The association of hu-8 and the feather condition is the first association of an immunogenetic species character with another genetic trait. Further, it is the first autosomal linkage group known in the genus *Streptopelia.*

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15 January 1964

Pollen Wettability as a Factor in Washout by Raindrops

Abstract. *Easily wettable pollen particles (contact angle $\theta < 90°$) can be distinguished from poorly wettable particles ($\theta > 90°$) by a simple laboratory test. Although some differences in degree of wettability were observed among the 15 pollens tested, all were wettable and most were strongly wettable. Grain wettability is not likely to suppress rain-scavenging efficiencies.*

When I was summarizing recent calculations (*1*) of rates of rain-scavenging of airborne pollens and spores before a group of palynologists (*2*), my conclusions concerning the high efficiency of washout were questioned, in the ensuing discussion, on the grounds that pollen grains and spores may be nonwettable. The cited evidence thereon was equivocal, but the question demanded consideration. To examine this point, I have carried out two studies. First, I analyzed theoretically the effects of partial wettability on the results of rain-scavenging, thereby extending the theory of Pemberton (*3*) to cover all contact angle θ from 0° to 180° (*4*). That analysis has been reported in detail (*5*). Some of its results will be used in this report. Second, I carried out a series of direct checks on pollen-grain wettability. The theoretical analyses plus the laboratory studies of grain wettability jointly indicate that wettability will not alter my previous conclusions (*1*) concerning the high efficiency of the washout of airborne pollens by rain.

It was necessary to have some wettability test which distinguished between grains having θ less than 90° and those characterized by θ larger than 90°, because the theoretical analysis (*5*) established that the efficiency of raindrop collection only begins to be suppressed appreciably when θ exceeds 90°. This circumstance obviated the carrying out of exact microscopic θ-determinations, which is fortunate inasmuch as such a task would be very difficult for grains whose diameters are of the order of a few tens of microns.

The following simple method proves satisfactory. A sample of pollen grains is dusted onto a limited area of a clean microscope slide and a single drop of distilled water is placed nearby. A common pin is next laid on the slide with its sharp end immersed in the water, and it is then slid broadside toward the near edge of the pollen deposit. This action carries a band of water along ahead of the shaft of the pin and into the field of pollen. With × 600 magnification, it is easy to observe the events occurring as the advancing of the water makes contact with individual grains. The advancing surface of the water has an angle of inclination estimated (by depth-of-focus methods) to be 30° to the surface of the glass slide (Fig. 1) as a result of meniscus formation with the shaft of the pin, and this wedge of water proceeds to slip under the spheroidal grain until first contact is made at some point of the underside of the grain.

Ensuing events depend critically upon the angle θ. If θ is less than 90° (hydrophilic case), meniscus formation occurs as a neck of liquid climbs up around the first-contact point. In Fig. 1, the dashed locus schematically indicates how such a meniscus might appear at instant of formation in a hypothetical case where θ is about 45°. Surface-tension forces act in such a direction that they lie both (i) normal to the water line along the meniscus edge, and (ii) at the angle θ to the local grain surface. In the

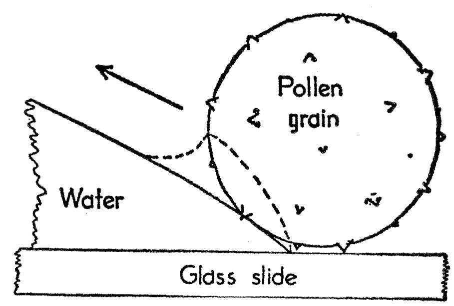

Fig. 1. Diagram of wettability test.

hydrophilic case, the combined action of all the surface-tension forces propels the pollen grain rapidly upward along the sloping surface of the water and, at the same time, down into the liquid, the process coming to equilibrium only when the grain is sufficiently immersed in the water to yield a balance between the buoyancy forces (assuming the grain density less than that of water for the moment) and the surface-tension forces acting around the final waterline.

It may be shown that this floating equilibrium, for fully wettable grains of density less than 1 g/m^3, will entail immersion of all but a tiny cap near the top of the grain. If the grain is strongly wettable but denser than water, it will, again, be propelled towards the water on first contact, but now no floating equilibrium will be possible, and the grain will be engulfed and sink. Only a few pollens are believed to have densities greater than that of water (*6*), and of the pollens I tested there was no indication of sinking. The evidence for sinking is perhaps not conclusive under the conditions of the test; but since this question is not directly relevant here, details will not be elaborated.

However, the foregoing remarks may serve to draw clear distinction between particles that are wettable, in the sense of surface chemistry usage, and those which sink on contact with water. Apparently this distinction has led to some confusion in palynological work. It should be noted that a small particle of density exceeding that of water can float if its surface is strongly hydrophobic, and that bladders influence flotation of many conifer pollens (*4*). The important point here is that, regardless of density, particles sufficiently wettable to have angle $\theta < 90°$ will, on first contact with the waterfront in the described test, form menisci along whose lower portions (near the glass slide in Fig. 1) surface-tension forces will have resultants directed to the left, that is, tending to force the grain into the waterfront.

On the other hand, if θ exceeds 90°, no meniscus will climb the grain. Rather, the advancing surface of the water will be depressed just after first contact is made, and the grain will subsequently be rather sluggishly nudged ahead of the water. The closer θ is to the upper limit of 180° (complete nonwettability), the farther the advancing surface of the water must creep in under the particle before the latter begins to respond to this surface action.

It appears, then, that this simple test is almost ideally suited to answer the very question which the scavenging theory for partially wettable particles (*5*) poses, namely the question of whether angle θ exceeds 90° for a given particle. To check the method, observations were made on a number of particles of known angle θ (*4*). Silicate grains (fully wettable, angle $\theta = 0°$), a few tens of microns in diameter, moved very actively into the water at first contact, whereas irregular fragments of paraffin 50 to 75 μ ($\theta = 110°$) did not pass into the water phase at all, and the deformation of the water surface became readily apparent through the refraction effects when viewed by transmitted light under the microscope. Particles of talc ($\theta = 87°$) and of graphite ($\theta = 85°$) provided test materials for which the forces tending to propel the grains into the water were still positive, but extremely small. Their response was in full accord with the mechanisms outlined. On first contact, they were drawn toward the water side, but instead of being shot a distance of 100 μ or so toward that side, as were the silicates, these two materials were only barely drawn inside the water itself before coming to rest.

Having made the aforementioned checks confirming the validity of the test, 15 pollen samples were then tested for wettability. Of this total, 11 exhibited very strong wettability since they passed into the water phase with great force, being carried a number of grain diameters (order of 100 μ) into the water before coming to rest. Four others responded noticeably less actively upon first contact. However, even these four were engulfed by the water considerably more vigorously than the test samples of talc and graphite, showing that even these less wettable pollens have contact angles well under the 90° value which the collection theory indicates as critical. Most of the samples were gathered in the vicinity of Tucson, Arizona, and hence they represent pollens of desert plants; a few were pollens of local montane trees, and two were samples of ragweeds from New York. All tests were made within a few weeks after collection.

The 11 pollens that move actively into the water phase and hence are evidently strongly wettable are from the following species: Hopbush (*Dodonea viscosa*), canyon ragweed (*Franseria ambrosoides*), desert hackberry (*Celtis tala*), dock (*Rumex sp.*), four-winged saltbush (*Atriplex canescens*), Russian thistle (*Salsola kali*), great ragweed (*Ambrosia trifida*), common ragweed (*Ambrosia artemisiifolia*), Chihuahua pine, (*Pinus canariensis*), Alleppo pine (*Pinus halopensis*), and Arizona cypress (*Cupressus arizonensis*).

The four pollens reacting much less vigorously, yet to an extent that indicates a hydrophilic rather than hydrophobic surface, were from Bermuda grass (*Cynodon dactylon*), a desert ragweed bearing no common name (*Franseria confertiflora*), bear grass (*Nolina microcarpa*), and silverleaf oak (*Quercus hypoleucoides*).

If the results of these wettability tests on a limited number of pollens may be extrapolated, there does not appear to be a wettability barrier to raindrop collection and washout. Whether similar conclusions hold for wettability of spores is unknown.

These results and considerations indicate that my earlier calculations (*1*) of collection efficiencies need no revision for pollen grains.

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30 September 1963

Visual Pigments of Single Primate Cones

Abstract. *Single parafoveal cones from human and monkey retinas were examined in a recording microspectrophotometer. Three types of receptors with maximum absorption in the yellow, green, and violet regions of the spectrum were found. Thus the commonly held belief, for which there has previously been no direct and unequivocal evidence, that color vision is mediated by several kinds of receptors (possibly three), each containing photopigments absorbing in different regions of the spectrum, is confirmed.*

Rushton has detected by reflection densitometry at least two pigments, absorbing at approximately 590 and 540 $m\mu$, in the living human fundus (*1*). Brown and Wald (*2*) have also detected two pigments absorbing at 565 and 535 $m\mu$ in human foveas and at 565 and 527 $m\mu$ in monkey foveas. Nevertheless, these investigators were unable to demonstrate reliably any blue-sensitive pigment. Indirect evidence for the existence of a number of cone pigments has also been obtained from psychophysical and electrophysiological experiments (*3*). From none of these experiments could it be determined whether the pigments are segregated in individual cones or whether two or more of them are present in each re-

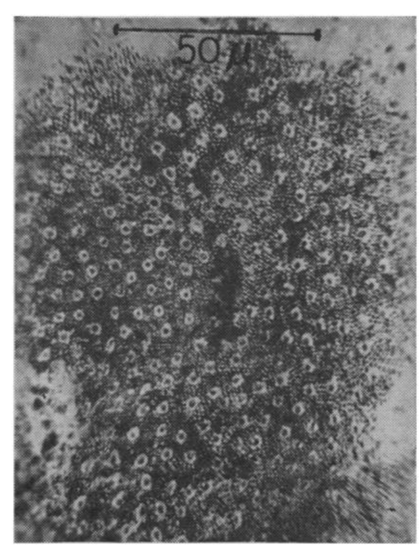

Fig. 1. "End-on" view of parafoveal receptors (*Macaca nemistrina*). The outer segments of the cone appear as dark spots centered in clear areas (defocused cone ellipsoids). These are separated by the outer segments of rods closely packed together and each measuring about 1 μ in diameter.