10^{-3} roentgen. Although not specially doped for optimum high-temperature TL efficiency, our CaF_2 samples show reasonably intense TL peaks at low temperatures. At exposures above 100 milliroentgens the measurement precisions of both the local RITAD current and the TL photomultiplier current are limited by shot noise (signal fluctuation due to the discrete nature of the entities being measured). For the same samples, the same exposure, and the same electronic instrumentation, the signal-to-noise power ratio of the local RITAD current readout is at least 40 db greater than that for the most sensitive TL peak signal. The 200°K local RITAD peak is closely correlated with a corresponding TL peak, but the 330°K RITAD dosimetry peak falls near a minimum within a group of three incompletely resolved TL peaks characteristic of these CaF_2 samples.

For exposures below 100 milliroentgens the measurement precision of the RITAD current becomes limited by the instrumental noise of our present system, which has a noise figure (ratio of the instrument's actual output noise to the theoretical minimum noise arising from thermally generated fluctuations in the resistive elements) in excess of 20 db. In spite of such poor electronic performance, however, and an unnecessarily large instrument bandwidth of about 1 hertz (that is, a rise time of ~ 0.15 second), the local RITAD signal-to-noise ratio is about 200 : 1 for a 75-milliroentgen exposure. Integration over about 100 seconds to obtain the total charge release, even without any improvement in the existing dosimeter geometry or instrumentation noise figure, gives a 6000 : 1 signal-to-noise ratio on the RITAD charge output at 75-milliroentgen exposure.

We do not understand, as yet, the detailed mechanisms producing the local RITAD effects, except that they seem to be generated by the thermally activated mobility of trapped electrons or holes, or both. There are two possible explanations. According to the first explanation, during irradiation the transient mobility of electrons and holes allows them to separate in the bias-polarization field, leading to a frozen-in transportative polarization (polarization attributable to charge transport); during subsequent thermally induced mobility, the recombination of electrons and holes produces the RITAD depolarization signal. According to the second explanation, trapped electrons and holes are formed with an essentially uniform spatial distribution during irradiation; during readout, however, thermally activated mobility allows the detrapped carriers to drift without total recombination and to produce the RITAD signal as they attempt to depolarize the preexisting bias-polarization state. Our experiments indicate that both processes may simultaneously occur in the observed RITAD phenomena.

The particular CaF_2 RITAD states described here can be utilized for some special-purpose dosimetry techniques, for example, fast neutron activation dosimetry. Unfortunately, they fade too rapidly to be really practical for use in routine room-temperature dosimetry. The principle, however, is clearly established. Our preliminary work on SrF_2 shows a local RITAD peak occurring at a temperature about 40°K higher than the CaF_2 peak 2. We believe that the local RITAD properties described above, namely, high radiation response, low intrinsic noise, the absence of any requirements for good optical quality crystals, the absence of any necessity for electrical conductive integrity of the sample, the flexibility of dosimeter fabrication, and the simplicity of readout, ensure a very great potential for local RITAD phenomena as an important new technique in sensitive radiation dosimetry.

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Blue-Green Algae: Why They Become Dominant

Abstract. *The injection of carbon dioxide and the addition of nitrogen and phosphorus to a lake population dominated by blue-green algae results in a rapid shift to dominance by green algae. The basis for the change and its implications are discussed.*

Possibly the most perplexing problem presently facing limnologists concerns the relative abundances in lakes of various types of algae. This is particularly true for certain of the blue-green algae, which have earned the sobriquet "nuisance algae" because they are extremely abundant and dominant in situations where nutrients are plentiful, and which usually become dominant when nutrient inputs increase. A variety of hypotheses have been proposed ranging from the suggestion that blue-green algae are symbiotic with bacteria that abound under such enriched conditions to the supposition that blue-green algae require the organic compounds that enter lakes with high concentrations of nutrient wastes, such as domestic sewage effluents. However, none of these hypotheses has been given confirmation and the problem persists. Recently, King (*1*) suggested an explanation that is not only apparently supported by the facts but that is also experimentally testable. Using his own data and those from the literature, King suggested that blue-green algae are more efficient at obtaining CO_2 from low concentrations than green algae, and that under circumstances when the *p*H is high, as in enriched lakes, blue-green algae should predominate.

My tests of this hypothesis were direct. I subjected a mixed population of algae under conditions as natural as possible to a variety of treatments including high concentrations of nutrients (nitrogen plus phosphorus), high concentrations of CO_2, and high or low *p*H (5 to 6). The experiments were carried out in duplicate in a series of 12 polyethylene bags, each 1 m in diameter and 1.5 m deep, suspended from a raft in Lake Emily, a small shallow lake in the vicinity of St. Paul, Minnesota. The treatments used are summarized in Table 1.

Table 1. Treatments used in bag experiments. The nutrients consisted of nitrogen and phosphorus added in the form of NH_4NO_3 and KH_2PO_4, respectively, as described in the text.

Bag No.	Treatment
1	Low *p*H
2	Low *p*H
3	None
4	None
5	Low *p*H; nutrients
6	Low *p*H; nutrients
7	Nutrients
8	Nutrients
9	CO_2; nutrients
10	CO_2; nutrients
11	CO_2
12	CO_2

The *p*H selected with HCl (5 to 6) was similar to that in the bags with the CO_2 (5.5). The nitrogen and phosphorus were added as NH_4NO_3 and KH_2PO_4, respectively, over a 5-day period for a total addition of 700 μg of nitrogen per liter of water, and of 100 μg of phosphorus per liter of water. Carbon dioxide gas (100 percent) was continuously bubbled in at the bottom of the bags until small bubbles persisted at the surface of the water.

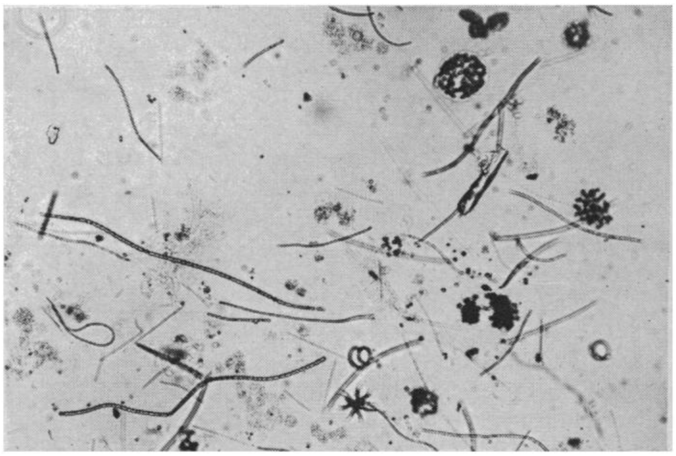
The results were spectacular. Although initially the populations consisted of blue-green algae (Fig. 1), 10 days later, on 23 July 1972, the algal populations in bags 9 and 10 (CO_2, nutrients) were dominated by green algae (Fig. 2). Somewhat similar but lesser changes in relative abundance occurred in bags 5 and 6 (low *p*H, nutrients), and slight changes occurred in bags 1 and 2 (low *p*H) and bags 11 and 12 (CO_2). Controls (bags 3 and 4) showed no changes, and bags 7 and 8 (nutrients) showed higher populations of blue-green algae and *p*H values of 10.7 as compared with 9.8 for the controls and the lake itself.

In summary, the addition of CO_2 or the lowering of the *p*H stimulated a shift from blue-green to green algae, especially when nutrients were supplied simultaneously, whereas just the addition of nutrients resulted in the appearance of more blue-green algae. Further experiments in which bag 8 received CO_2 confirmed the rapid shift in abundance, and, when the *p*H of bag 6 was raised by the addition of KOH, there was a slight tendency for filamentous blue-green algae to become more abundant.

It would appear then that King's hypothesis may be correct. Either the addition of free CO_2 or the lowering of the *p*H makes more CO_2 available, and the presence of the nutrients would allow the green algae to take advantage of this availability. There are other possible explanations for the change, but these are less likely. For example, it might be claimed that the low *p*H and CO_2 treatments killed the blue-green algae; however, they did not disappear, they only became less abundant. Or it may be claimed that the low *p*H and CO_2 treatments killed the grazing zooplankton and that this allowed the normally grazed-upon green algae to become abundant in their absence. Because this possibility was a fairly strong one, I investigated and found that indeed in bags 9 through 12 (CO_2) the grazers were not very abundant, but in bags 5 and 6 (low *p*H, nutrients) the grazers were abundant, and the green algae dominated there in spite of them. Furthermore, an investigation of the sediments in the bottoms of bags 9 through 12 (CO_2) and bags 1, 2, 5, and 6 (low *p*H) revealed that the blue-green algae had not settled out of the water in these experiments.

This demonstration of a rapid shift from blue-green algae to green algae is reminiscent of what happens to stratified lakes when they are artificially circulated by mechanical means or by the introduction of compressed air. Symons and his associates (*2*) were among the first to point out, and others have since confirmed, that frequently, when lake water dominated by blue-green algae is mixed, the blue-green algae decline and the green algae seem to become the dominant forms. Many possible explanations have been advanced for this phenomenon including changes in the light regime, temperature, and other factors. Bella (*3*) has expressed the view that the mixing process benefits the heavier algae.

On the other hand, mixing a stratified lake is closely analogous chemically to adding CO_2 and nutrients, as in the experiments described here. Not only are nitrogen and phosphorus and CO_2 brought up to the epilimnion from the hypolimnion but also CO_2 is allowed to enter from the atmosphere, and in consequence mixing usually results in a lowered *p*H. It is possible, therefore, that the phenomenon in the lakes depends on the same principles as those that prevail in the bags—the shift of conditions so that the kinetics of nutrient uptake and use by green algae allow them to win the competition with the blue-green algae. One may indeed



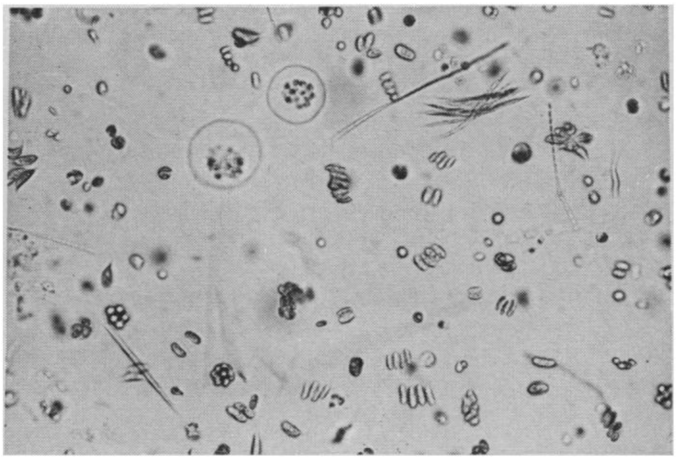


Fig. 1 (left). Photomicrograph of the algae in the bags at the beginning of the experiment. The most common algae are as follows: *Coelosphaerium, Microcystis, Lyngbya, Anabaena, Aphanizomenon, Oscillatoria,* and *Ankistrodesmus.* Fig. 2 (right). Photomicrograph of the algae in bag 9 (CO_2, nutrients) after 10 days. The predominant algae are as follows: *Sphaerocystis, Scenedesmus, Ankistrodesmus,* and *Oscillatoria.*

speculate that the whole pattern of dominance by blue-green algae is the result of a series of events allowing their kinetics of nutrient uptake and use to ensure their success. Thus, if we begin with a sparse mixed population of algae and a *p*H near neutrality, the productivity increases as nutrients are added to the point where free CO_2 disappears and bicarbonate CO_2 is utilized. At this point the *p*H rises. Their apparently advantageous CO_2 uptake kinetics allow the blue-green algae to begin to dominate. Furthermore, since, as I have recently found, the phosphate uptake kinetics favor blue-green algae over green algae, the phosphate supply of the blue-green algae is relatively assured (*4*). Because of this, the nitrogen-fixing blue-green algae are able to obtain nitrogen as well. Thus, one advantage leads to another, and so on.

Green algae are generally considered more desirable in that they do not form floating scums. Moreover, because green algae are more acceptable ecologically in that they are within the food chain, it would be reasonable to investigate the effect of the injection of CO_2 with or without air into lakes as a means of stimulating the growth of green algae at the expense of blue-green algae. I do not mean to imply that phosphate removal to control gross algal production should not be the ultimate goal, but, in view of the many lakes for which phosphates enter from diffuse sources rather than from controllable sources, alternatives are needed.

Finally, a disclaimer—this report should be taken to mean that I feel that the rate of supply of CO_2 is an important factor in regulating the qualitative nature of the phytoplankton. But I do not believe that the rate of supply of CO_2 from natural sources, in most cases, limits the gross production of phytoplankton.

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4. The as yet unpublished results of my experiments with algal cultures show that the half saturation constants for phosphate uptake by blue-green algae are significantly lower than those for green algae over a wide range of environmental conditions.
5. I thank the many students and technicians who helped in the construction, transportation, and maintenance of the rafts from which the bags were suspended. I thank the following for assistance in the experiments: B. Carlson, D. Hall, V. Lamarra, C. Manwiller, J. Yanko, A. Shapiro, and D. Shapiro. Supported under NSF grant GB-15675. Contribution No. 118 from the Limnological Research Center, University of Minnesota.

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Localization of Calcium Pump Activity in Smooth Muscle

Abstract. *A microsomal fraction isolated from longitudinal smooth muscle of guinea pig ileum actively sequesters calcium ion in the presence of magnesium and adenosine triphosphate in a fashion previously described for microsomes of the rabbit aorta. This activity in guinea pig ileum appears to be associated primarily with the plasma membrane as is found in the red cell. By contrast the uptake of calcium in aortic smooth muscle appears to be associated to an appreciable extent with intracellular membranes, possibly analogous to the sarcoplasmic reticulum of skeletal muscle.*

Calcium ion is the agent that activates contractile elements in all types of muscle fibers. However, the triad (or dyad), a subcellular organelle that serves as both a source and a sink for the divalent ions in skeletal (*1–3*) and cardiac muscle (*2–4*), has not been found in smooth muscle. Based on evidence obtained from numerous physiological studies performed on various types of smooth muscle fibers, there is currently a consensus that the calcium ions associated with mechanical activity in smooth muscle may arise from two different sources (*5, 6*). One is the pool of calcium that is present in the extracellular fluid or that is loosely bound to superficial sites in the muscle fiber; the other is a tightly bound pool of calcium that is sequestered in some intracellular location (or locations) in the fiber. Recent histological and histochemical studies have pointed to two specific loci inside the cell where mobilizable calcium may be sequestered. These are the sarcoplasmic reticulum and the mitochondria of the muscle fiber (*7, 8*).

The contention that an intracellular as well as an extracellular (or superficial) site may store the activator ions needed for contraction does not imply that an intracellular store of calcium plays an equally important physiological role in all types of smooth muscle fibers. For example, the main pulmonary artery of the rabbit, immersed in a calcium-free medium, retains its capacity to contract long after extracellular and presumably loosely bound calcium ions have been removed (*8*). By contrast, the taenia coli of the rabbit, under the same conditions, retains its capacity to contract for a much shorter period of time (*8*). Estimates of the amount of sarcoplasmic reticulum present in each of the two smooth muscles correlate with these findings. The main pulmonary artery was assessed as having over twice as much sarcoplasmic reticulum by volume as does the taenia coli (*8*). In another study carried out in the longitudinal smooth muscle of the guinea pig ileum, it was found that the degree of contractility exhibited by the muscle in a calcium-free environment bears a precise relationship to the level of calcium that is present in a loosely bound form in the tissue (*9*). This fraction of the calcium escaped from the tissue with a half-time of 4 to 6 minutes. It would appear, therefore, that a firmly bound intracellular pool of calcium supports mechanical activity to a significant degree in the main pulmonary artery of the rabbit, is much less supportive in the taenia coli of the rabbit, and is of negligible significance in the longitudinal muscle of the guinea pig ileum.

As a reasonable extension of these findings, one may postulate that differences in the magnitude and functional importance of sequestered depots of calcium should correlate with differences in the cellular locations of metabolically dependent calcium pumps. A smooth muscle fiber that utilizes primarily external or superficially bound calcium for contraction might be expected to have a large part of its capacity to bind or extrude cytoplasmic calcium localized in the plasma membrane. A fiber that also mobilizes intracellular calcium might be expected to contain some part of its capacity to actively transport or bind calcium in the membranes of its intracellular organelles. This postulate regarding the possible correlation between the sources of mobilizable calcium and the cellular locations of active calcium pumps was examined by investigating the sites at which active calcium pumps exist in two different types of smooth muscles.