

## CHAPTER 4

### STUDY OF CADAVER FAT AND ADIPOCERE<sup>1</sup>

919. It is common knowledge that after cadavers have been buried in humid soil for some time, all that is left are bones covered with membranous tissue in a more or less altered state and a material that gravediggers, who were aware of it before scientists, called *fat*.

920. Fourcroy<sup>2</sup>, to whom we owe the first chemical study of this fat, rightly considered it to be some kind of soap but he was mistaken about its characteristics since he likened it to spermaceti and cholesterol and grouped all three under the common name of *adipocere*. In Book II, I have established that there are considerable differences between spermaceti and cholesterol. In the present chapter I will show that the *adipocere* of fat is formed by several *immediate principles*, none of which can be confused with cholesterol or spermaceti.

921. In the first paragraph, I will deal with the analysis of the fat considered to be a soap and in the second, the properties of the adipocere and its immediate analysis.

#### § 1. ANALYSIS OF THE FAT EXTRACTED FROM A CADAVER FROM THE CEMETERY OF THE INNOCENTS

922. I removed a piece of fat from a shinbone, reduced it to a powder and sieved it. I put 50 g of it in a balloon flask with 7 dL<sup>3</sup> alcohol with a density of 0.822 (g/mL), allowed the material to digest at a temperature of 60 to 70°C and then poured it onto a filter.

923. On cooling, a large number of small needle shaped crystals were deposited in cauliflower-shaped clusters. I continued to wash the fat with alcohol. The second wash deposited only very little material on cooling and the last washes did not even become cloudy. The first washing liquor was filtered after it no longer became cloudy and all the other washing liquors were passed through the same filter one after the other.

924. The residue that was insoluble in alcohol weighed 4.85 g.

925. I will now examine 1. *this residue*; 2. *the deposit thrown by the alcohol washing liquors after cooling*; 3. *the alcoholic washing liquors from which this deposit precipitated*. Finally, I will present my conclusions regarding the composition of adipocere from this examination.

## ARTICLE 1

## EXAMINATION OF THE ALCOHOL-INSOLUBLE RESIDUE

926. It was treated with boiling water to remove everything it contained that was soluble in this liquid. This reduced the amount of material to 3.88 g; the water had therefore dissolved 0.97 g of residue.

Aqueous  
washing liquor

927. The washing water was yellow and noticeably acid. It was concentrated to a syrup and then mixed with alcohol; coagulation took place.

928. The coagulate was diluted in water, leading to a small deposit of a nitrogenous material containing some calcium. The solution contained a *yellow coloring material*, a *nitrogenous material* that yielded a large amount of ammonium bicarbonate<sup>4</sup> and ammonium carbonate on distillation, a *neutral calcium salt* that I think is a *lactate* and finally, a very small amount of a *potassium salt* that I think is a *lactate*.

929. The alcohol had dissolved the *yellow material*, a *free acid* that I think is *lactic acid* and finally some salts I presume to be *calcium and potassium lactate*.

Residue  
weighing 3.88 g

930. The residue (926) was macerated for several days with weak hydrochloric acid. Then it was heated, diluted with water and filtered.

Hydrochloric  
solution

931. The addition of ammonia released from the hydrochloric acid some *calcium phosphate*, *iron oxide* and *magnesium oxide*, probably in the form of phosphate<sup>5</sup>. When ammonium carbonate was added to the filtrate, this precipitated lime in the form of carbonate. The only matter left in solution was a trace of yellow material.

Residue that is  
insoluble in  
hydrochloric  
acid

932. Boiling alcohol dissolved the entire residue except 0.8 g of material that consisted of: 1. nitrogenous material that probably originated from the deterioration of the muscles; 2. small bits of fabric that were the remnants of the burial shrouds in which the cadavers had been wrapped. On cooling, the alcoholic solution deposited 2 g of crystallized adipocere. This adipocere did not dissolve when the fat was treated with alcohol because it was combined with calcium, whereas the adipocere that did dissolve was combined with potassium and ammonia. The alcoholic solution was cooled, filtered and then mixed with water. This yielded 0.4 g of a material, part of which was the same as the previous adipocere except that it had a lower melting point. The other part was in the form of white flakes that I have not been able to examine because the amount present was too small. The water used to precipitate these materials retained only a little calcium lactate.

## ARTICLE 2

EXAMINATION OF THE DEPOSIT FORMED  
DURING WASHING WITH ALCOHOL

933. It had little color and melted at 79.5°C. When kept in a molten state for a certain period of time, ammonia was released and its melting point was lowered. Treating 10 g of the deposit with hydrochloric acid yielded 9.7 g of slightly yellow adipocere melting at 54°C. When the acid liquid was evaporated to dryness, it left 0.73 g of material consisting of 0.60 g of ammonium chloride, 0.12 g of potassium chloride and 0.01 g of calcium chloride. Therefore, the deposit consisted of *adipocere* with some *ammonia* and *small amounts of potassium and calcium*.

## ARTICLE 3

EXAMINATION OF THE ALCOHOLIC WASHING LIQUORS  
FROM WHICH THE ABOVE DEPOSIT WAS SEPARATED

934. They were concentrated twice and each time they deposited a fairly large amount of material on cooling. I will now investigate these two deposits that I will call the second and third deposits.

935. The second deposit, after having been melted and cooled, started to become cloudy at 60°C but the major part did not set until 54°C. When 100 parts were treated with hydrochloric acid, they yielded 99.48 parts of adipocere melting at 53 to 54°C. When the hydrochloric acid had evaporated, it left a residue of 760 mg.

Second deposit

936. The third deposit solidified completely between 51 and 52°C but it started to solidify above that temperature. When 100 parts were treated with hydrochloric acid, they gave an adipocere that melted completely between 51 and 52°C. Evaporating the hydrochloric acid to dryness left 2.4 parts of residue.

Third deposit

937. This alcohol was mixed with water and heated to 60°C; this led to the separation of 2 g of a red adipocere with a melting point of 45°C and 0.2 g of a *white, flaky material*. The aqueous liquor from which these two substances were separated was concentrated to a thick, syrupy consistency. In this state, it weighed 0.67 g; it was reddish and acid. When one portion was incinerated, it evolved a large amount of ammonia; the ash consisted of *potash, iron oxide, calcium bicarbonate* and a trace of *silica*. Water was added to the other portion, which dissolved almost completely. When this solution was filtered and evaporated, it left a residue that I treated with alcohol, which caused a *nitrogenous matter* and *calcium lactate*

Alcoholic  
mother liquor  
of third deposit

to precipitate. It dissolved some ammonium *lactate*<sup>6</sup>, some *potassium lactate* and the *yellow coloring material*. The liquor I am talking about displayed great similarity with the aqueous washing liquor of the fatty residue that did not dissolve in water. These experiments made me think that the acid in these liquors was lactic acid: it was solid; it did not crystallize; it did not precipitate lead salts; even with lead oxide it formed a salt that was soluble in water and alcohol; its reaction products with potash and soda ash are deliquescent; and it seemed to me that it formed a salt with zinc oxide that is insoluble or poorly soluble.

## ARTICLE 4.

### CONCLUSIONS FROM THE ABOVE EXAMINATIONS

938. 1. Cadaver fat in a pure state (that is to say without the lactic acid, lactates, nitrogenous matter, etc.) is not a simple reaction product of adipocere and ammonia since an appreciable fraction of the fatty matter is bound to calcium and potassium.

2. Adipocere should not be regarded as a single compound since different samples were found to have different properties. Thus the adipocere of the first deposit (933) and that of the second one melted at 54°C, that of the third one at 52°C and the one obtained from the aqueous mother liquor melted at 45°C. These adipoceres also differed in color.

3. The adipocere with the highest melting point seemed to have more affinity for bases than the lower melting adipocere, since the adipocere of the calcium soap (932), which melted at 54°C, was saturated with calcium, and that of the first deposit (933) that also melted at 54°C contained a large proportion of the base, whereas the adipocere from the mother liquor with a melting point of 45°C contained none or hardly any. The reaction of bases with adipocere with the highest melting point was one of the reasons why this adipocere could be separated from the lower melting adipocere; when I applied the same alcohol treatment that I had used for natural fat to fat from which I had eliminated the bases with hydrochloric acid, I was not able to obtain adipocere with such widely differing melting points as those isolated from the natural fat.

### § 2. EXAMINATION OF ADIPOCERE

939. Since the fatty matter is a soap, it is likely that I would observe the characteristics of a saponified fat in the adipocere from which it is formed, that is to say, the property of dissolving in large amounts in boiling alcohol with a density of 0.820 (g/mL), that of turning litmus tincture red and that of reacting with caustic potash with the greatest of ease without losing any weight or any of its other properties<sup>7</sup>. If we examine

these three properties of adipocere, we observe: 1. that it is totally miscible with boiling alcohol with a density of 0.820<sup>8</sup> (g/mL); 2. that this solution turns litmus red and here I must point out that in the fat being analyzed, the adipocere was present as an acid salt<sup>9</sup> because when the fatty matter was dissolved in cold alcohol it turned litmus red without having been treated with an acid; 3. that the adipocere reacted readily with caustic potash without losing weight and without any change in its melting point or other properties. I ascertained this by allowing 10 g of adipocere with a melting point of 51.5°C to react with 6 g of pure potassium hydroxide<sup>10</sup>. By acidulating the soap with hydrochloric acid, I obtained 9.9 g of adipocere with the same melting point of 51.5°C<sup>11</sup>.

940. I still had to determine the nature of the immediate principles in adipocere. First I tried to isolate them by means of boiling alcohol. The sample I examined had a melting point of 47°C. The materials into which I split the sample were always colored. One of them melted at 49.75° and the other at 41.24°C. Accordingly, I treated it with caustic potash. I knew for certain that this base would not alter the adipocere in any way since I knew that a fat that has already been saponified does not undergo any change when it is exposed to an alkali with which it has already reacted and I also knew that the adipocere was a saponified fat.

941. I heated 60 g of adipocere having a melting point of 45°C with 420 g of water containing 30 g of potassium hydroxide in solution. On cooling, a soft, opaque soap separated from the orangey colored mother liquor.

942. When the soap was dispersed in water, it formed a deposit of more than 40 g of a *pearly material*, which looked very much like potassium bipalmitate. When the soapy liquid was separated from this deposit and acidulated with tartaric acid, it yielded 16 g of a *reddish adipocere* with a melting point lower than of the adipocere that had reacted with the caustic potash, 1.5 g of a *flaky adipocere* that melted in boiling water and a material that was partly orange, partly white. The white part seemed to me to be similar to the material I have discussed before (937): it was too small an amount to be examined. All the adipoceres were collected together and allowed to react with aqueous potassium hydroxide. After the resulting soap had been separated from all the *pearly material*, the former was acidulated with tartaric acid. This yielded an *oily acid, liquid* at 7°C. I will now examine:

1. *The deposits of pearly material;*
2. *The oily acid, fluid at 7°C;*
3. *The aqueous mother liquor of the adipocere (941), which has been combined with all the aqueous liquids originating from the soap*

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\* I recovered 40 g but some was lost.

solutions that have been acidulated with tartaric acid and from which pearly deposits had been removed.

## ARTICLE 1

### EXAMINATION OF THE PEARLY MATERIAL FROM ADIPOCERE SOAP

943. It was purified by the method described in Book III, Chapter 1, Section 1, § 1, Article 1 (603). When 3 g were acidulated by hydrochloric acid, they yielded 2.79 g of a solid fatty acid and 382 mg of potassium chloride, which corresponds to 242 mg of potassium oxide<sup>12</sup>. Thus:

Acid <sup>13</sup> .....	2758	100
Potassium oxide.....	242	8.78

944. The fatty acid melted at 56°C. It crystallized into extremely fine needles arranged in such a way that they presented an undulating surface. Palmitic acid from human fat with a melting point of 56°C is often found in the same form. It was completely miscible with boiling alcohol and crystallized into beautiful pearly lamellas on cooling. The solution turned litmus dark red. It formed a compound with potassium oxide<sup>14</sup> in a ratio of 100 to 18.2. In short, it had all the properties of palmitic acid.

## ARTICLE 2

### EXAMINATION OF THE OILY ACID

945. The acid was fluid at 7°C, orangey colored and turned litmus very red. It was miscible in all proportions with alcohol and formed a soap with potassium hydroxide that was highly soluble in water; the solution was yellow. This acid seemed to me to react with barium carbonate in the same way as oleic acid. Consequently, I consider it to be identical to oleic acid, the only noticeable difference being its color that must certainly stem from a foreign substance.

## ARTICLE 3

### EXAMINATION OF THE AQUEOUS MOTHER LIQUOR OF THE ADIPOCERE SOAP

946. As I have already indicated (942), this mother liquor was combined with the aqueous liquids originating from the various soapy solu-

tions that were acidulated with tartaric acid and from which the pearly material had been separated. The liquor resulting from this combination contained an excess of tartaric acid. It was distilled.

947. The water that was evaporated carried a little *ammonia* with it and a principle that had an adipocere odor.

Product

948. The residue had an orangey yellow color. It was further evaporated in a dish; at a certain point, orange droplets which I thought were oleic acid could be observed on the surface of the liquor but in the end, they dissolved again in the excess of tartaric acid when this had become more concentrated. The excess of this acid was neutralized with potassium carbonate. After evaporation to dryness, the residue was treated with concentrated alcohol to separate the potassium tartrate from the potash that could be in excess.

Residue

949. The *alcoholic solution* was evaporated; its residue was dissolved in water and mixed with barium chloride. This led to a precipitate of *orange colored barium oleate* mixed with traces of tartrate and barium carbonate. The oleic acid was obtained by treating the precipitate with tartaric acid, slowly evaporating to dryness and treating the residue with alcohol, which dissolved this fatty acid together with its yellow coloring principle, and finally mixing the alcohol with water.

950. The liquor that was separated by the barium chloride was evaporated to dryness. The solid material was mixed with alcohol, which resulted in the separation of a small amount of *barium oleate* that was less colored than the previous one. The solution was filtered, concentrated and mixed with a small amount of potassium sulfate to obtain potassium chloride and barium sulfate. After evaporation to dryness, alcohol was added. This took up an orangey yellow material that was very bitter and soluble in water. This material retained a trace of oleic acid.

## ARTICLE 4

### CONCLUSIONS

951. Adipocere is not a simple immediate substance since it can be split into: 1. palmitic acid; 2. oleic acid; 3. a yellow coloring principle; and 4. an odoriferous principle. The first two compounds are the main constituents of adipocere. There is much more palmitic acid than oleic acid present since 100 parts of adipocere with a melting point of 45°C yield at least 90 parts of a pearly material containing an acid with a melting point of 56°C and only 6 to 7 parts of oleic acid. 100 parts of adipocere with a

melting point of 54°C yield 100 parts of pearly material and only 0.7 parts of oleic acid.

952. The bond between the oleic acid and the coloring principle is very strong and it is certainly the latter that provides the oleic acid with its tendency to dissolve in water and tartaric acid.

953. It is evident that the differences observed in the melting points of the various adipocere samples stem from their different ratios of palmitic to oleic acid.

### § 3.<sup>15</sup>

954. I examined quite a large number of fat samples and although they all gave results that are more or less close to those I have just described, it is nevertheless worth recording here what I observed in two fat samples produced under circumstances quite different from those where fat is formed in cadavers buried in the earth.

## ARTICLE 1

### BONE MARROW PARTIALLY CONVERTED INTO FAT

955. I will now describe the marrow obtained from a sheep's shin bone that was broken at both ends and found buried amongst fecal matter when excavations were carried out near the Chaumont mound for the Saint Martin canal. According to information received, it must have been buried here for about a century.

956. It gave off a fecal odor and had a white to slightly pink color. When a red litmus paper was introduced into the mass, it turned blue since there was ammonia present. When the marrow was mixed with alcohol at a temperature of 30°C, it dissolved only partially and the solution had no effect on litmus since it had not yet lost its ammonia by exposure to heat.

957. Boiling water removed from the marrow only traces of a rust colored extract that was slightly acid, salty and contained sodium chloride and it seemed to me also ammonium chloride<sup>16</sup> but no glycerin. When boiled, it released ammonia with traces of hydrogen sulfide.

958. On analysis, 100 parts of marrow that was assumed to be dry were found to contain 66 parts of calcium and magnesium soaps, the acids of which melted at 42°C, 9 parts of ammonia soap and 25 parts of a non-

acid fatty material with a melting point above 37°C. However, I noticed that the marrow was not homogenous because parts of it yielded 0.50 parts of soap whereas other parts only yielded 0.20 parts.

## ARTICLE 2

### RAM FAT FORMED IN THE MIDDLE OF A POOL OF STAGNANT WATER CONTAINING CALCIUM SULFATE AND CALCIUM CARBONATE

959. It was white and partially covered with calcium carbonate that produced a lively effervescence with hydrochloric acid. In this fat, there were portions that consisted only of calcium soaps whereas others were a mixture of calcium soap and free adipocere.

960. In boiling alcohol, it released only calcium soaps.

Calcium soap

961. When treated with weak hydrochloric acid, it released some calcium oxide and traces of iron oxide. After the muscle fibers had been separated, an almost white adipocere, melting point 44°C, with a disagreeable, acrid smell, rose to the surface of the water.

962. This adipocere was completely acid since it dissolved instantaneously in weak, warm aqueous potash. When separated from the alkali again, it had the same weight and melting point as before. It had lost only some traces of hircic acid and a bitter, yellow substance.

963. This adipocere dissolved in very weak aqueous potassium hydroxide was converted into a pearly material containing an acid that melted at 57°C and oleate containing an acid that had hardly any color.

964. This material was converted by means of alcohol into free adipocere that melted at 54°C and soap containing an adipocere that melted at 45°C. These two adipoceres were present in a weight ratio of 1 : 3. I have every reason to think that these adipoceres contained stearic acid in addition to palmitic and oleic acid but I did not identify it during analysis.

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<sup>1</sup> See endnotes 15, Book II, Chapter 9, page 125 and endnote 19, Book IV, Chapter 1, page 206.

<sup>2</sup> Antoine François de Fourcroy (1755-1809) had occasion to study fat from cadavers when the Parisian authorities decided in 1786 to clear the Cimetière des Innocents in the centre of Paris; it was full and presented a health hazard. So the Royal Society of Medicine appointed Fourcroy and Michel-Augustin Thouret (1749-1810) to advise the police during the excavation and transfer of the cadavers. See also Wisniak, J. Antoine François de Fourcroy, *Revista CENIC Ciencias Químicas*, **36**(1), 54-62 (2005).

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<sup>3</sup> The deciliter (dL) is a metric unit that is not used very much. It stands for one tenth of a liter, so 7 dL is 0.7 L. Another unit the author used occasionally is the centiliter (cL), which is one hundredth of a liter.

<sup>4</sup> The words used by the author can be translated literally as 'ammonia hydrocyanate'. According to the Oxford English Dictionary, hydrocyanic acid is a solution of hydrogen cyanide in water and like the acid, its salts will be called cyanides and not cyanates. However, Google France, provides a possible answer in that various authors from the first half of the nineteenth century mention that ammonia hydrocyanate is an ammonium carbonate. Since 'sous-carbonate d'ammoniaque' is also mentioned, this must stand for ammonium carbonate, which contains less carbon dioxide than the hydrocyanate, which therefore is the ammonium bicarbonate.

<sup>5</sup> Remember that salts were not yet regarded as a combination of anions and cations but assumed to be a combination of oxides. Accordingly, magnesium phosphate was seen as a manifestation of magnesium oxide.

<sup>6</sup> The French is *lactate acide d'ammoniaque* but since both lactic acid and ammonia are monovalent, an acid salt is unlikely. The reason why the original mentions the salt being acid could well be that lactic acid is a stronger acid than ammonia is basic, so that the salt itself is also slightly acid. Accordingly it has been translated as *ammonium lactate*.

<sup>7</sup> The author touches here on a sore point concerning the difference between inorganic chemistry and what we now call organic chemistry. In inorganic chemistry, reactions could often be reversed. Bubbling carbon dioxide through limewater causes a precipitate of chalk but heating the chalk liberates the carbon dioxide, leaving burnt lime, which can then be converted into limewater by slaking. Heating organic compounds on the other hand often leads to their destruction, exemplified by loss of weight and change in properties; here the author notes the absence of these traits.

<sup>8</sup> The author uses alcohol of this density quite frequently. It contains 91.0% by weight or 94.0% by volume.

<sup>9</sup> The original calls this a 'sursel' indicating that it contains more of one of the components than normally; hence the translation 'acid salt'.

<sup>10</sup> This pure potassium hydroxide is the 'potasse à l'alcool' referred to in the foreword.

<sup>11</sup> Not only was the amount of adipocere recovered the same, but its melting point had not changed either.

<sup>12</sup> Given the relative molecular masses of potassium chloride of 74.5 and of the potassium oxide equivalent of  $(2 \times 39 + 16) : 2 = 47$ , 382 mg of the chloride does indeed correspond to 242 mg of the oxide equivalent:  $(382 : 74.5) \times 47 = 241$ .

<sup>13</sup> The potassium oxide equivalent weight of 242 mg corresponds to 5.13 mmol; using this figure to calculate the relative molecular mass of the acid gives  $2758 : 5.13 = 538$  which is a much higher value than would be expected for a free fatty acid but could correspond to a bipalmitate.

<sup>14</sup> Assuming that the 100 parts refer to the free acid (relative molecular mass = 256.4), they would require 0.39 'partmol' which would allow the relative molecular mass of the base to be calculated as  $18.2 : 0.39 = 46.7$ . This is very close to the value for the potassium oxide equivalent calculated in endnote 10 above.

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<sup>15</sup> Up till now, all paragraphs had a title but this one hasn't. I had a look at the 1823 edition in Google books and that didn't either.

<sup>16</sup> Because salts are now regarded as combinations of positive and negative ions and because sodium chloride and ammonium chloride both contain a chloride anion, we now call both of them 'chlorides'. However, the author regarded ammonium chloride as a combination of hydrochloric acid with ammonia and therefore called it 'ammonium hydrochlorate'. Sodium chloride, which contains no hydrogen, was just called a 'chloride'.