Except for one Mid-Atlantic sample (AD3-2), the Rb/Sr ratios of these samples are actually too low to generate the observed Sr^{87}/Sr^{86} values, if the earth began with a Sr^{87}/Sr^{86} ratio of 0.6984 as suggested by Hedge and Walthall (*11*) and Gast (*13*, as rectified by Hedge and Walthall). This relation is additional evidence for some sort of differentiation in the past in the source material of these magmas. Either the source had a slightly larger value of Rb/Sr than observed for a long period of time (minimum 0.02 for 4.5 billion years), with the differentiation being recent or a much larger value of Rb/Sr early in earth history, for a short period of time. An example of the first case is a magma not representative of its source, perhaps because it was generated by partial melting of the source material. One example of second case could be a Rb/Sr of about 0.024 for the first 3.5 billion years of earth history and 0.011 for the last 1.0 billion years. In this second example, the magma could be representative of its source but the source has changed during geologic time. We prefer the second case because studies with lead isotopes suggest a rather long differentiation age (*9*).

The crust-mantle differentiation is most pronounced within a few hundred kilometers of the outer layers of the earth, and most radioactive elements accumulated in these upper layers (*8*, *14*). Tatsumoto (*5*) suggested that tholeiites may be generated from the basic residual layer in the upper mantle, from which most radioactive elements were previously transported to the crust. If this mode of derivation is the case, we are only comparing extremely differentiated products with achondrites, chondrites, or carbonaceous chondrites, and the contents of potassium, uranium, and thorium in most of the mantle may be different from that observed in oceanic tholeiites. However, the mantle-crust differentiation in oceanic regions is not pronounced compared to that of the continents (*14*); therefore the chemical character of the oceanic tholeiites is of primary importance as a guide to estimate the chemical composition of the upper mantle.

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Thunderstorm Electrification and Raindrop Collisions and Disjection in an Electric Field

Abstract. *Raindrop collisions in an electric field selectively transfer charges of one sign to the larger disjected drops. The disjected drops, falling away from the smaller drops, separate free charge to establish electric fields as large as those observed in thunderstorms.*

An experimental method for obtaining reproducible collisions between freely falling water drops has been described (*1*). With this method it has been found that whenever the relative kinetic energy between two falling drops approaches that observed in typical natural rainclouds, the collisions result in forceful tearing apart of the drops and scattering of the drop remnants. This mechanical action is called "disjection."

With the use of two "synchrodroppers" which are located at different levels and whose relative phase is regulated by electric circuits, it is possible to secure serial collisions between pairs of drops whose sizes and relative kinetic energy are controlled. Drop collisions were arranged to take place between two insulated horizontal parallel plates excited by a direct current of 5000 volts; an electric field intensity of 600 volt/cm was thereby established between the plates. Holes 3 cm in diameter were drilled in the centers of the plates, permitting the freely falling drop pairs to fall into the region of high electric field and to collide there; the secondary drops—that is, those formed by collision—then continued on through the bottom hole and were caught in a highly insulated Faraday cage. This cage was connected to an electrometer and recorder to measure the convected free drop charges.

Direct collisions between the drop pairs produced a neutral mixture of numerous highly charged positive and negative secondary drops. On the other hand, primary drops encountering an off-center (eccentric) collision usually develop into a linear distribution in which the drops at the bottom are considerably larger than those at the top. An intermediate step in the development of such a drop distribution is shown in Fig. 11 of reference *1*, which clearly shows the excess water accumulating on the bottom side of the disjected drop pair. Eccentric collisions are far more probable in nature than direct collisions. Accordingly, my coworkers and I considered it important to determine experimentally whether the selective production of larger secondary drops at the bottom of the generated distribution had important electrical effects.

In order to evaluate the free electrical charges produced by disjection in an electric field, we arranged for a continuous series of drops having radii of 0.2 cm to overtake and collide serially with drops having radii of 0.15 cm, at a relative velocity of 170 cm/sec. The smaller drops were arranged so as to have a small horizontal component of velocity; the larger drops were allowed to fall vertically. The collisions took place in an electric field of 600 volt/cm. By moving the position of the hole in the bottom plate with respect to the point of collision, it was possible to capture *independently,* in the Faraday cage below, the large majority of either the larger or the smaller secondary drops.

We discovered that both of these fractions were highly and equally electrified but that the charges were of opposite sign. Specifically, the larger secondary drops acquired a charge of the same sign as that on the top plate, while the smaller drops had the same charge sign as the bottom plate. The larger drops always fall faster in the free atmosphere, so that once the direction of the inducing electric field E is specified, the arrangement of positive and negative charges is determined. Our measurements show that the induced free charges, Q, in electrostatic units on the oppositely charged fractions are

$$Q = 4\, E_o a_o^2 \qquad (1)$$

where, in order to simplify the application of our measurements, we have approximated by assuming that a_0 is the radius of the larger drops *before* collision. The coefficient of Eq. 1 is dependent on the relative kinetic energy at collision; the value given applies to the conditions of our experiments, which we have selected as typical of heavy rain.

Since the larger raindrops always fall away from the slower-moving, smaller drops, the net result of disjections in an electric field is a separation of free charge and the establishment of a bipolar pair of free-charge sheets vertically spaced a few kilometers apart and serving as the upper and lower boundary of a volume distribution of a nearly neutral mixture of highly charged positive and negative drops. Moreover, the charge separation under the action of gravitational acceleration is always in such a direction as to neutralize any preexisting electric field. Usually this neutralization is not complete. It appears that the disjection electrification process is normally a stabilizing influence.

In considering the application of disjection electrifying processes to thunderstorms, one notices first that this electrification does not occur when atmospheric electric fields are absent, and therefore it plays little part in the initiation of thunderstorm electrification.

I have emphasized that the typical lightning discharge not only neutralizes the observed initial electric fields but frequently produces a reverse field that approximates the intensity of the initial field (*2*). During the main part of typical storms this electric field is due to a persistent free positive charge maintained at relatively low altitudes. This charge establishes a more or less continuous positive electric field above it so that at the altitudes where rain is formed and where disjection of colliding raindrops is frequent, the electric field is outward and positive. The resultant generated bipolar free charge sheets tend to neutralize this field, and free positive charge accumulates at the upper boundary of the rain-forming regions and free negative charge a few kilometers below.

Such a charge distribution results in quite rapid discharge of the positive free charge at the top and thus contributes to the maintenance of the fair weather field, whereas the negative charge at the lower altitude may build up to produce lightning. The net result is that the generated bipolar sheets are unstable and shortly degenerate into predominantly negative charge sheets somewhere near or below the freezing level. Wind shear also sometimes plays a part in converting bipolar sheets into effectively unipolar distributions of free charge. A qualitative evaluation of collisions and disjection of raindrops in the earth's persistent electric field during periods of electrical activity shows that disjections are extremely important. Their outstanding result is that charges of opposite sign are induced predominantly on the larger and smaller secondary drops; gravitational forces thereafter naturally account for the observed gross separations of free electricity necessary to produce lightning.

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Differentiation of Tobacco Plants from Single, Isolated Cells in Microcultures

Abstract. *Single cells isolated from pith callus of fresh stem of hybrid tobacco* (Nicotiana glutinosa ♂ × N. tabacum ♀) *gave rise to small colonies of cells in microcultures which upon transfer to agar medium produced clones of callus tissue. These single-cell clones differentiated roots, and shoots with green leaves, on a completely defined nutrient medium. The rooted shoots developed into normal plants after transfer to soil in pots in the greenhouse. Buds and flowers were produced by these plants.*

During the last 10 years evidence for the growth of fully differentiated and organized plants from free cells, either suspended in liquid medium or dispersed on semi-solid medium, has come from several different laboratories. The earlier reports emphasized the importance of substances like coconut milk in the medium (*1*). The same results have, in the last couple of years, been achieved on defined synthetic media (*2*). This work has thrown considerable light on problems of totipotency and morphogenesis, yet single cells of flowering plants removed from the vicinity of other cells and grown in complete isolation have failed to give rise to entire plants. We now report, for the first time, the differentiation of completely organized plants, capable of producing flowers, from single cells grown in isolation from all other cells and without the "nurse tissue" or the "conditioned medium."

An earlier communication (*3*) dealt with the growth and tissue formation from single, isolated tobacco cells in microculture. These single-cell clones of tissue failed to differentiate roots and shoots, possibly because the callus from which the single cells were isolated had been subcultured for about 8 years. Fresh callus was, therefore, isolated