In a typical experiment as given in Fig. 1, after 4 min the twitch amplitude had dropped about 15 percent, and after 60 min it had declined only about 35 percent. After cessation of stimulation, the response increased 15 percent in 2 min and approached the initial amplitude at a slower rate. Both the rise and relaxation time remained fairly constant during the stimulation period, except for a change during the first few minutes; for the case shown in Fig. 1, the rise time decreased 15 percent during the first 2 min of stimulation, while the relaxation time increased 25 percent during the first 6 min of stimulation.

After each experiment, a potassium contracture (with $0.1M$ KCl) was recorded to check whether the fibers were phasic or tonic. Phasic fibers gave the usual contractures which relaxed after a minute or so, whereas the contracture of tonic fibers declined slowly over a period of many minutes.

Our finding that tonic fibers fatigue much more slowly than phasic ones confirms on the single muscle-cell level the previously made conclusion for such units derived from studies of the relative fatigability of corresponding whole muscles (*5*). Further research is required to determine whether there is any relation between this difference in fatigability and other fundamental properties distinguishing phasic and tonic fibers (*6*). The decrease in twitch output of a phasic muscle fiber occurs along a smooth curve until it finally fails completely to respond. Thus these fatigue changes and the corresponding ones we have observed in the tonic fibers are quite unlike the sudden total obliteration of response which Ramsey (*3*) describes, and which we also have seen, in a single fiber undergoing a tetanus of rather high frequency. Considering that the fatigue and recovery processes of the fibers occur, in general, in two steps, it would seem that fatigue may be attributed to two separate factors. The first may be due to changes in the excitation mechanism or in the excitation-contraction coupling, the second to changes at the level of the contractile mechanism. In elaboration of the results reported here, our future studies will deal with the effects of activity on the membrane process and with the role of individual fiber behavior in the development of fatigue of the whole muscle (*7*).

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References and Notes

1. W. M. Fletcher, *J. Physiol. London* **28**, 474 (1902); G. Marechal and X. Aubert, *J. physiol. Paris*, **50**, 404 (1958).
2. E. Asmussen, *Skand. Arch. Physiol.* **70**, 233 (1934); S. E. Steiman, *Am. J. Physiol.* **140**, 269 (1943).
3. R. W. Ramsey, *Conference on Neuromuscular Blocking Action of Anti-Cholinestrase Compounds, Chemical Corps Medical Laboratories Report No. 27*, 10 (1953).
4. S. M. Ross, *Rev. Sci. Instr.* **29**, 319 (1958).
5. K. Wacholder, *Arch. ges. Physiol. Pfluger's* **229**, 133 (1931).
6. S. W. Kuffler and E. M. Vaughan Williams, *J. Physiol. London* **121**, 318 (1953).
7. This research was supported by a grant from the Muscular Dystrophy Associations of America, Inc.

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Isolation of Abscisin, an Abscission Accelerating Substance

Abstract. A crystalline substance, designated *abscisin*, which accelerates abscission of excised debladed petioles at 10^{-2} microgram per abscission zone, has been isolated from cotton burs. The yield was approximately 1 milligram from 10 kilograms of dry plant material.

The presence in plants of a substance (or substances) which accelerates abscission has been reported by several investigators. Osborne (*1*) found that the diffusates from senescent petioles of several plants accelerated abscission. Biggs and Leopold (*2*) discovered a factor from senescent leaves and fruits which accelerated abscission of debladed petioles. Herrero and Hall (*3*) found that extracts of pulvinoids from abscising leaves of cotton accelerate leaf abscission. Carns (*4*) and Carns *et al.* (*5*) reported that extracts of young cotton fruit walls accelerated abscission of debladed leaves and of young fruits. These findings, together with other evidence, led Addicott (*6*) to suggest that the substance(s) represents a new type of plant hormone, one that accelerates abscission. This report announces the isolation and preliminary characterization of such a substance from cotton burs (dried, mature fruit walls after dehiscence and removal of seed and fiber).

The bioassay used to evaluate abscission-accelerating activity during the investigation was a modification of the explant test employed by Addicott *et al.* (*7*). Explants were cut from cotton seedlings when they were 18 to 20 days old. They consisted of 5-mm stumps of the cotyledonary petioles, 5 mm of the stem, and 10 mm of the hypocotyl. Test substances were applied in 1-percent agar as 0.005-ml droplets. Explants were held upright in stainless steel holders in petri dishes containing a layer of about 5 mm of 1.5-percent agar. Abscission was determined by the application of a uniform load of 10 g to the petiole stumps.

Approximately 134,000 ground cotton burs (364 kg) were extracted for 6 hr in batches with a total of 1725 liters of Skelly-solve B (petroleum ether, boiling point 60° to 75°C). The extract was concentrated to 9 liters in a falling-film concentrator. A 3-liter aliquot of this concentrate was extracted twice with 4.5 liters of a water-methanol (1:4) solvent, and the top lipid-rich layer was discarded. The methanol extract was taken to dryness and then exhaustively extracted with 5-percent sodium bicarbonate and filtered off, and the filtrate evaporated to dryness under reduced pressure. Subsequent extraction of the dried residue with anhydrous acetone yielded 10 g of an acetone-soluble solid which accelerated abscission in the explant bioassay at 5 μg per abscission zone.

A sample of 5.7 g of the active solid was subjected to partition chromatography on a silicic acid column (6 × 25 cm) that had been treated with sodium bicarbonate; water was used as the stationary phase (7 g of water per 10 g of adsorbent), and chloroform followed by *n*-butyl alcohol was used as the mobile phase (*8*). The butanol

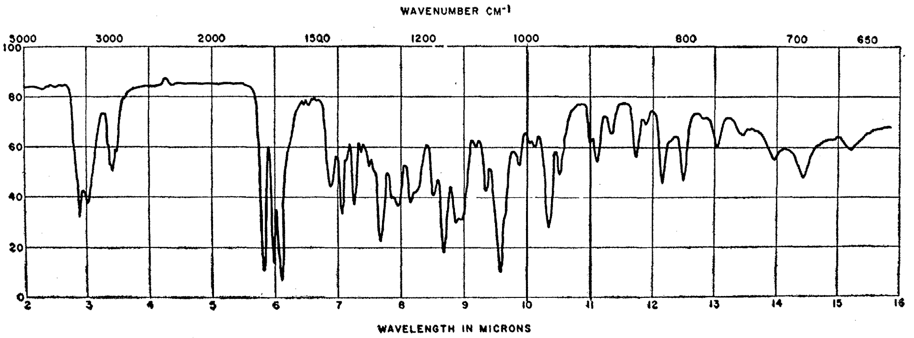

Fig. 1. Infrared spectrum of abscisin.

fraction contained 1.5 g of solid which accounted for most of the abscission-accelerating activity in the sample. A quantity of 0.8 g of this material was rechromatographed on a similar column (3.5×20 cm), chloroform being used as the eluting solvent. A number of visible bands separated on the column, characterized in the order of dark-brown, yellow, yellow, yellow, and red. The third band was found to be highly active, and from it abscisin was induced to crystallize as diagonal prisms from ethyl acetate. The crystalline substance accelerated abscission in the cotton explant test at a quantity as low as $10^{-2} \mu$g per abscission zone. In a typical experiment, for example, when abscission was determined 64 hr after the application of abscisin, the controls had 40 percent abscised while the explants with abscisin at 10^{-2}, 10^{-1}, and 1 μg per abscission zone had 52, 60, and 82 percent abscised, respectively.

The compound was crystallized to a constant melting point of 197° to 198°C, with a yield of 3 mg. Abscisin is an acidic compound soluble in chloroform and dilute sodium hydroxide, slightly soluble in ether but insoluble in dilute hydrochloric acid. It contains 67.93 percent of carbon and 6.26 percent of hydrogen. Its ultraviolet absorption maximum in methanol is at 250 mμ, and its infrared spectrum in KBr pellets is shown in Fig. 1 (*9*).

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References and Notes

1. D. J. Osborne, *Nature* **176**, 1161 (1955).
2. R. H. Biggs and A. C. Leopold, *Plant Physiol.* **31**, supplement XX (1956).
3. F. A. Herrero and W. C. Hall, *Proc. 12th Ann. Cotton Defoliation and Physiol. Conf.*, 1957.
4. H. R. Carns, *Proc. 13th Ann. Cotton Defoliation and Physiol. Conf.*, 1958.
5. H. R. Carns, J. L. Lyon, B. J. Counts, *Proc. 14th Ann. Cotton Defoliation and Physiol. Conf.*, 1959.
6. F. T. Addicott, *Encyl. Plant Physiol.*, vol. 15 (in press).
7. F. T. Addicott, R. S. Lynch, R. S. Livingston, J. K. Hunter, *Plant Physiol.* **24**, 537 (1949).
8. Silicic acid was washed with 10-percent sodium bicarbonate until effervescence ceased, then thoroughly washed successively with water, methanol, and acetone before activation at 100°C for 8 hr.
9. This investigation was supported in part by funds from the National Cotton Council administered through the U.S. Department of Agriculture. The assistance rendered by the U.S.D.A. Fruit and Vegetable Laboratories, Pasadena, Calif., in making their facilities available for the extraction and concentration of the plant material, is gratefully acknowledged. We are particularly grateful to Dr. F. T. Addicott, Department of Botany, and Dr. Charles A. West, Department of Chemistry, University of California, Los Angeles, for their interest and advice, and to Mrs. J. L. Lyon for her technical assistance throughout the investigation.

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Effect of Major Meteoric Showers on the Densities of the Upper Atmosphere

According to the recent results obtained by satellite measurements, reported by Lagow and Alexander (*1*), Dubin (*2*), and Nazarova (*3*), the amount of meteoric dust entering the earth's atmosphere is quite significant. From their data we have found that during a major meteor shower the energy injected by these particles into the atmosphere is sufficient to raise the temperature at 110 km by at least 5°K. This rise in temperature should produce an increase in density at the higher levels by 5 to 10 percent. A preliminary analysis of the density data obtained by drag measurements on the satellites at 300 and 600 km indicated a small rise in density on the day of a major meteoric shower.

Our calculations are based on data which indicate that the daily accretion rate of the interplanetary dust is of the order of 10^9 g. This implies a rate of approximately 2.10^{-15} g cm^{-2} sec^{-1}. If the mean velocity of these particles is assumed to be 30 km/sec, the energy brought in is found to be approximately 1.10^{-2} erg cm^{-2} sec^{-1}.

During a major meteoric "shower" the rate of influx of particles increases by a factor of 10 to 100, although Nazarova (*3*) reported an increase by a factor of 10^4 on 15 May 1958, which was attributed to a major meteoric stream (probably O-cetids). If, however, an increase by only a factor of 20 in the particle density during an average "major shower" is assumed, the energy input into the atmosphere will be as high as 0.2 erg cm^{-2} sec^{-1}. (A conservative value of velocity has been used. Major showers are known to have velocities up to 65 to 70 km/sec, which implies an increase in energy by another factor of 4.)

The energy brought in by the meteor particles can be given up to the earth's atmosphere, probably in the 100 to 120 km region, in three possible ways: (i) luminous radiation, (ii) ionization, and (iii) heating.

According to Whipple, the "luminous efficiency" factor for the meteoric particles is given by

$$\tau = \tau_o V$$

where log τ_o is -9.07 and V is the velocity of the particle (3×10^6 cm/sec), giving

$$\tau \approx 3 \times 10^{-3}$$

that is, only 0.3 percent of the energy will go as visible radiation. This can be regarded as negligible.

The "ionization efficiency factor," as given by Kaiser, is 0.1. The remaining 90 percent of the energy—that is, 0.18 erg cm^{-2} sec^{-1}—therefore goes immediately in heating. Since the major meteoric showers last, on an average, at least several hours, the energy available for heating the *E*-layer is of the order of 600 erg cm^{-2} hr^{-1}.

Table 1 gives the amounts of energy per square centimeter column required to heat the atmosphere above the altitude *Z* by 1°K, as calculated from the Jastrow-Kyle atmospheric model (*4*).

As the table shows, if the meteoric showers give up their energy in the 110- to 120-km layer, this region will be heated up by 5°K in 6 hr. This increase in temperature will produce an increase in density in the upper layers of the atmosphere given by the following relation:

$$\rho_{(Z)} = \rho_{(Z_o)} \frac{T_o}{T_m} e^{-\int (mg/KTm)\, dz}$$

where T_m is the molecular scale temperature and $KT/mg = H$ (scale height).

Table 2 presents estimates of per-

Table 1. Energy required to heat the atmosphere above altitude *Z* by 1°K.

Z (km)	Mass of atmosphere above *Z* km (g)	Energy (erg/cm^2 column)
90	1.858×10^{-3}	2.207×10^4
100	3.366×10^{-4}	3.999×10^3
110	8.348×10^{-5}	9.917×10^2
120	2.796×10^{-5}	3.322×10^2
150	5.856×10^{-6}	6.957×10^1
200	1.756×10^{-6}	2.086×10^1

Table 2. Estimates of percentage density increases resulting from a 5°K temperature rise over a 10-km layer.

Layer	Increase (%) in density at altitude			
	120 km	200 km	300 km	600 km
90 to 100 km	6	8	9	10.5
100 to 110 km	2	5	6	7
110 to 120 km		3	3	4