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THE ANCIENT EGYPTIAN BALANCE

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ABSTRACT

The oldest known balances are equal-armed instruments that have been found in Egypt and are represented on Egyptian drawings and reliefs. In its simplest form the beam was made of wood or stone and provided with a central boring for the balance suspension and two borings at the ends of the beam for the pan suspensions. The existence of a balance standard in the Fifth Dynasty is testified. A plummet line was hung parallel to the balance suspension so that the horizontal position of the beam could be checked by comparing the right angles formed between beam and plummet line. From the time of the Middle Kingdom the pans were suspended by four cords. In the New Kingdom tubular beams were introduced whose ends were shaped in lotus flower or papyrus form. The strings of the pans came out together from inside the beam and diverged to the sides, the lower beam ends acting as knife edges. In most cases a pointer is either missing or so short that it is hardly helpful. This type of elaborate standard balance which was also distributed in Syria, Greece and Persia, is often depicted in the Books of Death of the New Kingdom in the scene showing the "Death Tribunal" with "Weighing of the Heart".

Unclear drawings led to misinterpretations as to the design and mode of operation of these balances. By style analysis and comparison with finds exhibited in the Cairo Egyptian Museum, it was possible, however, to clarify details.

HISTORY OF THE ORIGIN

For several reasons the balance was, and still is, highly valued: weighing or balancing in its meaning as judging, estimating, levelling and equalising appears to be a fundamental mode of human thinking. The balance at first was a very important instrument for use in trade and commerce, and the development of money is based on the weight. The standardisation of weights and the administrative surveillance of balances were introduced at a very early stage. It is not astonishing that in many cultures the balance has symbolic significance and that the invention of the balance has been given a mythological background (refs. 1-3). There are reasons to backdate the invention of the

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balance to the early mesolithicum (10000 B.C.) (refs. 29,33), in connection with the settlement of nomadic tribes, the specialised production of goods and the extension of trade.

It is still disputed whether the first balance was a symmetrical-beam balance or a single-armed balance. But if primitive steelyards existed in prehistoric time, they were completely replaced in written history by the more accurate equal-armed balances which were characterised by higher sensitivity, a clearer working principle and the easier possibilities for observers' surveillance. Not until metal was used and sliding weights were invented, did steelyards conquer the market on account of their quicker operation.

The earliest finds are weights: polished stones of cubic or cylindrical shape or, highly artistic, in the form of animals or heads. The oldest weights - attributed to the Amratic era - have been found in the Nile valley and dated back as far as 9000 years. Much more popular, but hardly identifiable, are simple stones as they are still in use today.

The very first balances were made of natural organic materials: wood was used for the beam, textile cords or leather strips as hangers, and wood, leather, plait-work, etc., were used for the pans. Only very few finds have therefore been made, the earliest ones originating from Egypt. Burial rites and the climate in Egypt were extremely favourable for the conservation of many artefacts, but also the cultural and sociological situation suggests that the equal-armed balance was in fact invented in the east-mediterranian area, most probably in Egypt. The oldest balance beam, dated back to 5000 B.C., was found in a prehistoric tomb of the Amratic era in the Naquada district. It is 85 mm long, consists of reddish limestone and is provided with three holes for the cords, one in the middle and one each at the two ends. Complete balances are available from the 18th Dynasty (1550 B.C.) and later ones come from Mesopotamia, Greece, Persia, India and China. Steelyards, the invention of which is attributed to the Etruscans, appeared from about 1400 B.C. throughout the Mediterranian area; later on (400 B.C.) also bismars were found (ref. 1-35).

Independently, but doubtlessly later, balances were also developed in South America. The conquerers' reports mention scales and steelyards being used by the Incas. Balance beams from later than 500 A.D. have been found in the coastal regions of Peru (Tiahuanacu style) (refs. 27,36).

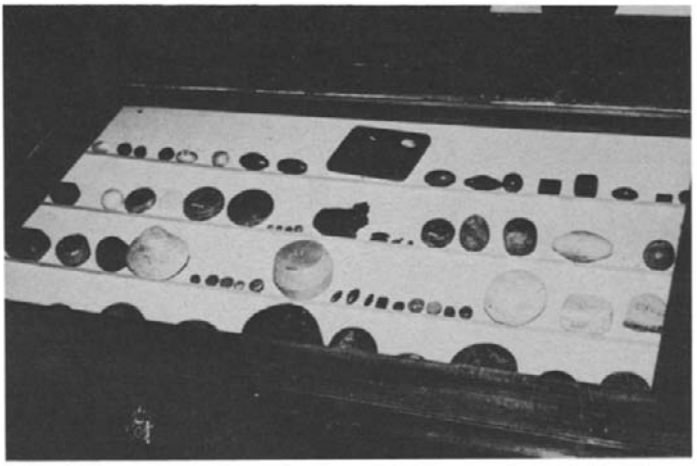
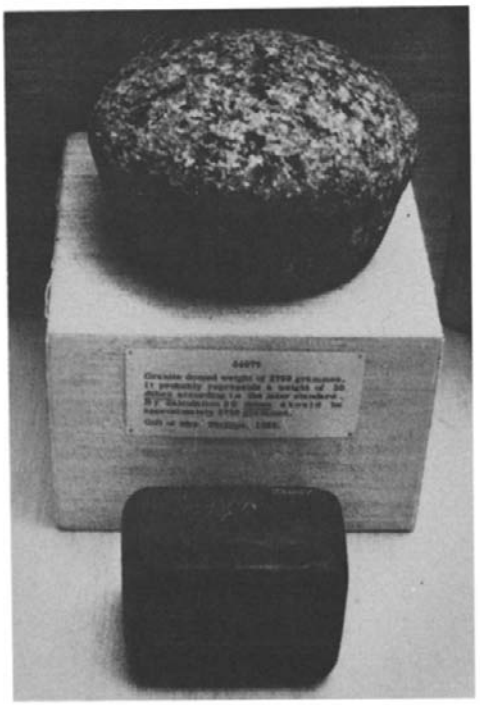


Fig. 1. Weights: polished stones of different shape.(Egyptian Museum, Cairo)



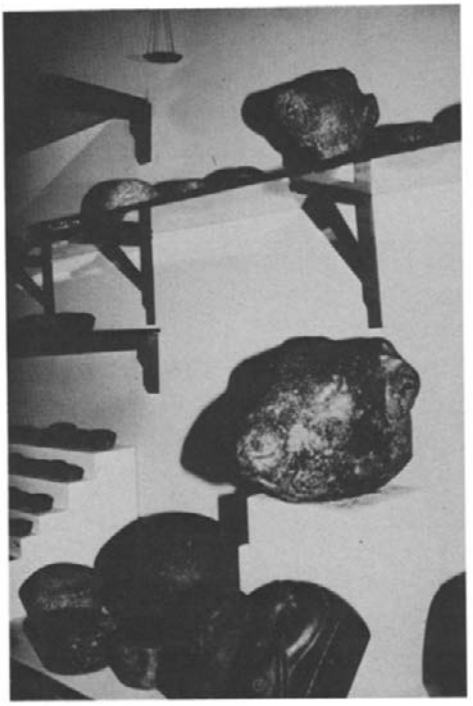


Fig. 2+3. Weights: polished stones of cubic or cylindrical shape or in the form of animals or heads.
(Egyptian Museum, Cairo) (British Museum, London)

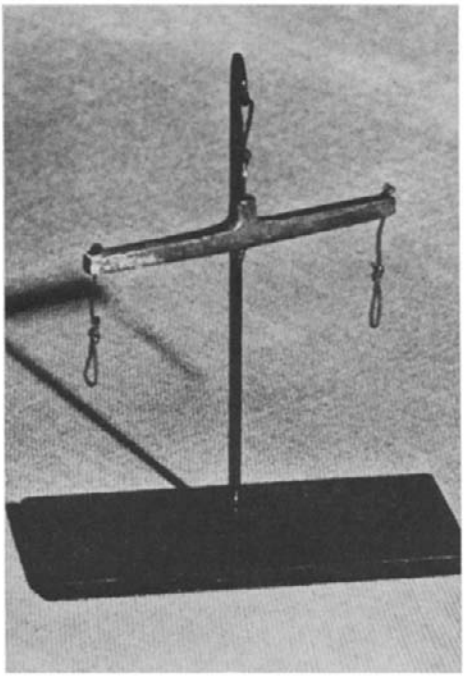


Fig. 4. Balance beam, limestone, 5000 B.C. (Science Museum, London)

Fig. 5. Hithite coin balance, 3000 BC

Fig. 6. Balance of Assurnasirpal II. (883-859), Assyria

Fig. 7. Balance of Arkesilaos of Cyrene, 550 B.C. (Bibliothèque Nationale, Paris)

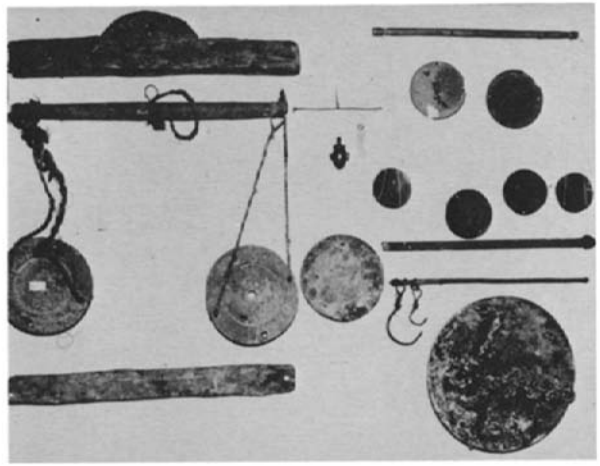


Fig. 8. Primitive Egyptian balances and steelyard (Egyptian Museum, Cairo)

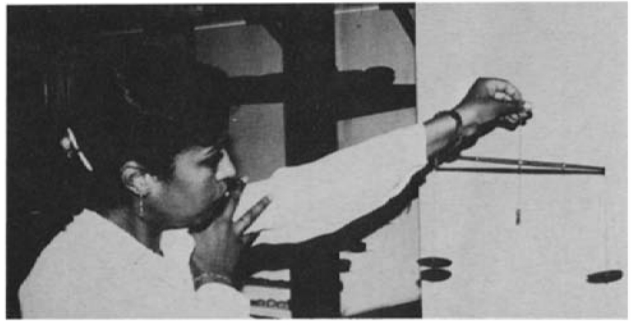


Fig. 9. Egyptian Standard balance (see Fig. 31) (Egyptian Museum, Cairo)

In various old documents, such as the Egyptian Books of Death, the Bible, and Persian, Indian, Greek and Chinese literature, we find descriptions of the weighing process, and frequent remarks on the falsification of results.

Documents on the standardisation of weights are known from Sumer (2260 B.C.) and Crete (1700 B.C.). In Egypt a general standardisation did not exist. Furthermore, we should bear in mind that weights for different materials in ancient times could well be of different mass, designating the value of the goods rather than its mass. The typical Egyptian decimal units are based on the gold deben or stater standard = 12 to 14.2 g; 1 sep = 10 deben = 100 kite. Besides, during the New Kingdom, the kedet standard (also called kite or kat) = 8 to 9.5 g existed especially for weighing metals; 1 deben = 10 kedet = 140 grains = 91 g (ref. 27,44). Furthermore, the weight systems of neighbouring countries, local units and also natural weights were used for comparing the masses of goods.

THE EGYPTIAN STANDARD BALANCE

Towards the end of the Middle Kingdom (2133 - 1680 B.C.), a special type of balance became something like a standard in Egypt and abroad for about 2000 years. The starting point of our considerations were drawings of the "Books of Death", describing ceremonies which the dead person has to practice to enter eternity (ref. 37-48). In prehistoric times and during the Old Empire (3rd to 6th Dynasty, 2780 - 2280 B.C.), immortality was reserved exclusively to the Pharaoh and a few of his intimates. When the Pharaoh's authority declined, the underworld was opened first to other persons of merit and then more and more to the general public. This process was accompanied by the promotion of the "democratic" god Osiris who became emperor of the underworld.

Detailed entrance ceremonies were codified during the New Empire (18th to 20th Dynasty, 1567 to 1085 B.C.). They included a long voyage, in the course of which the dead met with risky adventures. After this, his heart was weighed, and the dead person was examined by 42 judges headed by Osiris. The individual Book of Death, which consisted in an illustrated papyrus roll added to the sarcophagus or in wall paintings or reliefs in the tomb, may be considered a sort of "crib" for the oral examination.

The heart-weighing ceremony may be explained by the papyrus of Hunefer (20th Dynasty): The dead is introduced by the jackal-

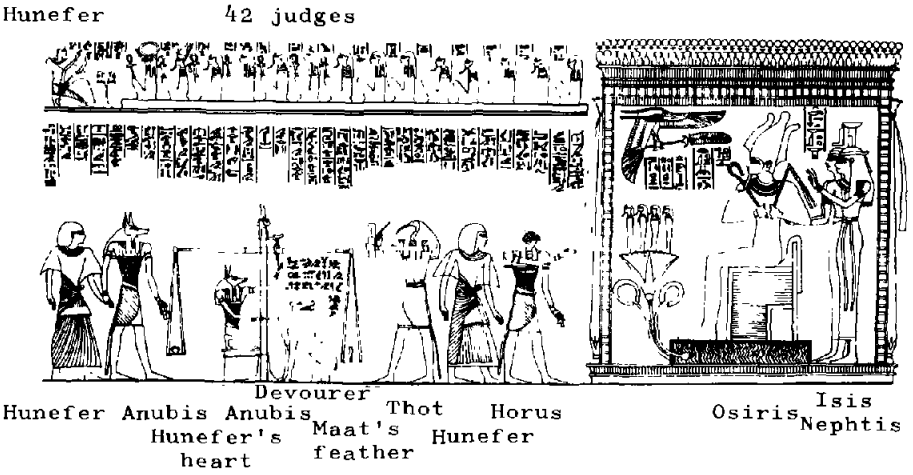


Fig. 10. Papyrus Hunefer (British Museum, London)

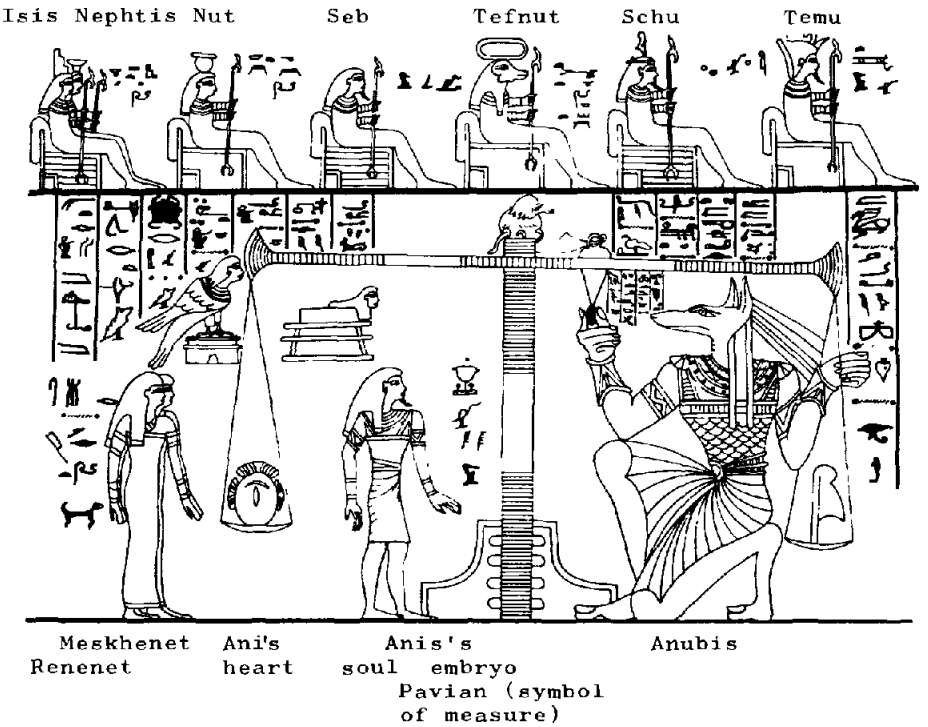


Fig. 11. Papyrus Ani (British Museum, London)

headed Anubis, the tutelary god of the embalmers. His heart is placed on one of the balance pans and weighed by Anubis against a feather, which represents Maat, the goddess of truth, justice and harmony. The ibis-headed writer-god Thot supervises the ceremony and records the result. The balance must come to equilibrium, thus showing that the life of the dead person has been in harmony with the world. If this was not the case, the Devourer sitting underneath the scales pounces upon the deceased. On top, the deceased kneels before his judges, confesses his life and speaks his prayer. After he has been judged, the falcon-headed Horus conducts him to Osiris, the emperor of the West, who is enthroned on a dais and attended by Isis and Nephtis. It should be noted that many variations of this scene exist, depending on the deceased, his profession, his position in life, his domicile, etc. The ceremony of weighing the heart, however, is always the same.

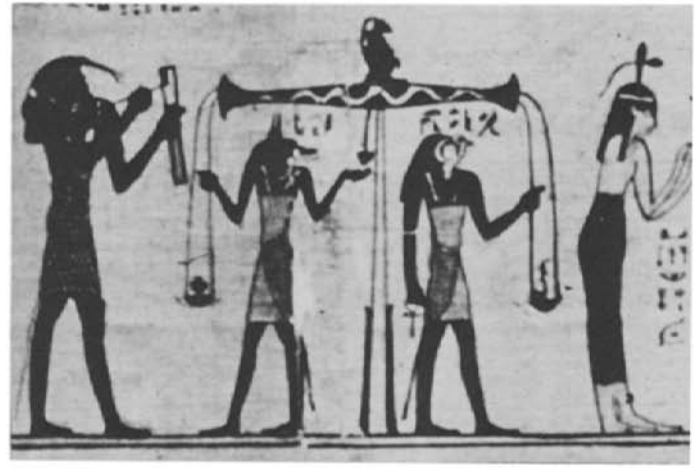
The balance is an equal-armed scale of man's height, sometimes equipped with a short pointer and always provided with a plummet. Similar balances of various size are also shown in some pictures of real life which are also found in tombs or temples as reliefs or wall paintings. This is not astonishing, because all these ceremonies were understood as belonging to reality rather than being symbolic, and as all Egyptian drawings were unterstood not as copies of things but as representations of reality. To be useful for the task in hand, the balance which is represented must be as realistic as possible in every detail.

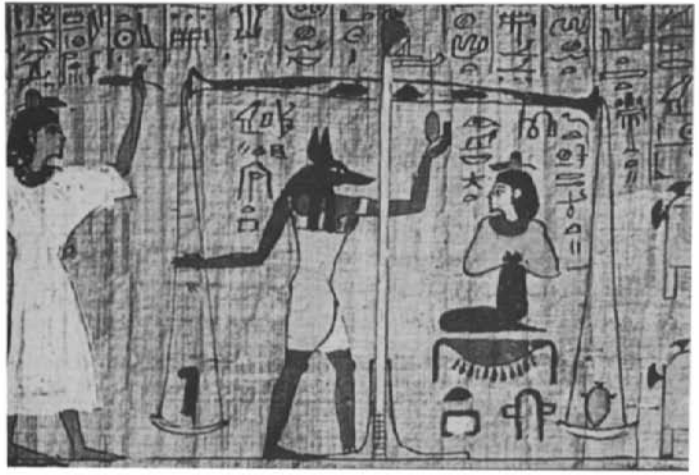
Considering this, we should expect that the paintings are clear, permitting the design of the balances to be easily deduced. This is indeed possible if it is taken into account that

- each artist makes mistakes and simplifications and judges different details to be important, and
- that the Egyptian style had other rules than the present-day style.

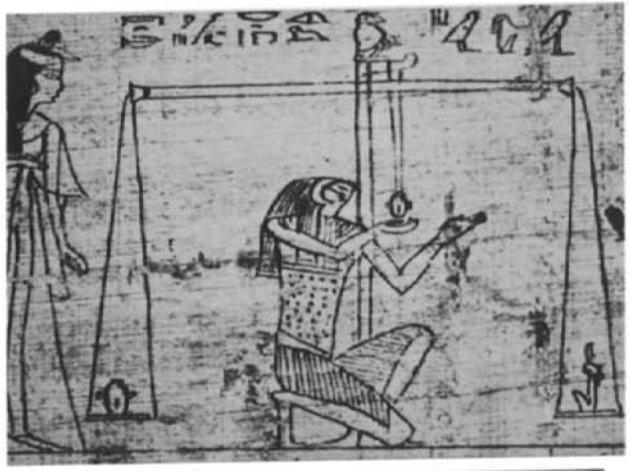
In Old-Egyptian paintings, each subject is shown as a silhouette, and possibly the shadow has been used sometimes to make a draft painting. Each part of the object, however, is shown from its most detailed side. For example, depictions of the human body always show the face in its profile, breast and arms mostly from the front, and hip and legs again from the side. This results in strangely twisted bodies.

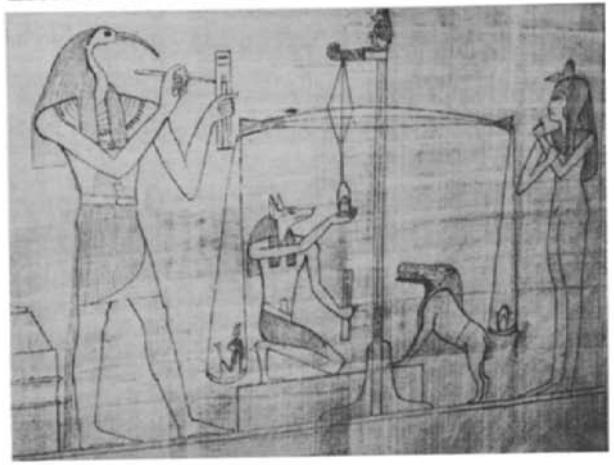
Similarly, a scale is depicted in such a way that the beam with hangers and pans is seen from the front, whereas the stand is



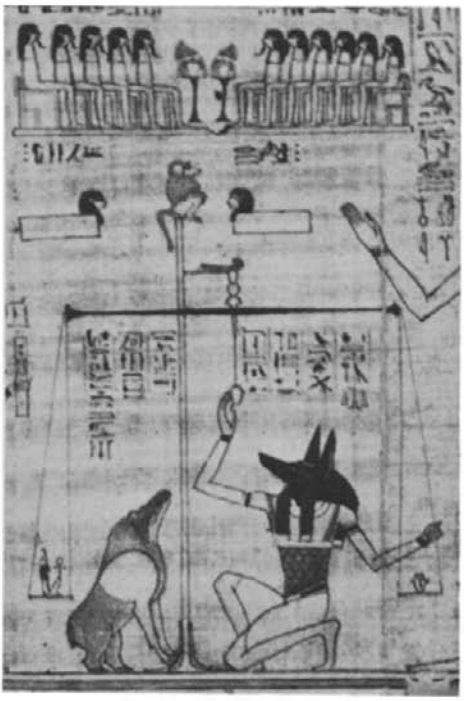


Figs. 12-15. Heart-weighing ceremony from various Books of Death





Figs. 16-19. Heart-weighing ceremony from various Books of Death



Figs. 20-23. Heart-weighing ceremony on mummies' sarcophagus (British Museum, London) and various Books of Death.

Figs. 24-27. Heart-weighing ceremony on mummies' sarcophagu (British Museum, London)

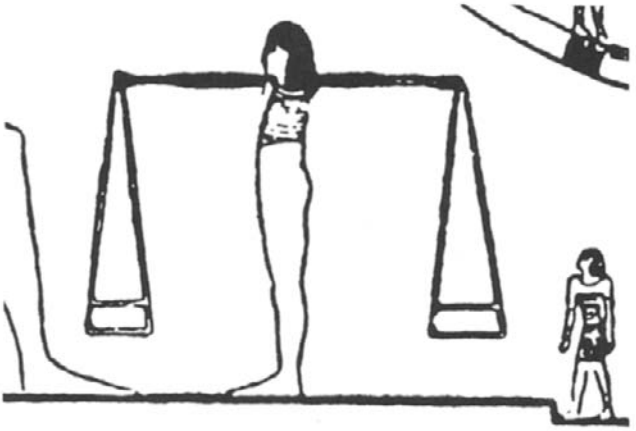


Fig. 28. Symbolic balance from a Book of Death (ref. 43).

Fig. 29. Heart-weighing ceremony. Painting on textile. (British Museum, London)

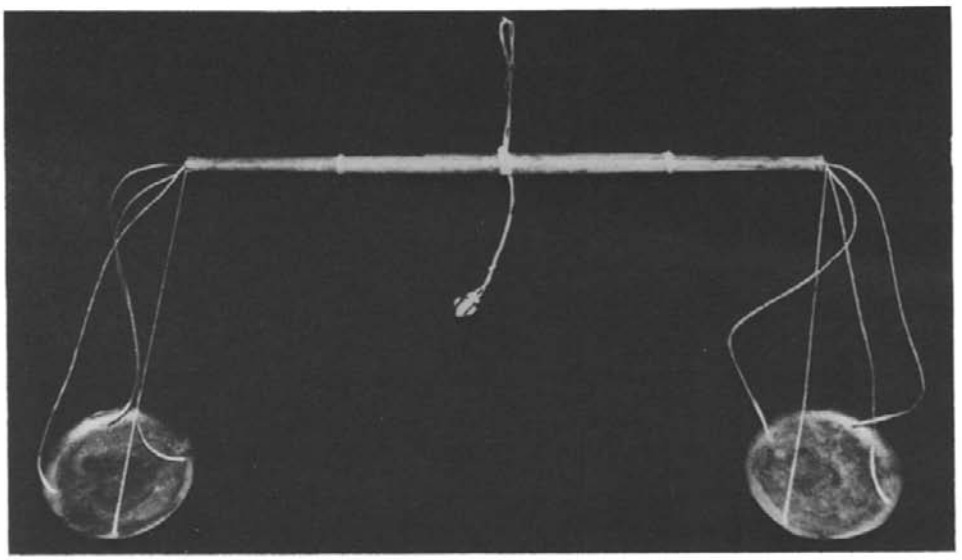
Fig. 30. Weighing of gold, tomb of Neb-amûn (ref. 38) or Rekhmara (ref. 31), Thehen-west, 1500 B.C.

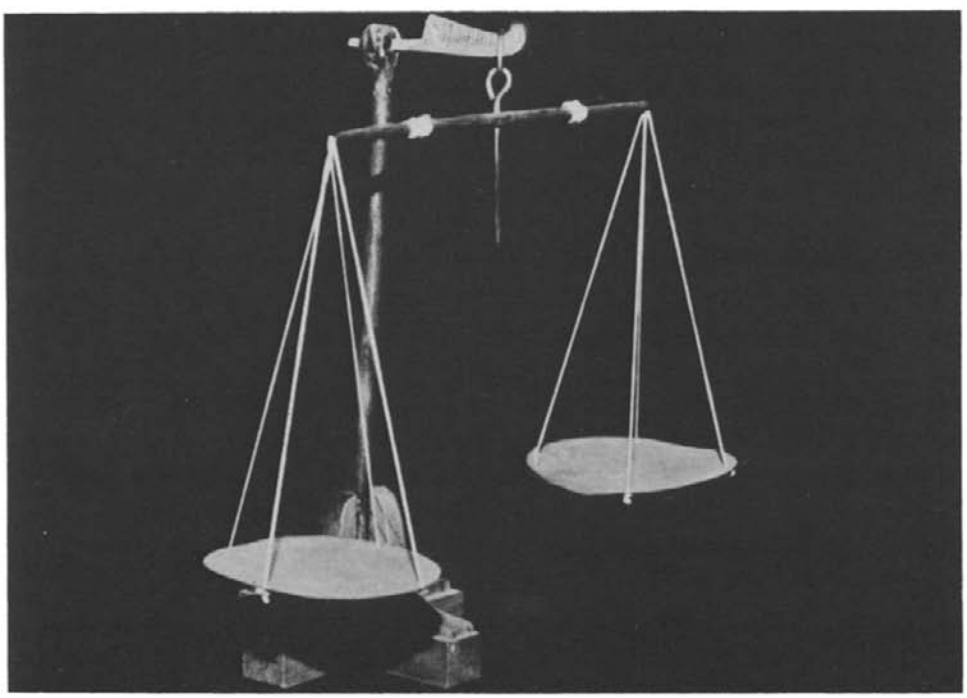
shown from the side, to show the cantilever with beam suspension and plummet. Furthermore, the operator of the balance is shown from the side. In the case of this symmetric object, however, this method implies a difficulty: because the beam suspension and the plummet are always seen beside the stand, the mid-point of the beam either coincides with the stand or with plummet and suspension Both kinds of representation exist.

Another source for understanding the balances are two small scales from the 21st Dynasty (3rd Interim, 1085 to 715 B.C.) which are exhibited in the Cairo Egyptian Museum. Disregarding the size, they are exactly similar to the balances shown in the older drawings, one without and one with a pointer.

One of them consists of a beam made of wood, 22 cm in length and about 1 cm in diameter and tapered towards the ends. The ends are enlarged and decorated by carving. In addition the ends are provided with axial borings extending about 5 cm into the beam through which run the four suspension cords. The cords are passed to the outside through borings perpendicular to the beam, wound around the beam and knotted. The cord loop for the balance suspension is passed through a third perpendicular boring at the centre of the beam, the ends wound and knotted in a similar way as above. By this design the points of application of the hangers and the pivot are well defined and the latter is situated only a few millimetres above the axis of the beam. The position of the pan was easy to adjust. We have seen, however, that in most cases the height of the two pans differed; therefore, we assume that the horizontal zero position of the beam was adjusted by varying the length of the cords. The maximum load of the balance is estimated at more than 200 g on the basis of experiments with a model instrument. A mass difference of 0.1 g was easy to observe (about 10 degrees of deflection). Thus, the ratio of maximum load to resolution amounts to about 2×10^3.

In the second balance, the cantilever, which is made of bronze in the form of the Maat's feather, is mounted on a stand in the form of an arm. The stand is fixed in four wooden corner angles, which in Egypt has been typical since the Old Kingdom. The sharp edge of the feather resembles a knife edge, but it is not used for this purpose. It carries a ring holding a hook (both made of bronze) which is pierced through the beam, and whose lower end forms a short pointer. On account of its high pivot, this balance is rather insensitive.





Figs. 31+32. Egyptian Standard balances, 3rd Interim, 1085 - 715 B.C. (Egyptian Museum, Cairo)

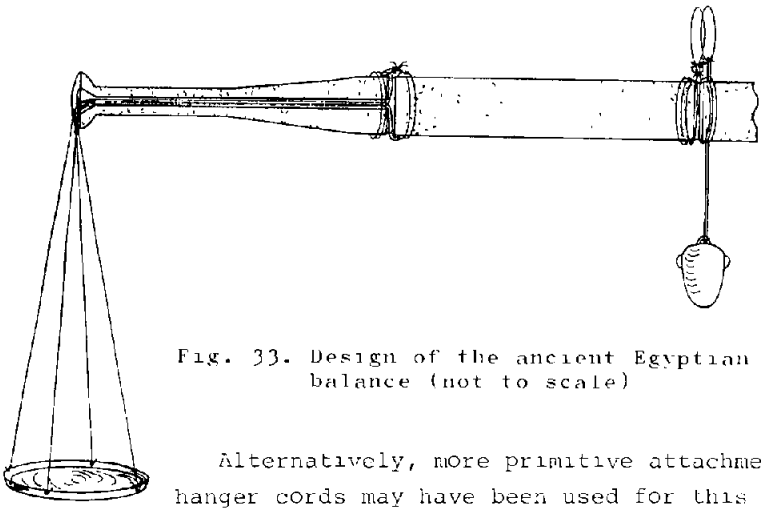


Fig. 33. Design of the ancient Egyptian standardised balance (not to scale)

Alternatively, more primitive attachments of the hanger cords may have been used for this type of balance (ref. 27). In some paintings, artistically formed chains are shown as hangers, which were fastened at holes in the lower part of the tapered ends of the beam.

In the weighing process, the balances were equilibrated. Equilibrium was observed by comparing the right angles between the beam and the plummet, which was suspended independently from the support. There is no evidence for the suggestion that the plummet was occasionally fixed to the beam by means of three threads, the tension of which was used to confirm equilibrium. Experimentally, however, we did not find any advantage of this sophisticated method over direct observation. If a pointer was attached, it was very short, giving only poor help in the observation with respect to the plummet, but it was not suitable for reading degrees of inclination. Operating such a balance is not too easy; we do not understand why the Egyptians carefully observed just the plummet, and we suspect they did not know either.

The lower limit of resolution of such balances is estimated at 0.1 g. We estimate the upper limit of the ratio of maximum load to resolution to be 10^4, and this is probably better than respective values achieved by other instruments used at that time.

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REFERENCES

1 R. Vieweg, Kulturgeschichte der Waage, Bizerba, Balingen 1966
2 R. Vieweg in: Th. Gast, E. Robens (Eds.), Progress in Vacuum Microbalance Techniques, Vol. 1, Heyden, London 1972
3 E. Robens, Thermochimica Acta 24 (1978) 205-217
4 Sokeland, Ein antiker Desemer aus Chiusi und über analoge Desemer, Z. Ethnol. 32 (1900) 327-343
5 H. Ducros, Etude sur les balances egyptiennes, Annales du Service des Antiquités de l'Egypte 9 (1908) 32-53 + 10 (1910) 240-253
6 T. Ibel, Die Waage im Altertum und Mittelalter, Diss., Erlangen, 1908
7 H.L. Roth, Oriental Steelyards and Bismars, J.Roy.Anthr.Inst. 42 (1912) 200-233
8 H.Bauerreiß, Zur Geschichte des spezifischen Gewichtes im Altertum und Mittelalter, Diss., Erlangen 1914
9 F.M. Feldhaus, Die Technik der Vorzeit, der geschichtlichen Zeit und der Naturvölker, Leipzig 1914, reprint of 2nd. ed. München 1970
10 A. Neuburger, Die Technik des Altertums, Leipzig 1919, reprint of 4th ed. Voigtländer, Leipzig 1981
11 E. Washburn (Ed.), International Critical Tables, McGraw-Hill, New York 1926
12 F. Petrie, Ancient Weights and Measures, London 1926
13 F.M. Feldhaus, Die Technik der Antike und des Mittelalters, Potsdam 1931
14 P. Welden, Maß, Zahl und Gewicht in der Vergangenheit, Stuttgart 1931
15 N.T. Belaiew, On Bismars in India, Seminarium Kondakovianum, Praha 6 (1933) 137-156
16 A. Fruhm, Die Waage im Wandel der Zeit, Kramer, Frankfurt am Main 1934
17 S.F.K. Glanville, Weights and Balances in Ancient Egypt, Proc. Roy.Inst.Gr.Brit. 29 (1935) 10-40
18 Ch. Testut, Mémento du Pesage, Paris 1946
19 A.J. Machabey, Mémoire sur l'histoire de la balance et de la balancerie, Paris 1949
20 W.C. Dampier, Geschichte der Naturwissenschaft, Humboldt, Wien 1952. German translation of: A History of Science, 4th ed., Clarendon, Cambridge 1948
21 F.M. Feldhaus, Die Maschinen im Leben der Völker, Birkhauser, Basel 1954
22 H.J. von Alberti, Maß und Gewicht, Berlin 1957
23 P. Omm, Meßkunst ordnet die Welt, Buchschlag 1958
24 L. Sanders, A Short History of Weighing, 2nd.ed., Avery, Birmingham 1960
25 S. Needham, W. Ling, K.G. Robinson (Eds.), Science and Civilisation in China, Vol. 4, Part I, University Press 1962, p.15 ff
26 U. Häussermann, Ewige Waage, Köln 1962
27 B. Kisch, Scales and Weights, A Historical Outline, Yale University Press, New Haven 1965
28 J.T. Stock, Development of the Chemical Balance, A Science Museum Survey, London 1969
29 K.E. Haeberle, 10000 Jahre Waage, Bizerba, Balingen 1966
30 F.M. Feldhaus, Kulturgeschichte der Technik, Gerstenberg 1975
31 H. Sachsse, Anthropologie der Technik, Vieweg, Braunschweig 1978

32 J. Hawkes, Bildatlas der frühen Kulturen, Bertelsmann, Gütersloh 1977, German translation of: The Atlas of Early Man, MacMillan, London 1976
33 H.R. Jenemann, Die Waage des Chemikers, DECHEMA, Frankfurt am Main 1979
34 J. Stock, Anal. Chem. 52 (1980) 1518A-1529A
35 H.R. Jenemann in: E.H.W. Giebeler and K.A. Rosenbauer (Eds.) Historia scientiae naturalis, C-I-T Verlag, Darmstadt 1983
36 M. Münzel, pers. comm.
37 A. Skira (Ed.), Ägyptische Malerei, Skira/Weber, Genf 1954
38 G. Posener (Ed.), Lexikon der Ägyptischen Kultur, Löwit, Wiesbaden 1960. German translation of: Dictionnaire de la Civilisation Egyptienne
39 C. Gravenkamp, Ewige Sphinx Ägypten, Agis, Baden-Baden 1962
40 K. Lange and M. Hirmer, Ägypten, Hirmer, München 1967
41 P. Braquet, Le livre des morts des anciens égyptiens, Paris 1967
42 G. Allen, The Book of the Dead or Going Forth by Day, Chicago, Ill. 1974
43 A. Champdor, Das Ägyptische Totenbuch, 3.ed., Knaur, München 1977. German translation of: Le livre des morts
44 T.G.H. James, An Introduction to Ancient Egypt, British Museum, London 1979
45 M. Lurker, The Gods and Symbols of Ancient Egypt, Thames and Hudson, London 1980, English translation of: Götter und Symbole der Alten, Scherz/Barth, Bern 1974
46 A.C. Carpiceci: Das alte Ägypten. Weber, Geneva 1980
47 A. Wild and H. Ragab, Papyrus - Historisches Schreibmaterial neu präsentiert, Gutenberg-Museum, Mainz 1980
48 H. Ragab, Catalogue of the Dr. Ragab Papyrus Institute, Cairo 1982