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 mμ, in the living human fundus (*1*). Brown and Wald (*2*) have also detected two pigments absorbing at 565 and 535 mμ in human foveas and at 565 and 527 mμ 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-

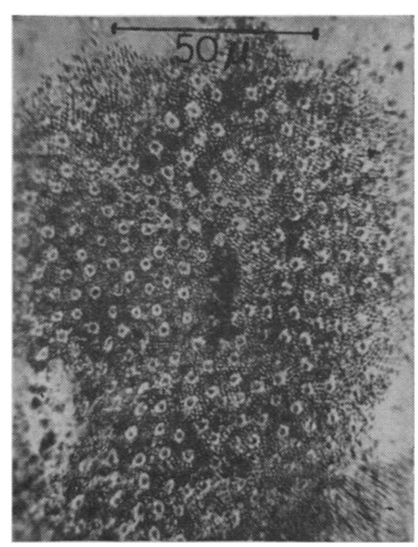

Fig. 1. "End-on" view of parafoveal receptors (*Macaca nemistrina*). The outer segments of the cone appear as dark spots centered in clear areas (defocused cone ellipsoids). These are separated by the outer segments of rods closely packed together and each measuring about 1 μ in diameter.

ceptor. Our experiments indicate that the former is basically true.

For several years it has been possible to obtain absorption spectra from single vertebrate rods (*4*) and cones (*5, 6*). Nevertheless, primate cones could not be readily examined because of their small size. However, by mounting the retina so that light traverses the main axis of the receptor, signals well above noise can be easily obtained.

Such an "end-on" preparation is illustrated in Fig. 1. It is essentially similar to that described by Schultze in 1866 (*7*). The outer segment of each cone is centered in a clear area due to its much larger ellipsoid.

To make this preparation, small pieces of retina were dissected from the parafoveal region of fresh, dark-adapted eyes, placed receptor-side up on a cover slip, and immersed in a drop of 6 percent gelatin in unbuffered mammalian Ringer solution. A second cover slip was placed over the retinas, and the edges were sealed with paraffin wax to prevent evaporation. As much as possible of this procedure was carried out in total darkness, by means of an infrared image converter tube. The dual-beam automatic recording spectrophotometer used from these experiments is of our own design (*6*) and is a modified photomicrography apparatus with a very sensitive photomultiplier tube (EMI 9558A) in place of the camera.

The two beams are focused by an apochromatic objective upon the microscopic field and appear as 2-μ spots. The mechanical stage is adjusted so the reference beam falls in a blank area and the test beam passes through a receptor. With an infrared image converter in place of the eyepiece of the microscope, suitable receptors are found and oriented in the measuring beam entirely without visible light.

A mechanical chopper alternately selects the measuring and reference beams; the successive signals from the photomultiplier are then amplified and switched into two separate channels. A commercial strip-chart recorder is used to take the ratio of the two signals. A digitizer and paper tape punch permit simultaneous recording in a form suitable for computer analysis. A feedback circuit controls the illumination of the specimen, giving a constant quantum flux independent of wavelength. The absolute value of this flux has been measured, enabling the calculation of the number of photons absorbed by the pigment during bleaching. The similarity between these experiments and some others done on human rods indicates that the concentration and photosensitivity of the pigments in these two kinds of receptor do not differ greatly.

Spectra have been recorded from a number of cones and are plotted together in Fig. 2. The two curves indicated by open parentheses are from human cones, those indicated by numbers from monkey cones.

They appear to fall into three major classes with maximum absorption at about 445, 535, and 570 $m\mu$. It will be necessary to record spectra from many more units, as was done for the goldfish (*6*), and to obtain more precise spectra before we can be certain of the number of receptor types. A thorough evaluation of the effects of photoproducts and distortion due to bleaching by the measuring beam will also be necessary. Furthermore, the data suggest the possibility that the "red" receptor may contain red and green pigments coexisting in a single cone. Partial bleaching experiments will be necessary to resolve this question.

Although they are very incomplete, the results of our experiments provide direct and unequivocal evidence that the two commonly held beliefs are true. (i) Primate color vision is mediated by several kinds of receptors each containing photopigments absorbing in different regions of the spectrum. (ii) Blue sensation is mediated by cones which have absorption maxima at shorter wavelengths than the rods.

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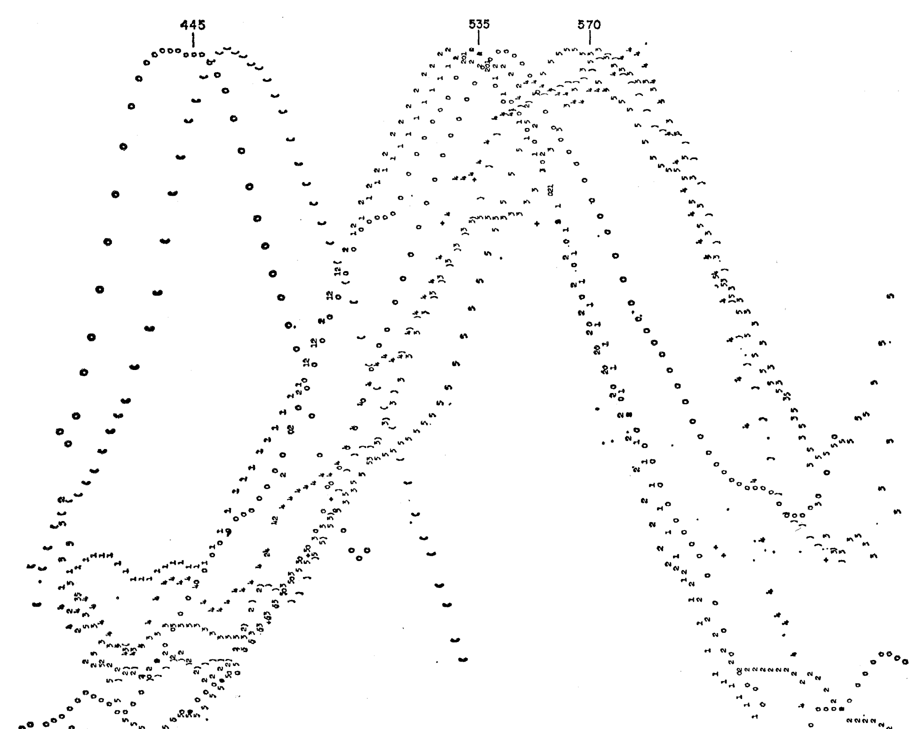

Fig. 2. Absorption difference spectra from ten individual primate cones, corrected for bleaching by the measuring beam. Curves recorded from monkey cones (*Macaca nemistrina* and *M. mulata*) are represented by numbers, those from humans by open parentheses. Maximum absorption, 3 to 6 percent, except the human blue, 0.4 percent, is decreased by light scattered past the receptor. This figure is a photograph of the original record plotted automatically by a digital computer.

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5 February 1964

Moisture Release from Cut Alfalfa

Abstract. *Mechanical treatment of alfalfa to increase its drying rate is of only limited value because little damage is done to the cellular organization. Killing the plant material with steam markedly increases the drying rate by modifying the permeability of the cuticle or cell membrane, and this may have practical significance in forage preservation.*

Extensive studies by plant physiologists on the moisture relationships of plants have established that adequate turgidity of plant cells is of prime importance; lack of turgidity results in immediate cessation of growth. Adaptations which prevent excess loss of moisture, such as a waxy cuticle and a sensitive means of stomatal control, are vitally necessary for growth but constitute large obstacles to the removal of water during the drying of forage. The initial rapid movement of water from a severed plant soon ends because of stomatal closure, and thereafter water must move through the cuticle or through wounds caused by mechanical treatment (*1*). In this report we present the results of an investigation of water movement from alfalfa, which was treated in various ways and subseqently dried in a laboratory drier.

Crimping and crushing are common practices for increasing the drying rate of forages since they produce wounds, particularly in the stems. In order to determine the extent of damage caused by such treatment, portions of alfalfa stems that had been crimped in a meshed set of gears and then exposed to steam for 2 minutes were cross-sectioned and examined under the microscope. Such a cross section is shown in Fig. 1, from which it is apparent that the epidermis had been cracked and the cells split apart toward the pith, but few cells had actually been broken.

To test the effects of such mechanical treatments on the drying rate, crimped and control samples of Narragansett alfalfa, each having an average weight of 65 g, were dried in a laboratory drier regulated to give a rate of air movement of 17 m^3/min at 35.5°C and 28 percent relative humidity. Four replications were used and the results were statistically analyzed on a computer. Figure 2 shows that there was an initial rapid loss of moisture from all samples, but in the control samples the rate decreased markedly after only 30 minutes of drying. This early flattening out of the drying curve probably resulted from stomatal closure. In the crimped sample, where there is considerably greater access of the moisture to the air, the drying rate may have been limited by the decreasing permeability of the cell walls and cytoplasmic membranes. It has been demonstrated that the resistance of mesophyll cells to viscous flow increases rapidly with loss of moisture (*2*).

Killing the alfalfa by exposure to steam for 2 minutes significantly increased the drying rate, whether or not a mechanical treatment was also used. The increased rate of moisture movement after steaming may be due to the disruption of the plasma membrane and the more rapid movement of the cytoplasmic water as well as the vacuolar water (*3*).

It has been demonstrated that the leaves of alfalfa do not appreciably influence the removal of water from the stem during drying (*1*). In the steamed samples it is not yet clear whether the leaves function as an evaporating surface for an extended length of time or whether the cuticle of the stem, or its waxy covering is modified. Leaf impressions were made of steamed leaves to see if stomatal action had been affected, but the extreme distortion of the leaves prevented measurements. This aspect of the problem is being studied further.

Results of this study reveal that mechanical treatments can increase the rate of drying only up to a point and that the rate of water movement within the plant may also be a limiting factor. Killing the plant prior to drying has important practical implications since the total energy required to dry the plant is much lower. A hot-water treatment was designed by Watson (*4*) to speed the drying process, but it was considered impractical and was not studied further. Because of the increased use of mechanical harvesters and driers, the killing of plants with either steam or hot water may be a fruitful approach to the problem of moisture release from drying forage, provided no serious effect on nutritive value is found.

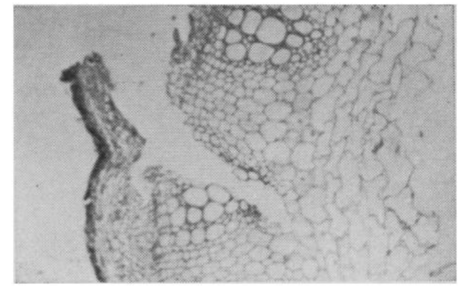

Fig. 1. Cross section of a portion of alfalfa stem which had been crimped and steamed after harvesting.

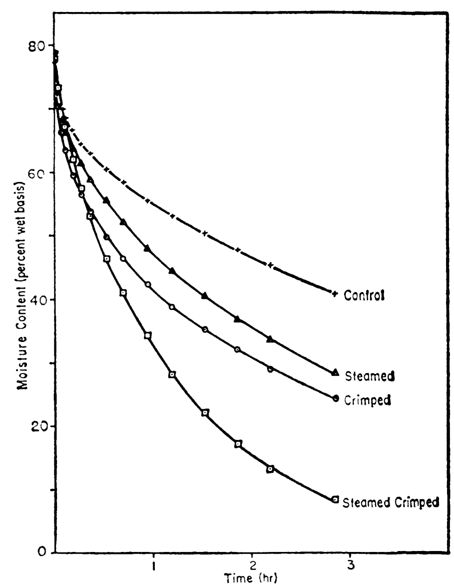

Fig. 2. Comparison of the drying rates of alfalfa after subjecting it to steaming or crimping, or both. The drying conditions were air movement, 17 m^3/min; 35.5°C; relative humidity, 28 percent.

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18 November 1963