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By Guido Majno and Isabelle Joris

The knowledge, wisdom and intellectual elegance of Dr. Jean Starobinski have been for many years, to the authors, a model of the highest standards. This modest work is dedicated to him, on the occasion of his sixty-fifth birthday, as a token of deep gratitude, admiration and friendship.

A fair evaluation of Arabic [1] medicine and surgery is not yet possible, because so many of the texts are still in manuscript form, and not a single one of the great treatises has been critically analyzed, let alone translated in full [2, 3]. Whoever attempts to pass any judgement over the Arabic medical art must be aware of this severe limitation. It is therefore dangerous to ask the blunt question: *what was new* in Arabic medicine?

At the conceptual and social level, there is no question that the influence of Arabic medicine swept the Mediterrean basin truly as a new wind. Its basic values—the praise of knowledge, the respect for teachers, the emphasis on scholarly work emanating from the highest ruling authorities—would be welcome today. In the words of A. A. Khairallah [4]: "The Arabs' lasting contributions were the dignity and clarity they gave to medicine, the separation of surgery as a special and honorable branch of medicine, the founding and development of pharmacy and pharmacopeas, the establishment of [public] hospitals, the extension of humane care to all classes, especially the poor and mentally unfit, the high standard of public health placed at the disposal of the common man, and above all the attempt to separate science from religion ...".

This being said, it is also true that—from the Arabic texts available—it is difficult to extricate medical procedures that may be called new, i.e. not found in Greek or Indian sources.

In surgery, it is often said that Arabic physicians invented reabsorbable sutures (catgut). This is only partially true, and in a roundabout way. Rhazes (died A.D. 923) is said to have introduced sutures made of gut [5] (others say lute-strings, which would still be made of gut; Rhazes had been a musician). Albucasis (died A.D. 1013) mentions several types of suture, namely silk, linen, "gut, well scraped" and lute strings [6], but his rationale for

choosing lute strings is quite the opposite of what we might expect. He explains that silk and lute strings have the advantage of being *more resistant* to "corruption", i. e. to the digestive effect of pus in an infected wound. Eight centuries later, when thin threads of catgut began to be used in sterile surgery, they turned out to be reabsorbable: thus catgut was eventually retained for a reason that would have condemned it in Antiquity. The seton was almost certainly an Arabic invention[7] (with roots in a Hippocratic procedure, the treatment of anal fistulae with a string[8]); it lasted a full millennium, but it can scarcely be considered progress. As regards medicine, whenever we take a sweet tasting cough medicine we may have to thank the ancient Arabs: for they introduced sugar from India, and professionalized the concept of hiding foul-tasting medicine in syrups (but surely mothers all over the world had long used a spoonful of honey for the same purpose).

The one major technique that Western medicine definitely inherited from the Arabic world is the plaster cast for fractures, which spread to Europe (from southern Persia) long after the rise and fall of classic Arabic medicine.

The history of the plaster cast has been told several times[9]: the purpose of this short paper is to examine more closely two of its phases: the original document from 1795 which conveyed the news to the Western world[10]; and the earlier Arabic fracture dressings that led to the plaster cast.

The letter from Persia

Shortly before 1795 William Eton, the former British consul at Bassora (at the southern tip of Mesopotamia, now Iraq) wrote to his friend Matthew Guthrie who was professor at St. Petersburg; Dr. Guthrie sent the letter with a few comments to Philadelphia, where it was published in the Medical Commentaries[10]; the text is reproduced below.

Account of the Arabian Mode of Curing Fractured Limbs Communicated to Dr. Guthrie of Petersburgh by Mr. Eaton, formerly Consul at Bassora

"Having often seen much mischief occasioned by tight bandages, I am astonished the able surgeons of Europe have never discovered a better method of reducing fractured limbs than that at present in use; more

especially as I observed amongst the Arabs one infinitely superior (in my opinion) in every point of view, and accompanied with every possible advantage and conveniency, whether to the patient or surgeon.

However, to enable others to judge of it, I shall here relate a case, where I attended the reduction of the fracture, and saw the cure completed, although of that desperate kind which would scarce have been attempted in Europe without amputation.

An Arab, one of my soldiers at Bendernck [a] on the Gulf of Persia, having had his leg and foot fractured, and almost crushed to pieces, by the falling of a field-piece from its carriage upon him, which forced the ends of the bones through the skin, our European surgeon proposed immediate amputation above the knee as the only means of saving his life, and prognosticated the death of the patient, from his obstinacy in refusing to submit to the operation. The Orientals in general, particularly the inhabitants of those parts, will never consent to have a limb cut off; so that the people of the country overtook his cure in their own way, which succeeded beyond expectation, and which it is the intention of this letter to describe.

Arabian Mode of Treatment

After having transported the wounded soldier into an aiwan (or open recess, arched above), and placed him on the floor, his legs lying on an *oiled mat*, they reduced the bones and shattered parts into as good a form as they could, to be inclosed in a case of gypsum or Paris plaster; an operation they perform much in the same way as is practiced by statuaries to take a cast of a limb, with some little variation to serve particular purposes in the cure, which is to be effected in a light case of this matter, to keep the parts in a proper position, and defend the wounds from insects, air, and external injury.

To accomplish this purpose, then, they first poured the Paris plaster under his leg, till it rose to such a height as to touch its whole lower surface and part of the thigh, filling up all inequalities, so as to form a sort of bed for the wounded leg to repose equally upon in all its parts; placing at the same time a few pieces of hollow reed at proper distances, and in such position, as to serve to conduct away through the plaster any fluid that might collect in the gypsum case, from the wounds, &c.

When this plaster cushion was become firm, which it does in a very short time, the whole leg was next covered with the same Paris plaster, so as to inclose it completely, and, on hardening, to form a light case or plaster boot,

to keep the parts in as natural a position as the shattered state of the leg would admit of, leaving small openings opposite to the projecting pieces of bone, to admit of their exfoliation.

They next made a sort of furrow or channel in the soft plaster, on the upper surface, the whole length of the shin bone, and directly over it, to receive such vulnerary fluids, during the treatment, as they think conducive to the cure, and which filter through the plaster or gypsum, to humect the leg at pleasure.

Lastly, to render this upper shell or covering more easily removed and changed during the cure, if necessary, to examine the state of the parts, &c, they make deep incisions into the soft plaster, both lengthways and across, though not quite through to the leg; by means of which, the upper case is removed without disarranging the limb, whilst the cushion or plaster bed on which the leg reposes, is seldom either changed or touched during the whole process, although the *oiled mat under all* prevents the adhesion of the gypsum to the floor, and makes transporting the whole boot or plaster case practicable, should such a measure at any time be found expedient.

By this simple and curious Arabian practice, the soldier was perfectly cured. As to the duration of the treatment, the accident happened in May, and on the Colonel's return from a second expedition in September, he found the patient walking about, and enjoying the use of his leg, in spite of considerable deformity, the natural result of so terrible and complicated a fracture, where both the bones of the leg and foot were broken and splintered in a very uncommon manner, with several sharp pieces of them projecting through the muscles and skin.

The fluid employed was an ardent spirit drawn from dates, a species of arrac [b] made in that country, poured into the through or furrow over the shin bone from time to time, so as to filter through and keep the leg always moist, till the wounds were cured.

The writer thinks, that an improvement on the Arabian plaster-of-Paris case would be, to make it with a moveable cover, or upper case, joined at pleasure to the lower [c] by means of holes in the edges of both, in the manner casts are taken; which would enable the operator to examine the state of the parts when he pleased, without breaking to pieces the cover every time he removed it, as is the practice of the Arabians, although they seldom touch the limb, till it be cured except to pour on the spirit of dates.

I must remark [d], upon the curious communication of my ingenious friend, that the Arabians seem not to be unacquainted with the excellent effects of

ardent spirits on wounds, a discovery the Europeans thought they possessed exclusively, and have long been drawing great profits from, under the name of *Aquebusade Water*, l'Eau de Colonne[e], Baume de Riga, &c.; which are all nothing but spirit of wine disguised by some additional ingredient, which contributes nothing to its virtues, as I have found by using the spirit of wine with great success for many years past, without any admixture, in all cases of fresh wounds; and which generally cures without suppuration, where there is no considerable loss of substance."

Notes

a We interpret *Bendernck* as a misreading of *Benderuck* from a handwriten letter: presumably it refers to Bandar-e Rig, on the northern (Persian) coast of the Gulf (bandar is Arabic for city).

b *Arrack* is a generic name applied to spirituous liquors distilled in the Far East. The name is of uncertain origin (Arabic or Indian).

c This modification of the plaster cast was already used in France by 1816[11].

d These last few lines are comments by Dr. Guthrie.

e Presumably Eau de Cologne.

Mr. Eton referred to this episode also in his *Survey of the Turkish Empire*[12] (referred to hereafter as STE) where he adds a few more details:

"I saw in the eastern parts of the empire, a method of setting bones practiced, which appears to me worthy of the attention of surgeons in Europe. It is by inclosing the broken limb, after the bones are put in their places, in a case of plaster of Paris (gypsum) which takes exactly the form of the limb, without any pressure, and in a few minutes the mass is solid and strong. If it be a compound fracture, the wounded part out of which an exfoliated bone is to come, may be left uncovered, without any injury to the strength of the plaster encasement. This substance may be easily cut with a knife, and removed, and replaced with another. If, when the swelling subsides the cavity is too large for the limb, a hole or holes being left, liquid gypsum plaster may be poured in, which will perfectly fill up the void, and exactly fit the limb. A hole may be made at first by placing an oiled cork or bit of wood against any part where it is required, and when the plaster is set, it is to be removed. There is nothing in gypsum injurious, if it be free from lime; it will soon become very dry and light, and the limb may be bathed with spirits, which will penetrate through the covering. Spirits may be used instead of water, or mixed with it (or vinegar) at the first making of the plaster.

I saw a case of a most terrible compound fracture of the leg and thigh, by the fall of a cannon, cured in this manner. The person was seated on the ground, and the plaster case extended from below his heel to the upper part of his thigh, whence a bandage, fastened into the plaster, went round his body. He reclined back when he slept, as he could not lie down. During the cure, where they saw matter or moisture appear through the plaster coating, they cut a hole with a knife to dress the wound, or let out the matter more freely".

The plaster cast described by William Eton

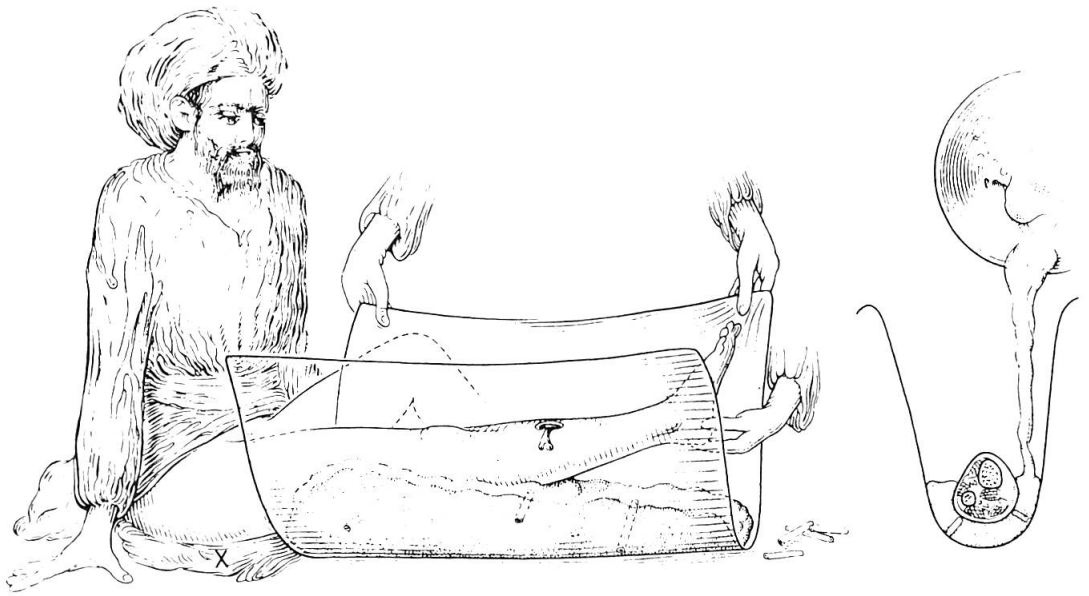
In attempting to reconstruct—pictorially—the plaster cast from W. Eton's letter, we found that the text was not free of ambiguities. The artistic result is a compromise (Fig. 1).

Figure 1 (top) shows the pouring of the bottom part with the help of an oiled cloth. The cross section at the right shows how the plaster is poured until it covers the lower half of the limb. This section of the cast is then allowed to set, and in the meantime short pieces of hollow reeds are placed where it is anticipated that an outflow will be required (in STE, instead of reeds Mr. Eton mentions *oiled corks or bits of wood,* to be pulled out after the hardening of the cast). At the proximal end of the cast, on both sides, one end of a bandage is embedded in the plaster (STE); the other end, at this stage, is allowed to hang loosely, as shown (X).

Figure 1 (center) shows the cast after the upper half has been poured. The cast is said to be "easily cut with a knife" (STE), presumably while still wet; we understand that at this point the upper and lower halves were almost, but not completely, separated by deep horizontal cuts, so that the upper half could snap off as a lid if later required (the horizontal cuts are better seen in the cross section at right). Later, on the lid itself, more "deep incisions ... lengthways and across" were made; they are not shown in the figure. Their purpose, apparently, was to make it easier to break off a small piece of the lid without destoying it entirely. The bandages affixed to the cast are now tied around the waist.

Just above the fracture a longitudinal trough was carved, so that "vulnerary fluids" could be poured onto the leg, which they reached by filtering through the remaining thin roof of plaster (Figure 1, bottom). However, at the bottom of the trough, we also indicated an actual opening, because Mr. Eton later explained (STE) that "during the cure ... they cut a hole with a knife to dress the wound or to let the matter out more freely".

Figure 1. An artist's rendition of the plaster cast described by W. Eton in 1795. Not represented are the incisions made in the top of the cast (so that pieces could be broken off more easily at a later time, if required for inspecting the limb). The completed cast was attached to the waist of the patient by bandages (X) fixed to the plaster. It seems that the patient sat in this position until healed.
Further explanations in the text.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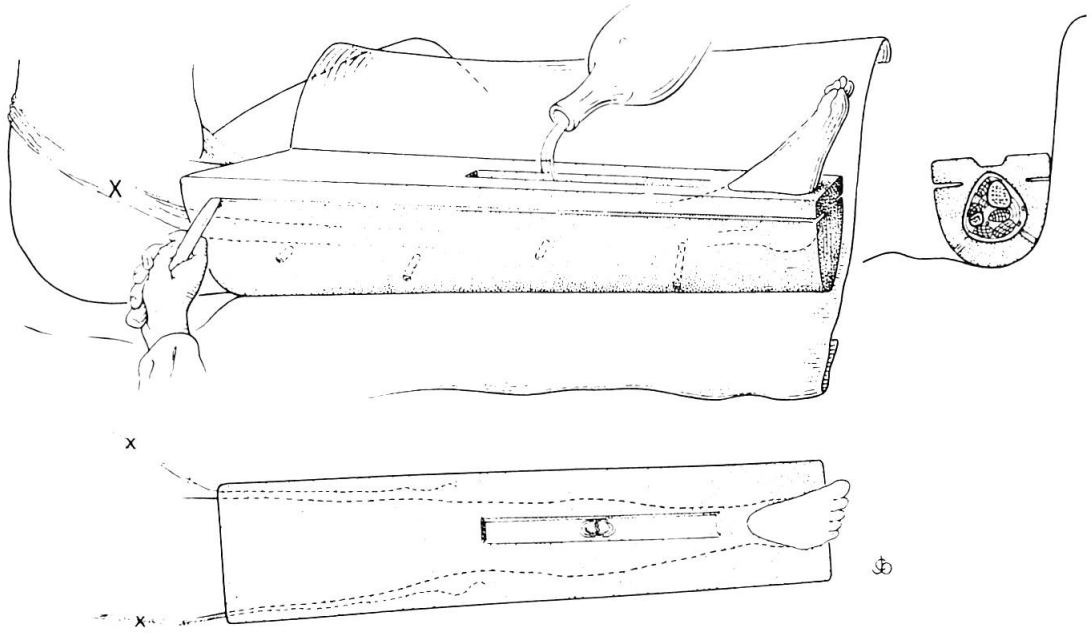
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The oiled mat, specifies Mr. Eton, served the laudable purpose of preventing the patient from becoming one with the floor; it could also serve for transporting the patient "if expedient"; but in SAT we learn that the patient may not have moved from the place where the plaster cast was made. The weight of the apparatus must have been forbidding (although Mr. Eton, a military man, refers to it twice as a "light case"). Surely there was no question of walking with it; indeed, the patient was bound to it in such a way (with a strap around his waist) that he could not even lie down to sleep (STE).

In terms of modern medicine this plaster cast represents a great improvement over the old, unstable dressings with splints; besides immobilizing the fractured stumps, it introduced the modern principle of immobilizing the adjacent articulations; the "vulnerary fluids" chosen for dressing (distilled alcoholic solutions, vinegar) were certainly painful but truly antiseptic. The recovery of the patient speaks for itself. Note also the contrast with the treatment offered by the European surgeons: amputation.

This was the state of the art, it seems, in southern Persia by the late 1700's. What were the precedents?

The road to the plaster cast

The need to immobilize and support a fractured limb by means of splints would seem almost instinctive, thus it comes as no real surprise to find splints on Egyptian mummies dating from about 2450 B.C.[13]. It might seem that the conceptual leap from the splint to the cast should not be a great one, and that any potter with a broken leg might have thought of it[14]; yet the idea developed very slowly. Materials for making a cast were currently available in Antiquity, namely clay, gypsum and lime, alone or in combination.

It may be appropriate to summarize their nature. (1) *Clay* consists of very fine grains of silicates usually mixed with some sand, iron salts, and a number of lesser components. It could have been applied wet and simply allowed to dry, as was done in nineteenth century India (14); (2) *Gypsum*, a hemihydrate of calcium sulphate ($CaSO_4 \cdot 1/2\ H_2O$) is a powder obtained by heating, i.e. calcinating, natural gypsum ($CaSO_4 \cdot H_2O$) (two varieties of natural gypsum are common chalk and alabaster). When the powdery calcinated gypsum (the hemihydrate) is mixed with water and allowed to dry, it quickly sets again as the solid form (hydrate). Plaster of Paris is simply a special brand of calcinated gypsum: it was quarried at *Montmartre* and ground at the *Moulin Rouge*[15]. (3) *Lime* (a basic component of cement) is also called quicklime, unslaked lime, or calx: chemically it is calcium oxide, CaO, obtained by heating (calcinating) natural carbonates such as marble ($CaCO_3 \rightarrow CaO + CO_2$). When slaked, i.e. mixed with water, CaO swells, generates heat and becomes $Ca(OH)_2$; the latter, upon drying, combines

again with atmospheric carbon dioxide and slowly hardens. Lime alone cannot be used for binding purposes, because it shrinks upon drying; however, when mixed with a sand or similar materials, it forms a paste called *mortar* which has excellent binding qualities. (The term *cement*, strictly speaking, should be reserved for Portland cement, a 19th century invention: it is prepared by heating a mixture of calcareous and argillaceous materials to vitrifying temperatures and then grinding the resulting "clinker").

For the purposes of the present paper, the main point is to distinguish between gypsum (the constituent of modern plaster casts) and lime (which belongs to the family of mortar and cement).

The terms *plaster* and *stucco* refer to basically similar materials, made primarily of gypsum mixed with lime, clay, binding additives such as hair, and other components in various combinations. The art of finishing walls with plaster was highly refined in the golden age of Greece, but plasters were used much earlier in parts of the Egyptian Pyramids. In the first century A. D., Pliny the Elder explains at length how plasters should be made[16].

Despite all this there is no record of a fractured limb treated with a molded cast of any kind in classical Antiquity. We can attempt to rationalize. In the first place, it is not immediately apparent that rough building materials can be compatible with human flesh (would we not shudder at the thought of having a leg enclosed in cement?). Furthermore, quicklime is a dangereous caustic, and gypsum—although basically innocuous—was thougt to be poisonous: Pliny mentions gypsum together with hemlock and quicksilver, suggesting ass's milk as an antidote[17]. He even mentions a case of suicide with gypsum[18]. Paulus Aegineta (about 640 A. D.) shared these beliefs, and Francis Adams, who edited the text of Paul of Aegina in 1846, reminds his readers that gypsum was currently used as a poison for rats and mice[19]: quite a deterrent against its medical or surgical application. (Mr. Eton must have had this traditional notion in mind when he wrote in STE: "*There is nothing about gypsum injurious*, if it be free from lime".)

According to the historical review by Malgaigne in 1841[9], the plaster cast is first mentioned by Rhazes in the *Continens* (Al Hawy). Malgaigne states that (according to the Continens) a certain Abugerig or Albugerig, "whose name would have perished were it not for Rhazes", treats fractures successfully with plasters of gum arabic. Albugerig (Malgaigne continues) also recommended bitumen, a mixture of pounded salt and rice ("still used by the people of the Hindustan, it is said") as well as *calx extincta et gypsum mortificatum:* slaked lime and calcinated gypsum. Always according to Malgaigne, a certain Arthuriscus then "modified these first inventions"; he

prepared lime by *cooking* [sic] certain shells, and made a paste by mixing it with the mucus of the same shells. "The result was admirable", but his best method was based on a mixture of lime and eggwhite. No precise reference is given by Malgaigne as to book or chapter.

We undertook the task of checking these quotations in the huge 1486 Brescia *editio princeps* of the Continens in Latin [20]; the largest and heaviest incunable on record [21], as thick as three volumes of an average encyclopedia and tightly printed in two columns. In Book XV, Cap. 2, we were fortunate to find a key passage, which confirms many—but not all—the statements of Malgaigne. Because the Continens is not easily obtainable, let alone perused, we reproduce the passage in full (Figure 2).

Abugerig is first dealt with in six words ("Abugerig [says]: gum arabic solidifies broken bones"). No mention of the other treatments listed by Malgaigne, including lime and gypsum.

There follow the treatments of Athuriscus, in four steps:

1. "*Athuriscus dixit*": *pound the flesh of shells with* "*ossa*" *and apply to the injury, and there will be great benefit.* Malgaigne interprets *ossa* not as bones but as the shells; he may be correct, since *ossa* can be used in a general way to denote the hard parts of a plant or even the skeleton of a discourse [22]. Although we cannot exclude that the text refers to true bones, in either case the final result is a gritty paste of *raw* shellfish: a plaster in the medical sense, not in the architectural sense.

2. *[Athuriscus dixit:] The fracture ... can be strengthened with shells and* "*os*", *broken and burned.* This introduces a new step: burning (as opposed to cooking), i.e. calcination. The wording *conculae et os fractum et ustum*, literally translated, again suggests that Athuriscus may have been using powder of calcinated bone (calcium oxide = unslaked lime), somehow mixed with "shells". Were the shells calcinated as well? Were they only pounded, with the mollusks, to make a paste? The text, specifically attributed to Athuriscus, is not clear; the next sentence is presented as an explanation by Rhazes himself:

3. "*Athuriscus, dico*" ["I say", common in the Continens, to distinguish quotation from personal statements] *calcinates a shell, then spreads [the powder] on the fracture, and thereafter mixes with moisture from the shells, and [the result] is admirable.* Here the sequence is clear: pieces of shell, which are mainly calcium carbonate, are calcinated into lime, applied to the limb as a powder, then slaked *in situ* with a sort of clam juice (marine shells, incidentally, were used in antiquity as a source of lime [15]).

pe narcisci mꝫsceant cū melle ⁊ supponat: etiā terant radices cānaꝝ ⁊ folia cuꝫ modico oleo sisamino ⁊ supponant loco dolenti.

Ad cōtusi onē ossis ⁊ fracturā ipsius ⁊ liget cū cōtēpie. ¶ Abugerig: gūmi arabicū ꝯfirmat ossa fracta. ¶ Athuriscus dixit: tere carnē cōcularū ⁊ ossa ⁊ suppone ꝯtusioni ⁊ magnū erit iuuamētū ipoꝝ. cōcule ⁊ os fractū ⁊ vstū si supponūtur fractu re ossiū cadētiū eā corroborāt. ¶ Athuricus: dico: vrat cōcula deinde illiniat cū ea sup fracturā postea asset cū būditate cōculaꝝ ⁊ mirabile erit ⁊ si vis fiat ℔ cū calce ⁊ albugine oui ⁊ mirabile erit ⁊ erit melius ⁊ vtilius valde: qꝛ fiet ad modū lapidis ⁊ si erit opoꝛtuna eius diſſolutio nisi post sanationē. ⁊ dixit: pinguedo vrsi cōfert valde dislocationi toꝛture nodul diuturnis ⁊ cōtusioni neruoꝝ ⁊ subtiliat grossitiē neruoꝝ valde si cū ea fit fricatio moderata in lole ad leniēdū ossa cū sit in vltima lenitione. ¶ Tabri: sareo colla refirmat fracturā ⁊ toꝛturā quotiens illinitio fit de ea cū melle. ¶ Retulit mihi qdā qꝝ ipse faciebat illinitionem de piris tritis in aq̄ ⁊ mixt cū aceto sup fracturam ⁊ bona erat valde: qm̄ refirmat ⁊ corroborat. ¶ Vidi vetulā in q̄ erat dislocatū adiuuamētū ⁊ extētū fuit cū manu cirugici ⁊ rectificatū stati ⁊ nō erat opoꝛtunū ei instrumētū appellatū ouik neqꝫ scala neqꝫ aliud. ¶ Dixit: ipsa erat vetula vidi quēdā virū in cuius akeb erat grossitudo vcb. mēs cuꝫ soliditate cui dixi: tu cecidisti de loco alto sup calcaneū tuū ⁊ dixit sic: manus nō aut pes si toꝛti fiūt frāgant sicō ⁊ iterū reformet. sed dubiū erit ne rūpat penes fracturam os: qm̄ si rūpit ⁊ vlcerat de eo egredient pticula aut coꝛtex: iō oꝛ supponi ei aliq̄ res plana ⁊ frāgat sup eā. sed si pticule ossis puule remanent ⁊ sonitū dant absqꝫ vulnere glutinabunt ptes ipaꝝ cū ptibus ⁊ solidabunt ⁊ iust modū multitudinis ossiū fractoꝝ ⁊ remotiōis ptis de p:e erit sup ossū ⁊ ℔ magis nociuū erit sup articulos vñ pcede in eis cū pinguedine anat vrsoꝝ ⁊ aq̄ calida qꝛ attenuāt illud.

Figure 2. Part of a page of the *Continens* (Book XV, Cap. 2, from a 1486 edition). In the first 11 lines of the new paragraph Rhazes refers to the use of molded casts for fractures.

The actual procedures, in this passage, leave no doubt: *the critical event is that slaked lime appears for the first time in the context of a fracture dressing;* it is obtained from a biological source, and mixed with a biological fluid, yielding a mass which is bound to solidify as an unusual form of mortar. However, it is somewhat puzzling that Athuriscus is said to calcinate *a shell* in the singular (lit. *urat[ur] concula,* let a shell be burned). A single shell, however large, could not yield enough lime for a cast. Several explanations are possible and even compatible; we list them here in order of increasing likelihood: (1) the singular is a slip of the translator, or conceivably of Rhazes himself; (2) "the shell" really stands for "the shell material" (in the next sentence, juice is obtained from "shells" in the plural); (3) "the shell" is a legitimate interpretation, by Rhazes, of the text of Athuriscus, which says "bone, broken and burned". Rhazes himself never refers to the use of true bone; he might well choose to explain "bone" in the singular as a single shell; (4) there was no intention here of producing a cast, but only of feeding the fracture with two helpful materials; however, the final result—a mixture of lime and fluid—turned out to be a plaque of bone-like (or stone-like) consistency, which suggested the next step:

4. *and if you wish, let [the mixture] be made with "calx" [lime] and eggwhite: [and it] will be admirable and better and much more useful, because [it] will become [hard] like stone and it will not be necessary to remove it until after healing.* Rhazes appears to suggest here that rather than taking the trouble of preparing lime from calcinated shells, one may just as well obtain commercial lime, and make it into a paste with eggwhite.

Comparing this passage of the *Continens* with the free rendition of Malgaigne we do find the cast made of lime, but not the cast of true plaster *(gypsum mortificatum)* which became—almost a millennium later—the standard method. Missing is also the indication that Athuriscus "modified" the methods of Abugerig.

The treatments listed by Rhazes call for several comments.

a. Treatments 1 and 2 amount to the application of a gritty paste or of a powder. With such procedures there can be no intention of providing the fracture with mechanical support. Then what is the rationale for applying shells, and perhaps also bones, directly onto it? It seems to us that the purpose here is to provide *medicine* to the broken limb, by using natural materials that appear helpful because they are hard, or even an animal that "knows" how to produce a hard skeleton. This concept of *feeding* the fracture is supported by the text of Albucasis, to be examined later.

b. In treatment 4 the principle is definitely that of mechanical support; but surprisingly, the lime is hydrated directly on the limb. This amounts to mixing mortar on the skin, a reaction that generates heat and a potent caustic. This danger could not have escaped Athuriscus or Rhazes. Perhaps it was obviated by covering the skin with a waterproof oiled cloth; however, this drawback may well have prevented the method from becoming popular. Gypsum would have been a much better choice.

c. An interesting detail: according to Athuriscus (and Rhazes), the lime is not hydrated with plain water, as it would be on a construction site, but with either eggwhite or shellfish juice. The theory here must be that of helping the fracture in two ways: the lime gives it strength; the fluid feeds it (with eggwhite) or "tells it" how to make bone (with shellfish juice). A combined approach of this kind seems to have been used also by the eighteenth century Persian practitioners described by Mr. Eton (STE): the plaster could be mixed with disinfectants ("vulnerary fluids", spirits or vinegar).

d. *We found no reference to the cast of plaster (gypsum).* Yet, if we believe that rather vague wording of Malgaigne, we should have seen it mentioned as another discovery of Athuriscus. Could we have missed the right passage? We doubt it. It so happens that the *Continens* also includes a book on drugs or *simples;* among these, number 183 is precisely gypsum (Lib. XXI Cap. V). Rhazes mentions it as a component of "plasters" in the general sense of "applications", but never refers to casts. He quotes Galen, *Dyascorides* and Paul of Aegina: gypsum has "the drying properties common to all stony bodies"; it hardens when made into a plaster *(indurat emplastrando)* with eggwhite and "dust from a millhouse" (two "glutinous simples" that we will discuss later as favorite drugs of Albucasis); it will work even better if mixed with the fur of a hare (presumably a reference to its styptic property, because it also "opposes bleeding and sweating"); if swallowed it kills by choking; and if burned *(combustum)* it loses its viscosity. To sum up, with due respect to Malgaigne, we believe that he or someone for him was misled by a hasty association of the words "gypso combusto" and "indurat emplastrando". If gypsum had been known to play a role in the treatment of fractures, the encyclopedic Rhazes would have mentioned the fact in this chapter.

Although Rhazes judged the cast-method important enough to be recorded, there is no indication that he ever used it [23]. In Book XV of the Continens, most of the material on fractures covers 23 consecutive pages (Cap. 1). The treatment of each fracture is presented in detail, with special concern for

methods that do not hurt the limb; casts are not mentioned. The critical passage on casts (Fig. 2) amounts to barely 11 lines; it is inserted in a brief chapter—less than a page—which reads like a catch-all of sundry additional plasters based mainly on plant products. Thus, the cast method is certainly not emphasized; the skimpy Table of Contents does not mention it. Overall, we believe that Rhazes listed the method as an interesting idea that others might want to try. Whether the idea was old or recent in his day hinges on the dates of Athuriscus.

Who was Athuriscus? According to Leclerc, a physician named *Athursoqos* appears often in the Continens, the name being rendered in 20 different ways[24]; we assume that *Athuriscus* is one of them. Leclerc speculates (as Fabricius did before him) that Athursoqos may be identical with an author known to Galen, *Atheuristi*[25]. Galen (remarks Leclerc) imputes to him the use of drugs that were either repulsive, such as human flesh, or fanciful such as parts of mythical animals; in the Continens, Athursoqos does recommend unsavory "drugs" such as stale, smelly human urine ... His birthplace is unknown. For the time being, we must conclude that—until more is known about the nebulous Athuriscus-Athursoqos—the invention of the molded cast, although recorded by Rhazes, was not necessarily born within the Arabic sphere. If Galen knew of Athuriscus, the molded cast may have appeared in the second century A. D. or earlier.

The molded cast after Rhazes: the notion of "feeding the fracture"

Surely the idea of treating fractures with molded casts was in the air at the time of Rhazes. It was apparently known to another tenth century Arabic physician, Abu Mansur Muwaffaq[26]. However, Avicenna (980–1037) ignores it. His Canon refers only to *attellae*—splints—or similar methods[27].

Albucasis, writing in Spain at the turn of the millennium (died c. 1013), deals extensively with fractures in his famed treatise of Surgery, the Tasrif[28]. He, too, never refers to a molded cast; however, he does recommend a mixture of flour and eggwhite that can easily be misconstrued as a "precursor" of the plaster cast, and has been misinterpreted as such. An example:

"Take mill dust, that is, the fine flour that sticks to the walls of a mill as the grindstone moves. Pound it as it is without sieving, with eggwhite, to a medium consistency; then use".[29]

There is no reference to stiffening the bandages with this paste. Such is not his purpose. It is helpful to read Albucasis through the eyes of Guy de

Chauliac (1300–1368), who draws a great deal from the Tasrif. In discussing fractures, Guy de Chauliac refers to the mixture of flour and eggwhite, but never alludes to *stiffening* properties of the paste: instead, he refers to the ingredients as *glutinative* (sticky); and then he gives his own recipe, which is even more culinary than that of the Tasrif: flour, *beans*, and *honey*[30].

It is clear that the leading thought was to feed the fracture through the skin. The ingredients were chosen among those that were most nutritious and if possible also sticky, to help bind the broken ends.

In this context, eggwhite is certainly sticky, and one of the components of flour, *gluten*, is sticky—glutinous—par excellence. To this day children are given a mixture of flour and water as a harmless glue for play. Now looking back upon the text of Albucasis, when he advises to collect that particular flour that sticks to the wall of the mill, he probably has in mind that this is the stickiest part.

The very healing of the fracture was interpreted by Albucasis as similar to gluing: "Nature produces around the [broken] bone on all sides something like glue, with a certain viscosity, with whose help it joins, and it binds so that one part adheres to the other and they are linked ... good and firm as it had been before".[31] The notion of a *bone glue* was by no means far-fetched: carpenters use to this day a powerful glue obtained by boiling bones[32]. The microscopic fibers that hold together bone tissue as well as most other tissues are called *collagen* fibers precisely because when boiled, they *generate "colla"*, glue[33]. Another variety is obtained from parts of fish; it is still sold as fish glue.

Now the diet chosen by Albucasis for his patients suffering from fractures becomes clear: "When the broken bone has begun to mend, the patient should be nourished with very nourishing food, fat, strong, *having some glutinous* property, such as porridge, rice, ..., eggs, fresh fish, heavy wine".[34] Albucasis even recommends that the bandages be loose enough so that the nourishment may reach the bone[35]. Clearly, he is attempting to feed the fracture both ways: by the diet and through the skin surface as well. Thanks to this reasoning, Albucasis came up with a nutritious diet far more rational than the traditional Hippocratic method, which called for starvation[36].

As to the notion of feeding the body through the surface, it is not particularly "mediaeval". The cosmetic industry today has no difficulty in convincing its customers that the skin should be fed by rubbing into it the royal jelly of the queen bee.

Oddly enough, these "nutritious dressings", although worthless to the fracture itself, seem to have played a role historically by leading toward the plaster cast. The evolutionary sequence, suggested by the brief passage in the *Continens,* may have been the following:

1. feed the fracture with glue-like materials (such as eggwhite).
2. feed the fracture with bone-like materials (pounded shellfish).
3. feed the fracture with a powder of calcinated shells (which is similar to lime).
4. apply a mixture of eggwhite and calcinated shell powder (producing a mass similar to mortar).
5. apply a mixture of eggwhite and commercial lime (producing mortar).
6. replace lime with gypsum (producing the classic plaster cast).

The subsequent history of the cast needs not be repeated here. Suffice it to mention that eggwhite slowly lost its "feeding" aura and became the principal means of stiffening the bandages, up to Napoleonic times[37]. As far as we know, the cast prepared with slaked lime—a close relative of the brick wall—never reappeared; it may have been too dangerous and too difficult to break open. However, it is significant that the classic cast made of gypsum finally emerged, in 1795, in the same land in which Rhazes had recorded the molded cast of Athuriscus.

How the switch from lime to gypsum occurred is not yet clear. As the potters of India seem to have played a role in treating fractures with a mold of clay[14], the use of plaster may have been suggested by an artisan working on the elegant stucco decorations of a Persian mosque[38].

Notes

1. We use the traditional expression *Arabic* medicine, but it should be understood that "Arabic" medicine flourished outside Arabia and that its texts were not necessarily written in Arabic. The alternative is *Islamic medicine* (2).
2. Ullmann, M.: *Islamic Medicine.* Vol. II of Islamic Surveys, Edinburgh Press, 1978.
3. Elgood, C.: *A Medical History of Persia and of the Eastern Caliphate, from the earliest times until the year A.D. 1932.* Cambridge Univ. Press, 1951 (pp. 584-ff summarize the difficulties pertaining to the study of Arabic medicine).
4. Khairallah, A. A.: *Outline of Arabic contributions to Medicine and allied sciences.* Beirut, American Press, 1946.
5. Rhazes is invariably quoted as the inventor of catgut sutures (e.g. Elgood, op cit. p. 203) but the precise reference remains elusive.

6. Spink, M.S., and Lewis, G.L.: *Albucasis on Surgery and Instruments. A definitive edition of the Arabic text with English translation and commentary.* London, The Wellcome Institute of the History of Medicine, 1973. (Sutures used in Antiquity are listed in the notes on pp.538–540. It is said there that Albucasis does not mention linen, but he strongly implies it on p.550, where he also mentions «gut, well scraped». The passage referring to silk and lute-strings is on p.180).
7. Again, the seton is invariably attributed to Rhazes (e.g. Khairallah, op cit. p.106) but without a precise reference.
8. Littré, E. *Œuvres Complètes d'Hippocrate*, Paris, Baillière, 1849, Tome VI, p.451.
9. Malgaigne, J.F.: *Recherches historiques et pratiques sur les appareils employés dans le traitement des fractures en général depuis Hippocrate jusqu'à nos jours.* Paris, H. Cousin, 1841.—Monro, J.K.: The history of plaster-of-Paris in the treatment of fractures. Brit. J.Surg 23: 257–266, 1935–1936.—Bacon, L.W.: On the history of the introduction of plaster of Paris bandages as a fixation dressing. Bull. Soc. Med. Hist. Chicago III: 122–132, 1923–1925. (Other sources, on the more recent history of the plaster bandage, are quoted in R.Sœur: *Fractures of the limbs*, Brussels, Ed. «La Clinique Orthopédique», 1981, pp.45–48, 63).
10. [Eton, E., here misspelled Eaton:] Account of the Arabian mode of curing fractured limbs. Communicated to Dr.Guthrie of Petersburgh, by Mr.Eaton, formerly Consul at Bassora. Medical Commentaries, 10: 167–171, 1795.
11. Monro (op. cit.) quotes Hubenthal (1816) as the originator of an ingenious bivalved cast, made of plaster of Paris and ground-up blotting paper (p.268).
12. Eton, W.: *A Survey of the Turkish Empire.* London, T.Cadell, 1801, 3rd ed., pp.212–215.
13. Majno, G.: *The Healing Hand. Man and Wound in the Ancient World.* Cambridge, MA, Harvard University Press, 1975, pp.73, 75.
14. The idea of using molded clay as a support for fractured limbs must have surfaced in several cultures, but recorded examples known to us are relatively late. It has been reported that an American Indian tribe, the Shoshone, used "casts of leather, chicle [gum] or clay" (Ackerknecht, E.H.: *Medicine and Ethnology, Selected Essays;* H.Huber, Bern, 1971, p.98). An interesting eye-witness report from India is provided by Sir George Ballingall, Surgeon to the Queen, in 1855: "The practice of enveloping fractured limbs in splints and bandages, without undoing them for weeks altogether, is akin to that followed by the natives of India, of inclosing fractured limbs in moulds of clay. Of the successful result of this practice I remember a remarkable instance in the case of a little boy who was brought into my tent one morning, having been run over by a waggon on the line of march, and having sustained a severe compound fracture of the leg. I was preparing to amputate the boy's limb, when his parents came in and carried him away to the potter in an adjoining village, who enveloped the leg in clay, and I believe finally cured the patient" (Sir G.B., *Outlines of Military Surgery*, Edinburgh, Adam & Charles Black, 1855, p.382). This case is an astonishingly close replica of the case reported from Persia by W.Eton.
15. For this information we are indebted to a scholarly student of architecture in Milan, Mr. Gionata Rizzi.
16. Pliny the Elder: *Natural History.* Transl. by D.E.Eichholz, Cambridge, MA, Harvard University Press, and London, W.Heinemann, 1962, Vol.X, pp.142–145 (XXXVI, lvii–lix § 180–183).

17. Ibid., XXVIII xxiii § 129 (Loeb ed. Vol. VIII p. 91).
18. Ibid., XXXVI lix § 183 (Loeb ed. Vol. X p. 145).
19. Adams, F. A.: *The Seven Books of Paulus Aegineta, Translated from the Greek with a commentary embracing a complete view of the knowledge possessed by the Greeks, Romans and Arabians* ... London, The Sydenham Society, 1846, Vol. II, pp. 233–234.
20. Rhazes, Muhammad. *Liber Elhavi id est Continens artem medicinae.* Transl. by Abul Farrasch-Feragius. Edited by Johannes Bugatus. Brescia: Jacobus Brittanicus, 18 Oct. 1486 (At the Countway Library of Harvard Medical School, Boston, MA). The passage quoted is virtually identical in a later edition of the Continens, published in Venice in 1542 by Hieronymus de Saliis (available at the Biblioteca Braidense in Milan).
21. Morton, L. T.: Garrison and Morton's Medical Bibliography. London, Morrison and Gibb, Ltd., 2nd Ed., 1965, p. 540.
22. Lewis, C. T. and Short, C.: *A Latin Dictionary*. Oxford, Clarendon Press, 1962, p. 1282.
23. According to Malgaigne (op. cit. p. 26) Rhazes may have actually disapproved of the cast, as suggested by a supposed statement that "soft bandages are worthless, solid ones cause pain and inflammation". No reference is given. In Lib. XV Cap. 1 § 3 it is said that «ligatio mollis ... non servat, ... confert dolorem ... ligatio mediocris». This looks suspisciously similar to the "quotation" of Malgaigne, but if it is, his translation is not defensible.
24. Leclerc, L.: *Histoire de la Médecine Arabe*, 1876, I, pp. 267–268 (reprinted by B. Franklin, NY, 1971).
25. The names Athuriscus and Athursoqos are not listed in the index of Galen's *Opera Omnia* (C. G. Kühn, Hildesheim, G. Olms, 1965, Vol. XX).
26. This statement is found in Sarton, G., *Introduction to the History of Science*, Baltimore, Williams and Wilkins, 1962, Vol. I, pp. 678–679; and also in Elgood, op. cit., p. 291, but without reference. Leclerc, op. cit. (I, pp. 361–362) mentions the same author but with no ref. to plaster casts.
27. We have used the reprint of Avicenna's *Canon* by G. Olms Verlag, Hildesheim, 1964. The section on fractures is in Lb. III, Fen V, pp. 459–470.
28. For the translation of the Tasrif see ref. 6; fractures are treated in Book III (22 chapters, pp. 676–785).
29. Ibid. p. 690
30. Guy de Chauliac: *On Wounds and Fractures*. Transl. by W. A. Brennan. Chicago, 1923, pp. 149–150. This translation is poor; W. A. Brennan was not a physician and probably not a cook. Not knowing the French word for flour (p. 149) he inserts it in the English text as *farine;* on p. 150 he simply writes "farine, febues and honey" where febues is obviously ancient French for *fèves*, beans.
31. Albucasis (see note 6) p. 680
32. Glue is obtained by boiling animal tissues; it should be distinguished from gum, which is of plant origin. Glue obtained from animal tissues has been used since remote Antiquity. There is ample chemical proof that the Egyptians used glue (Lucas A., and Harris, J. R.: *Ancient Egyptian Materials and Industries*, London, 1962, pp. 3–5 and passim). Pliny believed that glue *(glutinum)* had been invented by Daedalus, together with carpentry (op. cit., VII lvi § 198/Loeb ed. II p. 641); he states, *inter alia,* that the finest glue is made from the ears and genitals of bulls (ibid. XXVIII lxviii § 236/Loeb ed. VIII p. 159). Glue can be obtained by boiling most tissues; however, we have found no proof that *bones*, too, were used for this purpose before 1680 (Italian Encyclopedia).

33. When animal tissues are boiled, the collagen fibers swell, become denatured, and dissolve; if the solution is cooled it solidifies as the familiar gelatin. Glue is obtained by drying gelatin.
34. Albucasis, op. cit. p. 678.
35. Albucasis, op. cit. p. 750.
36. Majno, op. cit.; starving as a cure for wounds: pp. 179, 182, 188, 335, 337 and *passim*.
37. Malgaigne, op. cit. pp. 72–73.
38. The present essay concerns the molded cast as it passed from Arabic medicine to Western medicine. A complete survey of the molded cast should include a survey of Chinese sources, in which comparable methods are most likely to be found.

Zusammenfassung

Die Frakturbehandlung durch einen fixierenden starren Verband war eine Erfindung der arabischen Ärzte. Der Aufsatz gibt die früheste Mitteilung in Europa aus dem Jahre 1795 wieder sowie die erste Beschreibung der Methode im *Continens* von Rhazes. Die Aufzählung der verschiedenen Materialien (Eiweiß, Mehl, Honig, Kalk) zeigt, daß anfänglich auch an eine das Gewebe ernährende und knochenbildende Funktion des Verbandes gedacht wurde, bis schließlich der reine Gipsverband daraus entstand.

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