The occurrence of considerable gibberellin-stimulated cell division in the cambial zone in the current season's growth of apricot spur shoots but not in that of the long shoots would appear to be connected with differences in the growth phases of the two types of shoot. At the time of treatment the terminal buds of the long shoots were still active, whereas those of the spurs had already entered their rest phase. Application of gibberellin stimulated longitudinal growth of long shoots and in no way interfered with their lateral bud and shoot development. However, it not only failed to break the rest of buds on spur shoots but actually retarded bud development, as is indicated by the smaller size of buds on treated spurs than on those of controls.

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References and Notes

1. R. M. Sachs and A. Lang, *Science* 125, 1144 (1957).
2. J. C. Crane and R. Campbell, in preparation.
3. "Gibrel," a potassium salt of gibberellic acid; supplied by Merck and Co., Inc.
4. K. Esau, *Plant Anatomy* (Wiley, New York, 1953).
5. ———, oral communication.

29 July 1957

Tidal Overmixing in Estuaries

The eddies and currents which move salt water from the ocean into coastal estuaries and then mix the salt water with the outflowing fresh river water are important in determining the concentration pattern and movement of all suspended and dissolved materials in the estuary. Concentrations of salt, pollutants, oxygen, plankton, nutrients, and silt are in part controlled by the pattern of motion.

Salt water moves upstream against the river flow by processes ranging from the advection of a pure salt-water wedge flowing in on the bottom of deep estuaries to eddy diffusion associated with tidal currents in shallow water (*1*). The purpose of this report (*2*) is to discuss one of the processes of eddy diffusion that is due to tidal currents in the Coos Bay and river estuary on the Oregon coast; the discussion may be applicable to similar estuaries in other regions.

The Coos Estuary would be classed (*1*) as a positive, vertically homogeneous estuary with the principal movement of salt water upstream being caused by tidal eddy diffusion. The salt content is nearly constant with depth everywhere in the estuary, and it increases linearly from the fresh river water at the head of the estuary to full sea water at the mouth. The estuary is cut through low, coastal mountains and might be called a mountainous coast estuary. Although much of its area is composed of shallow tide flats, its average width is less than 1 mile. A narrow channel with mean depths of 7 to 10 m extends inland for 15 miles. The tides are the characteristic mixed tides of the West Coast, with a mean range of 1.6 m and a maximum range of 3.1 m. At times, the surface currents exceed 6 knots.

Higher high water is usually followed by lower low water, lower high water, and higher low water, in that order. From observations of salinity, which are discussed later, it can be inferred that the tidal excursion is greater at the surface than along the bottom, where bottom friction tends to retard the tidal currents. Right after low water, the whole estuary is nearly vertically homogeneous, having the same salt content from the surface to the bottom in any given position. During flood tide, the surface water moves upstream more rapidly than the bottom water. This causes an unstable salinity and density inversion, with more salt, more dense water on the surface than on the bottom. The heavier water sinks and the lighter water rises, causing mixing throughout the water column all the way from the surface to the bottom. This instability should appear during flood and high water.

During ebb, the surface water again out-distances the bottom water, but stability which may be observed during ebb and at low water is set up. Ebb currents are combined with river flow to give maximum velocities. These in turn bring about some turbulent vertical mixing during flow over the relatively shallow bottom. This tends to inhibit the formation of strong vertical stability.

Seven hundred and eighty-nine sets of surface and bottom salinity and temperature observations were examined statistically (3156 observations in all) in order to determine how often, and to what degree, the above pattern was followed in the Coos Estuary. Data were available from five stations on the estuary. Figure 1 shows typical salinity data for higher high water and lower low water for 2 days during 1931. Note that salinity inversions were present at all stations at higher high water during both days.

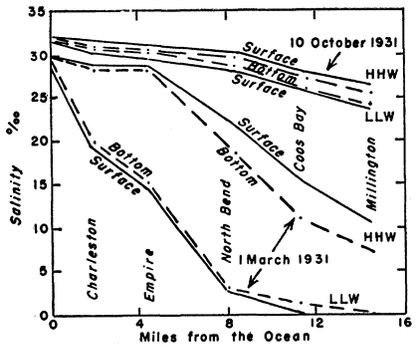

Fig. 1. The observed surface and bottom salinity distribution in the Coos Estuary on 1 March and 10 October 1931. Data for higher high water (HHW) and lower low water (LLW) are given. The place names are the locations where observations were made.

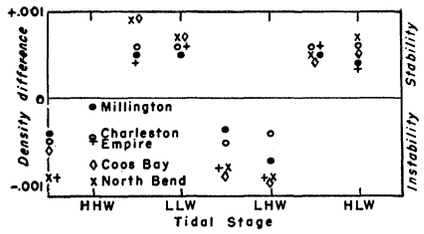

Fig. 2. Median density differences between the surface and the bottom water for five different stations at eight different tidal stages. Mean depths at station locations were Charlestown, 4.5 m; Empire, 4.5 m; North Bend, 8.2 m; Coos Bay, 7.5 m; and Millington, 3.9 m.

The available data had been taken at bi-weekly intervals of time over a 3-year period. Each station was visited from three to five times on any given day of sampling. All observations were made at the time of a high or a low water at the location of the station or at a time half way between a high and low water or a low and high water.

All temperature and salinity data were next converted to density, ρ. In each case, the relative density between the surface and bottom was desired, so that no correction was made for pressure. The density of the surface water was then subtracted from the density of the bottom sample to give a $\Delta\rho$ for each pair of observations. Positive values of $\Delta\rho$ indicate stability, while negative values indicate instability. The data for each station were then grouped into eight groups, according to the stage of the tide at the time the observations were made (higher high water, between higher high water and lower low water, lower low water, and so forth). The algebraic median values of each of the 40 groups of data were determined and plotted (Fig. 2). According to the above hypothesis, $\Delta\rho$ should be negative, indicating instability during both floods and high waters; $\rho\Delta$ should be positive during ebbs and low waters, indicating stability. The median values plotted on Fig. 2 have the expected sign in all cases. Of the 789 individual density differences, 87 percent have the expected sign, 3 percent were zero, and only 10 percent have the opposite sign from that expected.

It is clear that the process described, which we will call "tidal overmixing," must be of importance in the Coos Estuary and similar estuaries. The process of

the tidal flow setting up an unstable condition, which is followed by mixing of the whole water column during flood and high water, aids in the movement of salt against the mean flow of the river passing through the estuary. This occurs at all stations from the mouth to the head at all times of the year. The data were insufficient to show whether the density inversions were more likely to occur at any particular stage of the river.

In addition to assisting in the maintenance of the salt balance in the estuary, the tidal overmixing causes ventilation of the bottom waters at frequent intervals. Oxygen, nutrients, plankton, pollutants, and any other suspended or dissolved materials are mixed throughout the whole water column on almost every tidal cycle throughout the year.

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References and Notes

1. D. W. Pritchard, "Estuarine hydrography," in *Advances in Geophysics* (Academic Press, New York, 1952); H. Stommel, *Proc. Minn. International Hydraulics Convention* (Brown, Dubuque, Iowa, 1953).
2. This work was supported in part by an Office of Naval Research contract and by Oregon State College.
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X-ray Induced Chromosome Aberrations in Normal Diploid Human Tissue Cultures

In recent years, and particularly in recent months, the estimation of radiation hazards to human populations has become very important. While there is an enormous body of data on other organisms, there are few data on human beings. Without some indication of the sensitivity of humans in relation to the better known organisms, it is difficult to make quantitative estimates of radiation hazards to humans.

The recent development of simple, reliable methods of tissue culture, especially those developed for virus research (*1*), make it easy to grow mammalian cells for genetic and cytological studies. The discovery by Hsu and Pomerat (*2*) of an improved method of preparation of tissue-culture cells offered the possibility of making cytological studies of radiation damage to human chromosomes by direct examination for aberrations, as is done with the classical plant materials.

Such a study must, of course, be made on diploid cells derived from normal tissues. Many existing human tissue-culture cell lines derived from normal tissue have been examined cytologically by myself and other workers; but, unfortunately, they have all turned out to be polyploid, apparently basically tetraploid, with wide aneuploid variations. Since it was known from work on monkey kidney chromosomes in our laboratory that a newly set line did not become basically polyploid until after at least the sixth passage, a new line was set from normal human kidney. The newly cultured tissue was found to have 46 chromosomes and, from the first to the fourth passage, to contain an average of only 8 percent of polyploid cells.

Table 1. Aberrations in cultured epithelioid diploid human kidney cells after treatment with x-rays.

Time (hr)	Dose (r)	Cells scored (No.)	Chromatid deletions (No.)	Isochromatid deletions (No.)	Chromatid exchanges (No.)	Total breaks (No.)	Breaks per 100 cells (No.)
42	Control	150	1	0	0	1	0.7
42	25 r	147	2	6	1	10	6.8
42	50 r	74	3	11	1	16	21.6
49	Control	150	1	1	0	2	1.3
49	25 r	150	2	6	0	8	5.3
49	50 r	133	2	13	2	19	14.3
72	Control	67	0	0	0	0	0.0
72	25 r	60	0	2	0	2	3.3
72	50 r	43	0	2	0	2	4.7

For the present studies (*3*), epithelioid cells for the second to the fourth serial cultures were used. The cultures were made from a normal kidney which was removed from a 1-year-old female patient at the Johns Hopkins Hospital (*4*). The kidney cultures were prepared by a modified Younger (*1*) technique and grown in a modified Chang's medium (*5*). The experimental cultures were made on cover slips in Leighton tubes. When a good sheet of cells had grown on the cover slips (3 to 6 days), the tubes were used for irradiations.

The x-irradiations (*6*) were performed with a G.E. Maxitron therapy machine. It was operated at 250 kv (peak) and 15 ma with filtration through 1 mm of aluminum and 1 mm of copper. The half-value layer was 2 mm of copper. Two doses, 25 and 50 r, were used.

The nutrient solution was drained from the tubes before they were treated and was replaced with fresh solution afterward. Control tubes were handled in exactly the same manner in this and all other respects, excepting actual irradiation. About 15 hours before the cultures were to be fixed, colchicine was added to a final concentration of 10^{-7} *M*. The cells were first incubated for 20 minutes in a 20 percent BSS solution and then fixed in Darlington and LaCour's 2BD and stained by the Feulgen method.

Preliminary experiments had shown that the most favorable time interval between irradiation and fixation was 40 to 72 hours. Aberration counts were made on material fixed 42, 49, and 72 hours after treatment. Control material, fixed at each interval, was also examined. Only diploid cells were scored. All of the expected types of aberration were found in the irradiated material. A normal figure from control material is shown in Fig. 1*a*, and a figure containing a chromatid deletion is shown as Fig. 1*b*.

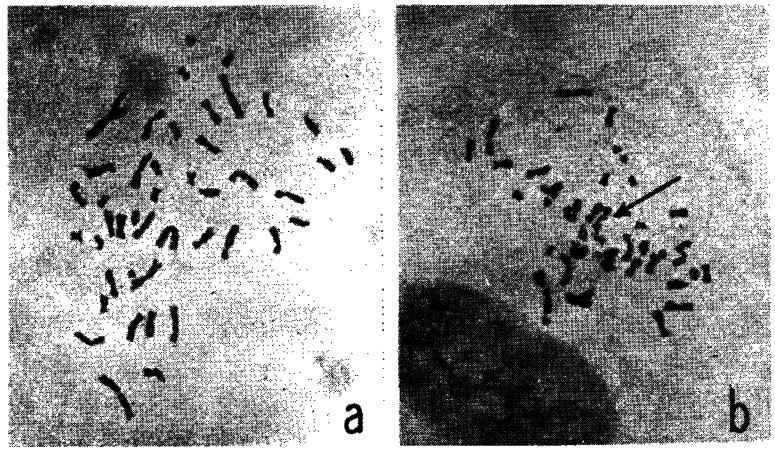

Fig. 1. Colchicine-treated metaphase figures from tissue cultured epithelioid diploid human kidney cells. (*a*) Normal figure from control material. (*b*) A figure from the 42-hour, 25-roentgen series, showing a chromatid deletion (arrow).