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This Week's Citation Classic

Ranson S L & Thomas M. Crassulacean acid metabolism. *Annu. Rev. Plant Physiol.* **11**:81-110, 1960. [Dept. Botany, King's College, Newcastle upon Tyne, Univ. Durham, England]

A review of selected fields of investigations published before 1959 covering *inter alia* occurrence, source and magnitude of acid fluctuation, effects of CO_2 and oxygen concentration in light and dark, and enzymic mechanisms is presented. [The *SCI*® indicates that this paper has been cited over 150 times since 1961.]

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"The review was written when for over a decade CAM had been a major research interest in Meirion Thomas's department in Newcastle and in several other centres worldwide. After this phase there followed a relatively quiescent period until the study of CAM was reactivated with surprising vigour in the wake of studies on C_4 photosynthesis. Probably, the frequent citation of the review is because it serves as a readily accessible compendium reference to earlier work. Presumably the content of Wolf's[1] excellent, very comprehensive, and possibly less subjective review written about the same time is less readily available to many currently involved in these studies.

"In the early 1940s, Thomas[2] came to the conclusion that if CAM plants could fix CO_2 into carboxylic acids in darkness, as had been demonstrated for bacteria by Werkman and Wood,[3] this would explain many facets of CAM. Plant material for experimental investigation was not immediately available, but a thorough appraisal of all relevant literature dating back to the early 1800s provided him with much supporting evidence.

"When a few *Kalanchoë* plants became available in 1946, Harry Beevers, then in his last few months as a postgraduate student in Newcastle, measured the gas exchanges of leaves accompanying changes in titratable acid in atmospheres enriched in CO_2 In the dark, the leaves absorbed oxygen and CO_2 simultaneously in the active phase of acid accumulation, and in the light, acid depletion was retarded or under appropriate conditions acid accumulated. I was then invited to continue the study and gladly accepted—not having given much thought to plant physiology during five years maintaining radar equipment in the army like several other contemporary UK botanists.

"There then followed a period of extensive gas exchange measurements in an attempt to relate these quantitatively with acid production and consumption. The Haldane apparatus was used and in view of present concern with mercury poisoning perhaps some of us are lucky to have survived unscathed. Carbon 14 and chromatography came to Newcastle in 1951 after I had spent a very enjoyable year with Martin Kamen in St. Louis, and the group extended its studies in various directions taking in amongst others John Brown, David Walker, Mary Stiller, four Bradbeers, Bob Lyndon, P.N. Avadhani, and Bill Cockburn, who have continued in the study of plant physiology. Interestingly, the last of these seems to have finally nailed down the coffin on the double carboxylation hypothesis which emerged from the group in the 1950s.[4]

"In more recent years attention has centred on regulatory mechanisms and has widened to take in taxonomic, anatomical, and ecological aspects.[5,6] New problems have arisen. Some old problems are not fully resolved; for example, how much, if any, of the C_3 moiety remaining when malate is decarboxylated in the light is directly incorporated into carbohydrate."

1. **Wolf J.** Der diurnale Saurerhythmus. (Ruhland W, ed.) *Encyclopedia of plant physiology.* Berlin: Springer-Verlag, 1960. Vol. 12. p. 809-89.
2. **Thomas M.** Physiological studies on acid metabolism in green plants. I. CO_2 fixation and CO_2 liberation in Crassulacean acid metabolism. *New Phytol.* **48**:390-420, 1949.
3. **Werkman C H & Wood H G.** Heterotrophic assimilation of carbon dioxide. *Advan. Enzymol.* **2**:135-82, 1942.
4. **Cockburn W & McAulay A.** The pathway of carbon dioxide fixation in Crassulacean plants. *Plant Physiol.* **55**:87-9, 1975.
5. **Osmond C B.** Crassulacean acid metabolism: a curiosity in context. *Annu. Rev. Plant Physiol.* **29**:379-414, 1978.
6. **Kluge M & Ting I P.** *Crassulacean acid metabolism: analysis of an ecological adaptation.* Berlin: Springer-Verlag, 1978. 209 p.