[p. 162] Chapter 5
Of Plant Humus

5.1 Research on the Composition of Humus

I mean by the term humus the black substance with which dead plants become covered when exposed to the combined effects of oxygen gas and water. The experiments that I reported in the preceding chapter tend to show that this substance is not the result of the combination of oxygen gas with the dead plant, but that it is the residue of the removal of some of the elements of this plant.

For most of my research, I used almost pure humus that was freed, by a fine sieve, of most of the undecomposed plants that are **[p. 163]** always mixed with it. This humus contained little but the mineral components that arose from the plants that produced it. I collected the humus from high rocks or from within tree trunks, where it could not have been modified by the foreign substances that are ordinarily introduced into the soil through livestock access, manures, and deposits by spring water. This humus seemed fertile to me, especially when mixed with a certain amount of sand or gravel, which serves as support for the roots and provides access to oxygen gas. I excepted, however, the humus that forms in the trunks of certain trees, such as oak. When the water has no outlet, the humus is rich with excess extractives, which block the vessels of the plants. These soluble constituents do not arise in this case entirely from the humus itself, but partly from the living tree, and thus are not suited to the nutrition of all plants.

The following operations provide an overview of the differences that may generally be seen between the composition of a humus and that of the plants from which it originates.

Distillation of Oak Wood [p. 164] 10.614 grams (200 grains) of dry oak wood, distilled at a heat up to red hot, in a luted glass retort, yielded 2,293 cubic centimeters (116 cubic inches) of methane, + 575 cubic centimeters (29 cubic inches) of carbon dioxide, + 4.25 grams (80 grains) of water holding in solution pyrolignate of ammonia with excess crude acetic acid [*de Saussure's term for crude acetic acid was "pyroligneous acid"*], + 589 milligrams (13 grains) of bituminous empyreumatic oil [*liquid oil obtained from the distillation of some organic substances*]. The charcoal remaining in the retort weighed 2.23 grams (42 grains). It contained 26 milligrams (1/2 grain) of ash.

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Distillation of Brown Humus of Oak Wood 10.614 grams (200 grains) of dry humus of oak wood, distilled as the previous wood was, yielded 2,456 cubic centimeters (124 cubic inches) of methane, + 673 cubic centimeters (34 cubic inches) of carbon dioxide gas, + 2.81 grams (53 grains) of water holding in solution pyrolignate of ammonia and carbonate of ammonia, + 530 milligrams (10 grains) of bituminous empyreumatic oil. The charcoal remaining in the retort weighed 3.13 grams (59 grains). It contained 424 milligrams (8 grains) of ash.

Distillation of Whole *Rhododendron ferrugineum* Plants [p. 165] 10.614 grams of dry plants, distilled at a heat up to red hot in a luted glass retort, yielded 1,982 cubic centimeters (100 cubic inches) of methane, + 634 cubic centimeters (32 cubic inches) of carbon dioxide gas, + 3.34 grams (63 grains) of water rich in pyrolignate of ammonia with excess crude acetic acid, + 1.7 grams (32 grains) of bituminous empyreumatic oil. The charcoal remaining in the retort weighed 2.813 grams (53 grains). It contained 159 milligrams (3 grains) of ash.

Distillation of Black Humus of the Above *Rhododendron* 10.614 grams (200 grains) of dry humus, distilled at a heat up to red hot, yielded 2,040 cubic centimeters (103 cubic inches) of methane, + 673 cubic centimeters (34 cubic inches) of carbon dioxide gas, + 3 grams (57 grains) of water rich in pyrolignate of ammonia and carbonate of ammonia, + 557 milligrams (11 grains) of bituminous empyreumatic oil. The charcoal residue of the distillation weighed 3.45 grams (65 grains). It contained 689 milligrams (13 grains) of ash.

Distillation of the humus of grass and spruce, **[p. 166]** and of these plants themselves, yielded products showing the same differences [*between plant and humus*]. It follows that undecomposed plants contain, at the same weight, more oxygen and less carbon than do their humuses. We do not know whether the carbon of these humuses is completely combined with their other constituents.

Nitrogen occurs in greater proportion in humus than in the undecomposed plant. This result is not surprising since plants that ferment in contact with air evolve almost no nitrogen gas. We cannot, however, attribute to this cause alone all the carbonate of ammonia that I obtained from the distillation of humus. It undoubtedly arises partly from the insects that live in the humus and that leave their remains in it.

The famous Klaproth obtained, by the distillation of peat, products[1] that undoubtedly contained very little nitrogen, since crude acetic acid was very abundant in it. But peat cannot be considered a true humus. It is the residue of plant decomposition **[p. 167]** occurring in stagnant water and partly without contact with air. In this case, the plants lose nitrogen in a gaseous form. Peat appears to contain less carbon than is found in a finished humus. In the table at the end of this chapter, compare the carbonizations of humus nos. 8, 15, and 19, with the carbonizations of peat nos. 32 and following.

Acids show no noteworthy effect when mixed with humus. They produce no effervescence; they do not completely dissolve the humus; and they take up some of the iron and earthy substances that the humus contains, but very little of the

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[1] *Beiträge zur Chemischen Kenntniss*. Vol. 3.

plant component. Concentrated hydrochloric and sulfuric acids reduce the plant component to charcoal with the aid of heat, and they disengage acetic acid from it, according to the comment of Vauquelin.

Alcohol does not dissolve humus. It usually separates from the humus a small amount of extractive substances and resin, equivalent at most to two or three hundredths of the weight of the humus.

Potash and soda dissolve humus almost completely. The humus releases ammonia through their effects. This solution is decomposed by acids. **[p. 168]** They precipitate from it a combustible, brown powder, which is not abundant compared with the weight of the humus devoted to the operation.

5.2 Extractive Substances of Humus

Humus is essentially insoluble in water. This liquid separates from it extractive substances that are not the humus itself. Via the following experiments, I will give an overview of the amount of extract taken up by pure water that falls on a fertile soil.

I filled a large vessel with nearly pure grass humus and watered it with distilled or rain water until it could absorb no more. After 5 days, it was subjected to the action of a press. Ten thousand parts, by weight, of expressed and filtered fluid yielded, on evaporation to dryness, a dry extract weighing 26 parts.

I performed the same experiment, for the same length of time, on the heavy soil of a vegetable garden that had been amended with manure. Ten thousand parts, by weight, of expressed water yielded a dry extract weighing 10 parts.

[p. 169] The same experiment, repeated under identical conditions on the light soil of a field that bore a fine harvest of wheat [*"blé"*], yielded, from 10,000 parts of water, 4 parts of extract.

The humuses were dry before the experiment, and the water used to moisten them contained no carbon dioxide. But that was no longer the case when the water was withdrawn. It then clouded limewater with calcareous carbonate, although not much more than ordinary spring water does. One hundred cubic inches of water from the humus, expressed into a retort in which I boiled the water immediately after expression, yielded an air containing at most 2 cubic inches of carbon dioxide gas. This determination may not be very precise, but other observations indicate that the amount of carbon dioxide that roots draw from common soil is not substantial.

When the entire upper part of a green plant rooted in humus is put into a globe, and the neck of this vessel is carefully closed at the origin of the stem, one may see a small improvement in the air of the flask only after several days or even several weeks, **[p. 170]** although a very large volume of water is given off by the leaves.

The amount of extract that boiling water can separate from humuses that are pure, natural,[2] and formed in the countryside is not considerable. I subjected such humuses

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[2] I mean by these terms a humus that leaves only a small amount of ash after it is burned, or no more than a tenth of its weight. I also assume that the humus was not amended with manure, or formed by an artificial accumulation of plants that died at the same time.

to twelve successive decoctions, each lasting a half-hour, with an amount of water weighing more than twenty-four times the weight of the humus. The amount of extract that I could collect by all these operations was no more than an eleventh of the weight of the humus, and often much less. It seemed to me that a pure humus that yielded, by the twelve decoctions I mentioned, an amount of extract equal to an eleventh of its weight, was, under the same conditions, less fertile for favas and peas than the same humus containing only a half or two-thirds of that amount.

[p. 171] If the amount of extract that a humus should contain in order to support a good crop must not be too large, it also must not be too small. I subjected an almost pure humus to twelve successive decoctions, with renewal of the water. In two garden pots full of the humus, I sowed seeds of fava, pea, and barley, and sprinkled them with rainwater, comparable in purity to distilled water. Other, similar seeds were sown at the same time in two pots like the preceding ones, and filled with the same humus, except that this humus had not been depleted of its extract. The plants in both experiments bore fertile seeds, but the weight of these plants and their seeds was one-quarter greater in the humus provided with its extract than in the exhausted humus. The action of decoction, however, had not changed the external characteristics of the exhausted humus. It could not be distinguished, by sight or feel, from the humus that still contained its extract. It seemed to me only that the exhausted humus was able to retain or imbibe more water.

One hundred parts of humus, dry and depleted of **[p. 172]** most of its soluble matter, were able to hold 477 parts of water.

Dry, unwashed humus could hold at most 400 parts.

Humus, like wood, cannot be entirely freed of its extractive substances by water, at least detectably and in contact with air. The first macerations or decoctions remove more extract than do the following ones, but soon a point is reached at which it yields an amount that is constant or no longer decreases appreciably. If the moistened humus, after it has reached this maximal exhaustion, is exposed for a long time to the effects of external air, it changes in such a way that it can produce more extract than it did by the preceding decoction. Ten thousand parts of dry, black humus of *Rhododendron ferrugineum*, which yielded by combustion 65 parts of ash, were boiled with twenty-four times their weight of distilled water. This decoction, after filtering, yielded an extract weighing 250 parts. The extract of the 9th decoction weighed 40 parts. The 10th and 11th decoctions each separately provided a similar amount. Humus exhausted to this degree, and moistened, was exposed **[p. 173]** to the effects of air, but protected from dust, for 3 months. After this period, it was subjected to a 12th decoction similar to the preceding, and it yielded an extract weighing 58 parts. Maceration in cold water produces similar effects. These macerations, if conducted for a long time and repeated more than 50 times, on the same humus already exhausted by decoction, always produced, at least in contact with air, infusions stained by a highly soluble extract.

Humus that has been partially freed of its extractive substances by decoction yields, at distillation, very nearly the same products as unexhausted humus, but the amount of charcoal residue from this operation is a little greater in the partly exhausted humus. One hundred parts of partly exhausted humus yielded 33-1/4 parts of charcoal, containing 5-1/4 parts of ash. One hundred parts of the same humus, provided with its extract, yielded, by the same operation, 31 parts [*de Saussure wrote "grains" but clearly meant "parts"*] of charcoal, containing 6-1/2 parts of ash.[3] This increase in the proportion of carbon in the humus is confined within very narrow limits. **[p. 174]** When I subjected this same humus, exhausted by several successive decoctions, to new decoctions, I could not continue to increase the proportion of carbon, although I removed a large amount of extract by these operations.

Humus extract is not deliquescent. It yields carbonate of ammonia at distillation. The aqueous solution of this extract, which is close to syrup in consistency, is neither alkaline nor acid. It has a sweet taste; precipitates in air; and is clouded after a few moments by limewater, carbonate of potash, and most metallic solutions. When mixed with alcohol, the alcohol dissolves a small part of it and separates another that is insoluble. The substance soluble in alcohol is very deliquescent.[4] [*Footnote 4, which appears at the bottom of p. 174, is not cited in text; it seems to belong here.*] The extract produced by the first macerations of humus in water contains, at equal weight, a greater proportion of the deliquescent substance than does the extract produced by the subsequent macerations.

5.3 Of the Salts Contained in Humus [p. 175]

Reagents do not usually reveal, if simply mixed with the infusion of a natural humus that formed in the countryside, significant amounts of potash, chlorides [*called "muriates" by de Saussure*], or alkaline sulfates, if the substratum on which the humus rests has added none. Most of the alkaline salts contained in plants manifest themselves only in the residue of their combustion. It is the same for the salts contained in humus.

Some writers have believed that plants themselves create the salts that they contain, because the ash of most naturally occurring humus does not lose salts to boiling water. This conclusion is undoubtedly premature. All the humus that I examined contained alkaline salts, although the ash of the humus was often resistant to water. But these salts were retained in the ash by semi-vitrification with the earthy substances, if the latter were very abundant. One hundred parts of grass humus yielded, **[p. 176]** by combustion, 50 parts of sand or ash that did not lose saline substances to boiling water. But 100 parts of dry extract of this same humus yielded 14 parts of ash, and 100 parts of this ash formed, with boiling water, a lye containing 25 parts of salts composed of free potash, chlorides, and alkaline sulfates. Further analysis showed me that the water had extracted only half of the salts contained in this same ash.

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[3] For the procedures used in these carbonizations, see the note at the end of this chapter.

[4] I do not know whether this deliquescent extractive substance is enclosed by the nondeliquescent substance, which is superabundant, such that the deliquescent substance is prevented from drawing humidity from the air, or whether the alcohol brings about a new combination in the extractive substances.

One hundred parts of *Rhododendron* humus contained 6-1/2 parts of ash. One hundred parts of this ash lost to water only 1/2 part of alkaline salts. But 100 parts of the ash of the extract of this same humus released to water one-third of its weight of alkaline salts, and this liquid was far from extracting the salts completely.

I did the same experiments on six other, very different, kinds of humus. They all provided me similar results.

5.4 Of Changes that Oxygen Gas Undergoes by its Contact with Humus [p. 177]

Humus is the residue of a putrefied substance but is itself no longer subject to putrefaction. It may even be considered an antiseptic, for the extractive substances that it contains are likely to proceed to putrid fermentation if they are isolated, but not if they remain united with the humus. For 1 year, I kept pure, unexhausted humuses in receptacles full of water and closed by mercury. They did not emit any gas, except perhaps for the small amount of carbon dioxide with which the water covering them became charged.

There is no doubt that humus, except for its saline and earthy constituents, is entirely destructible through the combined effects of air and water. Without recourse to detailed research to prove it, I can do no better than to transcribe here the observations of my father (*Voyages dans les Alpes*, § 1319) on the plant mold that covers the plains between Turin and Milan and **[p. 178]** whose cultivation dates back to remote antiquity.

> The thin layer of topsoil seen in these plains seems to me also to show that the amount of this soil cannot be regarded as a measure of the time that has elapsed since the land began to produce crops, for in this space of 10 leagues between Turin and Saint-Germano, I nowhere saw a layer as thick as a foot. Now in my opinion the shallowness of this layer shows that this soil is subject to a decomposition that sets a limit on its increase, for otherwise, why would a flat land, fertile and cultivated for more than 3,000 years, not have a thicker layer? This destructibility of the topsoil is a fact beyond exception, and farmers who have wished to replace manures by too-frequent plowing have had a sad experience. They have seen their soil gradually impoverished and their fields become barren by the destruction of the topsoil. Thus, since this soil is destructible, the amount destroyed must be, **[p. 179]** up to a certain point, proportional to its absolute amount, and as, on the other hand, only a limited amount is produced annually, its increase must necessarily have certain limits.
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> The limits of this increase must vary according to the climate; the nature and location of the substrate that serves as a base for the topsoil; the plants that grow there; the kind of cultivation they are given; and, finally, the fertility of the land. But even if all the forces that tend to increase the thickness of this soil layer were conjoined, this layer undoubtedly would finally reach a certain maximum beyond which the destructive forces, having become equal to the constructive forces, would allow no further increase.

Pure humus, imbibed with distilled water and enclosed under receptacles filled with atmospheric air or oxygen gas confined by mercury, formed carbon dioxide gas there, in causing oxygen gas to disappear. But the humus was never able to decrease the volume of this atmosphere by an amount greater than the volume of the water used to moisten it, whatever the amount of humus and **[p. 180]** the duration of the experiment, which was sometimes prolonged to more than a year. When this water was impregnated with carbon dioxide beforehand, the humus did not change the volume of its atmosphere. The oxygen gas consumed reappeared, in an exactly equal amount, in the carbon dioxide gas produced, and the humus released neither hydrogen gas nor nitrogen gas.

It is evident from these experiments that humus neither fixes nor assimilates atmospheric oxygen gas. The effect of the oxygen gas is limited strictly to removing carbon from the humus.

For the results given above to be obtained, the humus must not be rich in iron or clay deposits. Incompletely oxidized iron contained in these deposits combines effectively with oxygen gas, but this effect is not produced by humus or by pure earths, or even appreciably by iron and manganese that are combined with the plant part of the humus and that are revealed there by incineration.

Oxygen gas removes more carbon from humus that retains its extractive substances than from humus that is **[p. 181]** depleted of them by decoctions. The latter, at equal weight, formed half as much carbon dioxide gas with atmospheric oxygen gas as did the same, but unexhausted, humus.

Moistened humus, contained in vessels that do not allow its extractive substances to escape, loses, if considered in the dry state, some of its weight through contact with oxygen gas, and this loss is greater than the weight of the carbon that is removed by this gas. In a glass capsule, I mixed 30.57 grams (1 ounce) of *Rhododendron* humus, dried[5] in the shade at a set reading of the thermometer and hygrometer, with water until it could imbibe no more. I put this capsule under a large receptacle full of atmospheric air. This air was renewed several times and examined eudiometrically each time. The experiment lasted 4 months. The humus passed 3 of them under a receptacle, and 1 drying in the shade in open air to the same degree as it had been before being mixed with water. I then found that its weight **[p. 182]** had decreased by 849 milligrams (16 grains). During its confinement under the receptacle, it had removed 476 cubic centimeters (24 cubic inches) of oxygen gas and replaced them by the same volume of carbon dioxide. Thus, during the entire experiment, it had formed about 32 cubic inches of carbon dioxide gas, assuming that the production of carbon dioxide was the same during confinement and during drying.[6] Now, as 32 cubic inches of carbon dioxide contain, according to Lavoisier, 6 grains of carbon, the humus must have lost, besides this element, an amount of oxygen and hydrogen represented by 10 grains of water.

The proportion of carbon increases by the removal of water from the residue of plants that are being reduced to humus, but I believe that carbon is not increased by

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[5] For a long time this humus was completely dry to the touch, but although it was not deliquescent, its weight varied with the readings of the thermometer and hygrometer.

[6] Humus probably forms less carbon dioxide, other things being equal, under a receptacle than in open air. But as it has almost no effect on oxygen gas during the last stages of desiccation, which takes a long time, I believe that the amount of carbon dioxide that I attribute to drying is in excess rather than default.

this process in a finished humus. A finished humus must lose, due to the effects of **[p. 183]** air and water, its oxygen, hydrogen, and carbon in very nearly the same proportion. If it lost its oxygen and hydrogen in greater proportion than its carbon, we would often find, in a soil long denuded of vegetation, residues of nearly pure carbon or of charcoal. But we do not find this. They all yield, by distillation, products of which carbon makes up half, at most.

Carbon is a very powerful antiseptic, and the state in which it occurs in humus seems suited, in part, to give it this property. I filled several equivalent vessels with various kinds of humus, pure or almost pure. In each of them, I placed the same amount of beef flesh. The same experiment was done, under conditions otherwise the same, with sawdusts of the woods from which these humuses had arisen; with pure charcoal; with carcareous sand; with siliceous sand; with clayey sand; and in the open air. The flesh stayed fresh a little longer, without deteriorating, with the charcoal than with the humus, but much longer with the humus than with the sawdusts or with the various sands, or in the open air. It is partly **[p. 184]** because of this antiseptic property of humus that, for maintaining plant growth, there is a big difference between nourishing plants with extractive solutions, isolated and not renewed, and supplying them with humus. The insoluble part of the humus prevents the undecomposed plant substances from furnishing plants with fermenting juices that are always harmful to growth.

5.5 Summary

Carbon occurs in greater proportion in humus than in the plants from which the humus arises. The proportion of carbon that a humus contains, however, does not seem able to be increased significantly by the continued action of the causes that formed it.

Humus that is moistened, but considered in the dry state, loses weight at room temperature through contact with oxygen gas. Oxygen is not fixed in the humus, and does not unite with the hydrogen of the humus to form water. The oxygen gas removes only carbon from the humus. The humus, in losing this element, loses at the same time, in the form of water, its oxygen and its hydrogen, and an extract soluble in this liquid. **[p. 185]** Humus thus appears to be completely destructible at room temperature, by the joint action of oxygen gas and washings.

The extractive juices of humus contribute to a certain extent to its fertility: Their ash contains all the substances of plant ash.

Pure humus is antiseptic.

5.6 Note on the Carbonization of Various Plant Substances

When a plant or a substance derived from it [*a "proximate constituent"*] is distilled in a luted glass retort, the degree of fire that the retort can withstand without melting is often insufficient to expel all the hydrogen that remains combined with the charcoal and that could be disengaged at a higher heat. This procedure would not, however, be inexact for estimating the relative amounts of charcoal contained in non-volatile plant substances, if the various charcoals all retained the same proportion of hydrogen at the highest degree of fire that the retort can withstand. **[p. 186]** But it is not so. Plant substances such as certain seeds, that are dense and capable of softening through the effects of fire, retain a larger proportion of hydrogen than do those that are less dense and do not soften, as most woods.

In the results that I am going to give, the degree of fire used for carbonization was higher than that which melts silver, and, as the weight of the various charcoals did not change when they were subjected to a higher temperature, I have reason to think that they are comparable among themselves. I was consistent in the way I managed the fire and in the time taken to bring it to the highest level.

To carry out these carbonizations, I wrap the dry plant material in paper and form it into a compact ball that is introduced into a cylindrical iron box, or a gun barrel that is closed on one side and open on the other. It is 9 centimeters high and 4 centimeters wide. I lay a small iron disk, with a vertical handle, on the ball. This handle is used to remove the disk. The disk fits the inside diameter of the cylinder precisely. This plate is luted into this position with clay. **[p. 187]** It is covered with a layer of charcoal dust, and a second layer, of ash.

After the operation, I weigh the charred ball without defoming it, while it is hot, and I subtract the weight of the charred paper, which is known from an earlier operation.

The precautions taken in collecting, drying, and incinerating the plants are the same as those indicated in Chap. 9.

In some cases, the relative amounts of charcoal produced by different substances can be judged only by supposing them free of ash. It is this result that is entered in the fifth column of the table of carbonizations. I will give an example: 100 parts by weight of humus of spruce leaves (no. 19) produced 28 parts of ash; 100 parts of the same humus produced 52-1/2 parts of charcoal provided with ash. By subtracting the ash from the humus and from the charcoal, and setting up the proportion $100 - 28 : 52.5 - 28 = 100 : x$, I find that 100 parts of this humus devoid of ash would have yielded 34 parts of charcoal [*i.e.,* $100 - 28 = 72$; $52.5 - 28 = 24.5$; $72 : 24.5 = 100 : x$; *therefore* $x = 34$] (Table 5.1).

Table 5.1 Table of Carbonizations [**pp. 188–192**]

Carbonization No.	Name of substance	Weight of charcoal supplied by 100 parts of dry substance	Weight of ash contained in 100 parts of dry substance	Weight of charcoal supplied by 100 parts of dry substance, excluding ash
1	Wood of oak (*Quercus robur*) separated from the sapwood	19.75	0.2	19.69
2	Sapwood of the preceding wood	17.5	0.4	17.16
3	Wood and sapwood of the preceding oak, freed of their extract by repeated decoctions	16.75	0.2	16.54
4	Bark of the trunk of the preceding oak	26	5	22.1
5	Phloem of the preceding bark	24.8	6.2	19.82
6	Bark of oak branches 1 centimeter (5–6 lines) in diameter	26.6	6	21.92
7	Debarked oak branches 1 centimeter (5–6 lines) in diameter	17	0.4	16.66
8	Brown humus of oak wood	28.5	4	25.44
9	Oak wood that had become white due to decay without air contact	20	6.8	14.1
10	Oak leaves collected in May	30	5.3	26.1
11	Oak leaves collected in Sept.	26	5.5	21.69
12	Levant gall-nuts	30	2	28.57
13	Cork	22	0.87	21.31
14	Entire *Rhododendron ferrugineum* plants	23.5	1.6	22.5
15	Black humus formed by the preceding plant	31	6.5	26.2
16	Same humus stripped of its extract by repeated decoctions	33.25	5.25	28.58
17	Debarked wood of spruce (*Pinus abies*)	20	0.34 (according to Kirwan)	19.72
18	Leaves of the preceding spruce	24.5	3	22.16
19	Humus formed by leaves of the preceding spruce	52.5	28	34
20	Wood of mulberry (*Morus nigra*) separated from the sapwood	23.25	0.7	22.7
21	Sapwood of the preceding wood	17.25	1.3	16
22	Bark of the preceding tree	25	8.9	17.68
23	Phloem of the preceding bark	18.1	8.8	10.19

Table 5.1 (continued)

24	Debarked branches of hazel (*Corylus avellana*); they were 1 centimeter (5 lines) in diameter	16.5	0.5	16.08
25	Barks of the preceding branches	25.6	6.2	20.68
26	Leaves of the preceding hazel, collected in May	29.25	5.8	24.9
27	The same, collected in June	29.5	6.2	24.84
28	The same, collected in Sept.	28	7	22.58
29	Wood of hornbeam (*Carpinus betulus*)	17.75	0.6	17.25
30	Sapwood of the preceding wood	17.5	0.7	16.92. In this tree, the sapwood was very indistinct from the wood
31	Bark of the preceding tree	30.5	13.5	19.74
32	Peat analyzed by Klaproth	38.75	18.5	23.62. This carbonization, done in a glass retort, could not be completed
33	Holland peat	34.25	21.3	16.45
34	Wheat plants collected May 1, a month before flowering	25	7.9	18.56
35	The same, in flower, June 14	25	5.4	20.71
36	The same, bearing mature seeds, July 22	26.6	3.3	19.95
37	Straw of the preceding plants, separated from the seeds	23.6	4.3	20.13
38	Seeds of the preceding plants	20.5	1.3	19.45
39	Wheat flour	19.5	0.82	18.83
40	Bran	23.25	5.2	19.04
41	Starch	10.75	0.16	10.6
42	Gluten	22.75	1.25	21.77
43	Gum arabic	17.75	2.5	15.64
44	Gum tragacanth	16.75	2	15.05
45	Crystallized sugar	18.5	0.1	18.41
46	Unsized white paper	11	0.88	10.2
47	Holland linen washed several times	14	3	11.34

[p. 193] Green plant parts appear to differ from the other parts in having a larger proportion of carbon.

The proportion of carbon in the green parts decreases in autumn. They then deplete themselves of their glutinous and extractive juices. These substances are very rich in carbon, since, as we see, washed wood, linen, and paper contain only a very small proportion of this element.

The wood contains more carbon than does the sapwood.

Bark usually contains more carbon than does the wood or sapwood. This result is not consistent among all trees because the bark is not a homogeneous substance. Its epidermis alone is carbonized by contact with air. The phloem and the inner parts of the cork are not often changed by this cause, and the proportion of their carbon varies in different plants, according to circumstances that it is impossible for us to appreciate.