

OLD ARCHIMEDES TEASES THE MODERNS

Out of the Past of Twenty-two Centuries Has Been Resurrected a Puzzle Pastime Like the One His Fertile Brain Evolved for the Ancient Greeks and Romans—His Stomachion Described.



Archimedes.

Epidemics of brain teasers of many sorts have swept both this country and foreign lands in recent generations. In the past decade or two there have been crossword puzzle crazes and jig-saw puzzle fads—to say nothing of Mah Jong fevers and such games as Flinch and Lotto. Now, out of the past of twenty-two centuries, has been reconstructed a puzzle pastime of the old Greeks and Romans, similar in nature—one that was devised by the great mathematician Archimedes. Weird cubist shapes of men, animals and boats may be assembled from fourteen little pieces of various angles cut from a rectangle of cardboard or from some flat material. The existence of this ancient puzzle has been known to classicists, although they were not able to reconstruct it. It remained for the research of the author of the following article to restore for the modern world the entertainment Archimedes devised for the ancients. Some of the shapes into which the pieces may be arranged are reproduced on these pages.

By R. D. OLDHAM

WELL over two thousand years ago, in the third century B. C., there lived at Syracuse, in Sicily, a famous mathematician named Archimedes. He was not only the greatest of the Greek mathematicians and geometers, but also a fertile inventor. The discoverer of the method of determining the density, or, as it is now called, the specific gravity of substances, he installed an elevator in the palace of the King of Syracuse, invented a method of lifting water, and in the siege of Syracuse the Romans were met by one contrivance after another, of his design, by which their engines and arrangements for attack were destroyed, and the assaults repulsed with great loss. At last, if the besieged merely thrust a pole or threw a rope over the walls, the besiegers fled in terror of some new infernal machine contrived by the fertile brain of Archimedes.

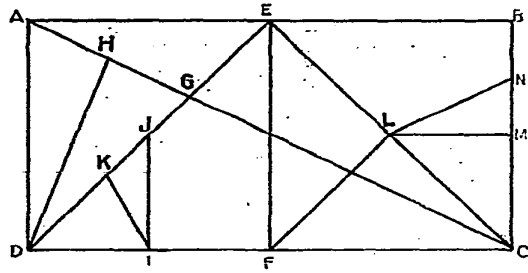
These inventions, however, he regarded as forced from him by necessity, and in themselves unworthy of the attention of a really intellectual person. Yet he was not averse to an indulgence in humor; there remains an elaborate joke in the form of a mathematical problem propounded by him to his rivals of Alexandria,

of bone, fourteen in number, representing geometrical figures, and by fitting these together in various ways pictures of countless objects could be produced—of fearsome ele-

phant and barking dogs, of savage boars, of geese in flight, gladiators in armor, a hunter crouching down, also a tower, a tankard and numerous other things whose variety depended upon the skill of the player. But while the harmonious arrangements of the skilled were marvelous, the jumbles of the inexperienced were ridiculous.

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From other sources we also learn that the pieces, besides triangles of various sizes and shapes, comprised some having a larger number of sides, and that the pieces were usually of ivory or ebony and that they were contained in a square box, whence came the name of *loculus*.



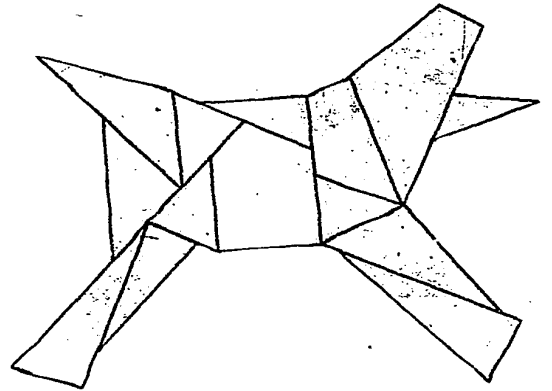
The Loculus of Archimedes.

These mentions of the pastime show that it was akin to, though more elaborate than, the familiar Chinese puzzle of *Tangram*, but they give no clue to the pattern on which the pieces were designed, and as no fragment of the writings of Archimedes himself was known, in which any mention was to be found of this pastime, it was even uncertain whether he was really the designer or had no more connection with it than with the Archimedean drill of the modern ironmonger.

before and the old writing erased, yet not so completely that it is not still possible to read a good deal of the

deduced from the Arabic manuscript, a square. The palimpsest manuscript has

This was the state of the question up to the end of the last century, when an Arabic translation from the Greek was first published. The manuscript definitely describes itself as a book of Archimedes on the division of the *Stomachion* and gives detailed instructions as to how this was to be carried out. Unfortunately, however, it omits to mention what was the exact shape and pro-



The Barking Dog.

original work, and to recognize that this was a copy of the works of Archimedes, containing much that had

been published since 1913, but it had not occurred to any one to combine the two partial descriptions, Arabic and palimpsest, before the latter end of 1925. Then, my attention having been drawn to the subject, I noticed that it was now possible to restore the complete figure as originally designed, so that any one who wishes to do so may reconstruct the *Stomachion* or *Loculus*. In drawing the lines, but one departure is made from the Arabic, and this appears necessary if the thing is to be used in the manner described and not as a mere exercise in geometry.

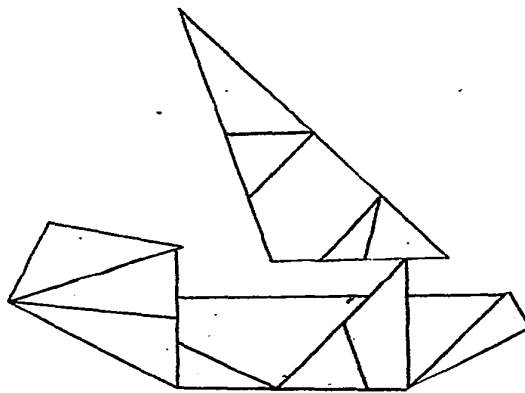
who had written contemptuously of some of his own work; and he was the author of a pastime which long amused the Greeks and Romans of succeeding generations.

Of this nothing was known, up to the end of the last century, except from some references in Latin writers of the third and fourth centuries A. D., by whom it was called *loculus Archimedi*, the first word meaning a small receptacle divided into compartments. The Greek name is uncertain; the lexicons give it as *ostomachia*, but the only authority quoted is the Latin writer Ausonius. This, however, is the form usually adopted by the editors of printed texts, though the word is sometimes given as *stomachia*.

What Drives One Wild

The question of choice between these two forms was discussed at length in 1907 by Professor J. L. Heiberg, who concluded that the first-named usual form is a mistaken emendation of editors and that the other is the correct one; it is also the form found in a palimpsest, deciphered by him in 1906, and the only known occurrence of the word in a Greek manuscript. If *ostomachia* is correct the interpretation would be a battle or struggle of bones, while *stomachia*, or *stomachion*, would mean "the thing that drives one wild."

The description of the Latin writers, being in each case a parenthesis in illustration of a very difficult subject, are naturally incomplete. The best of these descriptions is that of the Roman soldier-poet Ausonius, who wrote in the latter half of the fourth century, about a hundred years after Archimedes. According to this, it consisted of little pieces



The Lateen-Rigged Ship.

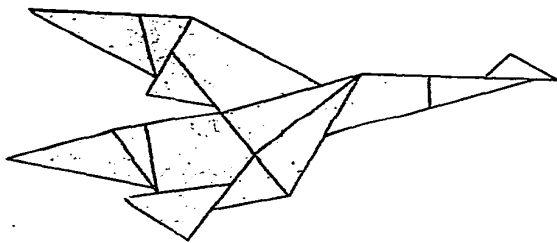
portion of the figure, taken to start with. The next step was the discovery,

not been known, and among other things the commencement of a book of the *Stomachion*. This goes just far enough to show that the pastime was in fact an invention of Archimedes himself, and contains just enough of the directions for constructing it to give the information which was wanting in the Arabic translation. The opening paragraph of this fragment says that as the thing called the *Stomachion* presents examples of the method of transposition of figures, he thinks it well to treat of these and to show how it is divided and how the parts resemble each other, so that in forming them into pictures one may see how the angles may be combined to form two right angles, and whether two sides,

Cardboard Will Do

The ambitious and skilled may emulate the ancients and make it of ivory or ebony, but good cardboard is more easily worked, and in any case is best to use for a first attempt. A piece of stiff card of good quality which will cut cleanly is the first thing; then draw on it a rectangle twice as broad as it is high; for size, about six inches by three will be found convenient; if less than four inches by two, some of the pieces will be too small to use conveniently, and if larger than eight inches by four, the amount of room required for moving the pieces about becomes too large for comfort. The exact size, however, is not material, but it is essential that the dimensions in one direction shall be exactly double the other.

Having drawn this rectangle, represented by A B C D in the figure, the next step is to divide the two longer sides in half and join the two points E and F. This gives two squares, side by side with each other, in each of which a diagonal is drawn from the centre point of the upper long side of the original rectangle, D E and E C of the figure, and the long diagonal A C of the rectangle is drawn from the top left-



The Flying Goose.

hand corner to the bottom right-hand corner. Then, in the left-hand square, the line joining A with the intersection of the diagonals at G is divided into two equal halves at H, and the line H D is drawn; the side D F of the square is halved at I, and I J drawn square with D F to meet the diagonal D E at J; finally a line is drawn from I in the direction I . o A, but only as far as the diagonal D E, which it meets in K. Turning next to the right-hand square, one-half of the diagonal F B is drawn from F to the centre of the square at L; the side B C is halved at M and the line M L drawn; finally B M is halved in N and the line N L is drawn.

Quite Easy and Simple

These instructions may seem complicated in reading, but if actually followed out, step by step, with a ruler and pencil, will be found quite easy and simple; and then, if the card is cut with a sharp knife or scissors along the lines, it will be found that there are two squares, each composed of seven pieces, or fourteen in all, with which a good deal may be done in the way of combination into figures of various forms; and a game will be made which was used by the ancients for

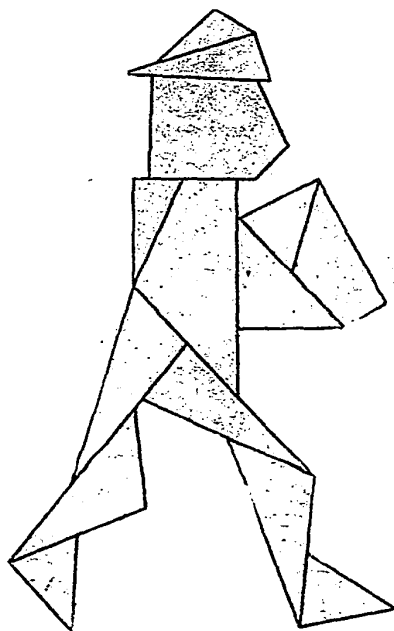
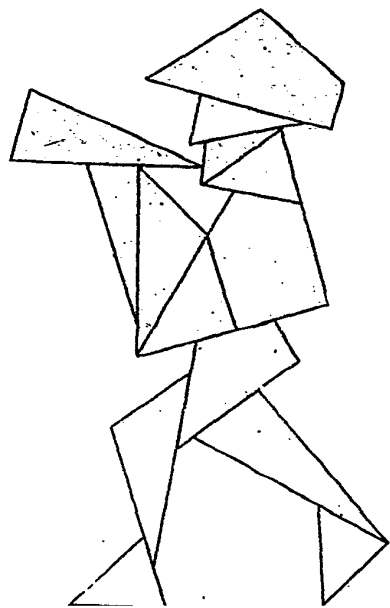
a straight line against which the side of another piece may be placed. And it is also needful that the lengths of the sides should match with those of other pieces, or with a combination of such sides. Now when the angles of the pieces are studied, it will be found that there are in reality only two sets of angles concerned, which may be combined in an almost infinite number of ways to form a solid block round a point, or to continue the straight line of one of the sides. The sides, too, are simple fractions of three units of length, and can be made to match either another side or a combination of other sides in many different ways.

To this general rule there is one exception in the two triangles on either side of the line D H; the line itself will not exactly match any other side, and the angles are about four degrees out from combining with the others to form a straight line or a complete circle. This slight difference in angle comes in very effectively, at times, in giving the parts of a figure a slight tilt from each other, which may increase the realism; and Archimedes himself was merciful in his instructions and specifically says that a figure otherwise satisfactory is not to be re-

ures will serve as a start, and it will be found that in each case they may be modified by a rearrangement of some of the pieces, and they will at least indicate the great variety of combinations which can be evolved from this ancient pastime.

A few words may be added on the comparison between this and the older and simpler Chinese puzzle, or Tangram. Though similar in pur-

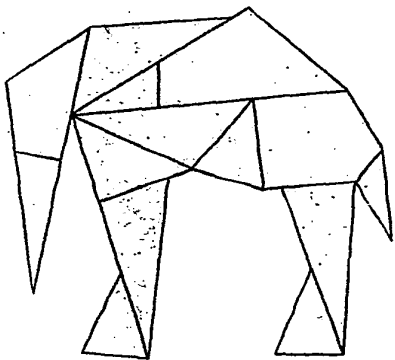
Right—
The
Pied
Piper.



Left—
The
Patient
Shopper.

about five hundred years and then lost for the next fifteen hundred.

It may be added that there is just a little uncertainty about the last line in the description, and it is possible that the point N should be at one-third, not one-half, of the distance between M and B; the former makes rather prettier geometry of the division, but the latter is so much better for composing into



The Elephant.

pose the two are quite distinct in pattern. The Chinese puzzle consists of only seven, instead of fourteen, pieces, and the only angles involved are right angles or the half of a right angle. These seven pieces can be combined in a large variety of ways to form figures of men, women, animals, buildings and domestic implements; but the figures are merely suggestions, often extremely effective, which indicate what is meant and leave details to the imagination.

The Loculus, on the other hand, produces what can be called pictures, which may be as little, or much more, like the originals as the products of modern cubist art. In each case the whole fourteen pieces are employed, this being, presumably, of the essence of the game. It happens at times that a satis-

medes are fragmentary, but for over twenty centuries mathematically inclined persons have been arranging them in the endeavor to solve the problem. By the employment of logarithms and higher mathematics answers in the billions and figures approaching astronomical distances have been obtained to Archimedes's cattle problem.

For versatility of inventions and mechanical devices, Archimedes might be termed the Leonardo da Vinci, the Benjamin Franklin or the Edison of his day. Even counting the exaggeration that goes with the telling of the history of antiquity, Archimedes's mechanical inspirations and mathematical discoveries reach an extraordinary number. Apparently he placed little store in the inventions which made for him a place in popular interest. To him they were "geometric playthings." His chief interest was mathematics, and in the contrivances that made him equally as famous as his work in the realms of pure science he had not enough pride to write about them. This was left to others, whose accounts vary to such an extent that much of the career of the old Greek mathematician is fascinatingly legendary.

In the study of physics every secondary school pupil the world over

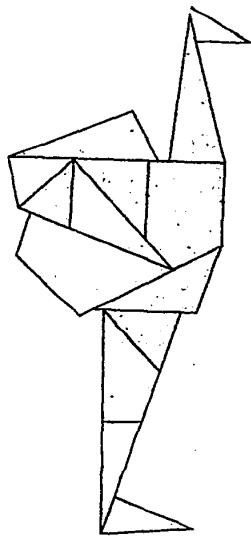
encounters the name of Archimedes in the exposition of a famous principle of hydrostatics to the effect that the loss of weight of a body immersed in any liquid equals the weight of the liquid displaced.

According to chroniclers of antiquity, Hiero, King of Syracuse, suspected that his new crown was not all gold, but that it contained considerable silver alloy. He could not prove this but thought that Archimedes might. The latter was deliberating upon the problem when he stepped into a bath and noticed the water running over. It occurred to him then that the presence or absence of an alloy in the crown could be proved by putting the crown in a vessel filled with water and observing the difference in overflow when an equal weight of gold should be put in the same vessel.

Archimedes Rushed Out

So excited was Archimedes over the discovery of this principle that he leaped from his bath, forgot his clothes and rushed through the streets to his home crying "Eureka!" The ancient accounts then neglect to inform posterity what happened to the man who adulterated the King's crown.

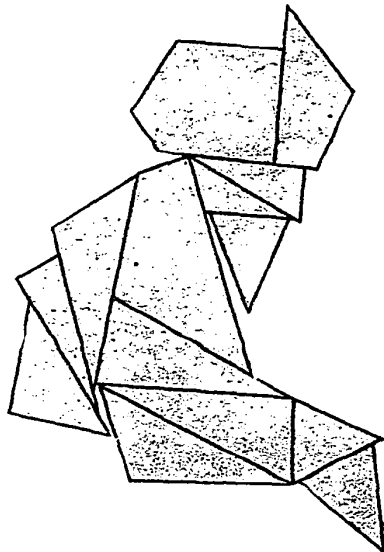
The same traditional abstraction exhibited when he ran out into the street without his clothes on exists in possibly legendary accounts of the death of Archimedes. In the fall of Syracuse, after a siege made more difficult for the Romans by defensive mechanical devices of Archimedes, Marcellus, the Roman commander, issued orders that the famous old mathematician should be spared. But during the general massacre



The Ostrich.

factory figure may be built up, with one or two pieces to spare; and then the fitting in of these superfluous pieces becomes the "thing that drives one wild."

The Loculus is not the only baffling problem Archimedes left to posterity. In an epigram addressed to mathematicians of another city the sage of Syracuse challenged them to determine the number of bulls and cows of four distinct colorings and contained in a space described by formula. The formulae of Archi-



The Pundit.

which followed the capture of Syracuse a Roman soldier came upon an old man drawing mathematical figures in the dust, and getting no answer ran him through with his sword. In the midst of his triumph Marcellus lamented Archimedes's death and decreed him an honorable burial. In accordance with Archimedes's request his tomb was marked by the figure of a sphere inscribed in a cylinder, for he regarded his discovery of the relations between the volumes of a sphere and its circumscribed cylinder as his supreme achievement.

pictures that it is to be preferred, even if the other was the original design, which is by no means certain.

Having cut out your set of pieces, you begin to try to piece them together. At first the attempt will seem to be hopeless of success—the pieces, nearly all different in shape and size, do not seem to fit together in any way. But, after a little practice, order evolves from this chaos, and one begins to admire the cleverness with which the apparently random division of the original rectangle has been in reality designed.

In any pastime of the kind, in which separate pieces are put together to form pictures—not a picture, as in the ordinary jig-saw, but new designs—invented by the player, or copied from those invented by other players, it is necessary that the angles should readily combine in as many different ways as possible, to fill in the whole circle, or to form

jected on account of any small gap introduced by this want of completeness in building up the straight line or complete circle.

A few examples, not all of my own invention, will give an idea of the great variety of results which can be produced from this set of pieces. The lateen-rigged ship gives a good example of the way in which the smaller figures can be combined to form larger triangles and rectangles, while the charging soldier is a figure full of life, which may be contrasted with the look of bored submission on the face of the patient shopper, impressed by his woman-kind to carry the parcels. The ostrich is full of dignity, and the flying goose is by no means a bad representation of the original. The barking dog is somewhat dropsical in the legs, but there can be little difficulty in recognizing the Pied Piper of Hamelin. This set of fig-