THE BASES FOR THE SYSTEMATIC DETERMINATION OF SPECIES IN THE GENUS RUSSULA.

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I. *Diversity of opinion amongst authors on the subject of the Russulae. The causes of this diversity, and consequent necessity for a methodical description of the species in this genus.*

The imperfect knowledge of the species of Russulae is due to the divergent descriptions of the writers on this subject, and this applies equally to the study of the majority of the fleshy fungi, but more especially so to this genus. First the old authors give insufficient descriptions of the species and many modern authors are no better in this respect. It is difficult and impossible to preserve their macroscopic characters by either drying them or immersing them in antiseptic fluids. It is also very difficult to describe correctly or illustrate with sufficient preciseness the fine distinctions observed by the author in a way that will convey his impressions to the reader. The microscopic details, too, are insufficient and would have given us, in many cases, some important characters, if they had been more carefully made. Secondly, the most important cause is the extraordinary uniformity of shape, structure and variations of colour which characterize the genus Russulae. This is so great that it is almost impossible even for a specialist to identify a species in the field, though a careful examination in the laboratory would easily enable him to do so. It is also very difficult to send useful specimens to correspondents because they are often attacked by maggots and after the lapse of a few hours become transformed into a shapeless, putrid mass. In consequence of all these unfavourable conditions and especially the omission by most authors of certain characters (such as the exact tint of the spores, taste, microscopic details, &c.) the systematic mycological works are incumbered with descriptions that do not agree with each other and with figures that cannot be identified. The same species is also described under many different names and one and the same name is given to very distinct species by the various authors. It cannot, however, be denied but that the study of the Russulae has made some progress in the last years of the nineteenth century. The eminent English mycologist

REA told us at Baslow during the session of the *British Myco-logical Society*, " I recognize pretty often the species described by modern authors but rarely those badly defined by the old authors." We think that opinion is quite accurate and we trust that the present time will realize the saying of Fries* " *Pleniorem dabit lucem futura aetas.*"

In order to accelerate this progress towards the light we must try, first, to make the descriptions comparable; secondly, to find specific characters that can be easily defined; and, thirdly, to record characters as much as possible that are capable of observation in dried specimens, so that it may be possible to control a determination made with the help of a description and of a drawing by comparing it with the type specimen. I have studied the Russulae deeply for some years and I can now for-mulate a method for the systematic study of the species of this genus. I make use of all the characters hitherto employed and I have added new ones. The application of this method to all the species that I could obtain either during my mycological excursions in France, Sweden and England, or by the assist-ance of obliging correspondents† enables me to control the value of the different characters that I have used so that I could in many cases satisfy the above desiderata. Before the publication of a Monograph on the European Russulae which I have under-taken I thought it would be useful to give to mycologists an exposition of my system with some examples of its application. I do not propose to give an exhaustive list of all the characters which can be used in the description of the Russulae. The future will certainly add new ones, especially microchemical ones, which will enable us to determine more easily the distinc-tive characters. I think, however, in the actual state of our knowledge that it is already possible having regard to these characters, which I will explain further on, to establish some reliable posts in the quicksands of the Russulae and to define certain types which can be recognized without being obliged to resort to tradition.

II. Outlines of my methods for the systematic study of the Russulae.—Critical study of the characters.

My method for the systematic study of the Russulae requires three series of observations: First, their macroscopic characters; secondly, their microscopic characters; and thirdly, their chemi-cal reactions. My method is therefore divided into these three parts.

A. THE MACROSCOPIC EXAMINATION OF THE RUSSULAE.

If we examine a Russula with the naked eye or with a pocket lens we are able to study : first its general appearance, secondly the characters of the stem, thirdly the characters of the pileus, and fourthly the characters of the gill. Before passing to these characters in detail we must remember that a Russula is only an organ of fructification, a *carpophore*, and therefore that it would be well to study its mycelium also. But this study, both macroscopic and microscopic, is very difficult and up to the present has not yielded any useful results. Cultures in artificial media will perhaps furnish in the future interesting characters. I shall content myself now with a study of the carpophore.

1. GENERAL CHARACTERS OF THE CARPOPHORE.

The general characters of the carpophore are its size, consistency, taste, smell, the general colour of the flesh and its change of colour, and the colour of the spores *in mass* (*Sporenpulver* of the Germans).

Size. This is measured by the diameter of the pileus, it is often variable and should not be neglected, but it must be used with caution. There are some species which are normally very large, although occasionally some smaller specimens are found, and I cite as examples *R. alutacea* Fr. where the pileus attains 20 cm. in diameter and rarely descends to 8 cm., *R. foetens* Fr., *R. cyanoxantha* Fr., &c. Others on the contrary are generally of small size and thin, and it is only rarely that one meets with some larger specimens. I cite as examples *R. chamaeleontina* Fr., which rarely exceeds 6 cm. in diameter, *R. nauseosa* Fr., *R. Turci* Bres., *R. lutea* Fr., &c. Between these two extreme types we find a middle one as exemplified in *R. heterophylla* Fr., *R. fellea* Fr., *R. emetica* Fr., *R. drimeia* Cke., *R. Queletii* Fr. &c. It is therefore advisable to indicate as far as possible the maximum and minimum dimensions of the pileus, and when these are aberrant to indicate the normal one. It is sufficient in the field to designate them as large, medium sized or small, because it is a point of not much importance.

Consistency. This is almost always the same. Firm and close in texture in young specimens becoming more or less loose and fragile in mature specimens. It has, however, some differences rather quantitative than qualitative that are very marked in some species. These characters were used by FRIES in conjunction with other characters for establishing his sections of this genus the *Compactae, Rigidae, Firmae* and *Fragiles*, and I cite as characteristic examples of the *Compactae R. delica* Fr., *R. nigricans* Fr. which remain hard and firm until old age, *R. chamaeleontina* Fr., *R. lutea* Fr. and some neighbour-

ing species which are on the contrary soon loose and fragile, *R. subfoetens* Sm. quite firm and elastic, *R. lepida* Fr. and *R. virescens* Fr. firm until quite old. In *R. cyanoxantha* Fr. the pileus is slightly elastic and the gills are both elastic and oily " lardacée "* Forquignon. The consistency is generally pretty constant in one and the same species but sometimes it varies in some specimens: thus certain forms of *R. melliolens* Quél. are firm and close in texture, whilst others of the same age are much more fragile and loose in texture. On the other hand consistency is a character difficult to define clearly and precisely, it may be used for the identification of a species well known, but one cannot rely on it alone for determination.

Taste. The taste is an important character that should always be noticed amongst the fungi and especially in the Russulae. It is either mild, bitter or acrid. The acridity of the Russulae seems to be due to the presence in more or less quantities of certain resinous bodies in the tissues which are not well known and seem to be confined to the lacticiferous vessels and cystidia. These bodies are unstable and change or decompose easily either by the action of heat or oxydation. Thus the most acrid Russulae lose their pungency when either cooked or dried or ground up in a mortar and treated with hydrogen peroxyde ($H_2 O_2$).† The acridity is perceived either almost immediately or slowly, it is more or less intense in different species. In addition to the characteristic tingling or burning of the tongue there is sometimes added a sensation of constriction in the region of the pharynx. I will now give some differences in their acridity. In *Russula grisea* Bres. the acridity is very slight and is confined to the young gills; *R. aeruginea Lindbl.* is a little more acrid and the acridity is not confined to the gills but is also perceptible in the flesh of young specimens. *R. fragilis* Fr. is distinctly acrid in all its stages but the acridity is not very persistent. *R. drimeia* Cke., and especially *R. emetica* Fr. and *R. sardonia* Bres. (non Fr.) have an intolerable and persistent acridity and the two last species particularly cause a constriction of the pharynx. In *R. fragilis* Fr. and *R. drimeia* Cke. the acridity is immediately perceived, whilst in *R. maculata* Quél. and *R. sardonia* Bres. (non Fr.) it is only felt after the lapse of some little time. In all the species the acridity diminishes with age until it entirely disappears in those species where it is only slight as in *R. grisea* Bres., *R. aeruginea* Lindbl., *R. decolorans* Fr., *R. atropurpurea* Krombh., *R. paludosa* Britz., &c. The acridity attains its maximum of intensity most often in the gills.

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*From lard (=bacon).

† The consequence of grinding up was first noticed by BOUDIER in the case of *R. fragilis* Fr. and I have verified it with that species and also with *R. sanguinea* Fr.

The mild taste, which is very frequent and common in all those species that are generally eaten, has sometimes an agreeable smell and the gills of *R. heterophylla* Fr. often have a distinct savour of walnut. The bitterness is much rarer and the bodies that produce it are still quite unknown. It distinctly characterizes *R. lepida* Fr. var. *amara* Maire. Some species have a mild taste at first and then become slightly bitter or sharp and somewhat astringent; such are *R. lepida* Fr. and especially *R. pseudo-integra* Arn. & Goris. PERSOON and FRIES considered that the taste was a very variable character, whereas ROMELL on the contrary maintains that it is a very constant one. The truth lies between these two opinons. Amongst the majority of species the taste is certainly remarkably constant. I have never found specimens of *R. virescens* Fr., *cyanoxantha* Fr., *punctata* Gill. and *xerampelina* Fr. that were not mild; and further I have never noticed the acridity absent in *R. drimeia* Cke., *emetica* Fr., *fragilis* Fr., *fellea* Fr., &c. But in some species otherwise well characterized the taste is evidently variable. Here are some examples. COOKE (1888) noticed that *R. atropurpurea* Krombh. is sometimes mild but more often acrid, and I have confirmed him as to this. *R. melliolens* Quél., a species quite mild, has a very rare variety *R. melliolens* Quél. var. *Chrismantiae* Maire which possesses all the characters of the type, especially the characteristic spores, and it differs only in the decidedly acrid taste of the mature plant. Again *R. lepida* Fr. is at first mild then slightly biting and has a variety intensely bitter and somewhat different in colour, *R. lepida* Fr. var. *amara* Maire. *R. paludosa* Britz. is mild in all its stages in the Vosges but is distinctly acrid when young in Sweden; *R. grisea* Bres. is generally a little acrid in the gills but sometimes it is entirely mild.

Smell. Smell is a character very difficult to define and like consistency is more useful for the recognition of a species than for its first determination. Very often it is possible to define a smell only by a more or less close comparison with some odorous substance, for it is but very rarely that the odour is produced by a definite chemical compound that can serve as a standard. Every mycologist, however inexperienced, can call to mind the odours given out by the fungi that they have studied, and easily recognise them. Most authors have however paid little attention to the smell of the Russulae and only a few like QUELET, ROMELL, &c., have accorded to them the importance that they deserve. In the majority of the Russulae the smell is faint and of no account; but in others on the contrary, it is very characteristic. Thus *R. melliolens* Quél. when it begins to dry or rot acquires a strong smell of honey or gingerbread, and this is why it is so named. This

smell persists for many weeks in dried specimens. Some other Russulae, especially *R. flava* Romell, have the same smell but not so intense and constant. *R. Turci* Bres., *R. punctata* Gill. and *R. foetens* Fr., have each a distinctive smell more or less intense in different specimens, hard to define but easily recognisable when one is acquainted with it. *R. maculata* Quél. has a smell closely resembling that of *Rosa rubiginosa* L.; *R. fragilis* Fr., *R sardonia* Bres. and *R. emetica* Fr. have all the same indefinable aromatic smell but easily recognisable. *R. xerampelina* Fr. (= *R. graveolens* Romell. = *R. vesca* Massee) has a characteristic smell, like that of the common crab, but this is only apparent in old specimens or when they have been cooked. *R. lepida* Fr. has when cooked a peculiar nitrous smell, due to a body that permeates the organism without becoming decomposed, the odour of this body is also found in the urine after eating this Russula. The smell is not always constant : COOKE has pointed out that *R. foetens* Fr., which is generally characterized by a very strong and distinct smell, can sometimes be found without any.

General colour of the flesh and its change of colour. The flesh of the Russulae is usually white. However in *R. aurata* Fr. and *R. drimeia* Cke. it is very often coloured citrine-yellow, in *R. ravida* Fr. bluish grey, and in *R. ochracea* Fr. ochre. A certain number of species moreover are distinguished by the characteristic change in colour of their flesh. On exposure to the air after a wound the flesh of *R. nigricans* Fr. and *R. densifolia* Gill. quickly turns red and then finally black; that of *R. adusta* Fr. changes directly to black under the same conditions. This blackening has been studied in its chemical aspect by BERTRAND (1896). This author has stated that it was due to an oxydizing enzyme, tyrosinase, which reacts in the presence of the oxygen of the atmosphere on the tyrosine contained in the cell sap of the fungus. *R. decolorans* Fr., *obscura* Romell and *flava* Romell become black more or less completely and rapidly on exposure to the air. *R. sardonia* Bres. (non Fr.) (= *R. luteotacta* Rea) turns yellow especially in the gills when wounded or dried up. This turning yellow however is not constant and is sometimes absent. A similar though less intense change to yellow is often observed in the gills of *R. sanguinea* Fr. var. *pseudorosacea* Maire. The flesh of *R. xerampelina* Fr. is spotted with brown more or less rapidly on exposure to the air and becomes entirely brown when cooked or dried and this last factor makes it easily recognisable in the herbarium. A rusty-brown colour can be observed on the gills of old specimens in many species but this browning is generally confined to more or less numerous and extensive spots; and it is moreover inconstant (*R. heterophylla* Fr. and *R. aeruginea* Lindbl.). In *R.*

melliolens Quél. this change to brown is constant and becomes general in old age.

Colour of the spores in mass. This character is *very import-ant and very constant,* but it is necessary that it should be observed in a careful manner, which few authors have done, except ROMELL and BRITZELMAYR. *The study of the colour of the spores seen with the aid of the micro-scope cannot in any way replace that of their exact tint when they are viewed in mass.* This ought to be deter-mined by *obtaining a deposit of the spores in sufficient quantity on white paper.* It is therefore necessary to try and obtain a deposit of the spores of all the Russulae studied, and if any-body sends a Russula to a correspondent they should enclose such a deposit as it is often very difficult to obtain one after it has travelled. Deposits on a slip of glass are useless because the reflection prevents the appreciation of pale tints ; neither should the deposits be obtained on black paper, so useful in many other cases, as the pale tints readily appear white. Further the *spore deposit should not be fixed to the paper by gum or varnish* according to HERPELL'S (1880) method, because these agents materially alter the tint of the spores. We must then be content, when we wish to send or preserve a spore deposit, to fold up the paper in a manner that will protect it. The spore deposit (map) thus obtained will last for some weeks or months but changes tint with age and becomes deeper in colour; their shade of colour ought then to be studied when quite fresh and in daylight. By working in the way indicated we find that certain Russulae, few in number, have pure white spores. Others, much more numerous, have more or less coloured spores vary-ing from very pale whitish cream to deep yellow ochre. The principal shades of colour may be approximately referred to the tints *stramineus, cremeus, ochroleucus* and *ochraceus* of Saccardo's Chromotaxia.* The following examples will readily show the utility of noting the spore colour of the Russulae, *R. violacea* Quél. so akin to *R. fragilis* Fr. and especially to *R. fallax* Cke. is easily distinguished by the whitish yellow *(stramineus)* spores, whilst the others have pure white spores. *R. alutacea* Fr. is easily distinguished from *R. xerampelina* Fr. by its yellow ochraceous *(ochraceus)* spores, whilst those of *R. xerampelina* Fr. are much lighter in colour *(ochroleucus).* I append here a list drawn up from my notes in alphabetical sequence of the species with purely white spores (Leucosporae) and of those with more or less coloured spores (Xanthosporae).

*The two copies of this work that I can consult contain very great differences in the shades of colour. The first edition appeared in 1891 and the second edition in 1894. The tints quoted above are for *stramineus* and *ochraceus* from the second edition ; those for *cremeus* and *ochroleucus* from the first edition.

We notice that many species which the authors thought possessed white spores in reality have yellow spores. I have omitted from this list those species which I have been unable to study myself when fresh.

RUSSULAE LEUCOSPORAE.

R. adusta Fr., *atropurpurea* Krombh., *azurea* Bres., *carnicolor* Bres., *cyanoxantha* Fr., *delica* Fr., *densifolia* Gill., *depallens* R. Fr. (an E. Fr.?), *emetica* Fr., *fallax* Cke. (an Fr.?), *fragilis* Fr., *heterophylla* Fr. (incl. *vesca* Fr. sensu Bres. et Romell), *lilacea* Quél., *nigricans* Fr., *sardonia* Bres. non Fr., *subfoetens* Sm.

RUSSULAE XANTHOSPORAE.

R. aeruginea Lindbl., *alutacea* Fr., *aurata* Fr., *badia* Quél., *caerulea* Cke. (an Fr.?), *chamaeleontina* Fr. (with var. *armeniaca* Cke. and *minutalis* Britz.), *consobrina* Fr., *cutifracta* Cke., *decolorans* Fr., *drimeia* Cke., *fellea* Fr.,* *flava* Romell, *foetens* Fr., *fusca* Quél., *grisea* Bres., *insignis* Quél., *integra* Fr., *lepida* Fr., *lutea* Fr., *maculata* Quél., *melliolens* Quél., *nauseosa* Fr., *obscura* Romell, *paludosa* Britz., *Postii* Romell, *pseudo-integra* Arn. et Goris, *puellaris* Fr., *punctata* Gill. (=*amoena* Quél.), *Queletii* Fr., *Romellii* Maire (=*integra* Quél. pro parte, non Fr.), *rosea* Quél., *roseipes* Bres., *rubicunda* Quél., *rubra* Fr. (non Quél. nec Cke.), *sanguinea* Fr., *sororia* Fr., *urens* Romell, *Turci* Bres., *veternosa* Quél., *violacea* Quél., *virescens* Fr., *vitellina* Fr., *xerampelina* Fr.

2. CHARACTERS OF THE STEM.

In the stem we have to consider its shape, size, the form and colour of its cuticle and its internal structure.

Shape.—The shape of the stem varies very little in the Russulae. This portion of the carpophore is always cylindrical or subcylindrical. In almost all the species some of the specimens are larger either at the base, or the middle or the apex of the stem so that they appear more or less bulbous, spindle-shaped or obconic. But these are unimportant and inconstant variations.

Size.—The size of the stem corresponds to the dimensions of the pileus in the Russulae and offers only some unimportant variations which are generally due to the conditions under which the fungus is developed. Thus *R. paludosa* Britz. has a very long stem when growing amidst thick tufts of mosses (hence its synonym *R. elatior* Lindbl.) but its stem is normal when it is found in habitats with scarcely any moss.

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*The spores are so pale in this species that it is doubtful whether it should not be placed amongst the leucosporae.

Form and colour of the cuticle.—The stem of the Russulae is covered with a pellicle that is generally loose, extremely thin and white, and is, especially when young, more or less pruinose or mealy to the naked eye or with the aid of a pocket lens. This pruinose condition diminishes and disappears with age in most of the species except at the apex of the stem close to the gills, where it persists for a long time. Consequently the stem in mature specimens of Russulae is generally glabrous, white and more or less wrinkled, because the cuticle is too thin and does not conceal sufficiently the longitudinal bundles of the flesh beneath it. There are, however, some species which pretty constantly depart from this rule and are therefore worthy of note. Thus in *R. drimeia* Cke., *R. Queletii* Fr., and *R. rubra* Fr. the cuticle is coloured (purple or purplish-violet) is thicker and is more pruinose than the general rule. The stem in these species is in consequence generally smooth, mealy and coloured until old age. Some forms of *R. Queletii* Fr. are found that have the cuticle of the stem less developed, the stem is then sometimes white, glabrous and wrinkled-striate, and the majority of the specimens come to this condition. In *R. alutacea* Fr. and *punctata* Gill. the stem also has a pretty thick cuticle and is often coloured purple. In the first of these two species it often cracks at maturity and thus gives to the surface of the stem a stippled appearance, and we observe this also sometimes in *R. rubra* Fr. Some other species have a more or less coloured stem but it is rarely constant. I cite *R. lepida* Fr. with a stem almost always red or tinted with red; *R. consobrina* Fr. with an olive coloured stem; *R. roseipes* Bres., *R. paludosa* Britz., *R. xerampelina* Fr. with stem normally rose coloured; *R. aurata* Fr. generally with a yellow stem; *R. cyanoxantha* Fr. and *R. emetica* Fr. with stems rarely washed with rose, &c. The flesh of the stem immediately below the cuticle is generally white, sometimes it is concolorous with the cuticle for a little distance (*R. Queletii* Fr., *R. drimeia* Cke., and *R. sanguinea* Fr. &c.) and rarely is it of another colour as in *R. subfoetens* Sm., where it is often yellow.

Internal structure. The stems of the Russulae are generally solid, firm and almost homogeneous when young, at maturity the flesh on the outside continues firm and dense, whilst that of the inside generally becomes more or less loose or else hollow. The mature stem then is either solid or hollow. In the former case the internal flesh is relatively firm or more or less spongy; sometimes it is lacunose, and this leads up to the hollow stem, which is pretty rare. When the external firm flesh passes more or less abruptly into the spongy flesh of the interior, then the stem becomes more or less distinctly corticate. Many of these variations are met with pretty frequently in the same

species, and for this reason the internal structure of the stem is often of very little use for the determination of species and moreover very frequently the interior of the mature stem cannot be observed because of the destructive action of larvae. Some species, however, vary less from this point of view. Such are for example *R. delica* Fr., *R. nigricans* Fr., *R. rubra* Fr., and *R. lepida* Fr., where the stems keep firm until extreme old age ; *R. pseudo-integra* Arn. & Goris where the stem is quite spongy when young ; *R. chamaeleontina* Fr. and *R. lutea* Fr. where the stems become hollow at an early stage.

CHARACTERS OF THE PILEUS.

Besides the gills, which we shall study separately, the pileus of the Russulae presents for our consideration its general shape, size, margin, cuticle and the colour of the flesh below the cuticle.

General shape. The general shape of the pileus is very similar in all the Russulae. Subglobose then hemispherical when young, the pileus opens out more and more and becomes generally depressed in the centre so that at maturity it is more often convex or convexo-plane with the centre more or less depressed. In FRIES' *Compactae* section of the Russulae the margin of the pileus is never completely spread out. In the other species, on the contrary, the margin is often turned up at maturity and the fungus then becomes more or less infundibuliform or cup shaped. One Russula is characterized by the shape of its pileus, this is *R. caerulea* Cke. which has a distinct and constant umbo to the pileus and this immediately distinguishes this species. Some other species of Russula are accidentally umbonate, as for example *R. Queletii* Fr., but then the umbo is generally indistinct and inconstant.

Size. I will not discuss here the average diameter of the pileus. Its thickness is generally pretty considerable at least in the centre. Towards the margin the thickness is very variable and often furnishes valuable characters for its determination.

Margin. When the thickness of the pileus gradually diminishes from the centre towards the somewhat thick edge, then the margin is opaque and smooth, and we cannot perceive the upper anterior ends of the gills. This characterizes all the species belonging to the Friesian section *Compactae*, such as *R. delica* Fr. and *R. nigricans* Fr. In the species placed in the sections *Firmae* and *Rigidae* by the same author, the pileus becomes somewhat abruptly thinner towards the margin and in old specimens some more or less distinct striations are apparent at the edge (*R. Queletii* Fr., *R. cyanoxantha* Fr. &c.). In the *Fragiles* section this thinning out towards the margin is much more pronounced, and it often begins abruptly at a considerable

distance away from it ; in consequence of this the margin becomes translucid and distinctly striate for a considerable width, and we can easily distinguish the anterior part of the gills. Many of the striations become furrows because the feeble and slow intercallary growth of the gills does not keep up with the rapid expansion of the pileus. The margin now exhibits a series of ribs which are often mixed with tubercles. These tubercles are situate on the inter-laminar veins which have impeded the expansion of the pileus. I cite as examples of species distinctly striate at the margin : *R. fragilis* Fr., *R. chamaeleontina* Fr. and *R. puellaris* Fr. The furrows and the tubercles are especially noticeable in *R. foetens* Fr., *R. elegans* Bres., &c. All these characters of the margin are very constant in some species, as in *R. foetens* Fr., much less so in some others as in *R. integra* Fr. and *R. Romellii* Maire, where the margin appears to be almost smooth, striate or furrowed and tuberculose according to the individual specimens. The involute margin at maturity of FRIES' section the *Compactae* is also a distinctive character. Other characters are provided by the margin, on a section of the fungus, which depend upon the shape of the gills, but I will direct your attention to this under another head.

Cuticle of the pileus.—The pileus is covered by a distinct pellicle, often called the cuticle, which gives it a particular colour and also some other important characters. The colour of the cuticle may certainly vary but within much more restricted limits than FRIES thought. In some species the colour is nearly constant if we allow for the variation of its intensity due to the action of light, rain, age, &c. I quote as examples *R. foetens* Pers., *R. subfoetens* Sm., *R. consobrina* Fr., *R. aeruginea* Lindbl., &c. In other species on the other hand where we have two pigments present, the one purple or violet and the other olive-green, the shade of colour varies very much owing to the distribution and proportions of these pigments ; (*R. alutacea* Fr., *R. xerampelina* Fr., *R. Turci* Bres., *R. cutifracta* Cke., &c.). The entire absence of one of the usual pigments makes certain species almost unrecognisable. This occurs in *R. punctata* Gill. and especially in *R. drimeia* Cke. This last species is generally purple-violet without any apparent mixture of colours, but sometimes specimens of it are found of a greenish-yellow and it then becomes *R. flavo-virens* Bomm. & Rouss. The red and green species with only one pigment do not generally vary except from white up to their deepest colour ; as in *R. fragilis* Fr. and *R. virescens* Fr. It is therefore necessary to include in the description the colour of the cuticle and to indicate as clearly as possible its variations. We ought also to pay great attention to the surface of the cuticle. This is more or less viscid in most of the species. The observation of this viscidity

should be carefully made; many viscid species in times of drought appear to have an absolutely dry and pulverulent cuticle. This change of appearance is very clearly seen in *R. alutacea* Fr. and *R. Turci* Bres. I have observed specimens of these species half covered with leaves after a storm of rain following on a period of fine weather. The covered parts retained their dryness and were pulverulent whilst the moistened portion had become completely viscid. It is better therefore before we declare that the cuticle is dry or viscid to wet it when gathered during a dry time. If we take these precautions we find that the greater number of the Russulae are viscid whilst some are always dry, a very important character for their accurate determination. These latter include *R. lepida* Fr., *virescens* Pers., *punctata* Gill., &c. BATAILLE bases his group *Siccae* on this important character but he includes also some species that are distinctly viscid in wet weather, such as *R. cutifracta*. When the cuticle is dry it is either dull or shiny. It is generally dull in the species that are not viscid, and more or less shiny in the majority of those that are viscid, but this does not apply to them all. These characters should be noted when they are clearly seen. In *R. grisea* Bres. the cuticle is very shiny when dry, whereas it is quite dull in *R. alutacea* Fr., *R. xerampelina* Fr., and *R. Turci* Bres. The dry or viscid cuticle is sometimes more or less cracked on the surface. These cracks are nearly constant in *R. virescens* Fr., but on the other hand they are accidental although frequent in *R. cutifracta* Cke., *carnicolor* Bres. and *grisea* Bres. In the first case where the cuticle is dry and thick the exterior portion has completed its development earlier and cannot keep up with the expansion of the underlying tissues. In the second case, on the other hand, the cuticle is thin and viscid and the cracks are only produced when they become incapable of stretching before the fungus opens out in consequence of dryness. The cracks of the first type are therefore only of importance to the systematist. Lastly the cuticle may be more or less separable from the underlying flesh. When the pileus will not peel the cuticle is said to be *adnate*, and when it does so it is termed *separable* or pelliculose. It is still a useful character in some cases although it varies considerably in the majority of species. In a great number of the Russulae the cuticle is adnate at the centre of the pileus but is more or less separable towards the margin. The extent of this separable zone varies in a greater or less degree in the different species and often in different specimens of the same species. Some species however have the cuticle completely separable or scarcely adnate in the middle, such as *R. fragilis* Fr., *R. chamaeleontina* Fr., *R. paludosa* Britz., &c. Other species have the cuticle entirely adnate, as *R. lepida* Fr., *R.*

virescens Fr., *R. punctata* Gill., *R. delica* Fr., *R. nigricans* Fr., &c. Generally the dry species have the completely adnate cuticle, but the viscid species become difficult to peel when they are dried.

Colour of the flesh under the cuticle. The flesh under the cuticle is either white or coloured, and this we ascertain by either peeling the fungus or by making a radial section of it. This character is often variable and depends on the depth to which the pigment extends, and which attains its maximum in the cuticle, but it is sometimes of great service in distinguishing some species where it is pretty constant. Thus *R. cutifracta* Cke., which greatly resembles *R. grisea* Bres., is distinguished by its violet coloured flesh under the cuticle of the pileus.

CHARACTERS OF THE GILL.

The gills ought to be studied individually and collectively. Individually a gill offers for our consideration its colour, general shape, width, thickness, edge, insertion and tear-like drops.* Collectively the gills lead to the study of their relation to one another their equality or inequality, either forked or connate, their spacing and intervenation.

Colour of the gills. The colour of the gills is an important character which should be carefully studied. It may be due either to the colour of the hymenium itself or to the colour of the spores that it bears or to a combination of both of them. In the three cases, but especially in the two last, they frequently differ very greatly with age. Thus in *R. Turci* Bres. the gills are at first pale sulphur yellow, then they become ochre after the spores have appeared; the yellow gills of *R. xerampelina* Fr., *R. integra* Fr., and *R. Romellii* Maire are white when young and at maturity are covered with an ochre-cream dust. In *R. alutacea* Fr. the gills are at first whitish and become cream coloured from the colour of the hymenium and then ochre-cream after the appearance of the spores. The yellow citrine colour of the gills of *R. aurata* Fr. and the beryl colour of those of *R. delica* Fr. var. *glaucophylla* Quél. are due to the colour of the hymenium itself; although the orange-ochre colour of those of *R. chamaeleontina* Fr. arises from a combination of the colours of the hymenium and of the spores. The edge of the gills sometimes appear specially coloured, it is so very often in *R. aurata* Fr. and *R. delica* Fr. var *glaucophylla* Quél., where the citrine or beryl colour is confined to the edge and its vicinity. The edge of the gill of *R. punctata* Gill. is often purple-violet or

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*The gills are pretty frequently covered when young with drops of water: they are then said to be weeping.

purplish. On the other hand certain Russulae frequently have the cuticle of the pileus decurrent on the edge of the gills, which then become coloured like the pileus for a variable length. This feature is present in a great number of species, as for example in *R. lepida* Fr., *R. alutacea* Fr., *R. paludosa* Britz., *melliolens* Quél., &c. ; but it is nowhere constant.

General shape of the gills. In order to ascertain the general shape of the gills one must make a radial section of the pileus. We find that in the greater number of species the shape of the gills is practically the same as BARBIER (1907) has well said. " In many of the Russulae before the pileus has either completely opened out or has become hollowed out the gills have almost the shape of separate petals or flies' wings ; they gradually decrease from the margin (in front) towards the stem (behind) until they terminate in a point on that side ; the edge* leaves the stem at a right angle and abruptly forms a semi-circle at the margin of the pileus where the gill reaches its greatest width." There are, however, some more or less constant variations ; in the young state the edge is generally quite straight and a little arched later on it often becomes ventricose ; the base is less abruptly arched at the anterior end at maturity and can also become almost completely straight when the pileus is fully opened out. In FRIES' *Compactae* section, however, of the Russulae the shape of the gills departs from this general type in the young state they are attenuated at both ends and the edge is parallel with the base or more or less ventricose. In *R. sanguinea* Fr. the gills are soon attenuated in front but in young specimens they are of the normal shape. In many other species we observe a similar early attenuation of the gills in front which causes the pileus to have an acute margin, and I cite as examples *R. cyanoxantha* Fr., *R. heterophylla* Fr., *R. fellea* Fr., *R. foetens* Fr., *R. sub-foetens* Sm., *R. Queletii* Fr., *R. drimeia* Cke., &c. The gills in the Russulae on the other hand preserve their typical shape up to maturity and their rounded anterior end makes the margin of the pileus very obtuse. This character is clearly marked in most of the species belonging to the Friesian sections *Fragiles* and *Rigidae.* It must be noticed, however, that this difference in shape of the gills in the mature fungus very frequently varies and we find every transition in the species well characterized from this point of view and one can also often observe it in the same species.

Width of the gills. This character also is very variable in the Russulae when compared at the same age. There are, however, some species where the gills are constantly narrow, as

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* It should be added " and the base."

R. foetens Fr., *R. subfoetens* Sm., *R. sanguinea* Fr., *R. drimeia* Cke., *R. heterophylla* Fr., and *R. delica* Fr. The breadth of the gills should be numerically given in the description. In the majority of cases, however, the variability and small importance of this character makes these measurements almost useless to the systematist, whilst in others the exact measurements would be of great service.

Thickness of the gills. The thickness of the gills varies very much, and their precise measurements would not be of sufficient utility in comparison with the loss of time given to it by the describer. It is sufficient in my opinion to indicate that in such and such a species the mature gills are exceptionally thick as in *Russula nigricans* Fr., *R. alutacea* Fr., and *R. Turci* Bres., or on the contrary that they are particularly thin, as in *R. heterophylla* Fr., *R. chamaeleontina* Fr., *R. lutea* Fr., &c.

Edge of the gills. I have mentioned above the colour of the edge of the gills in certain species and I will not repeat it. I further note that the edge is sometimes more or less floccose. This is a very rare character amongst the Russulae and is met with only in *R. pseudo-integra* Arn. & Goris and *R. punctata* Gill., and it is not always very pronounced.

Insertion of the gills. As BARBIER (1907) said, the shape of the stem, often a little widened at the summit, together with the variable attenuation of the gills, takes away much of the value that is to be attributed to their insertion. This insertion from the first varies with age, and FRIES (1836), in order to avoid this source of error, studied it when the pileus was still unexpanded. But still, under these conditions, we find that in the majority of species the insertion of the gills is not constant. Generally the gills are free or very slightly adnate, and we can find these forms of insertion on the same specimen. At maturity many of the species have their gills very slightly sinuate at their insertion on the stem. There are, however, some species which are distinguished by their gills being constantly adnate at every stage, such are *R. adusta* Fr., *R. subfoetens* Sm., *R. delica* Fr., and *R. sanguinea* Fr. In these two last the gills become also decurrent at maturity. But the slight taxonomic importance of this character is proved in the Russulae, because in *R. Queletii* Fr. and *R. drimeia* Cke., two species incontestably nearly related to *R. sanguinea* Fr., the adnate gills have no constancy.

Tear-like drops. This character is pretty frequent amongst the Russulae and ought to be noticed when observed, but it depends greatly on the meteorological conditions, to which it would be imprudent to attach too much importance. It is especially noticeable and constant in *R. delica* Fr.

Equality or inequality of the gills. In the majority of the

Agarics we find the gills of varying lengths. Some extend from the margin of the pileus to the stem whilst others are arrested at a more or less considerable distance from the margin. We call these last *lamellulae*. Generally gills and lamellulae of different sizes alternate pretty regularly. It is rarely so in the Russulae : the great majority of them have lamellulae only interspersed here and there without any order and often few in number ; it is the same in species where numerous specimens do not possess a single lamellula (*R. chamaeleontina* Fr., *lutea* Fr., &c.). It is in the section *Fragiles* of *Fries* that the lamellulae are reduced to their minimum. In the *Compactae* section on the other hand we find the lamellulae alternating with the gills almost as regularly as in other Agarics. In the *Compactae* therefore the inequality of the gills is an important character, whilst in the other sections it is extremely variable from one species to another and also in the same species, with the result that it is scarcely of any importance. Thus *R. fragilis* Fr., which generally has its gills all equal, often furnishes specimens with pretty numerous lamellulae. And *R. cyanoxantha* Fr. has either numerous lamellulae or scarcely any.

Furcate and connate gills. It often happens, especially in species with pretty numerous lamellulae, that many of them become joined to the neighbouring gill. This joining also occurs between gills themselves at equal or unequal heights and in the former case gives origin to forked gills. The forking may occur at a more or less considerable distance from the margin of the pileus ; when it proceeds from the level of the insertion of the gills upon the stem, then it is called *connate:* it has no connection with the furcation of gills and lamellulae but with that of two gills alone. The gills are forked or connate more frequently in certain species, as in *R. cyanoxantha* Fr., *R. foetens* Fr., and *R. aeruginea* Lindbl., they are also found more or less distinctly amongst almost all the Russulae with the exception of those included in the *Compactae* section and perhaps some few in the *Fragiles* section. It is then not necessary to exaggerate the importance of this character as FRIES did when he changed his section *Firmae* into *Furcatae.*

Spacing of the gills. The spacing of the gill varies much with age, it should therefore be always noted at maturity, at the time when the spores commence to appear and when the pileus has opened out without being deformed. In these conditions we can observe pretty clearly the spacing of the gills in some species. Thus in *R. nigricans* Fr. the gills are very distant, whilst in *R. adusta* Fr. the gills are crowded ; so also in *R. heterophylla* Fr, the gills are more crowded than in its neighbour *R. cyanoxantha* Fr. Apart from these species the differ-

ence of spacing of the gills is of little value and the individual variations exceed the specific. The exact record of this character is very difficult* and the spacing of the gills is practicably a negligible quantity except in the case where it is very striking.

B. MICROSCOPIC EXAMINATION OF THE RUSSULAE.

We can study a Russula with the microscope and investigate the flesh, the cuticle of the stem and of the pileus, the gills and the spores. The structure of the flesh is very constant in the Russulae. It consists chiefly: First of bodies that are either subcylindrical and simple or branched in the stem, or ellipsoid and round in the pileus, and of large round cells, termed *sphaerocysts*, which in a transverse section appear to be arranged in a rosette, generally around a central hypha; secondly of elongated hyphae similar to those in other Agarics, which fill up the interstices between the mass of *sphaerocysts*. More or less numerous lacticiferous vessels (FAYOD'S oleiferous hyphae) occur amongst the elongated hyphae, especially in certain regions. The variations in this structure are of little importance; they depend chiefly on the frequency of the lacticiferous vessels and the more or less distinct separation of the mass of sphaerocysts in the pileus. Again it is necessary to compare specimens of the same age, because variations of the same nature occur in the same specimen during the course of its development. The variations in structure of the flesh are then practically of very little use to the systematist. I will study more deeply the gills, the cuticle and the spores. The study of these can be combined with that of the gills and here is a way of proceeding to a complete and rapid investigation. We prepare three glass slips, on the one we place a drop of water on the second a drop of sulpho-vanillic reagent, and on the third a drop of sulpho-formolic reagent. These two last will serve for our microchemical studies, which I shall speak about further on. We then under a dissecting microscope and with the aid of a very sharp scalpel, make transverse sections as thin as possible of the gill, the cuticle of the pileus and the exterior portion and cuticle of the stem. The transverse sections of the gill ought to include the edge, they are very easy to make, and this is the case also with the stem. The sections of the cuticle of the pileus are difficult to make, especially when it is viscid and

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* To obtain it we should have to count the number of the gills and to measure the size of the pileus; this would necessitate numerous measurements and calculations without any sufficient precision being arrived at, because slight differences in age would be sufficient to cause a change and to conceal such feeble specific variations. Photography is certainly the best agent for recording the spacing of the gills in those species where it is characteristic.

separable; but after a little practice we are able to obtain satis-
factory sections. We place all these sections in a drop of water.
It is also advisable to add a small bit of the cuticle of the pileus
carefully skinned off when it is separable or obtained by a super-
ficial cut when it is adnate and a small piece of the cuticle of
the stem should be procured in the same way. Certain species
have the cystidia in their cuticles so distant that they may
escape observation in the transverse sections only. We deal in
the same way with the other sections and bits of the cuticle by
placing them in the drops containing the reagents on the glass
slips, and we cover all of them with cover-glasses. If we are
obliged to study dried specimens, which should only be done
in default of fresh ones, then we can very easily make satisfac-
tory sections with a razor of the dried material kept in position
by elder pith. The sections are next boiled either in
GUEGUEN'S reagent* (1906) or in AMANN'S lactophenol** (1896)
when we do not wish to stain them. On the other hand if we
desire to stain them, then we place the sections on a glass slip in
a drop of some reagent and cover it with a cover-glass, and we
carefully heat it so that the liquid between the slip and cover-
glass may slowly boil. Another process consists in treating the
sections for a quarter of an hour with a five to ten per cent.
solution of potash, and then they are stained with ammoniacal
Congo-red so that they may be studied in water. *When charac-
ters have been described from dried specimens we must always
indicate the technical details that have been employed in their
study.* For the study of the spores it is best to use a good objec-
tive with a homogeneous immersion. I use a LEITZ 1/16 immer-
sion; but one can also use a 1/12. The spores may be measured
either by a drawing with the camera lucida and a comparison
with it of a micro-metric scale obtained under the same condi-
tions with the same objective, or by means of a micrometrical
scale placed in the eye-piece, the micrometrical value of which
scale has been previously ascertained by a micrometer measure
placed on the stage of the microscope, that is to say the number
of divisions of the micrometer measure that correspond to the
number of the divisions in the micrometrical scale of the eye-
piece when used with the same objective. It is necessary to
determine this yourself instead of adopting the figures given by
the maker for the micrometrical values of their objectives, be-
cause they are very often wrong in this respect. Contrary to
the opinion of some mycologists the spores can be measured
very well in the sections of the gill. The section includes many

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* Solution of cotton blue C 4 B and Soudan III. in lactic acid, to which is added
a small quantity of an alcoholic solution of iodine.

** A mixture of glycerine, phenol and lactic acid.

ripe, detached spores which are motionless and in all possible positions in the preparation so that we can work with the microscope inclined. With a little practice we can very easily distinguish the ripe spores from the unripe. Further we can control it by an examination of the spores obtained from a deposit either on paper or glass. This control has always given me the same results that I have obtained by the other method. I will now detail the characters that we shall study in our preparations. We shall study in the section of a gill, the edge, the mediostratum, the subhymenium, the cystidia, the basidia and the spores. In the cuticle we shall study, the general structure, the viscidity, the cystidia and the differentiated hairs.

Edge of the gills. The edge may be *homomorphic* or *heteromorphic*. We call the edge homomorphic when the hymenium is continuous with the same structure on the lateral face of the gills; on the other hand we term heteromorphic, the edges where the structure is changed by the presence of hairs or other elements differing from the hymenial elements. Sometimes the edge, without possessing any special elements, is differentiated by a considerable predominance of cystidia, a normal hymenial element; in this case the edge may be designated *subheteromorphic*. In the Russulae the characters of the edge are of much less importance than in many other genera of Agaricaceae (such as *Lepiota, Inocybe, Mycena,* &c.), the edge generally being homomorphic. In *R. nigricans* Fr. however we find the edge distinctly heteromorphic and furnished with either fascicled, or cylindrical or moniliform hairs. In *R. adusta* Fr. the edge is equally heteromorphic but in a much less marked degree, the hairs are few in number and much resemble cystidia, and moreover the heteromorphic edge of this species may not be quite constant. On the other hand *R. densifolia* Gill., so near to *R. adusta* Fr., always has homomorphic edges. The edge is still more clearly heteromorphic in *R. punctata* Gill. and has numerous hairs swollen at their base, long and accuminate at the summit.* Sometimes we find similar hairs disseminated over the lateral faces of the gills, and we shall see on the other hand that the cuticle of the stem is covered with them. The hairs on the edge are sometimes coloured, and this is the case when the edge is purplish. These hairs, whether coloured or uncoloured, always make the edge a little floccose, as we pointed out a little higher up. Be that as it may, the very characteristic hairs of *R. punctata* Gill. (= *R. amoena* Quél.) enable us to recognize this species under all its numerous disguises. The edge is subheteromorphic in *R. pseudo-integra* Arn. & Goris, and the

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* These hairs have already been seen and figured by PATOUILLARD. Cf. *Tabulae analyticae*, No. 621.

cystidia become extremely numerous and projecting, and so produce the floccose appearance that I have mentioned.

Mediostratum of the gill. The mediostratum is the trama of the gill, it is the tissue which forms the frame and which through the medium of a differentiated peripheral layer, the sub-hymenium, supports the hymenium. The mediostratum in the majority of the Russulae consists of sphaerocysts mixed with filaments in various proportions. When the filaments or hyphae are of little importance, in comparison with the sphaerocysts, we call the mediostratum vesicular, when the filaments predominate then we term it filamentous. There is every form of transition between these two types, hence the structure of the mediostratum is of no importance except in those species where it is decidedly characteristic. It is so in *R. chamaeleontina* Fr., and *R. melliolens* Quél., where the mediostratum is vesicular, although in *R. punctata* Gill., and *R. cyanoxantha* Fr. it is filamentous. These variations in the structure of the mediostratum are the cause of the fragility and elasticity of the gills. Species with vesicular mediostratum have the most fragile gills and this fragility is due to the inversion of the density of the tissue. The species on the other hand that have a filamentous mediostratum possess gills more or less elastic. The mediostratum in the majority of species does not have any lacticiferous vessels, hence it is useful to note those species in which it occurs. These species are especially very acrid Russulae such as *R. drimeia* Cke., *R. Queletii* Fr., *R. sanguinea* Fr., *R. maculata* Quél. and *R. emetica* Fr.

Sub-hymenium. The sub-hymenium is a layer that separates the mediostratum from the hymenium and directly bears the basidia. The subhymenium is generally formed of filamentous cells more or less entangled, which are more and more branched and shortened towards the hymenium under which they are sometimes almost isodiametrical. This structure amongst the majority of the Russulae presents only insignificant variations; the subhymenium is either a little more or a little less thick, and either a little more or a little less dense, but it always has the same appearance. We call this type along with FAYOD (1889) the *branched subhymenium.* This structure in some species is modified by its tendency to become vesicular; the sub-hymenium then becomes less distinct from the mediostratum and the fragility of the gill is considerably increased. This type corresponds to the *cellular subhymenium* of Fayod and is well represented in *R. chamaeleontina* Fr., *R. lutea* Fr. and some other neighbouring species and varieties. FAYOD (1889) distinguished at the base of the subhymenium a layer formed also of thinner entangled elements which he called the hymenopode.

In my opinion the hymenopode is too little differentiated and too variable in the Russulae to be of any taxonomic value.

Cystidia. The cystidia are present in all Russulae except perhaps according to MASSEE in *R. virginea* Cke. & Mass. They are of deep origin and arise from the subhymenium or even the mediostratum. *Sometimes* but *not always* they are connected with the lacticiferous vessels when they are present in the gills. Their general shape is pretty constant in the Russulae; they are more or less fusiform and either somewhat acute or obtuse at the apex. Their contents vary much with age, as DE SEYNES (1867) and TOPIN (1901) have shewn. At first hardly granular and uncoloured, the contents are obscured by little oil drops often yellowish in appearance, then towards the commencement of the formation of the spores we see the oleaginous drops absorbed and vanished. The cystidia have then ended their function as secretive cells and have become excretive, and their contents are often filled with crystals, and sometimes the external membrane is encrusted with them on the outside. In this last phase the cystidia are extremely turgescent and break up when placed in water. The cystidia in the Russulae have often a tendancy to bud at the apex, in a way that they often appear to have either a little globular or cylindrical or moniliform body at the top: we then call them *appendiculate cystidia.* This character is not very constant and we almost always find appendiculate cystidia with others that are not so in one and the same specimen; however it is well to note that in some species the appendiculate cystidia are very abundant (*R. melliolens* Quél., *R cyanoxantha* Fr., *R. heterophylla* Fr., *R. Queletii* Fr., &c.) although in some others they are rare or absent (*R. chamaeleontina* Fr., *R. Turci* Bres., *R. aurata* Fr., &c.). The external incrustation of the cystidia is important because to our knowledge it is only met with in *R. pseudointegra* Arn. & Goris, where it was first drawn attention to by these authors. The incrusting substance forms a sheath to the cystidium up to a certain height leaving the apex free from it for a more or less considerable distance. This substance dissolves pretty quickly in water, but on the other hand it is insoluble in the sulphovanillic reagent. The length of the cystidia vary much more with the position they occupy on the gill than with the species; they are always shorter at the edge of the gill and longer towards its base. Their length is consequently not very precise and difficult to make use of unless we take into account various measurements at different levels. The width is more constant and sensibly varies from one species to another in some cases. Thus the cystidia of *R. nigricans* Fr. do not exceed 6μ in width, although those of *R. melliolens* Quél. and *R. decolorans* Fr. are hardly ever as low as 9μ and rise up to 12μ. The width is measured where the

cystidium is broadest. It is useful to note whether the cystidia project or not at maturity. This character is generally little noticeable and variable; however MASSEE (1893) drew attention to the fact that the cystidia of *R. cyanoxantha* Fr. generally project very much whereas they scarcely exceed the hymenium in *R. heterophylla* Fr. The Russulae of the *Compactae* section often have this last character, *R. nigricans* Fr., *R. adusta* Fr. and *R. delica* Fr.

Basidia. The basidia vary very little in the Russulae. They have four spores in all the species; and it is better to take no notice of anomalous forms with one to three spores. The shape of the basidia varies between two extreme types: the long basidium, narrowly clavate (*R. nigricans* Fr.) and the short, broad clavate basidium (*R. chamaeleontina* Fr.). The dimensions, although varying within somewhat extensive limits, ought to be noted, because certain Russulae have basidia of very large size, which are clearly distinct from those of medium and smaller sizes in other species. Such are the basidia of *R. melliolens* Quél., $45\text{-}55 \times 18\text{-}20\mu$, whilst those of *R. rosacea* Quél. are $30\text{-}35 \times 7\text{-}9\mu$, *R. chamaeleontina* Fr. $30\text{-}38 \times 10\text{-}11\mu$, and *R. nigricans* Fr. $50\text{-}60 \times 9\text{-}10\mu$.

Spores. The microscopical study of the spores furnishes, contrary to the opinion of the majority of the authors, many very valuable characters for their determination. It is then necessary to study the spore in its general shape, dimensions, colour, armature of the membrane and its contents. The shape varies within rather restricted limits: they are generally elliptical with an apiculus at the hilum and a little depressed on the interior side, the spores become shorter and subglobose in certain species (*R. melliolens* Quél., *R. pseudointegra* Arn. & Goris) and sometimes they are elongated (*R. xanthophaea* Boud.). Their dimensions usually vary very little. In the majority of species the length approximates to 9μ. Certain Russulae however have spores clearly much larger than the average; thus those of *R. melliolens* Quél. are generally $10\text{-}13 \times 8\text{-}11\mu$ and those of *R. decolorans* Fr. are $11\text{-}13 \times 8\text{-}9\mu$. Besides the species with large spores there are others where the spores are remarkably small, *R. heterophylla* Fr. (spores $5\text{·}5\text{-}7\text{·}5 \times 5\text{-}6\mu$), and *R. virginea* Cke. & Massee (spores having a diameter of 4μ according to MASSEE). Often very nearly related species are easily distinguished by the size of their spores: thus *R. obscura* Romell. so near to *R. decolorans* Fr. has spores $9\text{-}11 \times 7\text{·}5\text{-}8\mu$. These differences of size are habitually very constant. There are many important points that we should not forget when we measure the spores. First we should indicate in the measurement of the length of the spore whether it includes the apiculus

or not, as this has a length that is far from being of no import-
ance (·5-1μ in *R. heterophylla* Fr., 1-1·5 and also 2μ in *R.
decolorans* Fr., &c.). I do not include the apiculus in the
measurements given in this paper and probably MASSEE does not
include it in the measurement quoted above, but he makes no
statement as to this. Secondly, if the measurements are
obtained by a micrometrical scale in the eye piece, it is best, in
order to have sufficient preciseness, to use a high power
objective and preferably the homogeneous immersion the
1/16. Lastly, the measurements should be confined to ripe
normal spores and should indicate the maximum and minimum
dimensions of these, neglecting those abnormally small or un-
usually large and only mentioning these separately if we desire
to do so. The colour of the spore as seen through the micro-
scope should be noted, but we must not attribute the same im-
portance to it that we do to the colour of the spores deposited in
mass ; first because it is extremely difficult to observe when
they are very pale, and secondly because, without taking into
consideration the use of artificial light, it changes greatly with
the colour of the sky. *The determination of the colour of the
spores, as seen through the microscope, cannot in any case, replace
that of the colour of the spores as seen when deposited in mass.*
The spores are hyaline under the microscope in those species
that have white or cream-white spores; they appear slightly
yellowish in those with ochre-cream spores and distinctly yellow
in the species with yellow-ochre spores. The colour of the
spore, is not always due to its contents, as FAYOD has observed,
but it often, also, arises from the tint of the membrane. The
armature of the membrane of the spore is an important character,
which has almost been completely neglected, hitherto, by the
majority of mycologists. Few of them have noticed the almost
smooth spores of certain *Russulae*, *R. nigricans* Fr., and *R. vir-
ginea* Cke. & Massee. In 1908 BATAILLE still says " Their sur-
face . . . . is generally either echinulate or aculeate, sometimes
simply granular or warted, very rarely nearly smooth." The
little importance attached by the authorities to the armature of
the spore is due to the fact that they have always worked with
too low a power objective or with one insufficient in definition.
In certain cases this armature can be observed with a good dry
objective, but it is more often better defined by an immersion
objective.* To obtain the best figures as clear as possible it is

* These objectives are so much improved now and their price is so low that all
mycologists having a microscope can use them with an *Abbé* condenser in the sub-
stage. The management of immersion objectives is not much more difficult than
that of the ordinary dry objectives, and we can use them for the examination of
specimens in water and not mounted, provided that we do not leave too thick
a layer of cedar oil which we employ with the immersion.

best to use artificial light, either an AUER'S gas burner, or a NERUST'S lamp or an EDISON'S incandescent light with roughened glass; if these be unobtainable, then either a petroleum or alcohol incandescent or acetylene lamp should be used. Day-light is too inconstant and often too weak, especially in winter, to produce from the objectives their maximum of efficiency. The spores of the Russulae, when studied under these conditions, furnish differences in their armature which enable us to distinguish three distinct types; the echinulate, the cristate and the somewhat smooth. In the echinulate type, the spore is covered with long spines more or less pointed; in the cristate type, the spines are elongated in more or less anastomosing crests, so that they sometimes appear somewhat reticulate, and lastly, in the somewhat smooth type, the spore has sometimes either low warts very distant and scarcely visible, or some simple wrinkles which are irregular and little apparent. There are clearly numerous transitions between these three types: the most frequent is the warted spore with very distinct and pretty high warts which are more or less rounded. We can quote as examples of the type with echinulate spores: *Russula chamaeleontina* Fr. and *R. alutacea* Fr. The cristate type is very well represented by the spores of *R. Turci* Bres., *R. Romellii* Maire and *R. aurata* Pers.; and the somewhat smooth type by *R. nigricans* Fr., *adusta* Fr, and *melliolens* Quél. The contents of the spore are very constant in the Russulae; they consist of a parietal protoplasmic layer, containing two nuclei which are only visible after fixing and staining with an appropriate reagent, and of a central nearly spherical, large oil drop. Occasionally we find a supplementary little drop or two drops of medium size in place of the large drop. The contents of the spore, in the present state of our knowledge, are of no importance to the systematist. In concluding these remarks upon the spores we cite as an example of the utility of its careful study the case of *R. melliolens* Quél. This species is badly known by the majority of mycologists, is extremely polymorphic, and is very difficult to recognise with the naked eye, when it is young, and we have failed to determine it in the field although we have studied hundreds of specimens. But this species, so disconcerting to the naked eye, is easily recognised when we study its large, subglobose, somewhat smooth and hyaline spores. We cite again *R. cutifracta* Cke., which is distinguished from *R. grisea* Bres. by its cristate spores.

Cuticle of the pileus. The structure of the cuticle of the pileus often furnishes very important systematic characters in the Russulae, and as FAYOD has well remarked it is because FRIES based his descriptions on these macroscopic characters that his sections are so very natural. The most frequent type

of the cuticle of the pileus consists of an external layer (the *epicutis* of Fayod) formed of more or less upright and pigmented hyphae, with a slimy membrane, intermixed with cystidia, and an internal layer (the *hypoderme* of Fayod) with more or less procumbent hyphae, which are not slimy but deeply coloured and densely entangled. The internal layer passes either more or less abruptly or on the other hand gradually into the flesh of the pileus. *Russula fragilis* Fr. may be taken as an example of this type of cuticle. The slime of the external layer in this species very readily swells up, hence the viscidity of the cuticle : and we find very numerous uncoloured cystidia. The hyphae of the external and internal layers contain a red pigment dissolved in the cell sap which makes the vacuoles conspicuous. Numerous lacticiferous vessels are found in the internal layer and in the flesh of the pileus which generally have no connection with the cystidia belonging to the external layer. This type of cuticle varies in different ways : by the absence either of lacticiferous vessels (*R. decolorans* Fr.), or of cystidia (*R. carnicolor* Bres., *R. melliolens* Quél. and *R. lutea* Fr.), by the solubility of the great part of the slime, leaving the superficial hyphae relatively free in times of drought (*R. alutacea* Fr.), by the absence of swollen up or soluble slime (*R. lepida* Fr., *virescens* Fr. and *punctata* Gill.), by the transformation of the hyphae in the external layer into a pseudoparenchyma, and the external cells alone are elongated into short hairs (*R. virescens* Fr.), by the replacement of the cystidia by hairs clearly differentiated amongst the ordinary hyphae of the external layer (*R. caerulea* Cke., *R. Turci* Bres., *R. rosea* Quél. and *R. pseudo-integra* Arn. & Goris), by the juxtaposition of these hairs with cystidia (*R. ochroleuca* Fr., and *sororia* Gill.) and by the diminution of the distinct separation between the external and internal layers (*R. nigricans* Fr., *R. delica* Fr. and *R. adusta* Fr.) The differentiated hairs of the pileus are often warted (*R. ochroleuca* Fr.) or incrusted (*R. Turci* Bres. and *R. caerulea* Cke. These hairs are homologous to the cystidia but they are not generally secretive ; in *R. ochroleuca* Fr. we can clearly perceive the passage from hairs into cystidia. The cystidia of the pileus are generally of a similar shape to those of the gills, but they are more irregular and rounded at the apex. They are also sometimes furnished with appendages; their length and breadth are very variable. They are developed frequently by the ramification of the pigmented hyphae of the external layer but at other times they proceed from the internal layer. The pigmentation of the cuticle varies much. In *R. fragilis* Fr. we have seen that the colour of the cuticle is due to a red pigment dissolved in the vacuoles. In *R. atropurpurea* Krombh. the pigment of the cuticle of the pileus is made up of purple globules which are

developed in the vacuoles filled with an uncoloured cell sap. In *R. cyanoxantha* Fr., *R. grisea* Bres. and *R. Romellii* Maire we find a violet or purplish pigment in the vacuoles, and a greenish-black pigment disseminated in crystalline granules in the vacuoles. The tint varies from violet to olive according to the more or less large proportion of one or the other of these pigments. We are able to distinguish three types of pigmentation that can exist together in the same specimen, dissolved pigments, globular pigments and crystalline pigments. I cite, as an example of the utility of the study of the structure of the cuticle of the pileus in determinations, the cases of *R. chamaeleontina* Fr. and *R. lutea* Fr. These two species much resemble one another and decoloured forms of the latter are easily mistaken for the former. But the cuticle of the pileus in *R. chamaeleontina* Fr. always has cystidia which are absent in *R. lutea* Fr.

Cuticle of the stem. The cuticle of the stem is not very thick and is often lax, so it is consequently never separable. It generally consists of very thin layers of uncoloured decumbent hyphae, on which the hair-shaped, uncoloured hyphae and cystidia are placed, and these give the young stem its pulverulent appearance. Very often the cuticle of the stem is too thin and does not sufficiently conceal the projection of the strings of sphaerocysts beneath it and this explains the wrinkled-striate look of the stem. In this case the cuticle soon ceases to grow and disappears almost entirely except at the base of these wrinkles. This is the reason why the stem which is more or less mealy pulverulent when young becomes at maturity glabrous except at a few points. This structure varies in certain species, by increase in the thickness the growth of the cuticle is maintained for a longer period with the result that the stem at maturity is smooth and pruinose (*R. drimeia* Cke., *R. Queletii* Fr. and *R. lepida* Fr.); by pigmentation of the hyphae (*R. drimeia* Cke., &c.); by the absence of cystidia (*R. virescens* Fr., *R. alutacea* Fr. and *R. rosea* Quél.); by the conjunction of differentiated hairs and cystidia (*R. ochroleuca* Fr.); by the substitution of these hairs for cystidia (*R. caerulea* Cke. and *R. Turci* Bres.), and by the transformation of hyphae into a cellular tissue, the most external cells of which elongate into long and acuminate hairs (*R. punctata* Gill.). The cystidia of the stem, both in shape and length, are perhaps still more variable than those of the pileus, sometimes also they have appendages, they are often connected with the lacticiferous vessels which circulate in numerous species in the deeper parts of the cuticle of the stem and in the filamentous tissue, which separates the strings of sphaerocysts. The cuticle of the stem although generally more uniform than that of the pileus, can in many cases furnish very valuable characters for the systematist.

C. THE USE OF MACRO- AND MICRO-CHEMICAL REACTIONS.

Chemical characters are pretty frequently used in the descriptions of fungi, but only in their most rudimentary form, the indication of the smell and taste, organoleptic properties directly due to their chemical constituents. The coloured reactions usually employed by lichenologists have not as yet their counterpart in mycology. However the use of reagents capable of giving colour reactions has been applied in certain branches of mycology, and more especially in the Russulae and Lactarii. The chief reagents used up to the present in the study of the Russulae are, first, the alcoholic solution of guiacum, and secondly the sulphovanillic and sulphoformolic reagents,

The alcoholic solution of guiacum. SCHONBEIN (1856) showed that many fungi turned the alcoholic solution of guiacum blue because of the presence in their tissues of oxydizing enzymes or oxydases which act in the presence of atmospherical oxygen on the guiaconic acid contained in the resin of guiacum. To demonstrate this reaction it is sufficient to put some drops of the alcoholic solution of guiacum upon a radial section of the fungus, when it more or less quickly turns blue and generally within one or two minutes. When the change to blue occurs after the lapse of half an hour or an hour, it is not attributable to the oxydases, but to the direct action of oxygen or perhaps atmospheric ozone. All the Russulae contain oxydases which turn the tincture of guiacum more or less rapidly blue to a greater or less extent. Generally the change to blue is produced in all parts of the Russula, although often also with greater intensity in certain parts, as for example in the cuticle of the stem. Some species however possess constant peculiarities in this respect which enable us to distinguish them from the others. Thus *R. rosea* Quél. and *R. pseudo-integra* Arn. & Goris turn the alcoholic solution of guiacum blue in the gills, but only slowly and feebly elsewhere. *R. subfoetens* Sm. does not turn the solution of guiacum blue except in the cuticle of the pileus in young specimens.

Sulphovanillic and sulphoformolic reagents. These liquids are used as reagents of phenols, and render great assistance to the study of the Russulae. The sulphovanillic reagent was introduced into mycological studies by ARNOULD et GORIS (1907); it was first used in the micro-chemical research for phloroglucin by LINDT (1885), then by REICHL et MIKOSCH (1890) for the microchemical characters of the proteids, and lastly by RONCERAY (1904) for the investigation of orcin in the orchill-lichens. The formulae given by these authors differs in some details, and I have followed the one indicated by ARNOULD et GORIS after RONCERAY.

Distilled water -   - 2 cc.
Pure sulphuric acid - 2 cc.
Vanillin -   -   - o gr., 25.

It is necessary to use a very pure vanillin, such as *Merck's* for example, because some of the commercial vanillins give an abundant deep blue precipitate when they are mixed with water and sulphuric acid, and are useless. This reagent will keep for a very long time in a yellow glass bottle, but in consequence of the great percentage of sulphuric acid that it contains there is always a tendency to hydrate itself, which causes a precipitation of the vanillin. It is therefore necessary from time to time to add some drops of sulphuric acid and to renew the reagent when it has become too attenuated. The sulphoformolic reagent was suggested to me by ARNOULD, and I have much pleasure in thanking him specially here for his kind assistance in my work with the Russulae. We employed according to his indications the following formula : —

Distilled water   -   -   xxv. drops.
Pure sulphuric acid   -   1 cc.
Formol (40% solution) -   lxxv. drops.

This reagent keeps still better than the sulphovanillic reagent but it naturally has the same tendency to hydrate itself. The two above reagents give absolutely parallel reactions and may be employed indifferently the one in the place of the other, but it is better to use the two, because this gives us the advantage of a permanent control of the reactions. We can use them either for direct application on the fungus with the naked eye or for the microscopical study of sections. The second method of employment is the most useful in the majority of cases. We have indicated before how one prepares these sections destined to be studied by means of these reagents and how they are subsequently mounted. We find by microscopical examination that the tissues remain uncoloured under the action of the sulphoformolic reagent, although the cystidia and the lacticiferous vessels take in the majority of species a tint more or less deep of mahogany-brown, due to the colour of the oil drops in a more or less state of emulsion in their contents. Young cystidia give the most intense reaction ; when old they give little or none, because their contents have become rarified. We find moreover that the acridity of the fungus corresponds with the intensity of the reaction and the abundance of the organs reacting. Young specimens of the most acrid species, such as *R. drimeia* Cke. and *R. sardonia* Bres. become almost quite brown because of the great abundance of the cystidia and of the lacticiferous vessels and the intensity of their reaction, in the gills, the peripheral portions of the stem and in the cuticle of the pileus.

Absolutely mild species on the other hand do not possess lacti-
ciferous vessels, and very few cystidia give any reaction. We
know, on the other hand, that the acridity disappears in dried
specimens : and it is the same for reactions in the case of the
cystidia and lacticiferous vessels in dried specimens, so that their
study is of no use. These considerations lead us to suppose
that the acridity of the Russulae is due either to phenols or to a
body having a phenol molecule. Be that as it may the diverse
degrees of this reaction, as especially its absence, enables us to
characterize certain species. Thus in *R. maculata* Quél. the
cystidia of the stem and gills are coloured, but not those of the
pileus ; on the other hand they are distinctly characterized by
the absence of any reaction in *R. pseudo-integra* Arn. & Goris,
R. punctata Gill. and *R. lepida* Fr. *R. rosea* Quél. possesses a
reaction absolutely unique, in my opinion, and enables us to
recognise it in all its forms. No part of it becomes brown under
the action of the sulphoformolic reagent (except a few cystidia
which sometimes react very feebly) but *the flesh in all parts
of the carpophore becomes light blue after the expiration of a
few minutes.* The case of *R. rosea* Quél. is the first record of
the macroscopic employment of this reagent. The change to
blue is easily affected if we let a drop of the sulphoformolic re-
agent fall upon any part of the fungus (with the exception of
the cuticle of the pileus where the pigment obscures this obser-
vation). If we use the sulphovanillic reagent the reactions are
different but parallel. Whenever the tissue remains uncoloured
by the sulphoformolic reagent then the sulphovanillic reagent
colours it more or less red ; wherever the former stains
mahogany-brown there we notice a more or less blue tint. The
intensity of the blue colour and the abundance of the cystidia
and lacticiferous vessels which they represent corresponds here
also with the acridity of the species. The species that do not
give a blue reaction to the sulphoformolic reagent, give a red
reaction as in all other fungi. This red colour is due to the
protoplasm being coloured by the reagent ; it is very feeble in
the ordinary tissues and the spores, on the other hand it is much
more intense in the hymenium where the protoplasm is very
dense. In the protoplasm of the cystidia this red reaction is
often seen by the side of the blue reaction caused by the secreted
matter. Macroscopically there is no red tint or only a very
faint one, with the exception of that on the hymenium. This
red reaction is of no importance to the systematist ; it is very
general and has caused the use of vanillin as the reagent of pro-
toplasm. The blue reaction, on the contrary, has the same value
as the mahogany-brown reaction of the sulphoformolic reagent.
R. rosea Quél., which gives such remarkable peculiarities with
the sulphoformolic reagent behaves also in a very peculiar fashion

with the sulphovanillic reagent. It does not give the blue reaction, but on the other hand it produces instantaneously an *intense carmine-red reaction in all its tissues.* This reaction is easily observed macroscopically: every spot touched with a drop of the sulphovanillic reagent immediately becomes deep carmine-red; it acts therefore as a useful control to the reaction produced more slowly and with less intensity by the sulphoformolic reagent. The carmine-red reaction of *R. rosea* Quél. is quite different from the usual red reaction. This is much less intense, the red is more violaceous and is produced in the protoplasm: consequently it is little noticeable in the flesh, which is richer in cell sap than protoplasm. The former, on the contrary, proceeds from the cell sap, which it colours very strongly, and we can often see little purple crystals precipitated; it is then often very intense in the flesh. There are certainly other chemical reagents that may be of use to the systematist. Thus many of the aldehydes considered as reagents of the phenols have been used by LINDT concurrently with vanillin as reagents of the albumenoids, and may be employed in the study of the Russulae. Such are the following aldehydes, benzoic, salicylic, cinnamic, &c. M. ARNOULD has very kindly made some experiments with these different reagents, which were crowned with success. With the benzoic aldehyde, for example, he obtained a black coloration parallel to the blue one obtained by vanellin. But these reagents are much more difficult to use than the sulphoformolic and sulphovanillic reagents, so it is consequently best to employ these last. The same chemist has further found that the bodies which contain formol (urotropine, trioxymethylene, &c.) react in the same way, this may be of use to those people who are troubled by the irritating vapours given off by the sulphoformolic reagent. The membrane of the spores of the Russulae often turns blue either directly with iodine or with iodine and sulphuric acid; it would be useful to find out if we could systematically apply these reactions. Potash, which generally discolours the cuticle of the pileus, after changing to yellow, sometimes very pronounced, turns that of *R. fellea* Fr. into a greyish violet. Let me remind you that in the neighbouring genus the cuticle of *Lactarius turpis* Fr. is changed into violet.

III.   *Summary of the Method for the Description of the Russulae.*

I think it is useful to sum up in the following table the characters studied above, trusting that it may be of use to mycologists desirous of either studying or describing a Russula so that they may not omit any important character.

A.   Macroscopical characters.

1.   General characters.

Size—Taste—General colour of the flesh and its alterations—
Firmness—Smell—Colour of spores in the mass.

2.   Characters of the stem.

Shape—Appearance and colour of the surface—Dimensions—
Interior structure.

3.   Characters of the pileus.

General shape—Dimensions—Margin.
Cuticle : colour, viscidity, adnation, aspect of the surface, colour
of the flesh under it.

4.   Characters of the gills.

Colour—General   shape—Width—Thickness—Edge—Insertion
on the stem—Spacing—Intervenation.

B.   Microscopical characters.

1.   Characters of the gills.

Edge—Mediostratum—Subhymenium—Cystidia—Basidia.
Spores : colour, shape, size, armature of the membrane, contents.

2.   Characters of the cuticle.

Cuticle of the pileus : general structure, cystidia, hairs.
Cuticle of the stem : cystidia, hairs.

C.   Chemical characters.

Action on the alcoholic solution of guiacum.
Action of sulphoformolic and sulphovanillic reagents.
Action of potash.