z) G. Hoffmann in Lsdenburgs Zfazuf- gives the most detailed explanation of the etymology with your carefully cemmelised material.
="irRréurZ -frr *Ch- -ie* II 5 I8 and the article Chemie. Ee argues in favour of the derivation from the Egyptian cbEmf (heaviness, blackness) Pos, but is furthermore quite calm about the weirs that I seek to prove

tallverbesserung anzusehen und durch „Weißung" und „Gilbung" zum gewünschten Resultate der Goldmacherkunst hinführe, sind meines Erachtens vergeblich gewesen. Denn nach einem solchen Urworte chêmi suchen wir in den che-
?øe- -u Ü-? S- *Ü " Õ" -&e
gríwŸ -F-ø Animal wWm in -eø fi-ee,
fii- u lc heaven lerneø when, sozu sp&-m fi byzan-
.-nüs-?nea Zei-ø Ma-ch cío-. beø-ńners sci:Üeczzte é'- o- gwap ü
torch barmen, en isi es gavz - à , oöú dm frog '.beø
Sarr- derCb-meia usr des Prc-p Cm it not stab de*
wsten e a i <-ds y zo lesea ú s t , 'in sit Anfaog unœrer
Zeíœechnung in dev ägyptisckiea xmågär íił'erii-f'n-teø TenteD
diese ¥'oLale wie inn heeÖgeø Neu- grirmhiwh -bereinklingw
In der Tax finden sich in den Handvúriften neł'eii den Formen
mit e aucn Õie sit x- hăii£g ííberliefert. t*from these
ancà in the Syriac ñ i 'erłie- fertcn Fcrmen *t°hymes* and
Chimera is each merrier Mei- nutig ausgehw Of course, the
derivation con gepöș {SafQ does not lead to the goalĘ since this
in the 2dedisin and No- tanik übliche ¥Vort nienials von den
Tränken und Säfteo d':r fir'ldmacher verwendet wir'L V'ohl
aber stellt ein zn- erst in dem Hippokratischen Corpus von
Metallen gebrauch- t-:n, but then especially in the Septuagint
and other writings from Egypt, i s the word yópa (metal
casting) dat etymon, from which the art of metal casting,
which was at the centre of ancient chemical 'l'echnique, and
numerous derivatives are named.')

i) Z'ófiia, *õaä aanb* Hippocr. he crte r 2 zaer¥t ia dea üclı¥ckœ Ia- rna\ar-n (gê/ $guoo0e) aad io Oropoe iza j. }abrb. -. Cllr. ersc6clot (as icb hence" tI, or nncbwiesJ, gebraucbt der aiexendrinische Geogrnpb Aga- thsrchldes (um i 5o BC), wo er von der Goldbearbeitong in cbeæiscbcn 'Cerahils redct, de meri Eryihr. z8 ti z8, i z) oósò dł cot 2pnøfoc zt
χύμα βραχεῖαν εἴληφὸς ἀκουσίαν ἀπὸ τοῦ ψήγματος. Über ἀκουσία s. *Abh. d. Berl. Ak. (phil.-hist. Kl.)* 1913 n. 3 S. 10³. Von einer Honig-

Chemistry, or as it would be more correct to say, chemistry, is therefore first and foremost the art of casting metals, as is confirmed by the content of the ancient literary tradition and the legendary tales about the origin of the art. The same Zosimos, whom I have just cited for the etymology of the name "chemistry", tells a peculiar legend about the origins of this art.') According to this legend, this science is descended from the evil angels who, after the expulsion of the first human couple from paradise, courted the daughters of the land and in return revealed all the secrets of nature to them. This legend ties in with the story of Genesis, where it says in chap. Chapter 1 says: "And when the ldds began to multiply on earth, and begat them daughters, then the children of God saw the daughters of men that they were fair, and took them wives whom they would ... And there were tyrants in the earth in those days: for when the children of God had relations with the daughters of men, and begat them children, they became rulers of the world and mighty men of renown." From this seed, the Jewish legend has grown in the last centuries.

masse says Diodor ty, y5, 2 2iipe ttigopez ct yRuérqzt. Then in the Septnagint oiler and in Aristeas i . s77- 2ap*öeie is now derived from 2ßp".

Although the verbs on -r6ziv, which are derived from neutris set -po, are not frequent (Fränkel, *Denemiina da* p. i 9§), they are by no means absent: "tpaypiéti" already in Homer fi z53 to dpdype, aeppevciv tnb. Hersel. Collitz q6, s9, I i 36. \Yie here lies next to aäptta aappöp to support the derivation, so next to gtp" lies 2vpdp, which favoured the derivation. From this, 2vptfa, 26#tvaip, 2vpsvr 9, yp*urcsöp and the fabulous adp9t have now been derived. The meaning of the term still seems to be carried through in some phrases, e.g. what Suidas tells us Joannes Anäocbenna s. v. yprie about the Diocleaean verse: err dq rel zi atpl 2qjstf "t 2pvao9 sal dpyépov soft mNaiof oürez (the Egyptian) yrypat*pJva §*glfa dirprveqa'iprvop fzavae.

i) A. s. 0. p. z 3, z i F.

ture of the subsequent period until the end of the Middle Ages. This work was written around the year zoo BC in Egypt and represents the summary of the entire chemical-technical knowledge that flowed together from the Orient and the Occident, from the great libraries of Alexandria and the temples of Egypt, from Greek and non-Greek sources in Alexandria, the centre of world trade and the \Ve1t industry there at the time. The author of this collection is a certain Bõ1os, who between Theophrastus and Posei- donios (around cs -zoo BC) compiled a large natural scientific encyclopaedia from Greek science, Egyptian "l'echnical practice and ancient Persian hoax writings such as Hosthanes and Zoroaster, which included humans, animals, plants, metals and stars.') The author has now published this work under the name of the ab-derite Democritus, who appeared to be a particularly suitable representative of this secret science due to the versatility of his interests and his alleged contact with oriental ancient wisdom. A number of excerpts and adaptations have flowed from this source, among which a four-volume work entitled "D emo k r i ts Phys i k und d Myst ik" has become particularly important for chemistry and the alchemy that was quietly developing in the imperial era.

i) p. 2d. Wellnasn in Paaly Wlseowa III 6y6 (i 89y). He has extended his investigations into the sources more extensively, and through them reconstructs the whole book in order to be able to determine the time more precisely (according to Herinippos). It is to be hoped that this important sub-sochong w i l l soon be presented.

z) óqponpfcoo ifie0i xò not jzv0stad. Cf. Vor "oicr. II - i 3o, s3 If.

state of the books with certainty.') Only this is clear, that the four books dealt with gold, silver, pearls and precious stones, and finally purple jewellery. It can be seen that the same content of chemical teaching is outlined here, which is already mentioned in the Book of Enoch as the fatal morning gift of the fallen angel Asasel. It can also be seen that this Schmitt, like almost all alchemical literature, has a double face: On the one hand, it contains descriptions of truly technically possible processes and treatments that serve a specific purpose, and on the other, a cloud of natural philosophical and gnostic mysticism, combined with religious formulae, philosophical dwindling quotations, occult sorcery and magic, in short, a veritable hellish brew of sense and nonsense, Greek gnosis and oriental superstition, the like of which can only be explained by the Sycretic cultural state of the Alexandrian world, which combined Orient and Occident. A similar literary expression to the alchemical writings are the astrological writings of Pet osiris and Neehepso -) and the Hermetic writings, the beginnings of which, as recent research has shown, date back to the pre-Hermetic period of Alexandria. Alexandrian times b,

1) **Über dieses Grundbuch der Alchemie wie über seine Ausläufer**

1 13q z if. and in Hcctinge, *EricycIo;f. of Religion W (Art. Æcámy*) I z88. The Greek texts are available in the poor rcxension of Rsetle in Bertbelot's *Collecti'on* føs a tie ÆcfiJ "iùfc* green (Paris 188y. 1888) sit Berthelot's Ealeitong and elner Fmnzòsische Übersetzung der Tezte. The Syriac-Srabic texts, which also contain excerpts from Democritus (by Zoiiuios), in the same Zn Giinie an mpycn fee (iøit Franz. Über- *zøwring new* Doval) B. 11 (Paris i 893). S. dsrñber Rieß in the "Ari?räørn &m ' ed'i'fifnii von NańJ6aum g-wú6nre' (Leipzig-Wren i 9o9) 8. zzy g.

i) Vol. Rieß, Philol. m Suppl.; Usener, Nf. Ann/t. II s5ą.

3) Kroll, W. ÿ o f i r ó . /. ć?. *Phi. and* #ód. VII 39. Reitzensteio, Z-eimnridr r p. q 8.

as Z os imos, the most famous alchemist of later times (4-)ãhrs. A.D.), in his thick book "øIm0th", which he dedicated to his sister Theosebeia, completely filled himself with the spirit and forms of this theosophy.

Among the profound sayings that the alleged Democritus would have heard from the lips of the old magician Hosthanes is one of the most famous, which h a s dominated the literature of goldsmiths up to modern times'):

> One Nstu* rejoices the other, Eire
> Netur -wins the other, One 2'fstor
> defeats the cadre.)

The spell is intended to emphasise the relationship of all substances to each other and the possibility of obtaining the other from the one through suitable operations. Since alchemy has been concerned with the transformation of metals into one another since time immemorial and wants to discover the secret of turning copper into silver and silver into gold, the importance attached t o this magical saying is understandable. This art of goldsmithing can only be understood if you realise that in Egypt, as in antiquity in general, the electron, a light yellow gold-silver alloy frequently found in nature, p l a y e d a major role. \You can now make both pure silver and pure gold from this electron (Egyptian *asem,* in Greek alchemy da§poç) by separating it, so it was generally believed that any metal could be converted into any metal through the art of seheide. These empirical views, derived from the technology of metalworking

These empirical views, derived from the technology of metalworking, were given a more learned character in Egypt

in the age of science when

I) TJ$cßcr e. c. O. TCopp, /<*łr. ø. G<zrà. z/. "sú' I io8.

z) F°r- SSB 3°°- iy tu'i3i- 6)¢ m uw *# etun *¥e--*°' *°t 1 gdsç zj, gdov xşa*t1 wst # gdaç #* gde* *x#.

Greek philosophy flowed in there in the 3rd century. The unity of matter, which was a principle of ancient Ionian natural philosophy from Thales onwards, the conviction that all substances were only modifications of the one original substance, which could pass over into one another, from fire to air, from air to water, from water to earth and vice versa, is characteristic of all ancient physics with few exceptions. physics with few exceptions. Even Plato and Aristotle, who follow the Empedo- kleian doctrine of the four solid elements, allow these aggregate states to merge into one another.') But the main symbol of later alchemy is the Eleatic "Er ant xdr, as Olympiodo-

Abb. 48.

ros proclaims in his commentary on Zosimos: "Chymes e c h o e d Parmenides when he said: One is the universe, through the One the universe exists. For if the One did not hold the All, the All would be nothing."

Therefore, in the alchemical corpus, this *"Ev i'o "ät*' figures in the Egyptian serpent biting its tail as the primordial mystery (Fig. 48). Until recently, this speculation alone was given little positive value.

little positive value t o this sole speculation. If anything was certain in modern chemistry, it was the proposition that the elements, which had been gradually discovered towards yo , could not change into one another, but retained their constancy under all circumstances. Only the most recent experiences with the element radium, which was discovered by

1) Prmntl, D "1rü Fort{/o*r",r*r/r (Ste "g. i8;6) ij;A vLipp man, *Ahh.* u. rhrir. I ioy ; H 55. i o.

z) The hero Eponymos of chemistry , which 2osimos (see above p. i 09 note i) had established.

3) Paris. z3z7 f. i 96- (Berthelot, S/cA their'. s i, z i) end ydp Jan z

of emanation seems to transform gradually into the element helium, point to a decomposability of certain elements that could not be thought of earlier. The same substance radium has a number of other solid transformation products (radium A to F), and it is thought that the last transformation product must be identical with the element lead.') These investigations are still too new to be regarded as a reliable basis of science. But they do cast the monistic dreams of the old chemists in a milder light. Of course, the operations which the writings of the Greek chemists' corpus prescribe in largely incomprehensible and unintelligible verbiage in order to prepare the primordial substance, the holy water (&riop iidoip)) or the philosopher's stone (2f8op s3p 9'iloaogfap), have no technical value. They are mostly brainwashed speculations of deceived operators, which a r e not based on any real maths.

The situation is different with a series of technical recipe books, which are also fed from the same UrqueHe as that corpus and quote the Pseudo-Democritus and other related pre-Christian writings, but which leave aside the theosophical and miraculous haze -) and almost only excerpt what is technically useful or at least seemingly useful. Such re

r) Cf. on this e.g. Weinstein, Mir Grunf,j-ri ler drr Ja -r (Leipzig i gr i) p. .

z) Because of the sliding sound with Orfor (sulphur), this is also known as known fliissige SchweFelverbindungen is identified.

3) Blue must not conclude from this t h a t the original sources lacked any fif ysticism. For even the medieval extracts, which after all have the mysticism of Byzantine alchemy as their forerunner, almost completely ignore this element (£'om@si'üoncs saec. RID, J/or cfnimfo s. X-X II, 3/arcsi Groccei s. III etc.).

two copies of the papyri from the 3rd century A.D. w e r e found in Egypt 9o years ago when a Theban tomb was uncovered, w h i c h apparently once contained the body of a great friend of magic literature and the occult sciences. hlith some magical scrolls containing spell incantations, two chemical codices were found together, which, like the other papyri discovered there, d a t e from the 3rd century A.D.. At the end of this century, Diocletian, who had just put down a bloody Egyptian uprising (z9j), h a d the old gold-making books burnt in order to deprive the local inhabitants of the means of m a k i n g money through the use of these secret arts. 2These disreputable books now include the two chemical codices, which the owner may have had laid in his grave to spare his heirs inconvenience. So this entire treasure of occult wisdom remained hidden in the desert sands for i 5 centuries until it was allowed to celebrate its resurrection 8o years ago. Admittedly, the two codices, which are beautifully written in calligraphy but horribly unorthographically and have been preserved completely intact, had to wait a long time before they w e r e made accessible to the scholarly world. One codex, which came to Leiden with other pieces from the same find, w a s not published until i 885. It bears the designation *Papyrus dxnsis X -j*. The second codex, the *Papyrus Holmi'- ensis,* had an even stranger fate after its publication.

1) *Papyri graeci Musei Lugduni-Batavi* ed. C. Leemanns, t. II, Leid. 1885. Vgl. Berthelot, *Alchim. gr. (Introd.)* p. 19 ff., gibt eine franz. Über-

after its discovery. For after the Norwegian-Swedish vice-consul Anastasy had acquired it in Egypt around i 8z 8 and donated it to the Swedish Academy in Stockholm, it fell into a deathly sleep there again, from which a Swedish pliilologist awoke it to real life a few years ago after it had been transferred to Upsala.') The two twin manuscripts now complement each other in the most tested way. The Leiden Papyrus reveals to us the secrets of Egyptian metal painting and purple dyeing, while the Stockholm Papyrus lacks the beginning on gold alloys, but between the silver recipes and the very detailed section on purple dyeing is the long-missed chapter on pearls and precious stones.

Plan will already see from this that these two extracts, which go back to the same editor, reproduce the contents of the old book of democriths, which in its four books dealt with gold, silver, precious stones and pearls \, and finally with purple. But just as the later alchemists remodelled the old material of the Book of Democritus in various excerpts and adaptations, the Democritus material is also found in these two papyri, which surpass the oldest writings preserved in the Chinese corpus by at least a century, in various forms and fragmented. Even the two so

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i) *PoCyrus* ZZoZmirn*ii, Aesc§tc /Sr .fi?0w, *Strme* und P r,¡ er, edited by Otto Legercrentz , Upsala (Universitätsschrlfl) i g i 3- Cf. my advertisement in the Deitsch. ZJüraf--r". i9 i3 Sp. 9o i ff. from which I take some in the following. A valuable commentary on this publication is provided by v. Lippiiianii in the Cherrii*'ker-Zeiti-ng* I gi 3 n. 93. 9G. i oo. io I. This igt is also gratefully acknowledged below.

z) Tbeopbrast already counted pearls among the precious stones, Fr. de lapid. 3*-

gavJt), however, it is obtained by fire earthing or by superficial gold colouring on a cold \vee.

In addition to "test-containing" gilding with mercury, apparent gilding with fimisse is also recommended.

The art of decorating manuscripts with gold ink forms a special chapter in these recipe books* as well as in later similar medieval editions. Here, too, the genuine gold leaf suspension in gum or egg white solution stands alongside the cheap surrogates (lead and sulphur compounds, saffron, bile).

In addition to the colouring of the hfetals, the quantitative tion of these, the colouring, is also discussed in more detail. Thus, by adding copper with salt preparations or alum, a doubling '), by adding copper and tin a tripling can be achieved.-) One must not think that only a fraudulent plus-making was involved here.^) On the contrary, the whole of antiquity, right up to the latest adepts of the black art, is pervaded by the idea that, just as one grain placed in the earth produces a hundredfold fruit, just as a small piece of leaven leavens the whole mass, so a small piece of real metal, treated in the right way, produces an inexhaustible supply of further real ßmetal. An old scripture attributed to **Isis** says: "Grain brings forth grain, man brings forth man, so gold harvests gold."-) Consequently, in

) Homo. " j6. 3) 1loIza. // i $.

3) Of course, this also plays a role, as the author of Pap. Leid. 12, I introduces the doubling of the gold with the words: dot Grat ppqp pt¢ p{§qqt p, @) Bctbeot, Altüm. jo, z@ # 'UrOy gh@y y,gpy, Sgt g,gyppq g,_

Ppmsou anzfpti, oGe 9 um d 2pvaö9 2pvaßr fl'tpi{c" t¿ dpqtpp t} pqtp Iger pd'P9 *'tig d9 zé p'uarypio*'. similarly, pigp jg qtb jj yttt. tum believed that dle stones in the pits nnchyüebs. Plin. XXXVI t t .

-t titi §'y F rote ri xls Gel d ch mïeû e. ErkUreo g S. i eJ

in the chemical literature from i3rotteig (pâte), which rises with yeast and increases the mass, in the figurative sense. The Latins take up the word *tessa*, and so this alchemical term has become one of the most common expressions in European languagesœ') In the two chemical papyri, the term "inexhaustible class" is often used.
"inexhaustible class"), which serves to create ever new nickel silver from a piece of nickel silver.

The regulations dealing with pe rle ri and ede 1st e i- n e ri refer to their cleaning and polishing, but above all to the reproduction of these precious jewellery materials. Beads of piilverised àlaria glass are combined with wax and Q, uecksilber(?) to form a dough, which is kneaded with gum and F.iweifl in cow's milk and formed into beads, which are pierced while they are still moist. "They are then as good as the real ones."

i) v. Lippett, Kprtr. it. d6A. II i 6. i i y. i 35.
z) ;-éfa 'tréziriazo9 Leid. y, $9. Holm. § iy.
Holm. d j i lever ct ia4'cl i'9 dtf girl vul ñr dr.rl g -

Abb. 50. Eroten als Goldschmiede. (Erklärung S. 132)

The production of the ed e1st one (j9agJ, for which mainly porous stones are suitable, such as the Tabasis mentioned, "which is brought down from Egypt"). As Mr v. Lippert recognised, these are the tubers consisting of siliceous acid, which a r e deposited in the inter-stalk nodes of the East Indian bamboo *(Bain- bnsa arundi'nacea* Willd.) and have been an Indian export article since time immemorial. Since the Indian goods are sent to the Egyptian ports via the Red Sea and then shipped down the Nile to the Delta, the expression "brought down from Egypt" is now understood to refer to the Alexandrian origin of this literature, especially if one knows that the Alexandrians did not consider their city to be part of Egypt properQ Among the precious stones, the emerald is in the foreground of interest, for the production (;rof§atp) and colouring **(jgeQJ** especially copper compounds are used. The stones must b e pre-treated by soaking them in alum or vinegar. Furthermore, the

I) HolHi. § Ä 2tyÄpfHo9 Td Has JA Tj AfyÜMTfr for Ö@epÄptyo9.

z) Display of the fzmiéer-deimng (see above).

3) Cumont, Pro1. z. e. edition of Philo de aeternitste oiundi (Berl.
* 89 *) P- IX'.

Ruby **(aap2§tórvo9),** garnet (adptvoç), amethyst, beryl, etc. are mentioned.

The most technically valuable part of the newly discovered chemical papyrus is the chapter on colours and dyes. First of all, the signs of good dyes are presented: Ward, scarlet, orseille, madder, celandine, alum, vitriol. The pinnacle of the art of colouring is the imitation of real purple using cheap surrogates. The recipe book says literally') :

"Keep the recipe secret. For the purple is unusually beautiful in colour. Take the foam of woad, as supplied by the dyers (i.e. woad indigo), and imported alkanna as much (the foam is light in weight). Rub both together in a fine mixer. The alkanna dissolves in woad and gives off its strength to it. Then take dyer's varnish (6e&oy zò dnò **zör §"gZøv)** either from kermes (xòanop scarlet), which is preferable, or from grain varnish (xpfpeo#) and bring these grains warming into the hlörser together with half of the woad foam, put the wool there and dye it without mordanting. You'll see, the purple will be indescribably beautiful."

There is also no shortage of recipes for producing splendid purple on hot

\(-) As for the origin of these recipes in Pap. Holm., the compiler of this codex makes no bones about it.*) Same

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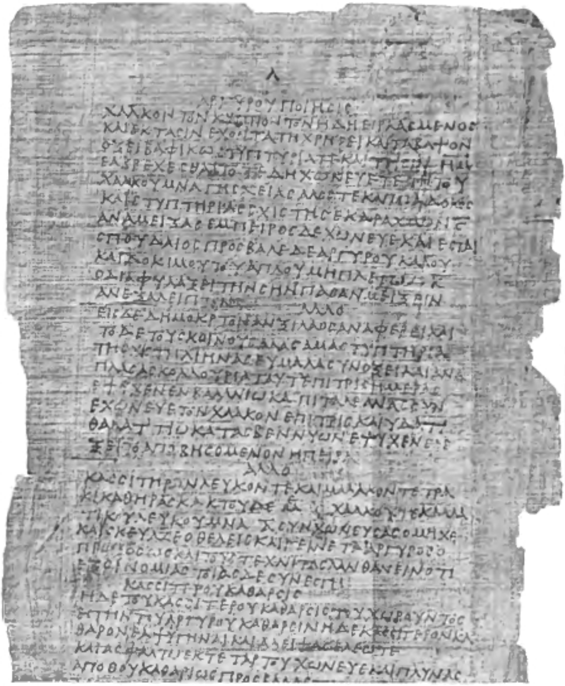
i) iț z9 (p. z8).

2) For red dyeing, øian used various scale insects (Kermes scale insects) or licks produced by the stinging of scale insects on fig obëuæs, such as the dyer's lick (focf-dyć), The lick colours a r e distinguished by their bright colours, which explains the Greek term d+i)'op.

g) The first side of the pep. Holm, the first z i lines of which are shown in Pl. IX , lnHtet in tJmscÓrift ao: N. A ÛpoD Ro{Ęvts. Kn2-



Chemisches Buch des III. Jahrh. n. Chr.

Papyrus Graeca Holmiensis.
Erste Seite. Z. 1—33.

At the beginning (see laf. IX) there is an instruction on the production of new fibres. As usual, a second one is followed by Miho (another). At the beginning, however, this bears the note "Anaxilaos also traces the following back to Democritus"). The old material of Pseudo-Democritus, on which the entire alchemical literature is based, is thus at least partially mediated here by A na x ila os, whom we know as a frequently used source writer of Pliny's great natural history Thus this -) traces back to him the tasteless joke of making the faces of guests at symposia appear pale like dead people by developing shive field vapours. The same PJinius -) mentions i\hn1ical jokes that make the attendees look like fleas. The church father Hippolytus also mentions the highly amusing conjuring tricks from a magical spell book.

nm rör itdspto" a §d9 pzfpnaapf "or (they) allowed Fnca0ir f2oi'vo cp 2p/ari

κα[ι]ταραψον οξει ραφικῳ στυπτηριᾳ τε και τρισιν ημ(εραις) εα βρε-
χεσθαι. τότε δὴ χωνευετε (d. i. χωνεύεται) τῇ τοῦ χαλκοῦ μνᾶ γῆς
Χείας ἁλός τε Καππάδοκος καὶ στυπτηρίας σχιστῆς ἐκ δραχμῶν ϛ̄ ἀνα-
ptfto9 Jarfpor (i.e. ἐμπείρως) δὲ χώνευε καὶ ἔσται σπουδαῖος· πρόσ-
βαλε δὲ ἀργύρου καλοῦ καὶ δοκίμου τοῦ ἁπλοῦ μὴ πλείω L (d. i. δραχ-
μῶν) κ̄· ὃ διαφυλάξει τὴν σήνπασαν (d. i. σύμπασαν) μεῖξειν ἀνεξάλειπ-
τον. Ἄλλο. Εἰς δὲ Δημόκρ⟨ι⟩τον Ἀν⟨α⟩ξίλαος ἀναφέρει καὶ τόδε·
[illegible]

λεανας συνεχωνευε τον χαλκον επι τρις και υδατι θαλαττιω καταρεν-
νύων ἔψυχεν. ἐλέ⟨γ⟩ξει τὸ ἀποβησόμενον ἡ πεῖρα. Ἄλλο. Κασσίτηρον
[illegible]

σκεύαζε, ὃ θέλεις, καὶ γείνεται ἄργυρος ὁ πρῶτος, ὡς καὶ τοὺς τεχνίτας
λανθάνειν ὅτι ἐξ οἰ⟨κο⟩νομίας τοιᾶσδε συνέστη. Κασσιτέρου κάθαρσις.
Ἡ δὲ τοῦ κασσιτέρου κάθαρσις τοῦ χωροῦντος ἐς τὴν τοῦ ἀργύρου

i) a i3 (see above p. i z note). z) 33, i 25.
3) 3°. '§i. Also in Sext. Pyrrh. Hypot. 1 6.

and crooks s guess similar origin.'} Now this Anaxilaos was in the year z8 s-. Chr. had been banished from Italy for sorcery. He probably continued the mystical studies of Xigidius fiigulus, who had attracted attention in Cicero's time with his Pythagorean secret societies, in which astrological and necrological arts were practised, and no less with his extensive but confused grammatical, scientific and occultist writings.)

All these studies show a unifying trait in antiquity. They shy away from the light of day and are disseminated in certain conventions as a gospel or honour.

-The people look at these dark men with shyness, even disgust. The emperors frown upon them and persecute them. How did this happen? \How could a technical science, which was already in possession of valuable natural knowledge and culture-promoting manufacturing methods, not develop freely, but instead sneak around in the dark for a thousand years?

The two chemical papyri allow us to answer this question as well. I have already mentioned the note by Holniiensi*) on the occasion of the production of primary silver: "Thus a silver of the first giite is produced, so that even the experts (cc2ufr "t) do not realise that it arose from such processing f,oixoro ")." Usually

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1) Hippolytos, Ref. IV 28 p. 66. Ganschinietz, *Hippolytos' Capp. g. d. Magier* (Harnack-Schmidt, Texte u. Unters. XXXIX 2, 12 ff.). Vgl. dazu

Kl. 3. 1913) S. 24 ff. Diese Scherze pflanzen sich mit der übrigen magischen Rezeptliteratur in die mittelalterliche Literatur fort. S. Marcus Grae-
ni bcl Berthelot, éñéstir as "-. '£ I i i .

z) Cicero, who scolded Ibui mnk , praises iha inn Tim. i , t all owr " rz'cJti@'ifrr- ed *diliyens* earn n rrrum poor a antara imofu6cr eñfe "Wr.

31 Holm. a z5 - Lcid. P. 6, go.

a lmitation of beryl is produced, which even the experts do not realise .') This intention to m i s l e a d not only the public but even the experts by passing off worthless alloys as genuine precious metal even leads to a strange technical term which, like "mass", has been inherited from the Middle Ages and modern times. In mining terminology, certain sulphur metals of a non-metallic or only semi-metallic habitus are known today as "pblenden", which blind or deceive about the ore content because t h e y contain either no ore at all or only ore mixed with other substances.-) The author of the Stockholm Papyrus expresses himself in the same way when he s a y s the following at the end of his recipe for making an imitation silver: "And when you take the ßletal out of the crucible, you get a dazzle (dpeiipnatr, literally a *dazzle of the eyes),* which only shows the real appearance of natural silver due to the mixture of the combined components (namely silver, copper, mercury). *)

So who were these recipe books intended for? Certainly not for the craftsmen (rr2rlznv), and even less for the public. So there is nothing left but to look for the author and the owner of this chemical library, found together with the magic literature, in the circles that have always exercised the privilege of the precious metal industry in Egypt and have placed technology and science at the service of their religious hocus-pocus.

s) Dgber bites at una a 2dischling also "Blendling", and the narrow liz*he éfend simply means "to mix". 3) Holm. }$ 33.

q) It should be noted that, together with the chemical codes, an extensive body of writing with magical content has been found and that a good part of the physical sleight of hand has been invented. *-orms that were described in the Automata Book and the Pneumatics of HeronL ') l'on the qGeiieioi- sneezes of the Go1dwerkstätten- tells us the temple *Dendera and other Egyptian documents'); Plutarch -) tells us of the marvellous bledikaœent Kyphi, which the Egyptian priests prepare while chanting sacred texts; Zosimos speaks of the deep secret with which the ancient chemists kept their knowledge, which they only shared with the priests.-) We may therefore assume that such beakers, such as those preserved by a unique accident in that Theban tomb from the 3rd century AD , were intended only for the priestly heads of the temple laboratories, for whom it served no purpose to prepare blue vapours. \A'e know through

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'ngcsteckt found, dns although not buried by the same hand, eh probably at the Praiis in Lnboratorium was veronodt. For we know
(S. unten Anm. 3), daß die ägyptischen Priester ihre chemischen Arbeiten unter
A bsiogaog beifiger Litxoeieo "olIsoge". Aacb io this Forœd 6aÂco sicb

2'tanien. wss ser Zauberei eon eon immer geb6rte.

i) See in. a bh. on alcohol (see above) p. z6 if.

z) Cf. op. cit. p. zy'.

3) de ls. et Oiir. 8o p. 383 E.

) Berthelot, Cüi "tii a- m. 'f. II zz8 (from the Ayrian text) je
r "ye er fcs u ocicnz ur zwite dr mer c rtt dr 'aföwü- n'Zcrr"irrnf
ces choses, mais ils les firent connaître en secret aux prêtres seuls. **Ebenda** 245 *ceux qui préparent le mercure doré sont les fabricants de lames d'or pour les temples et les statues de rois; mais ils cachent, eux surtout, leur art et ne le livrent à personne. Les fabricants de l'or et ceux qui travaillent finement le mercure, agissent comme s'il n'était pas naturel.* **Über die**
The Greek Zosiuios (Beribelot,
SlcWm. z40, S) 'fyov d0 ssi 16*o* éQyoer#q J*'xi'pAers x#t zo1*#
cvp "relc Jz z#c @§aiœc où pdvov sûr jç, d11& taf sky 2pvaœp su ' Pf yÀQ 89 $6QfGHfKaé dQdaa'oG, eÜ Q J Jt 5UR¥iO8ç pj (Àe 8yyQd$ aù*d Jaidiédeei. Ober dan 6tonopol der 2po¢o2orsj vgl. 6litteis-Wilehen, *Gru ndy. u. Ciment im. der* Papyt *ystundy* I I, 256 ; 2, *3 5* n.*$ 1 8.*

Heron, Hippolytus and Lucian (in his revelation of the prophet Alexander of Abonuteichos i ob- i y i A.D.) that some of these secret writings did reach the public, just as Pliny made extensive use of Anaxilaos and Pseudo-Democritus and other occult literature. For example, Pliny made a remarkable report on the production of niello vases, which show the black image of the god Anubis on a silver (or gold) background.) This technique is based on the production of sulphur compounds, and the instructions for this have been rescued from the Hellenistic recipe books (not by Pliny), like most of these instructions, by an equally subterranean route into the Middle Ages. Thus the secret of this niello technique can be found both in the Syrian Zosimos } and in the painter's booklet called *da ppae* rJawirv/a -), which contains a Latin translation of a Greek text that came to Gaul before the time of Charlemagne and was translated there. These Latin recipes often correspond word for word with the chemical corpus and the two ancient chemical papyri, so that one gets the impression of a thousand-year-old uninterrupted but completely secret tradition of technical recipes, which of course was only passed on with a guilty conscience from the beginning to the end of the Middle Ages. Zosimos already speaks of the oath of secrecy, which the Stockholm Papyrus and *the 3Iappae clac'iiuln* also recommend. Here the oath is even at the top of the list.

i) Plin. 33, i 3 i. z) Berthelot, CAL an i. ". II zo6 n. i3.
3) Arcfinc "f'gii t. 3z p. zoi f. Abh. über d. Alkohol p. z8.
-t) A. a. O. p. 189 c "nii'ro aut'rm jfrr iziognum free gus' irivenrrJ, molti

tradire visi clic'. Cf. p. i 96 'z/'scpndc zanrfum ef auff/ /radrndum serre - tum segue a/iii frderiir, ¢ r p ¢ L f o . Pap. Holm. z8 rqptt 'ta6npu'pov

The persecution that chemists and natural scientists suspected of magic had to endure in imperial times and later from both the church and the state forced the adepts to exercise extreme caution. In the Zfo,¡é/nu *clayicula*, for example, the alcohol recipe is given in chi8re writing'), just as Roger Baco similarly concealed the secret of gunpowder. \ And yet this Franciscan monk with his knowledge of nature was the first to courageously admit to the hated "secret science" and prove that everything here was natural and that the concept of hlagia was a foolish fantasy. The *doctor* mti-oéi'fii had to languish in prison for ten years for his bold attacks against medieval ignorance and monastic delusion and against the moral degeneracy of monasticism that went hand in hand with it. But the spell was broken. It led to the realisation of great discoveries that were still slumbering in the bosom of the times, and soon there were enlightened voices everywhere within and outside the clergy who showed nature to man not as his enemy, but as his friend and helper. The spirit of wine was now released on a larger scale around the turn of the i 3rd and i 4th centuries according to a probably ancient recipe and put to the service of mankind for any useful or harmful use. The explosive power of the long known powder mixture was now generally used openly for attack or defence. Humanity now felt itself to be under the control of the

r) S. Fig. on the alcohol 8. ry. z) 8. above p. ioo note z.

3) Cf. fig. on alcohol. The arguments put forward against the age of alcohol production by Prof. v. Lippmann in the Cbemiicer-Zeitung 19 r 3 a. 129. fi3s,

fi33. i 38. 139 are worthy of consideration, but do not support my grey analysis, which is based on the quality ratio of the recipes. On Tbaddüus Florentinus , the most important herald of alcohol, see Lippmann, dr*fiiv /. ' s*fi. d. 3fed. VII (i9 l) 329.

liberated from the bonds of narrow-minded paternalism and took the decision about good or evil into his own hands. The autonomy of morality, which had been subjugated for so long, could once again reign free as it had in the early Hellenic period. Technical knowledge, which had hitherto been used only for deception or jesting, now more and more fertilised the whole of human culture, and after Ghemie had been elevated to the rank of a 'science' by Lavoisier at the end of the i 8th century, it is Ghemie that has now taken over the leadership of the natural sciences in recent times and brought about the only combination of technology and science that is characteristic of our age.

---

i) Kahlbauni-Hoffmann, *Die* Aa/Inge drr Nfirmiz in Aeitr. ser "7cscA. *d. Chemie, dem Gedächtnis von Kahlbaum gew.* (Leipzig-Wien 1909)" S.98.

Explanation of the illustrations (4s) (--) s p. 1 2 2 and i 23.

Erotes as goldsmiths.

One of the charming, iuipressioniztiscb designed Amorctteascenen from the Haose of the Vetöer in Pompeii. blue, f-o"-@/i' 3$3 describes the bier in zyei Teüe zerlegien Friea as follows:

"On the right, the glass furnace decorated with the head of Hephaestus, on which someone is working with a plumb bob. Behind the furnace, someone is polishing a large golden or gilded disc: he* is w o r k i n g with his right hand, while his left hand is using a rod-like device to firmly hold the disc in place. Thus, the corpus, which is free and unobstructed, serves as an obstacle

The delicacy and caution of the arh€it is a driving force behind the view. p
für die starke Anspannung der Armmuskeln.

Weiter links hämmert einer auf einem kleinen Amboß. Auch hier i
Because the canteen table,' on which a small 6lobel in three p$tp. btebcqden drawers gold jewellery c a n be recognised. On a rod jj 2gy two trolleys.

The seller and the buyer. The jewellery is gtqqgq, both wipe with the open left hand a (iestps, which should express the ¢pt. attention to the state of the wnge: the jqgy stands.

At last, two Af*tngers in the anbo0: sorzägljeb nnty pbt iß ,jjt gg wegqng the one who puts the Af*tnll on the .anvil hdtyd q@g]¡qb$t y¡t away, dsmit him the jumping fqnkep .¡gbt tpqpqq --

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Technology and terminology of the trades and arts among the Greeks and Romans. VoeH.Bidmne,.,bde Mit zahlr. Abbildungen.

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I. Die Bereitung des Brotes. II. Die Verarbeitung der Gespinstfasern. 1. Verarbeitung der Schafwolle. 2. Die Verarbeitung der übrigen Gespinstfasern. III. Nähen, Sticken, Filzen. IV. Die Färberei. V. Die Verarbeitung der Tierhäute. VI. Die Fabrikation geflochtener Waren. VII. Die Fabrikation des Papiers und Schreibmaterials. VIII. Die Fabrikation der Öle und Salben.

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Naturwissenschaften und Mathematik im klassian antiquity.

Von J. L. **Heiberg.** Mit 2 Figuren. Geh. M. 1.—, geb. . . . . M. 1.25

„Der Verfasser weiß in fesselnder Sprache auf dem kleinen Raum den gewaltigen Stoff mit großer Kunst vor uns aufzurollen. Dabei ist kein Name von Bedeutung übergangen worden. Sehr erfreulich scheint mir der Umstand, daß auch die Medizin der alten Welt mit besonderer Liebe mit in die Naturwissenschaften

The decorative arts of antiquity. *'*,*

Sucht, auf der wissenschaftlichen Erforschung der Stilzusammenhänge fußend, die

Krouea cugUgkeb '¥u "zaacb co""Un or "Hctoo uog* lhr tot bootogiech co 5e "to mrd

$. AJtortonta l'sch o Omazaenu fi d er'ä r'-t heb -my Leon gebe ^stsl$ G rioch sche K o raa'k'
6. dolber. ioolacbor eod LozTat5i*cbor EU. t. D etloaist Ac b- rözai ecbe Ookoratioo.

Friedrich Lübkers Reallexikon des klassischen Altertums.

8. Auflage in vollständiger Neubearbeitung herausgegeben von **J. Geffken** und **E. Ziebarth.** In Verbindung mit **B. A. Müller.** Unter Mitwirkung von E. Hoppe, W. Liebenam, E. Pernice, M. Wellmann u. a. Mit 8 Plänen. [XII u. 1152 S.] Lex.-8. 1914. Geh. M. 26.—, geb. M. 28.—. Ausgabe mit Schreibpapier durchschossen in 2 Bänden geb. M. 32.—, geb.. . . . . M. 36.—

Die Neubearbeitung des Lübkerschen Reallexikons will den häufig geäußerten Wünschen nach einem Buche entsprechen, das in knapper Form, vor allem durch Hinweise auf die nötigen Quellen und Hilfsmittel, dem Suchenden Belehrung über

gehaltenen Stile den nötigen Apparat über die Tatsachen und die Forschung unter Verzicht auf alle subjektiven Urteile über Personen und Sachen, weshalb auch seine Artikel ohne den Namen des Verfassers bleiben. Das so völlig neugeschaffene Buch hofft sich als ein nützliches, die philologisch-historischen Studien in weiterem Umfange förderndes Unternehmen zu erweisen. Es wird insbesondere ebenso dem Philologen an den höheren Schulen in Verbindung mit den Fortschritten der Wissenschaft zu bleiben erleichtern, wie dem Forscher auf verwandten Gebieten, dem neueren Historiker, dem Kunst- und Literaturhistoriker, dem Theologen wie Juristen sich über die grundlegenden und verwandten Erscheinungen auf dem Gebiete der antiken Kultur bequem zu unterrichten ermöglichen.