small (1.72°) area subtended by the greatest extent of the test fields makes it unlikely that the results can be explained as being due to rod intrusion. The results I obtained when I increased the test-field luminance are contradictory to those expected for rod intrusion. Decreasing the background luminance by 0.5 log unit should decrease the latency differences if rod intrusion occurs, but it would not produce the 20-msec shift necessary to eliminate latency differences (*13*). Finally, subject JA was tested for two trial sets with the background luminance raised 0.5 log unit above the test-field luminance. Again latency differences were eliminated, contrary to what would be expected from intrusion.

In referring to the effects of wavelength on visual latency, no distinction has been made between effects of wavelength per se, that is, hue, and those of differences in saturation. Since only two wavelengths were used, 549 nm and 621 nm, and these are not of equal saturation, the importance of saturation cannot be evaluated on the basis of these experiments. The results of Vos and Walraven (*5*) and Walraven and Leebeek (*6*) indicate that relative visual latency is inversely proportional to the wavelength of light. Since the relationship between wavelength and saturation does not follow such a relationship, I think that the differences that are reported in this experiment are due primarily to hue and not to saturation.

The discrepant results obtained with the various methods of measuring wavelength effects on visual latency (*1–6*) can be reconciled by my results. Visual latency differences related to the wavelength of light exist, but they cannot be demonstrated if luminance increments are present. Apparently the luminance cues take precedence because they have a shorter latency than chromatic cues.

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References and Notes

1. J. Piéron, *Année Psychol.* **32**, 1 (1932).
2. J. L. Holmes, *Amer. J. Psychol.* **37**, 414 (1926).
3. S. L. Guth, *Vision Res.* **4**, 567 (1964).
4. J. D. Pollack, *Percept. Psychophys.* **3**, 17 (1968).
5. J. J. Vos and P. L. Walraven, in *Performance of the Eye at Low Luminances*, M. A. Bouman and J. J. Vos, Eds. (Excerpta Medica, New York, 1966), p. 91.
6. P. L. Walraven and H. J. Leebeck, *Doc. Ophthalmol.* **18**, 56 (1964).
7. B. G. Arden and R. A. Weale, *Proc. Roy. Soc. Ser. B* **142**, 258 (1954); J. A. Roufs, *Vision Res.* **3**, 81 (1963).
8. A complete description of the apparatus can be found in F. S. Weingarten, dissertation, University of Chicago (1971).
9. D. H. Kelly, *J. Opt. Soc. Amer.* **52**, 940 (1962).
10. The stimulus conditions were chosen on the basis of the results of the experiments of Vos and Walraven (*5*) and Walraven and Leebeek (*6*). These stimulus conditions maximized the possibility of finding an effect of wavelength on visual latency. It would be expected that latency differences would decrease with either an increase in overall luminance level or a decrease in wavelength differences between stimuli.
11. Although the response "none" (indicating no apparent movement) was allowed, it was rarely used by either subject; practically all responses were either "up" or "down"; thus, a forced-choice situation was essentially created.
12. A few trial sets were done with 621 nm on top and 549 nm on the bottom, with a luminance difference provided, to check the possibility of a response bias. The results were similar to those obtained with 549 nm on top and 621 nm on the bottom.
13. When both test fields were 621 nm, 0.5 log unit above background, no latency differences were found. Raising the top test field to 1.5 log units above the background resulted in a latency difference of 10.0 msec ($P < .01$). Thus, a difference of 1.0 log unit in luminance was equivalent to a difference of 10 msec in visual latency. With other equipment and a method of incremental stimuli, a difference of 2.5 log units in luminance was necessary to produce a difference of 20 to 23 msec in visual latency, and a difference of 0.5 log unit in luminance did not significantly change the visual latency. These results were reported in F. S. Weingarten [dissertation, University of Chicago, (1971)].
14. Support for this work was provided in part by PHS grants EY-0523-09 and EY-00277-05. I thank Joel Pokorny and Robert Shlaer for their suggestions in the design and execution of this experiment, Nicholas Yasillo for the design of the electronic circuitry, and my wife, Darlene, for encouragement during the course of this work. Jack Altman and Margaret Ikeda served as subjects. This report is based on a dissertation submitted to the department of psychology, University of Chicago, in 1971.

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Dual Mechanisms of Ion Absorption

In his report (*1*) describing a dual pattern of rubidium absorption in *Chlorella*, Kannan states that the species *C. pyrenoidosa* is "nonvacuolate and hence devoid of an inner tonoplast membrane." This key point in his argument that the plasma membrane is the seat of both absorption mechanisms is supported only by citation of a paper (*2*) in which a similar statement appears, but without any evidence or further reference.

In view of the current controversy [references in (*1*)] concerning whether the two types of absorption mechanisms operate in parallel in the plasma membrane or in series in this membrane and the tonoplast, it may be useful to point out that vacuoles have in fact been reported many times to occur in members of the Chlorococcales related to *Chlorella* (*3, 4*) and in *Chlorella* itself. Ultrastructural evidence for their existence is available for cultures named as *C. ellipsoidea* (*5*), *C. pyrenoidosa* (*6–8*), and *C. vulgaris* (*9*) [an Emerson strain which may not be the same Emerson strain used in (*2*)]. We can add unpublished observations on *C. pyrenoidosa* strain 211-8p (Fig. 1) which show

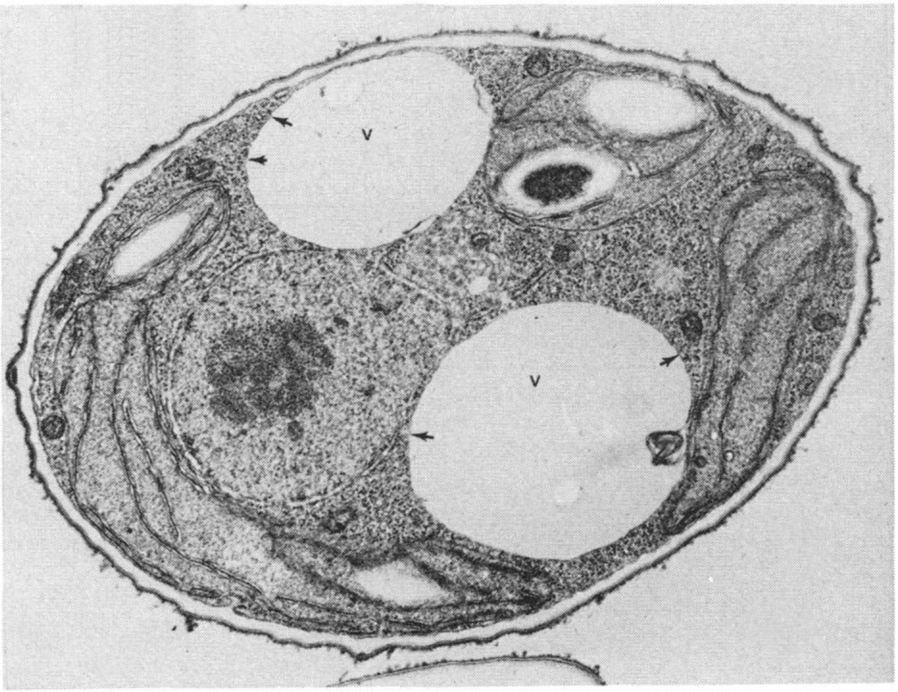

Fig. 1. *Chlorella pyrenoidosa* strain 211-8p showing vacuoles (*V*) and tonoplasts (arrows). Glutaraldehyde-osmium fixation (× 17,000).

that vacuoles with tonoplasts typical of plant cells occupy 8 to 13 percent of the cell volume, depending on the stage of the cell cycle. The vacuoles tend to fragment prior to cytokinesis, and calculations based on a simplified model in which four spherical vacuoles total 10 percent of the volume of a spherical cell with a radius of 3 μm show that the surface area of the tonoplast is nearly 35 percent of that of the plasma membrane. Further fragmentation and distortions from the spherical state (which are routinely observed) would raise the figure considerably.

These observations and calculations reveal nothing about the physiology of the tonoplast, but they do indicate that it should not be ignored.

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References

1. S. Kannan, *Science* **173**, 927 (1971).
2. J. Barber, *Biochim. Biophys. Acta* **150**, 618 (1968).
3. T. F. Bisalputra and T. E. Weier, *Amer. J. Bot.* **51**, 881 (1964).
4. J. D. Pickett-Heaps, *Protoplasma* **70**, 325 (1970).
5. S. Murakami, Y. Morimura, A. Takamiya, in *Microalgae and Photosynthetic Bacteria* (Univ. of Tokyo Press, Tokyo, 1963), pp. 65–83.
6. R. W. Treharne, *J. Mol. Biol.* **10**, 57 (1964).
7. E. Guerin-Dumartrait, *Planta* **80**, 96 (1968).
8. T. W. Budd, J. L. Tjostem, M. E. Duysen, *Amer. J. Bot.* **56**, 540 (1969)
9. D. A. Griffiths and D. J. Griffiths, *Plant Cell Physiol.* **10**, 11 (1969).

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Chlorella pyrenoidosa is classically considered a nonvacuolate system, consisting essentially of a cup-shaped chloroplast and cytoplasm. It has been used extensively as a test organism in nutritional studies (*1–3*), and ultrastructures like microvacuoles have been recorded in a few strains cultured under certain conditions. The strain of *Chlorella pyrenoidosa* that I used in my experiments (*4*) is 7-11-05 (*5*), in which a well-developed central vacuole compared to those in higher plant cells is absent.

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References

1. M. Scheadle and L. Jacobson, *Plant Physiol.* **40**, 214 (1965).
2. Y. J. Shieh and J. Barber, *Biochim. Biophys. Acta* **233**, 594 (1971).
3. J. F. Sutcliffe, *Mineral Salts Absorption in Plants* (Pergamon, London), p. 19.
4. S. Kannan, *Science* **173**, 927 (1971).
5. C. Sorokin, *Nature* **184**, 613 (1959).

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Nucleation and Lattice Disregistry

In the report of their experiments on the nucleation of ice by silver iodide containing bromine, Vonnegut and Chessin (*1*) use a very simple relation between supercooling and lattice disregistry δ^2. Unfortunately, things are not that simple.

In 1914 Lamplough and Scott (*2*) discovered that nucleation is a one-way street in the sense that, if crystal α nucleates crystal β at low supercooling, β does not nucleate α at low supercooling. This result was rediscovered by Sundquist and Mondolfo (*3*) and confirmed by Powell and Colligan (*4*). More than 20 metallic systems have been investigated so far, and in none of them has two-way nucleation been detected. This result is irreconcilable with the idea that disregistry is the controlling factor in nucleation; in many cases the disregistry from α to β is larger than from β to α. This and other findings have led Crosley *et al.* (*5*) to derive the following relation between supercooling for nucleation and the balance of interfacial energies:

$$\left(\frac{\Delta T_{\mathrm{R}}}{\Delta T_{\mathrm{H}}}\right)^{2/3} = (YZ)^{1/3}\left[1 - X\left(\frac{\sigma_{\mathrm{SL}} + \sigma_{\mathrm{NL}} - \sigma_{\mathrm{NS}}}{\sigma_{\mathrm{SL}}}\right)\right]$$

where ΔT_{R} is the supercooling for heterogeneous nucleation; ΔT_{H} is the supercooling for homogeneous nucleation; Y is the energy factor, ranging from 1 to 1.5; Z is the shape factor, ranging from 1 upward; X is the contact factor, ranging from 0 to 1, with 0.5 as the most probable value; σ_{SL} is the interfacial energy between nucleus and liquid; and σ_{NL} is the interfacial energy between nucleant and liquid, and σ_{NS} is the interfacial energy between nucleant and nucleus.

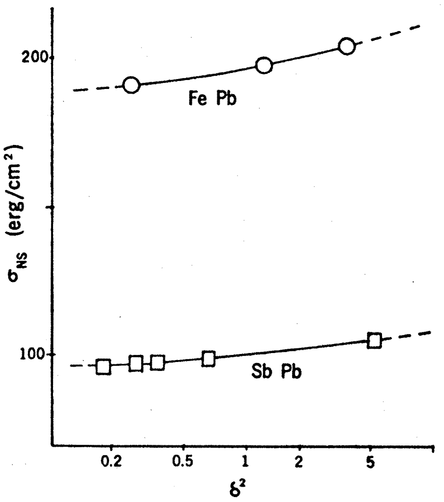

Fig. 1. Disregistry δ^2 as a function of the interfacial energy between nucleant and nucleus σ_{NS} for the nucleation of lead by iron and antimony.

In this formula the disregistry enters as part of the term σ_{NS}: the larger the disregistry, the larger the value of σ_{NS}, as shown in Fig. 1 for the nucleation of lead by iron and antimony, with the different orientation relations experimentally determined.

However, the energy balance is the controlling factor that decides whether nucleation at low supercooling is possible or not, and that balance can be favorable in only one direction. The similarity of the crystal structure and low disregistry are only minor factors, as evidenced, for example, by the nucleation of zinc (hexagonal close-packed) by bismuth (rhombohedral) or of lead by copper ($\delta = 37$ percent, $\Delta T = 0$).

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References

1. B. Vonnegut and H. Chessin, *Science* **174**, 945 (1971).
2. F. E. E. Lamplough and J. T. Scott, *Proc. Roy. Soc. Ser. A Math. Phys. Sci.* **90**, 600 (1914).
3. B. E. Sundquist and L. F. Mondolfo, *Trans. Amer. Inst. Min. Met. Eng.* **221**, 157 (1961).
4. G. L. F. Powell and G. A. Colligan, *ibid.* **245**, 1913 (1969); *Met. Trans.* **1**, 133 (1970); *ibid.*, p. 1349; *ibid.* **2**, 849 (1971).
5. P. B. Crosley, A. W. Douglas, L. F. Mondolfo, *Iron Steel Inst. London, Publ. ISI P110* (1968); P. B. Crosley and L. F. Mondolfo, *Amer. Inst. Min. Met. Eng. Trans. Met. Soc. Pap. F71-4* (1971).

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The relation in question was derived by Turnbull and Vonnegut (*1*) to describe coherent nucleation by catalysts having disregistries of a few percent or less. We pointed out that in the nucleation of aluminum by titanium carbide, titanium boride, and aluminum boride, for which the disregistries are only 4 to 6 percent, the equation gives values for supercooling that are orders of magnitude larger than those found by experiment. The equation clearly should not be applied to cases such as those cited by Mondolfo, where the lattice disregistries are 30 percent or more.

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Reference

1. D. Turnbull and B. Vonnegut, *Ind. Eng. Chem.* **44**, 1292 (1952).

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