NOTES.

ON THE APICAL GROWTH OF FUNGAL HYPHAE.—It is usually stated in the text-books (e. g. Gwynne-Vaughan (1), p. 1) that the growth of fungal hyphae is apical, and it is obvious that the greater part of the elongation does take place at the tip. One might, however, reasonably expect that some extension of the more recently formed segments also occurs, and that growth, while mainly apical, is also to some extent intercalary. I have been unable to find any published account of detailed observations maintained for any considerable period of time, and, as the question is of importance in connexion with rates of growth, a brief record of some experiments *ad hoc* may not be superfluous.

Spores or, in some cases, fragments of mycelium were sown on the surface of miniature agar plates, formed by pouring agar on cover-slips,¹ which were then inverted over van Tieghem cells and the preparations incubated at 24°–25° C. After germination had occurred and the hypha had reached a convenient size, the lengths of the segments already formed were measured, at varying intervals of time, over a period extending in different cases from five to fifty-six hours. Where septa were absent or difficult to distinguish, the intervals between successive branches were determined. The agar used was a batch of clear prune agar, and the observations were made at room temperature. Measurements were made with a Bausch and Lomb screw-micrometer eyepiece and Zeiss C objective.

It is unnecessary to give a detailed account of the observations with the different organisms examined, but abbreviated records of two experiments may be given as examples.

TABLE I.

Fusarium No. 18. (*Prune agar: measurements in μ ; times in minutes from the first measurement.*)

Time	0	100	161	249	323	407	489	1468
Segments 1–7	494.9	496.6	499.6	497.6	497.6	499.3	498.6	496.7
Segments 8		23.3	23.3	23.3	23.3	23.3	23.3	23.3
Segments 9–11		143.3	140.9	141.3	141.7	143.3	140.4	138.3
„ 12–14			138.7	138.4	137.3	135.9	137.7	300.7
„ 15–17				162.3	161.7	158.7	161.6	
„ 18–21					163.0	162.7	163.3	163.6
„ 22–25						305.9	306.9	305.6
To tip	186.7	206.7	190.0	200.0	183.3	70.0	235.0	2334.0
Whole hypha	681.6	869.9	992.5	1162.9	1307.9	1499.1	1704.5	3762.2

Table I shows the result of an experiment with *Fusarium* No. 18. When first measured the hypha showed seven segments or cells, which together measured 494.9 μ , and the length between the tip and the nearest septum was 186.7 μ . As the

¹ This may be done very conveniently by laying on a cover-slip a glass ring, such as is used in a van Tieghem cell (it must not be too small—1.7 cm. is a convenient size), and pouring into it melted agar to any desired depth. When the agar has set the ring is removed and leaves a circular platform of agar, which after inoculation is laid on the cell in the usual way. The growing organism is easily observed through the agar.

hypha grew, new septa were laid down, forming new segments. Every segment was measured separately, but, to economize space, adjacent segments are grouped together in the table.

It will be seen that during the period of observation no change takes place in the length of the segments after they are once formed. The measurements vary a little owing to the difficulty of every time bringing the comparatively broad cross-line of the micrometer exactly in the same place over the septum, and also owing to the fact that the hypha does not grow perfectly straight. These discrepancies are experimental, and would have been reduced had the camera lucida been employed. There is no evidence of increase in the length of a segment, once it is formed, although the whole hypha had grown over 3,000 μ .

The average length of the segments is 58.8 μ , and the distance from the nearest visible septum to the tip varied at the different observations from 70 to 260 μ , with an average of 191.5 μ , the length of about $3\frac{1}{2}$ segments. Each septum is no doubt laid down some time before it becomes visible: how much before it is not possible to tell exactly. The whole hypha elongated at a mean rate of 2.1 μ per minute during the first eight hours, so that it would require about ninety-five minutes to increase by the length of $3\frac{1}{2}$ segments. The elongation must occur in the portion between the tip and the nearest septum. It is, however, occasionally possible to get a measuring point much nearer the tip than the nearest visible septum. Branches may, and often do, arise from segments long after they are first formed; but sometimes a branch is begun immediately behind the tip, and its bud is perceptible very close to the extreme tip. In such cases the interval between the point of origin of the branch and the nearest septum then visible remains constant, showing that elongation is taking place only at the apex, and not at all in formed portions of the hypha.

A similarly abbreviated record of an experiment with *Pyronema confluens* is also given: see Table II. Here also the growth is entirely apical, the apparent small extension of the segments being probably due to errors of measurement, and in any case so very slight as to be negligible in comparison with the growth at the tip.

TABLE II.

Pyronema confluens.

Time	0	66	152	263	330	417	476	1469
Segments 1 and 2	25.1	26.2	25.8	26.2	26.9	27.3	27.0	25.1
Segment 3	15.7	16.4	16.4	16.8	15.0	14.2	16.1	16.5
Segments 4-6				73.4	75.3	76.0	74.9	75.7
Segment 7						47.2	48.0	47.9
„ 8								48.0
Segments 9-19								518.6
To tip	109.2	137.2	149.6	127.5	177.3	190.5	239.2	420.0
Whole hypha	150.0	179.8	191.8	244.1	294.5	355.2	405.2	1151.8

The following organisms have been examined similarly, and all show the same thing, that growth in length is exclusively apical. When septa were difficult to see, the intervals between successive branches were measured.

Phytophthora parasitica (Strain: Egg-plant, Nat. Coll. Type Cultures No. 1187).

No change in intervals between branches in 22 hours; hypha grew 389 μ .

Aspergillus niger (Nat. Coll. Type Cultures No. 594). No change in branch intervals in $7\frac{1}{2}$ hours; hypha grew $250\ \mu$.

Penicillium expansum (Washington 4189; Nat. Coll. Type Cultures No. 593). No change in branch intervals in 47 hours; four hyphae observed, of which one grew $719\ \mu$ in $9\frac{1}{2}$ hours.

Pyronema confluens (Birkbeck: Nat. Coll. Type Cultures No. 1245). No change in segments in 24 hours; two hyphae observed; mean length of segments, $39.7\ \mu$; mean length from tip to nearest septum, $136.9\ \mu$; one hypha grew $1,001\ \mu$.

Rhizoctonia solani (Jersey potato; Nat. Coll. Type Cultures No. 1007). No change in segments in 56 hours; two hyphae and five branches measured; mean length segments, $151.7\ \mu$; mean length tip to nearest septum, $179.6\ \mu$; one hypha grew $979\ \mu$.

Rhizopus nigricans (Roth. No. 13). No change in identifiable portions of hypha in 44 hours; hypha grew $4,149\ \mu$.

Botrytis cinerea. No change in segments in $10\frac{1}{2}$ hours; mean length segments (ten hyphae), $51.6\ \mu$; tip to nearest septum, $133\ \mu$; one hypha grew $1,710\ \mu$. With this organism the growth of aerial hyphae was also investigated, growth occurring also only at the apex.

Fusarium (three species).

1. No. 10 A a 4. No change in segments in 5 hours (two hyphae); mean length segments, $31.1\ \mu$; tip to nearest septum, $138.5\ \mu$; one hypha grew $176\ \mu$.

2. No. 13 c B b. No change in segments in $6\frac{1}{2}$ hours; mean length segments, $65.7\ \mu$; tip to nearest septum, $179\ \mu$; one hypha grew $1,288\ \mu$.

3. No. 18. No change in segments in 24 hours; mean length segments, $58.8\ \mu$; tip to nearest septum, $191.5\ \mu$.

SUMMARY.

These fungi are representatives of widely separated genera, and in all it is found that the growth in length is purely apical, no appreciable elongation occurring in any part of the hypha other than the tip. This then would seem to be the general rule for fungi, though exceptions may perhaps occur. It may be contrasted with what occurs in filamentous bacteria, where each of the segments expands equally at the same rate (Marshall Ward (2)), and in algae, where both types of growth occur, the purely apical and the intercalary (West (3)).

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