A balance – assay, analytical or bullion – must be accurate, reliable, and not too slow, and to satisfy all these requirements, various conditions, which may be contradictory, must be met.

First, the two halves of the beam must be of equal length, so the design of the beam-ends and central pivot is very important. In the ancient Egyptian red limestone balance (Fig. 3), the cords could wander about in the holes so the two halves of the beam were effectively not equal in length. In addition, the collar at the centre, which gives extra strength, would also provide a counter movement against the swing of the balance, and weighing would be jerky. The sketches, a to c, (Fig. 4)[4] show the development of beam-ends.

By about 500BCE, the classical ring and hole pivot, d, (Fig. 4) was common, as seen in small metal hand-held market scales (really small steelyards), which are still used in Asian spice markets today. This design was probably a backward step from that shown in c, (Fig. 4) as the ring could still wander around, but it did result in more all-metal balances being made.

Coinage was established in about 700BCE, and probably the first coin scales, used for checking coin weight in the 6th and 5th centuries BCE, often to detect counterfeiters, were similar to those used by goldsmiths and jewellers. Coin scales can still be found for sale in antique shops today.

There are only sparse records related to assay balance construction until the late Middle Ages, but during the Renaissance, the 14th–16th centuries, there was a huge surge in scientific discoveries as instrument making improved, trade increased, printing was invented, there was a big input from German mining ventures, and accurate weighing became increasingly important.

The first known pictorial evidence of a knife-edge as the central pivot is in a portrait of the merchant George Gisze, by Hans Holbein the Younger (1498–1543).[5] Experts who have studied the painting say that the central pivot is a pin fixed in the beam and formed into a knife-edge, though it's rather hard to see. The ends of the beam are curved over to form 'swan-neck' ends, as illustrated in g-j in Figure 4. These ends can be adjusted if necessary, to make the two half-beam lengths equal. On most assay balances, this adjustment is made by using the small screws at each beam end (Fig. 1).

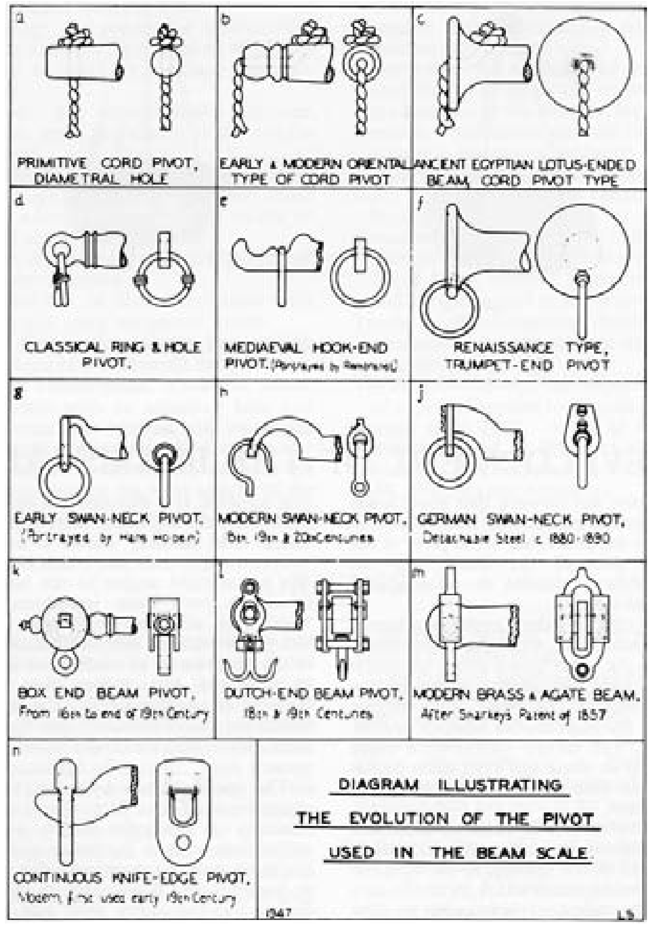

Fig. 4. Sketch of the development of balance beam ends

Figure 5 shows one of the most famous historical balances in chemistry, that used by Joseph Black (1728–1799). By the careful use of his balance in experiments on 'fixed air', which we now know is carbon dioxide, Black was the first to bring quantitative precision to chemical research, and his experiments are considered to be the beginning of modern chemical science. Note the swan-neck ends and the pointer, which indicates vertically upwards, little changed from the original Roman design. This balance could weigh to the nearest grain (one grain ~65mg/0.065g), and the central pivot is a knife-edge, though there are no knife-edges in the swan neck slots.

Later, knife-edges were developed for pan support bearings, as well as for the central support. The first were probably made of iron, but this can rust, so agate and even sapphire