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ON THE RELATION BETWEEN CELL-DIVISION AND ELONGATION IN THE ROOT OF *VICIA FABA*[1]

Hitoshi KOJIMA

INTRODUCTION

The manifestation of daily periodicity in the rate of cell-division as well as of growth in plants under normal external conditions has been a well-known fact since the nineteenth century. For instance, STRASBURGER (13) reported in 1880 that in *Spirogyra* the cell-division was most rapid at night and MEYER (8) found in 1827 that the elongation in the flower-stalk of *Amaryllis Belladonna* during the night was nearly twice as rapid as during an equal period of daytime. But as regards the question whether, when external conditions are kept constant, the daily fluctuations may still occur or not, there are not so many informations. KELLICOTT (6), KARSTEN (4, 5), FRIESNER (3), STÅLFELT (11) and others made observations regarding this point, but there is little concert of opinion among them, and the explanation offered with reference to the cause of the rhythmic variation cannot yet be considered conclusive. The observations described in this paper are designed to contribute something to the study of those questions.

The writer wishes to take this opportunity to express his very considerable indebtedness to Professor Dr. Riichirô KÔKETSU, for his cordial

[1] Contributions from the Botanical Laboratory, Kyushu Imperial University, No. 19.

advice and unceasing encouragement given throughout the progress of the work.

OBSERVATIONS ON CELL DIVISION, NO. I

Broad beans (*Vicia Faba* L., " wase "-line) of nearly uniform shape and weight[2] were selected and soaked in water on the evening of May 31, 1924. At 10:20 of June 2 they were sown in saw-dust of Coniferae wood and placed in a room facing the north and rather dimly lighted. Beginning at noon of June 4, at intervals of about 2 hours throughout a 26-hour period, more than ten seedlings each were taken out; among which several sound, and alike in development of root were selected for the examination. The root tips were fixed in FLEMMING's weaker solution[3], sectioned with paraffin longitudinally (exactly parallel to the axis of the root) 10μ thick, and stained in HAIDENHAIN's iron-alum haematoxylin. From each root, the five sections passing nearest the axis of the root were chosen and observed under the microscope.

A ZEISS' microscope with objective DD and ocular 4 (10×), tube length 160 mm, was used. A regular square frame corresponding to 0.2 mm square on the section under the microscope was traced out on the drawing table by camera lucida after ABBE, and the number of cell-nuclei transcribed by the apparatus within the square frame were counted in two groups, respectively in resting stage and in mitosis (the two daughter-nuclei of a cell in telophase were counted as one). The observation on the first 0.2 mm^2 was made at the growing point of the root, while the second was made on the periblem of the root in contact with the first; thus the third, fourth etc. in basifugal order, each contiguous with the previous one, were observed on the periblem. In this manner the part of the periblem within ca. 2 mm of root tip was observed[4].

The room in which the examination took place was dimly lighted

[2] S. F. TRELEASE and H. M. TRELEASE (15) reported that seedlings from seeds nearly uniform in size and weight were also uniform in vital force. The weight of broad beans used in this work was ca. 10 grams and the deviation was about 2%.

[3] Cf. CHAMBERLAIN (2) p. 27.

[4] SCHÜEPP (10) reported that in the root tip of *Vicia Faba* the mitotic figures were seen only within 4 mm on periblem, and 2—2½ mm on plerom, while the greatest value of the percent for cell division was on the portion ¼—½ mm above the growing point. PEKAREK's study (9) also showed that the mitotic figures were most abundant within 2 mm of root tip. In the present work the mitotic figures were found also on outside 2 mm of root tip, yet their number was so rare that the observation was omitted.

as it faced the north, and curtains were droped, and furthermore the seedlings were placed within sawdust, and no part of them was exposed to the light, so the influence of light may be considered negligible. The temperature of the room was 19°-21°C (compare thermal curve of Fig. 1). The humidity in the germination bed was always kept at the saturation point.

Table I.

Intensity of cell division indicated by quotient $\frac{a}{b}$ (%), where a is the total number of dividing cells and b is the total number of cells in given area.

Time	No. of slides	No. of cells in resting stage	No. of cells in mitosis			Total no. of dividing cells (a)	Total no. of cells (b)	$\frac{a}{b}$ (%)	No. of unit area examined
			Early*	Middle**	Late***				
12:00	5	7425	362	160	93	615	8040	7.64	160
14:25	5	8467	382	159	102	643	9110	7.05	160
17:25	4	8772	932	324	173	1420	10192	13.93	171
20:15	5	10420	829	318	145	1292	11712	11.03	201
22:25	5	8644	319	209	121	649	9293	6.98	162
23:45	5	10985	657	301	185	1147	12128	9.42	199
1:20	5	8680	304	267	160	731	9411	7.76	165
2:50	5	11033	838	308	167	1313	12346	10.63	202
4:15	5	9410	816	279	153	1248	10658	11.70	184
5:45	6	10630	485	252	164	901	11731	7.68	192
7:20	5	8599	1494	363	125	1982	10581	18.73	202
8:45	6	10498	406	271	214	891	11389	7.82	188
10:15	5	9574	414	300	162	876	10450	8.38	172
11:45	6	10743	590	280	181	1051	11794	8.91	195
13:45	5	8272	489	239	162	890	9162	9.71	157

*Prophase. **Metaphase and early anaphase. ***Late anaphase and telophase.

Some five root tips killed at a time were observed and the sum of the results of the observation on these root tips are given in Table I. The intensity of cell division is expressed by the quotient, obtained by dividing the number of cell-nuclei in mitosis in given area by the total number of cell-nuclei in the same area. Fig. 1 shows graphically the intensity of the cell division. In this time curve there are two maxima. The first maximum occurs during eight hours, between 14-15

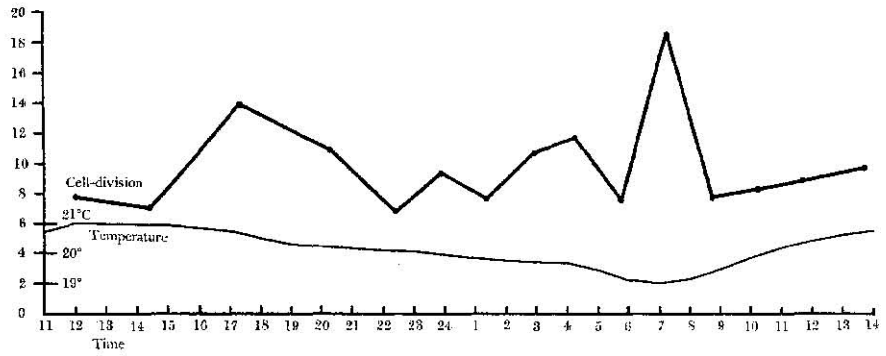

Fig. 1. Intensity of cell division.

and 22-23, having its highest point at about 17-18. From 22-23 to 5-6 is the first minimum stage (lasting about seven hours), following which the second maximum begins, the apex of it being at about 7-8. As the period of the second maximum is short the second minimum stage soon appears, which continues for six hours, from 8-9 to 14-15, and is again followed by the first maximum.

In other words, the first eight hours (from 15 to 23) are the primary active phase, the next seven hours (from 23 to 6) form a relatively inactive phase, the following three hours (from 6 to 9) the secondary active phase and the last six hours (from 9 to 15) the resting phase (compare also Fig. 5A).

OBSERVATIONS ON CELL DIVISION, NO. 2

Broad beans were selected as in the preceding observation, soaked in water in a dark room at 15:30, October 29, 1926. At 11 of November 1, they were sown in sawdust, and placed in a dark electric thermostat of 27°-28°C. From 8 of November 4, at one-hour intervals more than ten seedlings were pulled up; from among them several, sound and moderate in growth, were chosen and fixed in formalin alcohol mixture (formalin 4 cc + 70% alcohol 100 cc), then stained in alum carmin[5] in bulk 24 hours. Longitudinal paraffin sections of 10μ thick

5 Cf. CHAMBERLAIN (2) p. 53. Regarding the accuracy of stained figures this method is somewhat inferior to the iron haematoxylin method, but it surpasses that method in trouble saving when treating a great quantity of materials, and in getting preparations uniformly stained as it does not tend to overstain.

Table II.

Intensity of cell-division indicated by quotient $\frac{T}{A}$ (%), where T is the total number of mitotic figures and A is the relative value of the area examined.

Time	No. of slides	Total No. of mitotic figures (T)	Relative value of the area (A)	$\frac{T}{A}$ (%)	Total length of the root (cm)
8:00	5	2438	948	257	ca. 6
9:00	4	1567	737	212	6—8.5
10:00	5	2105	917	229	6—7.5
11:00	6	2426	1093	221	8—9
12:00	5	2476	966	256	7—9
13:00	6	2039	1096	185	6.5—8
14:00	5	1739	912	190	7.5—8.5
15:00	7	2678	1302	205	6—7.5
16:00	6	2105	1150	183	6—7.5
17:00	5	2155	913	236	7—8.5
18:00	5	1916	900	212	7.5—9
19:00	7	2173	1246	174	7.5—11
20:00	7	1897	1246	152	8—10
21:00	6	2185	1028	212	8—9
22:00	4	1710	707	241	8—10
23:00	6	1923	1056	182	8—10.5
24:00	6	2248	1026	219	9—11.5
1:00	5	2095	892	234	9.5—11
2:00	5	1678	850	197	9.5—11
3:00	5	1330	837	158	9.5—11.5
4:00	8	2563	1386	184	10—13
5:00	6	1455	996	146	9—12
6:10	8	1978	1300	152	9.5—13.5
7:00	6	1831	996	183	9.5—12
8:00	7	2615	1164	224	9.5—12
9:00	6	1963	1092	179	9.5—11
10:00	5	1517	841	180	11—13
11:00	6	1539	966	159	10—13

were made. From each root tip, five sections, those passing nearest the axis of the root were observed. The microscope used was the same as in *Observations, No. 1*. In order to express the intensity of the cell-division the following observations were made. The number of dividing cell-nuclei (from prophase to telophase) within the space of 3 mm from the root apex was counted. At distances of respectively 1, 2 and 3 mm from the root apex, the diameters of the root were measured. The sum of the numbers indicating the diameters thus measured was used as the relative value of the tissue area included in the space of 3 mm from the root apex. The intensity of cell division is expressed by the quotient obtained by dividing the number of cell-division by the relative value of the area[6]. In Table II the sum and average of results obtained in observation of the several roots killed at a time, are given. This table is represented as a curve in Fig 2.

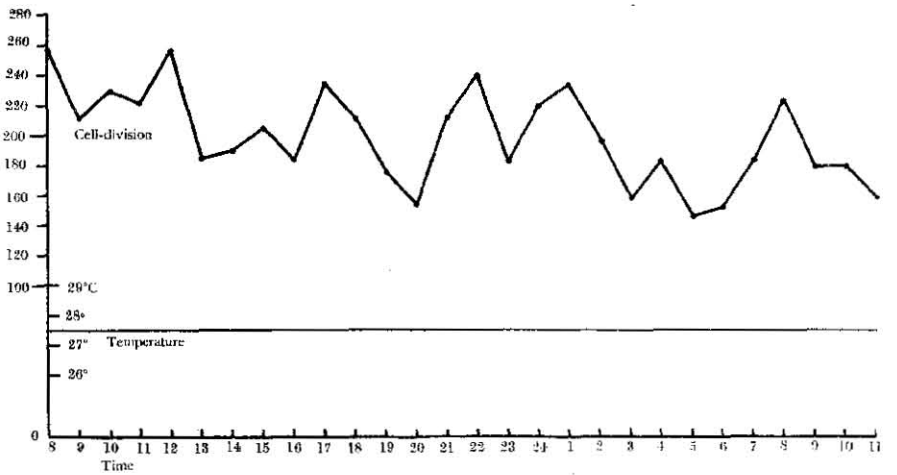

Fig. 2. Intensity of cell-division.

There are two provable maxima: the first maximum, with two crests, begins at 6 and finishes at 13; during the next seven hours (between 13 and 20) the first minimum takes place; following which the second maximum phase occurs and continues seven hours (from 20 to 3). Between 3 and 6 (during three hours) there is a second minimum stage, and then the first maximum recurs. In short, the first seven

[6] KELLICOTT (6) stated that the size of a part or organ is determined by the number of cellular elements contained in it, and not by variations in their size.

hours (from 6 until 13) is the primary active phase and following seven hours (from 13 to 20) is the primary resting phase, in the next seven hours (from 20 to 3) appears the secondary active phase and the last three hours (from 3 to 6) form the secondary resting phase. Thus the 24-hour period is completed (see also Fig. 5B).

As these materials were kept in a dark thermostat and in germination bed at the saturation point, these three external conditions would seemed to be constant.

OBSERVATIONS ON ELONGATION, NO. 1

The materials used in this experiment were the same as in *Observations on cell division, No. 1*. The length of the young root of the material was about 3 cm. The method emploid in this observation is as follow:

On a photographic glass plate (Ilford's Process), by photography, a scale each space representing 0.22 mm was produced. In order to fix the seedling on the plate, by means of a silver gilded pin, a block of cork was glued to it. The plates, with seedlings being thus prepared, were placed vertically in a glass box. The box was covered with black paper, and humidity within it was brought to the saturation point. At intervals of about 30 minutes the degree of elongation in the root was read under a normal microscope (Zeiss', Huygens' ocular 4 (10×), objective AA, tube length 160 mm) with aid of the ocular micrometer (Zeiss', ruled in tenth of a mm) and the scale on the plate.

Nine roots, under the same conditions, were observed in parallel. In Table III the results of observations are shown, in which the rate of elongation within each two hours is cited in mm. Though there appears some irregularity in the courses of some roots, due probably to individual difference, speaking in general, there are one active phase and one resting phase. That is, from 1 to 17 (i.e. 16 hours) the rate of elongation is rapid (active phase), and from 17 to 1 the rate is slow (resting phase). Fig. 3A shows the curve of the total average in time records of a day, while Fig. 3B is the curve of the total average summed up so that the beginnings of the active phases come in coincide. These curves represent clearly the relation of active and resting phases (cf. Fig. 5A).

These observations were made from 11:30 of June 4, 1924, and ceased at 13 of the next day; and throughout the observation tem-

Table III.

The rate of elongation, per two hours, indicated in mm.

Material / Time*	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	Total	Average	Added up so that the beginnings of the active phases come in coincide, regardless of time.	Total	Average
13:00	1.55	1.56	1.64	*1.29*	0.98	1.29			1.46	11.58	1.29		7.29	0.81
14:00							1.00	0.79						
15:00	1.27	1.29	1.31	*1.33*	1.01	0.96			*1.04*	10.10	1.12		11.13	1.24
16:00							0.90	1.05						
17:00	*1.07***	1.21	*1.00*	*1.03*	1.24	*0.69*			*0.73*	*8.87*	*0.99*		12.61	1.40
18:00							*0.75*	1.39						
19:00	*0.83*	*1.04*	*0.94*	*0.78*	1.03	*0.78*			*1.25*	*8.79*	*0.98*		12.71	1.41
20:00							*0.75*	*1.11*						
21:00	*0.87*	*1.18*	*0.91*	*0.98*	*0.92*	*0.64*			*1.35*	*8.54*	*0.95*		12.42	1.38
22:00							*0.85*	*1.13*						
23:00	*1.11*	*1.04*	*1.04*	1.55	*0.88*	*0.72*			*1.14*	*10.11*	*1.12*		12.04	1.34
24 00							*0.98*	*1.17*						
1:00	*0.53*	*0.81*	*0.77*	2.08	*0.51*	*0.33*			1.56	*8.06*	*0.90*		12.58	1.40
2:00							*0.47*	*1.20*						
3:00	1.33	*0.70*	1.13	2.02	*0.85*	0.85			1.56	10.24	1.14		11.22	1.25
4:00							0.73	*1.46*						
5:00	1.53	0.88	1.07	2.38	*0.92*	1.24			1.25	12.00	1.33		*8.91*	*0.99*
6:00							1.04	1.89						
7:00	1.39	1.04	1.43	1.92	1.22	1.39			1.35	12.09	1.34		*8.55*	*0.95*
8:00							1.18	1.47						
9:00	1.51	1.14	0.65	1.66	1.59	1.56			1.56	13.09	1.45		*8.26*	*0.92*
10:00							1.04	1.66						
11:00	1.68	1.21	1.29	1.69	1.25	0.96			1.87	12.68	1.41		*8.81*	*0.98*
12:00							1.26	1.74						
													7.29	*0.81*

*The time indicates the middle of the every two-hour period.

**The italics mean the resting stage.

perature, illumination and humidity were nearly constant (compare *Observations on cell-division, No. 1*)

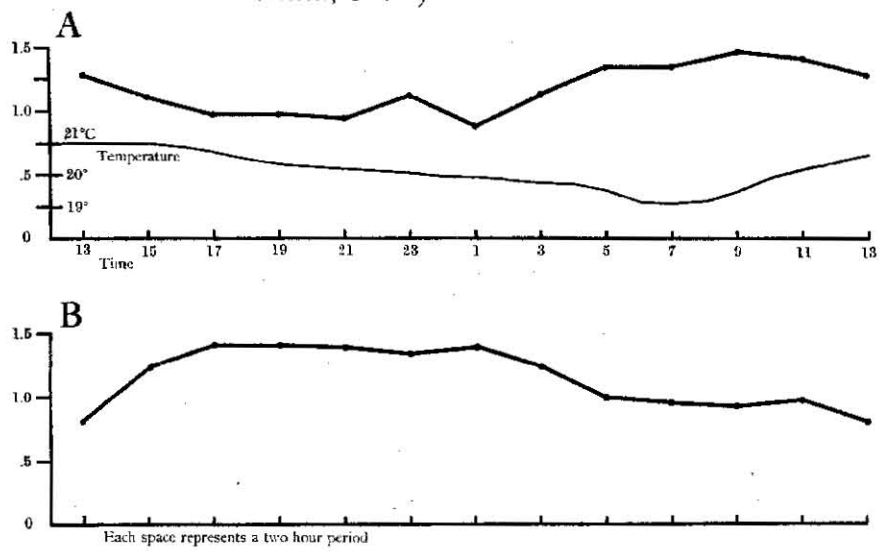

Fig. 3. Average curve of elongation. A based on the time of day by the clock; B based on rearrangement of curves in coincidence of phases.

OBSERVATIONS ON ELONGATION, NO. 2

In the afternoon of October 11, 1924, broad beans were soaked in water and in the morning of October 13 were planted in sawdust. From 19:20, October 15, the observation was begun. The method of observation was same as before. The temperature of the room was 23°C at the beginning, but it descended from the afternoon of the next day to 19°C (compare Fig. 4, thermal curve).

The other two factors were nearly constant as in *Observations, No. 1*. In this observation eleven root tips were measured in parallel. In Table IV the sum and average in the rate of elongation of these eleven, reduced in bi-hourly values, is cited. The descent of the temperature in the later half seems to have had a slight influence upon the root and the rate of elongation became somewhat slower[7]. In these cases also

[7] As regards the relation between temperature and elongation in *Pisum sotivum* LEITCH (7) reported that the descent of temperature has no influence upon the rate of elongation but the roots adapt themselves quickly to the new level of temperature. In this case the degree of descent in temperature was not so great, yet some influence upon the elongation must be recognized.

Table IV.

The rate of elongation per 2 hours, indicated in mm. The values given are totals and averages based on experiments on eleven root tips.

Time*	Total	Average		Total	Average
21:00	3.27	0.30	Added up so that the beginnings of the active phases come in coincide, regardless of time of day.	1.72	0.16
23:00	3.45	0.31		3.19	0.29
1:00	3.91	0.36		3.73	0.34
3:00	3.52	0.32		4.11	0.37
5:00	3.46	0.31		3.49	0.32
7:00	2.62	0.24		2.91	0.26
9:00	2.38	0.22		2.94	0.27
11:00	*2.29*	*0.21*		2.48	0.23
13:00	*2.22*	*0.20*		*2.03*	*0.18*
15:00	*1.92*	*0.17*		*2.01*	*0.18*
17:00	*2.15*	*0.20*		*1.92*	*0.17*
19:00	*1.66*	*0.15*		*1.83*	*0.17*
				1.72	*0.16*

*The time represents the middle of the two-hour period.

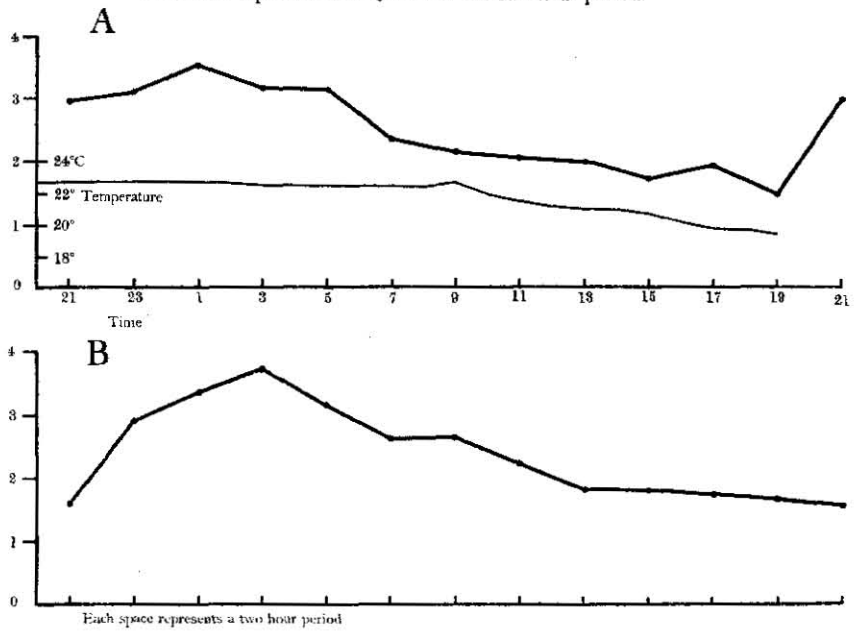

Fig. 4. Average curve of elongation. A based on the time of day by the clock; B based on rearrangement of curves in coincidence of phases.

some slight irregularity was seen among individual curves, yet generally they coincide each other. The table is plotted in the form of a curve in Fig. 4A and Fig. 4B; the former is summed up in terms of the time of day, and the latter as regards the coincidence of the resting and active phases respectively. Fig. 4A shows that from 19 to 11 (i.e. 16 hours) is the active phase and from 11 to 19 is the resting phase. This hourly relation of the two phases is more strictly seen in Fig. 4B.

OBSERVATIONS ON ELONGATION, NO. 3

The material used in this experiment was obtained as same as in *Observations on cell division, No. 2.* The measuring, at one-hour intervals, on the elongation of the root was done on the 4th and the 5th of November, 1926. The result is given in Table V, in which the first 15 hours (from 13 to 4) are the active phase and from 4 the resting phase begins. The observation ceased at 10, but this resting phase is likely to continue until 13 and the active phase probably recurs at that time.

Table V.

The rate of elongation, per one-hour period, indicated in mm.

Time	Elongation	Time	Elongation
13:00		24:00	
	1.36		1.69
14:00		1:00	
	1.76		0.44
15:00		2:00	
	2.72		0.68
16:00		3:00	
	1.80		1.21
17:00		4:00	
	1.71		*0.48*
18:00		5:00	
	1.95		*0.60*
19:00		6:00	
	1.91		*0.39*
20:00		7:00	
	2.36		*0.64*
21:00		8:00	
	0.80		*0.66*
22:00		9:00	
	0.96		*0.03*
23:00		10:00	
	1.93		
24:00			

This observation was done in a dark thermostat (27°-28°C) and humidity was at the saturation point. Only when measuring the length of the root a weak red light was allowed to illuminate it.

OBSERVATIONS ON ELONGATION, NO. 4

On the 29th of November, 1926, a germinated seedling was fixed in a glass tube (diam. 3 cm, length 20 cm) so that the root was immersed in water and the cotyledones were embedded in moist sawdust.

WINKEL's horizontal microscope (ocular 2, with micrometer, and objective A+B) was used. The measuring on the elongation was done at intervals of from 30 minutes to 1 hour. The results of the observations are given in Table VI, in which the numerals are calculated on bi-hour period.

The first 16 hours (from 5 to 21) are the active phase, and the next 8 hours (from 21 to 5) are the resting phase. Throughout this observation the temperature was about 26°C and nearly constant and it was always dark.

Table VI.

The rate of elongation, per 2 hours, indicated in mm.

Time*	Elongation	Time	Elongation
11:00	0.93	3:00	*0.55*
13:00	0.66	5:00	*0.58*
15:00	1.05	7:00	0.68
17:00	1.15	9:00	0.68
19:00	0.94	11:00	0.73
21:00	*0.62*	13:00	0.75
23:00	*0.61*	15:00	0.76
1:00	*0.61*		

*The time represents the middle of the two hour period.

CONCLUSION AND DISCUSSION

KELLICOTT (6) observed in the root tip of *Allium* that the first maximum in the rate of cell division occurs at 23 and the second maximum at 13 and that the first minimum at 7 and the second minimum at 15, namely there are two maxima and two minima during 24 hours. KARSTEN (4) found that from 21:30 to 1:40, the cell division in the growing point of shoot in *Pisum sativum* is most rapid, the minimum occurs at about 8 and there are slight variations during daytime; and also that in the growing point of shoot in *Zea* the maximum is at 4,

but in the case of the root there is no such regular rhythm. He (5) reported in the growing point of shoot in *Pisum austrica* the maximum is between 0:30 and 4. On the other hand STÅLFELT (11) stated, contrary to KARSTEN'S (4) observation, that in the case of the root in *Pisum sativum* there exists a rhythm, i.e. maximum at 9—11, minimum at 21—23. ABELE (1) observed three maxima in the rate of cell division in the root of *Vicia amphicarpa*.

According to these reports we may be certain that there are fluctuations in the rate of cell division during 24 hours, and in the two cases of the writer's experiments (*Observations on cell division, No. 1* and *No. 2*) it was observed that there are two recognizable maximum phases in the curve of intensity of cell division, although the time and extent of maxima and minima are not always definite

As regards the factors influencing this phenomenon, though there may be some external unknown factors aside from the commonly known ones, such as light, temperature, humidity etc. (cf. 12), yet it seems probable that some internal conditions may also be related to this oscillating phenomenon, namely, the variation of rate of cell division in root originating from the alternation of active phase, i.e. cell division, and resting phase which necessarily follows the cell division for re-emassing the energy that was lost during the active phase. Hence it would follow that there is not such a fixed time, in which the maximum or minimum regularly occurs. But for each individual there exists a peculiar periodicity, and further for individuals under similar conditions, a rhythm common to all. For this reason it can easily be understood why the observations of the above mentioned workers do not show an absolute similarity in regard the course in the rate of cell division.

About the elongation SIREHL (14) reported that in the root of *Lupinus* a maximum (at night) and a minimum (at about noon) were found. KELLICOTT (6) observed that there are the primary maximum at 17, the primary minimum at 23, the secondary maximum during 3 and 9 and the secondary minimum at 23 in the root of *Allium*. On the other hand STÅLFELT (11) reported that there was no such a constant rhythm regarding to the elongation. Yet in cases under our observations, although there was not always coincidence as to time between the courses of elongation in different individuals, yet it was found that, generally speaking, 16 hours formed active phase and following 8 hours were resting phase. Moreover as in *Observations on elongation, No. 1* and *No. 2*, it was shown that individuals under the same conditions agree in their courses.

Comparing *Observations on cell division, No. 1* with *Observations on elongation, No. 1*, we can see the correlation between the cell division and elongation. (The materials used in these two experiments were grown from similar beans and under the same conditions.) In Fig. 5A the correlation is diagramatically showed; the heavy line means the

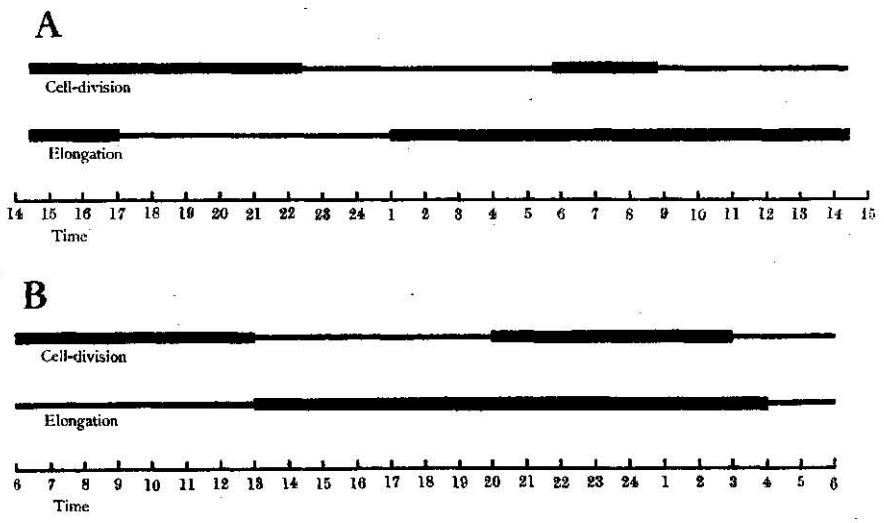

Fig. 5. The correlation of cell division and elongation shown diagramatically, where the heavy lines indicate the active phases, the thin lines the resting phases.

active phase and the thin line the resting phase. About 2 and half hours after the ending of the primary maximum phase in cell division (14—22), the active phase of elongation begins (at 1). This active phase of elongation continues for 16 hours (1—17), and followed by the resting phase of 8 hours (17—1). This resting phase of elongation nearly coincides in time with the primary maximum of cell division. During the active phase of elongation the secondary active phase of cell division occurs, yet there is no visible corresponding variation on the curve of elongation.

In the case of *Observations on cell division, No. 2* as well as *Observations on elongation, No. 3* (see Fig. 5B), the primary maximum phase of cell division occurs between 6 and 13, and concurrent with the ending of the phase, the active phase of elongation appears. This active phase of elongation continues from 13 to 4, and the resting phase takes place between 4 and 13. The first maximum of cell division coincides in time with the resting phase of elongation, while the second maximum

phase, which occurs during the active phase of elongation has no visible influence upon the rate of elongation.

Regarding the relation between cell division and elongation KELLICOTT (6) reported that the rhythms agree in time but always occur in opposite directions, i.e. when elongation is at a maximum cell division is at a minimum and vice versa. And FRIESNER (3) observed that the maxima and minima for elongation as compared to cell division were generally found to alternate with one another, only rarely occuring simultaneously.

Thinking for the relation between division and growth in a cell, it is evident that at first the division occurs then gradually increases the rate of growth until the maximum, and again decreases the rate; thus finishing the grand period of growth for a cell. And during the period in which a cell divides and finishes its growth, the positions of the cell gradually depart from the growing point, and in consequence, the position of a cell in the grand period of growth stands always at a definite distance from the position where the cell divided. In the case of the relation between cell division and elongation in the tissue of root tip, the former must be most vigorous around the growing point, and the latter must be most rapid in the part of "grand period of growth"; then the problem raises whether those two processes occur separately as independent physiological actions, or whether there exists a definite correlation between the two. If the two processes proceed in uniform rates respectively, no real problem is involved, but as the presence of the rhythmical processes is proved in both cases, consideration must be given to the existence and appearance of the correlation between the two.

It may be mentioned that cell division as well as growth are phenomena, which are carried out by using energy, therefore, within a limited tissue, when one phenomenon is active and spends much energy, the lack of sufficient energy for the other is apparent. As mentioned above, in the case of a single cell the division and elongation do not go on at the same time but alternately, and so the first half of total energy which is to be spent during the entire development, is used for the dividing and the latter half for the growth. From these reasons it may be evident that in a limited tissue or organ, energy must be used by cell division and elongation in a correlative manner. In our observations, the active phase of elongation followed after the primary maximum of cell division and thus reveals to us the true fact of the case.

But in the root tip the cell division and the elongation take place at separated points, hence the exact alternation of these two processes can not always be expected, and it can not be thought as irrationality that we could not find in the present observations the tendency of corresponding repression upon the rate of elongation by the secondary maximum of cell division

In short, it may be taken ascertain that, originating in the energy spending on the cell division and elongation in a root, these two phenomena appear in rhythmical variation in a reversed correlation in their principal courses. However it should be borne in mind that these rhythms of different materials do not agree in the time of day by the clock, but only in the length of period in any given phase of fluctuation.

SUMMARY

1. In the growing point of the root of *Vicia Faba* there is a daily periodicity in the rate of cell division under constant conditions of illumination, temperature and moisture. The curves indicating the variation of the rate are not always similar according as the differences in material and condition, but there is a certain definite curve for a knd of material under the same conditions, i.e. there are a primary maximum and a smaller secondary maximum during 24-hour period.
2. In the case of the elongation of the root under constant temperature, moisture and illumination, it is found to proceed in a rhythmical manner In accordance with the material and condition, the maximum and minimum do not always occur at fixed time of day by the clock, but they have some regular length of period, i e. the resting phase of 8 hours follows the active phase of 16 hours.
3. The primary active phase in cell division nearly coincides with the resting phase in the elongation, but the secondary maximum is accompanied by no recognizable resting phase in the elongation. However the active phase in elongation occurs several hours after the maximum point of primary active phase in cell division.

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