Table 1. Composition of amino acids mixture.

Amino acid	Amount (μg/ml)	Water-soluble amino acids in frog retina (*11*) (μg/g)
L-glutamic acid (excitatory)	30	69.3
L-aspartic acid (excitatory)	20	15.7
L-alanine (depressing)	20	98.4
Glycine (depressing)	10	40.8

Application of the mixture without glutamic acid (excitatory amino acid) resulted in a transient increase in the number of spikes, followed by a period of depression (Fig. 1C). Mixtures lacking either glycine or alanine (both depressing amino acids, Fig. 1, D and E) gave rise to a transient increase in the number of light-induced spikes, followed by a burst of spontaneous discharge. In either case, units irreversibly stopped firing.

These results suggest that there is a balance of action between excitatory and depressing amino acids. Withdrawal of one excitatory amino acid shifts the balance more to the depressing side, and withdrawal of one depressing amino acid shifts the balance more to the excitatory side. The composition of the mixture of four amino acids shown in Table 1 was obtained after various combinations of amino acids had been tried. Mixtures of the same ratio as in Table 1 but of higher amino acid concentration depressed the spike discharge in response to a flash, while mixtures of lower amino acid concentration had weaker spike-enhancing action. The composition may not be the optimum one, and a better ratio may be found by further experimentation.

The mixture having the same composition as the water-soluble amino acid fraction in the bullfrog retina (as shown in Table 1) slightly enhanced spike discharges. Various combinations of one excitatory and one depressing amino acid were also tried. Although some of them had effects similar to that of the mixture of four amino acids, results were not always consistent.

The electroretinogram simultaneously recorded from the spike-recording electrode (through a low pass filter) was not affected by the application of either group of amino acids. Amino acids thus applied were acting mainly on the retinal ganglion cells (see Tomita, *5*). Apparently the spike discharge pattern is not only the function of stimulus parameters and of the state of adaptation but also of the amino acid composition in the retinal layer.

Several authors have suggested that some amino acids, such as glutamic acid or GABA, could be transmitters in the central nervous system (*2, 8, 9*). The amino acid(s) applied to the retina in the present experiment are probably not acting as transmitters. First, the total amount of amino acids in the mixture is 80 μg/ml, while in the frog retina the amount of free glutamic acid, aspartic acid, alanine, and glycine totals about 225 μg/g. It seems more reasonable to assume that the effects observed were due to changes in the amino acid composition, rather than to the action of amino acids as transmitters. Second, there is no specificity in the type of amino acids in the mixture. Glycine or alanine could be replaced by GABA.

The results of this experiment imply that the excitability of the cells could be controlled by changing the amino acid composition in the external media (see McLennan, *10*). In this connection it is interesting to note that the excitatory amino acids, such as glutamic acid, could easily be converted into depressing amino acids, such as GABA, by decarboxylation. The control of excitability of a number of cells through amino acid metabolism appears as important as control of cells through synaptic inputs.

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24 February 1967

Plastic Films on Plants as Antitranspirants

Abstract. *Plastic-film-type antitranspirants are more permeable to water vapor than to carbon dioxide. Photosynthesis in treated plants is reduced to the same or greater extent than transpiration, except under conditions of stress, when photosynthesis in treated plants is greater than in controls. This exception is attributed to reduction of stress, as the selective permeability of the films to gases would tend to produce the reverse effect.*

Wax and plastic-based emulsions were long ago suggested as antitranspirants (*1, 2*). The emulsions are usually sprayed on plants in order to form a film on the surface of the leaves that will be more permeable to carbon dioxide and oxygen than to water vapor. Such a film would decrease the transpiration : photosynthesis ratio, thus reducing the irrigation requirement and alleviating the effects of water stress under dry conditions.

It is widely accepted that certain plastic materials, such as polyethylene, possess the desired selective-permeability characteristics (*1*). Permeabilities of plastic films are, however, very difficult to determine; the methods used and the units in which the results are expressed often cannot be compared. The high permeability of polyethylene to carbon dioxide has often been compared in the literature to its low permeability to water vapor (*3*), but such comparisons can be misleading. Polyethylene is in fact four to five times more permeable to water vapor than to CO_2 (Table 1), but, in comparison with other plastic films, its permeability is low to water vapor and high to CO_2.

Gas permeabilities of plastic films have been compared in terms of the same units; Table 1 summarizes typi-

Table 1. Relative permeabilities of plastic films to water vapor and carbon dioxide. Approximate ranges calculated (from *4, 5*) on the basis of volume-diffusion rates.

Film	$P_{H_2O} : P_{CO_2}$
Poly(vinylidene chloride)	48–3500
Rubber hydrochloride	145–1044
Poly(vinyl chloride)	170–255
Polystyrene	7.7–38.5
Polyethylene (density, 0.954)	4.2
Polyethylene (density, 0.922)	4.45
Polypropylene	6.8–7.6
Natural rubber	22.6
Silicone rubber	3.5–17.7

cal data on the relative permeabilities of various plastics to water vapor and to CO_2; the values are calculated from data collated by Stannett and Yasuda (*4*) and Lebovits (*5*). These data make it apparent that none of the plastic films possesses the desired selective permeability; that is, (permeability) $P_{H_2O} : P_{CO_2} < 1$. We could find in the literature no reliable data showing $P_{H_2O} : P_{CO_2}$ ratios lower than those given for polyethylene and silicone rubber (Table 1).

In practice, however, measurements of photosynthesis and transpiration by plastic-coated plants do not usually show the expected increase in the ratio of transpiration to photosynthesis. This point is evident from data (Table 2) based on the net photosynthesis and transpiration of bean plants (*Phaseolus vulgaris*) sprayed with different plastic emulsions. Unfortunately, no reliable gas-permeability data are available for these substances.

Under the conditions of this experiment (Table 2) both transpiration and photosynthesis are diffusion-dependent processes. Since the $P_{H_2O} : P_{CO_2}$ ratios of plastic films are very large (Table 1), it appears that the results in Table 2, showing approximately the same reduction in photosynthesis as in transpiration, are anomalous. The (transpiration) $T : Ph$ (photosynthesis) ratios (also calculated on a mole:mole basis in order to be dimensionally compatible with the data of Table 1) do not differ significantly in the treated plants from those in the controls.

A possible explanation of this anomaly is that coverage of the leaves by the films was incomplete. Direct microscopic examination, and inspection of silicone-rubber impressions made from the leaf epidermis, show that the films were of uneven thickness and contained many gaps and micropores. Thus most of the diffusion would be by way of the pores and not through the film itself; photosynthesis and transpiration would thus be reduced to the same degree. Moreover, there are only two main series resistances in the transpiraton-diffusion pathway (boundary and stomatal resistances), but three in the CO_2 pathway. The CO_2-

Table 2. Photosynthesis (*Ph*) and transpiration (*T*) in bean leaves sprayed with emulsions of film-forming plastics. Conditions for measurement: leaf temperature, 25°C; relative humidity, about 60 percent; light intensity (fluorescent lamps), 2.58 phot. Carbon dioxide and water-vapor contents of the airstream, before and after passing the leaves (attached to the plant), were measured with a Beckman differential infrared gas analyzer and a Hygrodynamics narrow-range hygrometer, repectively.

Spray	Main ingredient	Net photosynthesis: Abs. CO_2 (mg dm^{-2} hr^{-1})	Net photosynthesis: Percentage of controls	Transpiration: H_2O given off (mg dm^{-2} hr^{-1})	Transpiration: Percentage of control	T:Ph(H_2O:CO_2) mg: mg	T:Ph(H_2O:CO_2) Mole: mole
None	None	14.8±0.4	100	1340± 46	100	91	222
Dow 512-R*	Styrene-butadiene	9.7±0.3	66	1052± 24	79	109	266
Allied Chem. A-C-3*	Polyethylene	10.3±0.5	70	1024±103	77	100	244
Calif. Chem. Co. 94 + 76†	Unspecified	11.1±0.7	75	1067± 28	80	96	234

* Sprayed in 10-percent emulsion (dry weight). † Experimental latex sprayed in 5-percent emulsion (dry weight).

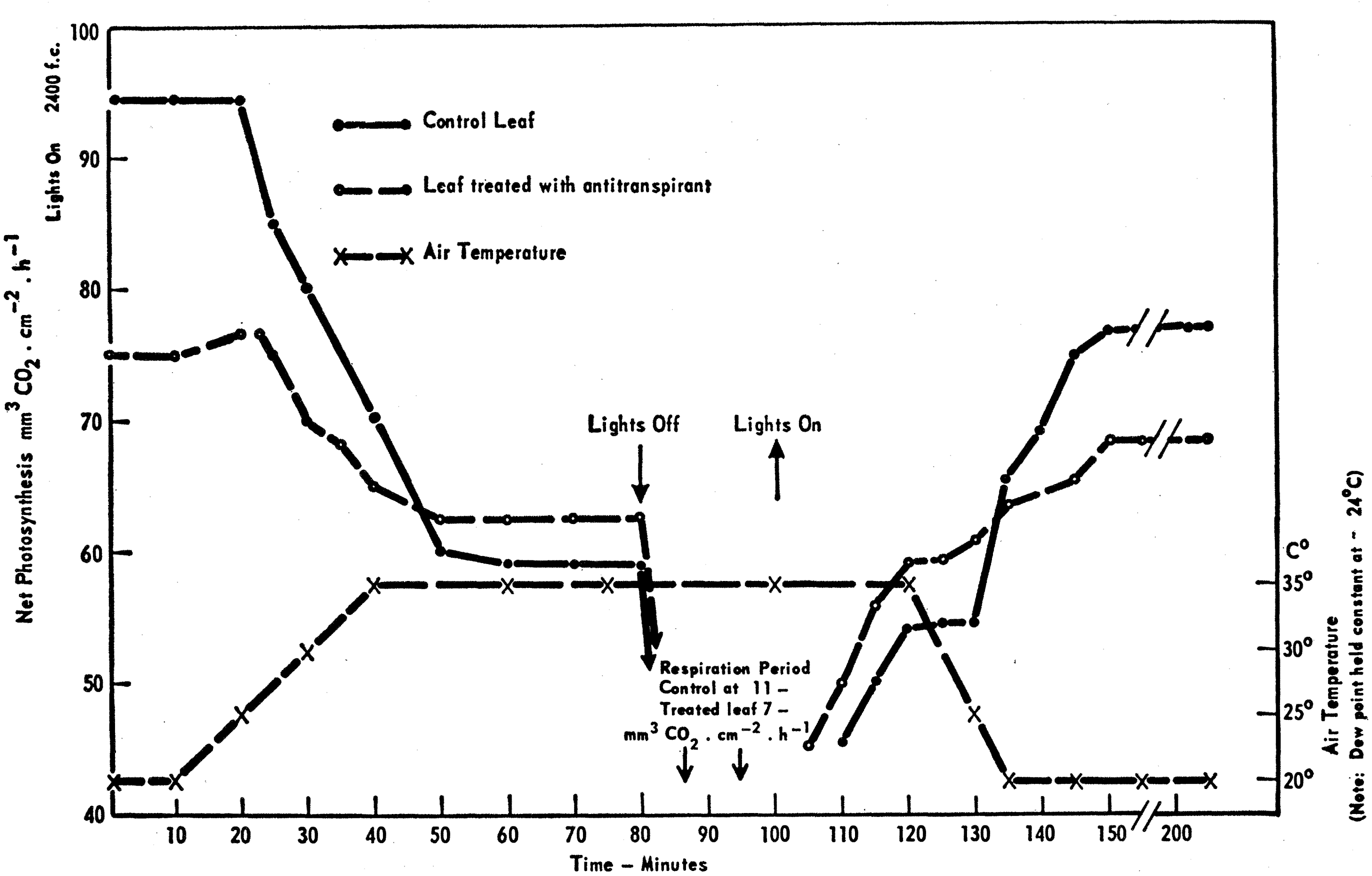

Fig. 1. Effect of heat stress on photosynthesis in bean plants either untreated or treated with an antitranspirant—Dow 512-R (a styrene-butadiene latex). For other experimental conditions, see legend to Table 2.

diffusion pathway contains an additional mesophyll resistance, equal in magnitude to the other resistances. This should result in transpiration being reduced more than is photosynthesis when an extra resistance—the plastic film—is placed in the diffusion pathway. This should be so even if the film has a $P_{H_2O}:P_{CO_2}$ ratio of 1.

However, under conditions of water stress, such as may be induced by low levels of soil moisture or by high evapotranspiration potential, film-type antitranspirants may in fact increase photosynthesis relative to that in untreated plants growing under the same conditions. The theoretical basis of this interaction, which has been reviewed (*1*), was demonstrated in the laboratory (Fig. 1); the experiment showed the effect of stress, induced by elevation of the air temperature, on the photosynthesis of bean leaves.

Figure 1 shows that under mild conditions (25°C and high humidity) photosynthesis in the treated leaf was 20-percent lower than that by the control. When the temperature was raised to 35°C, photosynthesis in the control fell to a lower level than that in the treated leaf. When the air temperature was returned to 25°C, photosynthesis in the control rose above that in the treated leaf even though the rate of photosynthesis did not return to its former value in either plant. These data are preliminary; more detailed but similar results will be reported.

We conclude that whenever treatment with an antitranspirant lowers the *T:Ph* ratio, the effect is not a result of the film's selective permeability to gases but is indirectly due to the treatment's ability to reduce stress.

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Magnetic Fields around the Torso: Production by Electrical Activity of the Human Heart

Abstract. *A search was made outside the torso for fluctuating magnetic fields produced by the heart. Detector and subject were housed in a highly shielded enclosure. Magnetic signals with amplitudes of 10^{-8} to 10^{-7} gauss were detected synchronously with the electrocardiogram, confirming previous reports. A magnetocardiographic chest map, consisting of the magnetic field plotted against time at various spatial positions, shows general QRS and T-wave structure, as in the electrocardiogram; this structure varies with spatial position.*

Techniques for measuring weak, alternating, low-frequency magnetic fields have been developed so that, under certain conditions, fields as low as $\sim 10^{-9}$ gauss can now be detected. One interesting source of such weak, fluctuating fields is the small ion currents in living material. The most detectable of such currents would supposedly be produced by large masses of excitable, synchronously firing tissue, such as heart muscle, which produces the potentials and currents easily seen with electrocardiograms (ECG). If one were to explore the fluctuating magnetic fields produced by living material, he would perhaps begin with the human heart fields outside the torso. Such measurements are important because new, needed fundamental information about the heart's electrical properties may be obtained and because such measurements might have diagnostic value; the experience gained would be instructive in the extension of the techniques to measure the smaller fields of less synchronous muscles and of the nervous system.

The detection of human heart signals has been reported by two groups (*1, 2*). I made a search for these signals using a different and more direct technique. Positive results were obtained, verifying the previous reports; in addition, some magnetic maps were made which showed changing patterns around the chest and the same temporal sequence of events as occurs in the ECG.

The amplitudes of the heart magnetic fluctuations were usually in the range of 10^{-8} to 10^{-7} gauss at 10 cm from the torso; these are $\sim 10^{-7}$ of the earth's steady field and $\sim 10^{-4}$ of the fluctuating background of earth plus typical city "noises," in a bandwidth of ~ 1 to ~ 30 cy/sec (always used in this study). The major problem in detection of heart signals is therefore to somehow reduce this background so that the heart signal predominates. Baule and McFee (*1*) used the technique of gradient detection in which the detector consisted of two adjacent identical coils 30 cm long, 9 cm in diameter and each consisting of 2 million turns. The coils were connected in opposition so that the induced voltages from the spatially uniform magnetic background fluctuations were almost completely canceled; the induced voltages from the nearby heart were not canceled, and the voltage difference was then a measure of the rate of change with time of the gradient of the B-vector component parallel to the coil axes. The Russians (*2*) reported a similar gradient technique, except that the subject and detector were placed inside a shielded enclosure with 1.5-cm thick iron walls, which presumably reduced the background by a factor of perhaps 10. Both groups were successful in obtaining magnetocardiograms with the coils very close to the torso; Baule is currently interpreting many gradient measurements. My measurements were made inside a highly shielded enclosure which reduced the background by about a factor of 1000; this was sufficient so that two-coil canceling was no longer necessary, and only one coil could be used. The coil voltage was then a measure of the rate of change with time of the direct B-vector component.

The enclosure, described in detail elsewhere (*3*), consists of two nested cubical shells of 0.15-cm thick molypermalloy, 2.3 m on the inside. "Shaking" and negative feedback loops were used to enhance the shielding and bring the relatively low east-west background component down from the value of $\lesssim 5 \times 10^{-5}$ gauss r.m.s. (root mean square) obtained when there was no shielding whatsoever to $\lesssim 5 \times 10^{-8}$ gauss r.m.s. On magnetically quiet nights, the background was reduced below the resistive coil noise. The coil consisted of several units of 200,000 turns stacked in series. Each coil was about 5 cm long and 8 cm in diameter;