Weights and Measures in Early Medieval Europe

"It is needful that weights and measures should be identical and fair throughout the realm" - Admonito Generalis, 789 AD

31 March, 2012

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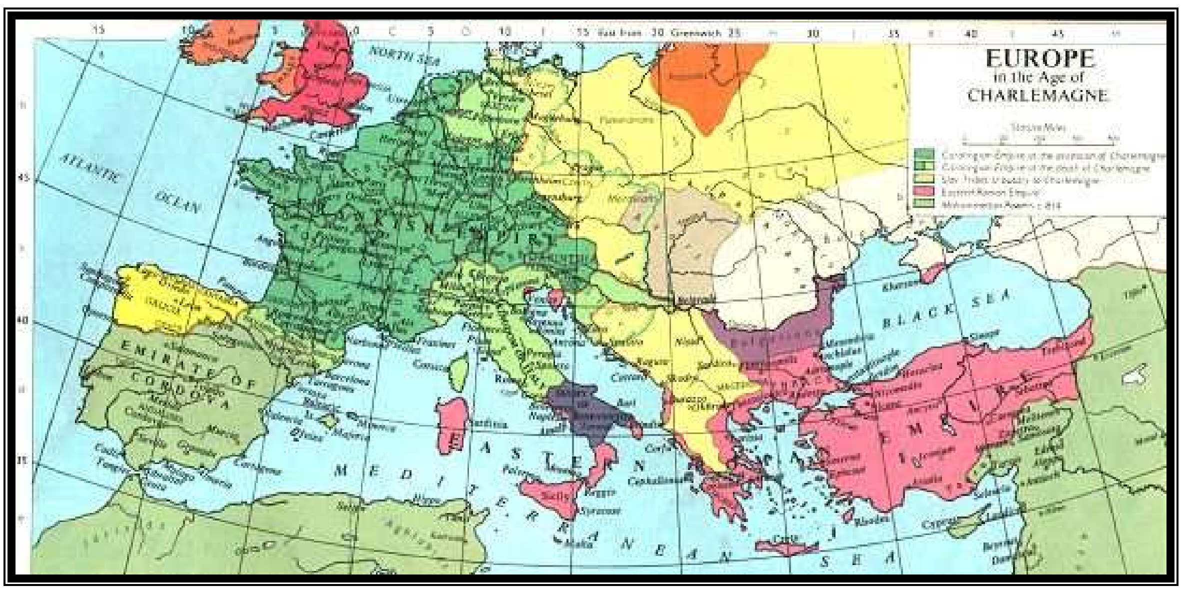
Introduction

The story of weights and measures in early Medieval Europe is a combination of two related conditions; the state of knowledge of Greek and Roman science, and the re-establishment of central authority following the collapse of the western Roman Empire. As peoples moved across Europe, they brought with them their own measures, adopted existing Roman ones, or gave up using them entirely. As central authority grew, trade grew, communications improved and means of communicating were needed. Thus, when Charlemagne complained to Offa of Mercia that the cloth he was receiving was too narrow, they needed some way of determining just what each expected of the trade deal. Similarly, as coinage became more widespread, a standard measure of a silver coin was required for consumer confidence in the new trade medium. So, not only the size and weight of the coin needed to be standardized, but the quality of the silver as well. Measurement systems grew in parallel with the need for them.

The time period we will look at runs from the 7th to the 12th centuries. Due to the written evidence available, a lot of the information comes out the 9th and 10th centuries as first Charlemagne, then Alfred the Great, make concerted efforts to document surviving Greek and Roman texts, as new information begins to trickle in from Andalusian Spain, and as economic factors drive the requirement for standardization.



Standards

I began with a quick survey of the use of terms related to measurement systems in early medieval legal codes:

Salic Law, Clovis, 466-511	Denarii, shillings
Law of the Alamans, 717-19	Measures, tremissis
Law of the Bavarians, 744-8	Measures, arpentum, bales, leagues
Æthelberht, King of Kent, 560-616	Shillings, scaetts, inches
Hlothhære and Eadric, Kings of Kent, 673-686	Shillings
Ine, King of West Saxons, 688-95	Shillings, hides, fingerbreadths
King Alfred, 871-899	Pounds, shillings, hides
Edward the Elder, 901-924	Shillings
Alfred and Guthrum	Shillings, ores, marks, hides, thrymsas
Athelstan, 924-939	Pence, shillings, pounds, feet, ells
Edmund, 942-46	Shillings
Edgar, 946-63	Shillings, pence, pound (money), pound (weight)
Aethelred, 980-1016	Marks
Canute, 1020-34	Pence, shillings, mancuses, pounds

Athelstan wrote:

> *Of moneyers.*
>
> *15. Thirdly: that there be one money over all the king's dominion, and that no man mint except within port. And if the moneyer be guilty, let the hand be struck off that wrought the offense, and, be set up on the money-smithy but if it be an accusation, and he is willing to clear himself; then let him go to the hot-iron, and clear the hand therewith with which he is charged that fraud to have wrought. And if at the ordeal he should be guilty, let the like be done as here before ordained.*

Edgar elaborated in his laws:

> *8. and one coinage shall have currency throughout all the king's realm and no one shall refuse it. And there shall be [as a standard] one measure (and one weight) as used at London and at Winchester...*

Aethelred, too, demanded punishment for counterfeiting, as well as standard weights and measures:

> *32....and the coinage shall be so improved that one coinage, free of all false issue shall have currency throughout the whole land. And weights and measures shall be made exactly right, to the exclusion in the future of all wrong ones...*

Edgar's decree that standard measures be kept at Winchester (and London) lead to the establishment of the Winchester Measure of physical artefacts to act as the standard for weights and measures. The standards themselves were relocated to London after the Conquest. A tract, possibly written by Wulfstan circ 1000, entitled *Episcopus,* deals with the duties of a bishop. Included in these is the responsibility to ensure each borough-measure (*burhgemet*) and pound-weight was true. This implies first that standards were kept in each borough, likely calibrated against the Winchester masters, and that they were kept in the church. This is perhaps borne up by a grant from Burgred of Mercia to the Bishop of Winchester (c.857) with mentions scales, weights and measures used in a port.

Similarly, in 11th century Seville, templates for bricks, beams, and other standardized building materials were kept in the mosque and used by the building inspectors.

At first, different measurements were used for completely different purposes and therefore had no correlation to each other; an ell or yard of cloth had no need to be related to a furlong of land, nor the weight of a penny to the weight of a bale of wool. These developed later and, as a necessity, the basic measurements needed to be altered to make the calculations work out. Physical artefacts as standards remained in use until modern science allowed natural universal properties to take their place; except for the kilogram which is still a lump of metal sitting in Paris. In May 2011, Canada's official kilogram was sent to Paris to be checked against the International Standard.

Weights

Coinage:
As central authority was re-established one of the key institutions created was a return to locally minted coins. Byzantine gold coins were available in the 6th century, as were the Frankish solidus and triens, but were too costly for ready use. Also, the Byzantines regularly re-minted their coins to maintain quality and since the soft gold wore easily. Those coins outside of their sphere of influence quickly wore down. In the early 7th century, south of the Seine, in Gaul, coins were in regular use possibly due to a lingering Roman influence. North of the Seine there was less acceptance of coinage, and less confidence in the quality of the metal. As the century progressed, the manufacture of coins spread rapidly in Gaul, without royal control and with a corresponding degradation in quality. Further, as continental Europe had no native sources of gold at this point, the Franks, and then the Anglo-Saxons, switched to a silver standard. The Carolingians introduced the silver denarius c. 650 with a weight of 1.13 to 1.28 grams. The size and quality remained fairly stable until the end of the 8th century.

The Carolingians instituted a number of monetary reforms; they reserved the right to mint coins themselves, foreign coins were melted down and re-made as dinarii, and they ensured consistent weight and quality. Succeeding generations increased the weight of the coins so that the c.650 denarius of 1.13g became 1.3g and then 1.7g. A basic search of Anglo-Saxon coins found a similar trend, plus the introduction of a half-penny in the 9th century.

Beorhtric of Wessex	786-802	1.33g
Ecgberht of Wessex	802-839	1.30
AEthelwulf of Wessex	839-858	1.35
AEthelberht	858-865	1.27
AEthelred	865-871	1.26
Alfred – lunette	871-899	1.0
Alfred – cross and lozenge		1.26
Alfred – two-line		1.5
Alfred – half-penny		0.7
Edward the Elder – two-line	899-924	1.6

The Carolingians also fixed the equivalent value of gold to silver based on the current market price. Thus 1 libra=20 solidi, and 1 solidi=12 denarii. This same system was adopted by the Anglo-Saxons in the 9th century with the same conversions of 20 shillings to the pound, and 12 pennies to the shilling. (Up until the modern era the shorthand for penny was 'd' from denarius). This gives 240 pennies to the pound, or, using modern weights, a penny weight of 1.9g. Perhaps this conversion drove the base weight of the penny upwards, and created the niche for the half-penny. Perhaps as the use of coins spread there was simply the need for larger denominations. Both the Anglo-Saxons and the Carolingians fought against counterfeiting and devaluation of their coinage, as can be seen in the lawcodes quoted above. The important part of this is that the ready availability of coins, and the relative stability of their weight, gave a source for small weight measurement that anyone could access. Thus, Theophilus uses pennyweights to measure his silver (c.1120).

Anglo-Saxon balances and weights have been found through-out the period under discussion. Early weights, from the 6th and 7th centuries, tended to be old Roman coins, Byzantine weights, or thin bronze discs. There is then a gap in the archaeological record, until a return of finds from the 9th century onwards. Dating lead artifacts, or even positively identifying them as balance weights is difficult. Perforated discs may be balance weights, fishing weights, or spindle whorls. Plain discs may be counters. Discs stamped with coin dies may be test pieces or possibly trade tokens. Truncated cones, pyramids, and spheres are also in the record. Assessment of Scandinavian weights and comparison to silver ingots has lead to a tentative base weight of 25-26g, but this needs more study.

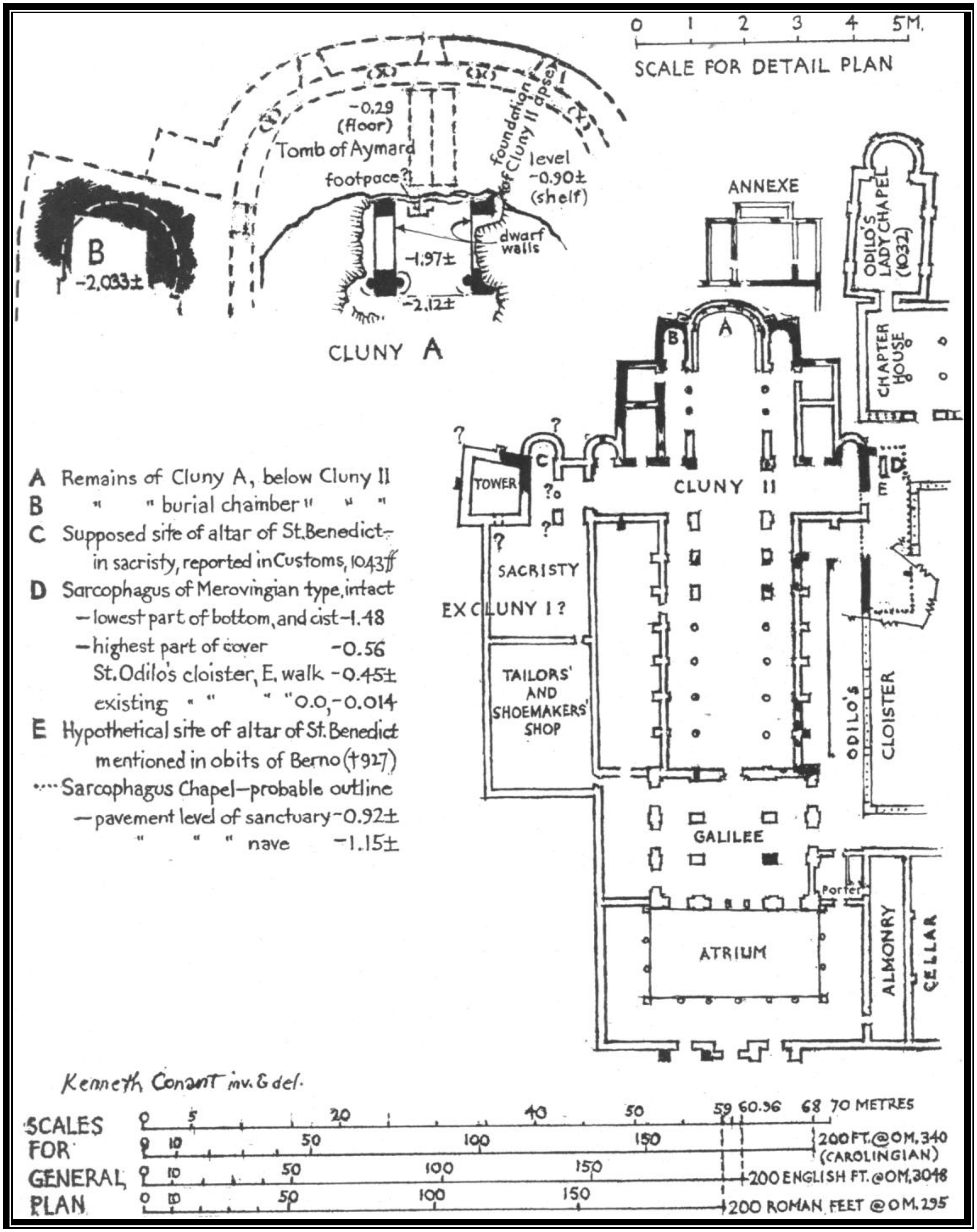
Length

The great Abbey of Cluny was built in a number of phases from c. 900 to the mid 12th century. Each phase is built using a modular system, of increasing complexity which, while fascinating to the history of mathematics, won't be discussed here. Instead what we are interested in is the measurement standard used, that is, what was a foot?

Phase	Circa.	Foot	Module
Cluny A	c. 900	Roman = 29.6cm	module of 1½ feet; walls are 1½' thick, piers are on 6' centres (i.e. module of 4)
Cluny I	915-927	Carolingian = 34.0cm	
Annex	c. 950	Carolingian = 34.0cm	
Cluny II	950-981	Carolingian = 34.0cm	Dimensions are laid out in multiples of 7
Cluny III		Roman = 29.6cm	Very complex layout
Other buildings	1049-	Roman = 29.6cm	Possibly under Italian influence

Here we see that each phase used a consistent measurement standard. The Abbey of St Gall, c. 800, was built using a Carolingian foot (34.0cm) using a module of 2½'; the main elements are squares of 16 (40' x 40') while smaller elements used 1 module (2½' x 2½') squares. In 800, Charlemagne was asked by the Patriarch of Jerusalem to provide financial assistance in repairing the buildings. Being a practical man, he sent surveyors to Jerusalem to determine the size of the buildings and the extent of the repairs required. The report they wrote gave measurements of the various buildings in "dexters" of 5 feet. Thus, if we use the Carolingian foot, a dexter is 1.7m, or using a Roman foot a dexter is 1.48m. When compared with the extant buildings these did not work out to the correct dimensions, leading some historians to question the accuracy of

Charlemagne's surveyers. However, if the Byzantine foot of 31.2cm is used, giving a dexter of 1.56m, the measurements work out to within 1% of accuracy.



Anglo-Saxon architecture also used a repeatable unit of measurement. Mathematical analysis of the ruins of Jarrow (c.680) and Yeavering (7th) gave a base unit of 28.0 and 28.1cm respectively. Interestingly, a similar analysis of Great Paxton church (1050-1100) resulted in a foot of 30.48cm, the same as the modern foot. Larger measurements, such as used in town planning, used a measurement called a perch. There is some evidence, borne up by architectural surveys, that would give a perch equal to 16.5 modern feet, or 5.03m, which is also the length of the modern rod. From the early 10th century Burghal Hideage, Winchester had a wall to be defended by 4 men to the perch, with 1 man to be supplied per hide. Winchester was assessed at 2400 hides, or 600 perches. The actual wall length is 3034m, giving a perch of 5.05m. Yeavering again comes up in the argument, as it has a nave width of 5.03m and aisles of 3.36m, or a module of 2/3 perch. (Since 28.1cm divides into 5.03m 18 times it can be used for either argument). The cathedral at Ely (late 11th century) is made to the same proportions as Yeavering, but at twice the scale, that is it has a nave 10.06m, aisles of 5.03m, and a wall thickness of 1.68m. As a comparison, a series of pit buildings were excavated at Coppergate, York. The only complete building measured 7.6m x 3.8m. If we use a 5.03m perch, the measurement would then be 1.5 perches x 0.75. That being said, buildings laid out at Fishergate and in London used a width of 5.5m. It is interesting that Isidore of Seville (c.560-636) recorded a Roman perch of 17 feet, 17 x 29.6cm = 5.03m. (It is also interesting to note that there are 3 Carolingian dexters to an Anglo-Saxon perch!)

Roman foot		29.6 cm
Carolingian foot		34.0 cm
Byzantine foot		31.2 cm
Anglo-Saxon foot		30.48 cm?
Carolingian dexter	5 feet	1.7 m
Anglo-Saxon perch	16.5 feet	5.03 m
Roman perch	17 feet	5.03 m

Lengths were referenced in agriculture as well, but here it is much harder to define partly because there are no easily datable structures and partly because local measurements varied widely and continued to do so right up to the early 19th century. The never-ending debate on the size of a hide has consumed academics for a century. Roughly speaking, a hide originally meant a family, then gradually came to mean the land the family lived on, then became a measure of a man's wealth and status. Similarly for the Frankish *mansus* (c.650) and Germanic *huba*. All of them are related to the ploughland (Latin *carrucatae*) meaning the land that could be ploughed in one year, nominally 120 acres. The acre then is the land that could be ploughed in one day, and the furlong (furrow-long) the length of the acre. In Latin, the furlong is given as *quarentina* or '40', and is presumed to mean 40 rods (perches) in length. An acre then becomes 4 x 40 perches = 160 perches^2.

Volumes

Measures of volume appear regularly in grants describing annual taxes, and in estate accounts describing the annual production and consumption of foodstuffs. Thus we have Offa of Mercia (741-96) granting 80 hides of land belonging to Westbury. The rent to the king included: 2 tuns of clear ale, 1 coomb of mild ale, 1 coomb of Welsh ale, 30 ambers of rye corn, and 4 ambers of meal. The monastery of St Germain-des-Pres produced 15000 measures of wine a year, and the Lombard monastery of St Giulia of Brécia consumed 6600 measures of grain. Measures are also used for barley-beer and bread. We also see pot of honey, bale of flax, sextarius of wine, and modium of millet. What exactly these measurements represented varied with time and place.

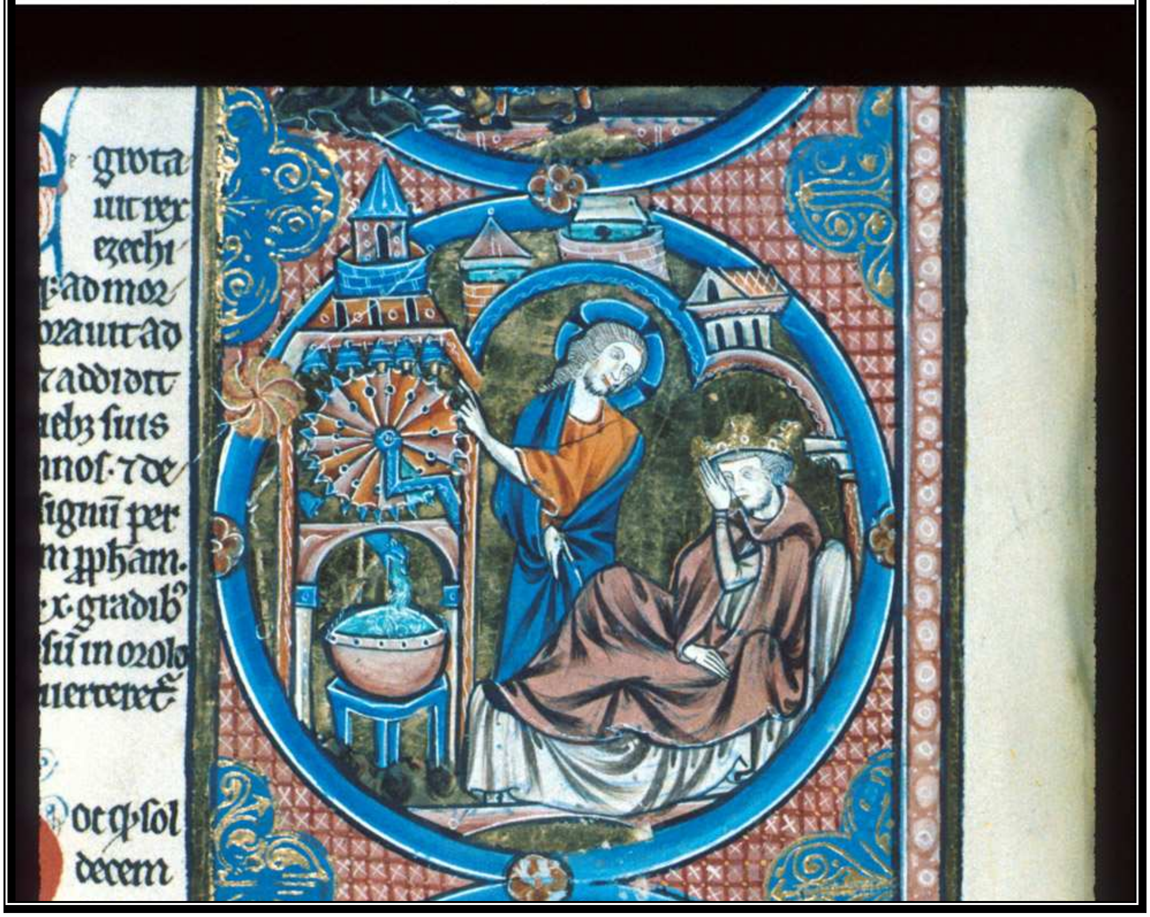
Time

Julian calendar came into effect in 46 BC to equalize the calendar with the solar year using a year of 365 ¼ days. Unfortunately, this was still off by about 11 minutes so by the time that Bede wrote his tract *On Time* c. 702, the calendar was off by several days. For Christian leaders, the problem arose when trying to determine the date of Easter as it involved correlating the lunar calendar with the solar. In 315, the Council of Nicaea declared that Easter would fall on the first Sunday after the first full moon after the spring equinox. But, with the errors in Julius' calander, the vernal equinox was shifting towards summer. Much argument ensued, and continued to do so until Pope Gregory III ordered it corrected in 1582.

The calculation of Easter, referred to as comptus, was set out by Bede in his *On Times*, and again in *On the Reckoning of Time*. Bede used a 532 year cycle to bring the lunar year into line with the solar calendar. He took this one step further by using a sundial and careful daily observation to track the equinoxes. In 730, he proved that the spring equinox didn't fall on the accepted date of 25 March (it was actually between 18-19 March). By keeping track of his sundial readings, he found that at the spring equinox of 731, the shadow fell on a slightly different line, proving that the year of 365 ¼ days was off. Dissatisfied with the results from his sundial, he then turned his attention to marking the tides and found a relationship between them and the lunar phases.

A second problem arose for medieval monks as they tried to determine when to pray. John 9:9 states there are 12 hours in the day, and thus there had to be, creating a system of unequal hours. The canonical hours – matins, prime, tierce, sext, none, vespers, and compline were divided up into these twelve divisions. The unequal hours system began to be displaced in the 1330s, possibly as mechanical clocks became more commonplace in the towns and cities.

On his creation as Emperor, Harun al Rashid the Caliph of Baghdad gave to Charlemagne a waterclock. According to accounts it ran for 12 hours, dropped balls onto cymbals to mark the hours, and had 12 little horsemen who moved back and forth on the hour. The use of water to measure time was well established in Roman times and the tradition seems to have been continued, especially in Muslim areas. In southern Spain, allocation of irrigation water supply was by time units. A tarjahãr was a metal bowl with a hole in the bottom. When the sluice gate was opened, the bowl was placed in a pond of still water. When the bowl sank, the gate was closed. Eighteen different water clocks were described by al-Murãdĩ in a treatise composed in Andalusia in the 11th century. The clepsydra is a dish with a hole in the bottom; it was filled with the amount of water that would discharge in the 15 hours of sunlight seen in Cordoba at the summer solstice. Since that was the longest day, all the other days could be scaled to match. The Benedictine monastery of Santa Maria de Ripoll is credited with the earliest known European water clock (c.mid 10th-11th); the description is incomplete but there was a complicated mechanism using cams that used the weight of the water to release weights, striking bells to ring the hours – a strikingly similar concept to the one reputedly given to Charlemagne a century or so earlier. A later illumination shows a similar system:



MS. Bodl. 270b, fol. 183v (detail) © Bodleian Library, University of Oxford

Santa Maria, being located at the base of the Pyrenees, likely benefited from it's proximity to the caliphate of Cordoba. Cordoba reached it's height in the 10^{th} century, just as the power of the Carolingians was waning. They established schools of mathematics and astronomy in the second half of the 10^{th} century. Santa Maria itself created a series of treatises on astrolabes, other astronomical instruments, geometry, and obviously, water-clocks. Isidore of Seville wrote about timekeeping and the calendar. Other texts in monasteries included the use of sundials and the nocturnal, a similar device used to determine the time at night by observing the stars around the north celestial pole.

A number of sundials have survived from Anglo-Saxon times on the exterior of churches. A fascinating small pocket sundial was also found at Canterbury.

St Andrew Bishopstone, c. 950

St Michael and All Angles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Music

The music of this period, dominated by Gregorian chants, used the flow of the words to dictate the structure of the musical line. That is, there was no metre. By the end of the first millennium, the repertoire for a musician to achieve mastery was so extensive his apprenticeship took a decade. Musical notation took its first form in this time period, but the problem of pitch remained. The invention of the staff is attributed to the Benedictine choirmaster Guido of Arezzo. He noticed that the notes he required were all contained in the phrases of a hymn to John the Baptist:

Ut *queant laxis* ***Re****sonare fibris*
Mi*ra gestorum* ***Fa****muli tuorum*
Sol*ve pollute* ***La****bii reatum*
S*ante* ***I****ohannes.*

Some time later Ut was replaced with Do, leaving us with the familiar:
Do Re Mi Fa Sol La Si (Do)

By using a standard hymn, Guido was able to shorten the time to produce a properly trained singer by years.

Theophilus, in his manual *On Divers Arts*, describes the process to make bells and pipes for organs. He refers to tables, likely based on Pythagorean theory, to determine the size of bell for a desired pitch. What is interesting is that he doesn't provide the table, he simply says:

> *When you are going to make the small bells, first get a table and make the moulds according to it's directions.*

He assumes that such tables are readily accessible to the reader, a telling comment in itself.

Conclusion

There is a tremendous amount of variability in the use of weights and measures prior to the technological revolution of the 13th century, but to assume that there was no standardization does a great disservice to the peoples who struggled to restore the achievements of their Roman predecessors. They understood the importance of establishing reliable and repeatable measurements, and found innovative ways of achieving their ends. They formed a solid foundation for the gothic renaissance, and should receive all due credit for that.

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