Hunt Institute for Botanical Documentation
5th Floor, Hunt Library
Carnegie Mellon University
4909 Frew Street
Pittsburgh, PA 15213-3890
Telephone: 412-268-2434
Email: huntinst@andrew.cmu.edu
Web site: www.huntbotanical.org

The Hunt Institute is committed to making its collections accessible for research. We are pleased to offer this digitized item.

Usage guidelines
We have provided this low-resolution, digitized version for research purposes. To inquire about publishing any images from this item, please contact the Institute.

Statement on harmful and offensive content
The Hunt Institute Archives contains hundreds of thousands of pages of historical content, writing and images, created by thousands of individuals connected to the botanical sciences. Due to the wide range of time and social context in which these materials were created, some of the collections contain material that reflect outdated, biased, offensive and possibly violent views, opinions and actions. The Hunt Institute for Botanical Documentation does not endorse the views expressed in these materials, which are inconsistent with our dedication to creating an inclusive, accessible and anti-discriminatory research environment. Archival records are historical documents, and the Hunt Institute keeps such records unaltered to maintain their integrity and to foster accountability for the actions and views of the collections' creators.

Many of the historical collections in the Hunt Institute Archives contain personal correspondence, notes, recollections and opinions, which may contain language, ideas or stereotypes that are offensive or harmful to others. These collections are maintained as records of the individuals involved and do not reflect the views or values of the Hunt Institute for Botanical Documentation or those of Carnegie Mellon University.

About the Institute
The Hunt Institute for Botanical Documentation, a research division of Carnegie Mellon University, specializes in the history of botany and all aspects of plant science and serves the international scientific community through research and documentation. To this end, the Institute acquires and maintains authoritative collections of books, plant images, manuscripts, portraits and data files, and provides publications and other modes of information service. The Institute meets the reference needs of botanists, biologists, historians, conservationists, librarians, bibliographers and the public at large, especially those concerned with any aspect of the North American flora.

Hunt Institute was dedicated in 1961 as the Rachel McMasters Miller Hunt Botanical Library, an international center for bibliographical research and service in the interests of botany and horticulture, as well as a center for the study of all aspects of the history of the plant sciences. By 1971 the Library's activities had so diversified that the name was changed to Hunt Institute for Botanical Documentation. Growth in collections and research projects led to the establishment of four programmatic departments: Archives, Art, Bibliography and the Library.

The American Society of Plant Physiologists

Office of the President

November 19, 1975

Dr. H. Currier
Department of Botany
University of California
Davis, CA 95616

Dear Herb:

I am writing to confirm our telephone conversation concerning your membership on the Honors and Awards committee. The other members are Fred Addicott and Ernie Jaworski, with Ernie Jaworski being chairman. I am delighted that you are willing to take on this assignment. You should hear directly from Jaworski concerning your first task, the nominating of somebody for the Edward W. Browning award offered by the Society of Agronomy. They have just asked us to submit such a nomination!

With warmest regards,

Winslow R. Briggs
President

WRB:kk

The American Society of Plant Physiologists

Office of the President

November 17, 1975

Dr. E. G. Jaworski
Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, MO 63166

Dear Ernie:

I am writing to inform you that you now have the dubious distinction of being chairman of the Honors and Awards committee of the American Society of Plant Physiologists, happily of which you are already a member. Seriously, I would very much like to have you take on this chairmanship. The other remaining member is Dr. F. T. Addicott at Davis, and a new member is Dr. H. Currier, also at Davis. I enclose something which I received not too long ago, indicating that the Honors and Awards committee will indeed have a job to do this year. I notice that the deadline for receiving our society's nominations is February 9,1975, so there is at least some time!

I gather that my colleague Olle Bjorkman has just recently visited with you. Perhaps he could answer some of the hard questions about C_3 and C_4 photosynthesis that your people put to me!

With warmest personal regards,

Winslow R. Briggs
President

WRB:kk

Enc.

AMERICAN
SOCIETY OF AGRONOMY

HEADQUARTERS: 677 SOUTH SEGOE ROAD • MADISON, WISCONSIN 53711
TELEPHONE 608-274-1212

MATTHIAS STELLY
EXECUTIVE VICE PRESIDENT

October 20, 1975

Dr. Winslow Briggs, President
American Society of Plant Physiologists
Department of Plant Biology
Carnegie Institute of Washington
Stanford, CA 94305

Dear Dr. Briggs:

The American Society of Agronomy is now accepting nominations for

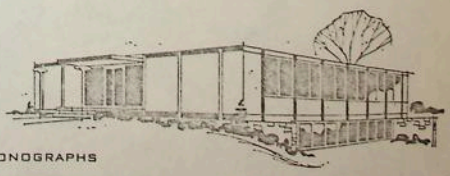
The Edward W. Browning Award.

The Award consists of $5,000, a bronze medal, and a framed certificate.

Your organization is eligible for submitting a nomination. Only one nomination per association or society is permitted. By following this procedure two objectives should be accomplished, namely, 1) your organization will have the opportunity to select the most highly qualified individual known to your group - the nominee need not be a member of your organization, and 2) the number of nominees received for consideration will be kept to a reasonable figure. The nomination must be forwarded to the American Society of Agronomy, but not necessarily written, by the President or an officially designated representative of the sponsoring organization.

It would be very much appreciated if you would contact the appropriate committee or person in your organization in regard to the preparation of a nomination for this very impressive award. One suggestion you may wish to try would be to solicit nominations from the various departments at colleges and universities; nominations received in this way could be screened by a committee in your society and the best candidate in the group could be submitted as your society nominee. At any rate, please do not put off selecting and submitting a nominee - the deadline date will be upon you all too soon.

Several copies of the Edward W. Browning Award brochure are enclosed for distribution as you deem appropriate for obtaining nominations from your people. The brochure is believed to be self-explanatory; however, if you have any questions, or desire additional copies of the brochure, please feel free to telephone or write to us.



A carbon copy of this letter, and a copy of the brochure is being sent to the executive officer or secretary of your organization. Hopefully the two of you will communicate immediately and will work together on obtaining a nomination from your organization for this prestigious award. Meanwhile, please acknowledge receipt of this invitation and as soon as possible, please inform us as to whether or not you plan to submit a nomination.

Please act now. The deadline for receiving nominations is February 9, 1975.

Sincerely,

Matthias Stelly
Executive Vice President

MS:DMK:cew

CC: Dr. Houston Baker

March 3, 1976

Dr. E. G. Jaworski
Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, MO 63166

Dear Ernie:

Here is yet another one for the Honors and Awards Committee. I am remiss in not getting it to you sooner, but plead a combination of being first, out of town, and then home with the flu for a week. It may be too late for any action, but I thought I would send it along just the same. It could be that among various people that you have considered, there might be somebody who fits.

Best regards,

Winslow R. Briggs
President

WRB:kk

Monsanto

MONSANTO AGRICULTURAL PRODUCTS CO.
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166
Phone: (314) 694-1000

December 4, 1975

Dr. Winslow R. Briggs, President
The American Society of Plant Physiologists
Carnegie Institution of Washington
Department of Plant Biology
Stanford, California 94305

Dear Win:

I shall be happy to take on the job as Chairman of the Honors and Awards Committee of the American Society of Plant Physiologists. Time is probably too short to do much on the Edward M. Browning Award for 1976 but I will see what Addicott and Currier think.

Yes, we had Olle Björkman here for a seminar and enjoyed his visit thoroughly. We hope to stay in touch with you fellas at the Carnegie since your areas of research are focused on problems related to the basic aspects of applied problems we are interested in. Hope we can continue the exchanges in the future.

With warmest greetings to all for the Holiday Season.

Sincerely yours,

Ernest G. Jaworski
Distinguished Science Fellow

EGJ:jo

The American Society of Plant Physiologists

January 14, 1976

Office of the President

Dr. E. G. Jaworski, Chairman
Honors and Awards Committee
American Society of Plant Physiologists
Monsanto Co.
800 N. Lindbergh Blvd
St. Louis, MO 63166

Dear Dr. Jaworski:

I am delighted with your Committee's nomination of Dr. Robert Burris for the Edward W. Browning Award from the American Society of Agronomy. It is appropriate that you serve as the official delegate of the American Society of Plant Physiologists in communicating our Society's nomination to the American Society of Agronomy.

Sincerely yours,

Winslow R. Briggs
President

WRB:dcm

cc: Houston Baker

Monsanto

Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166
(314) 694-1000

December 23, 1975

Dr. F. T. Addicott
Dr. H. Currier
Department of Botany
University of California
Davis, California 95616

Dear Gentlemen:

As chairman of the Honors and Awards Committee of the American Society of Plant Physiologists, it is a pleasure to have two such distinguished scientists as yourselves on the committee. I am not completely certain as to our mission, but apparently, it is our task to handle awards and honors that are not formally granted by the American Society of Plant Physiologists (see attached). That is, we are responsible for insuring that a worthy member of our Society is considered for an outside award if requested to do so by the President of our Society.

In the case of the Edward W. Browning Award for 1976, the information was transmitted rather late with a deadline of February 9, 1976. You both have copies describing the award and requirements for nominees. I discussed this with one of you (FTA) during a recent visit to Davis and hope you have both had a chance to do some thinking about possible nominees.

I spoke to the people at the American Society of Agronomy office and learned that the following people have received the Browning Award:

Dr. George Harrar - Plant Pathology Research
Dr. Ben Burmester - Poultry Science Research
Dr. Orville Vogel - Wheat Plant Breeding
Drs. E. Mertz and O. Nelson - High Lysine Corn Development
Dr. Glenn Burton - Forage Plant Breeding.

While the award is presented to an individual who has made outstanding achievements in the improvement of food sources, I am told the contribution need not be a direct one. Thus, it would be reasonable to consider a scientist whose basic studies would have contributed to potential improvements of food sources.

May I ask you to consider some names that might fit the criteria set forth and send them to me with a priority rating of 1, 2, 3, etc. I can see if we then have time to contact someone at the nominees institution to fit together a suitable application and resume. This would, of course, be done only with the concurrence of Dr. Briggs.

Since time is so short, would you please let me know your thoughts no later than January 12, 1976.

Thank you for your cooperation and may I take this opportunity to wish you a happy Holiday Season and a prosperous New Year.

Sincerely yours,

Ernest G. Jaworski
Chairman, Honors and
Awards Committee

EGJ:jo

cc: Dr. Winslow R. Briggs

P. S.

What would be your feeling about considering Dr. Robert Burris for his contributions in nitrogen fixation or Dr. Sterling Hendricks for his contributions to the field of plant growth and differentiation?

The American Society of Plant Physiologists

Office of the President

January 28, 1976

Dr. Ernest G. Jaworski, Chairman
Honors and Awards Committee
Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, MO 63166

Dear Dr. Jaworski:

It is a real pleasure to write a letter in support of your nomination of Dr. Robert H. Burris for the Edward W. Browning Award of the American Society of Agronomy. From the very first demonstration of nitrogen fixation in vitro, he has made continued important contributions to our knowledge of nitrogen metabolism and fixation in plants and procaryotes. His continued productivity is revealed in one way by inspecting Dilworth's 1974 review of nitrogen fixation. Burris is cited in the context of the biochemical details of the process no less than ten separate times. A few years back, he was the unanimous choice of the faculty of the Harvard Biology Department to deliver the distinguished Prather lecture series, which this writer had the privilege of hearing. It was clear that Burris's own contributions over the years have been major ones, and that they have been sustained for over twenty five years.

I gather that a letter such as this one should mention the relevancy of the nominee's work to agriculture, but I think this sufficiently obvious in the case of nitrogen fixation as to need little documentation. Biological nitrogen fixation is the only energy-cheap way available to obtain urgently needed fertilizers, and must inevitably play an increasingly dominant role in agriculture.

I hope that these rather brief remarks are of assistance to you. Burris is clearly an outstandingly strong candidate for the Society to nominate.

Sincerely yours,

Winslow R. Briggs
President

WRB:kk

June 23, 1976

Dr. Nathan M. Newmark, Chairman
President's Committee on the National
Medal of Science
National Science Foundation
Washington, D. C. 20550

Dear Dr. Newmark:

The American Society of Plant Physiologists wishes to place in nomination the name of Dr. Folke K. Skoog for your consideration for the National Medal of Science. The enclosed supporting document presents the information you requested in your letter of December 31, 1975, to Dr. Winslow R. Briggs.

Please let me know if you have need of any further information as your committee deliberations progress.

Sincerely yours,

Ernest G. Jaworski
Chairman, Honors and Awards Committee
American Society of Plant Physiologists

EGJ:jo

Enclosure

bc: Dr. F. T. Addicott
Dr. W. R. Briggs
Dr. H. Currier

June 23, 1976

Dr. Robert Burris
Department of Biochemistry
University of Wisconsin
Madison, Wisconsin 53706

Dear Bob:

It was great to see you in New Orleans and to have an opportunity of meeting your charming wife.

This is just a note to thank you for sending me all the valuable material on Prof. Skoog. We beat the deadline by a week and are grateful for your assistance.

With kind regards.

Sincerely yours,

Ernest G. Jaworski
Distinguished Science Fellow

EGJ:jo

bc: Dr. F. T. Addicott
Dr. W. R. Briggs
Dr. H. Currier

NOMINATION OF
DR. FOLKE K. SKOOG
FOR THE
NATIONAL MEDAL OF SCIENCE

The growth of higher plants is regulated by plant growth substances; these sometimes are referred to as plant growth hormones. The first of the growth substances to be clearly identified were the auxins, substances which move in the plant and induce cell elongation. Other growth substances influence flowering, germination, elaboration of amylases, abscission, etc. A group of growth substances known as the cytokinins were first characterized by F. Skoog and his colleagues. The cytokinins control cell proliferation and hence have a crucial role in the control of plant growth and development.

Responses to crude cytokinins had been observed earlier, but the compounds eliciting the responses had not been identified. Skoog in collaboration with F. Strong and C. Miller isolated, purified and identified kinetin as 6-furfurylaminopurine. It was particularly interesting that as a derivative of adenine, kinetin was related to nucleic acids. Kinetin is a specific compound and cytokinin is a generic term used to refer to a family of compounds with related effects on growth.

Cytokinins have diverse effects on plants, but as agents in control of cell proliferation they are essential for normal growth. They are elaborated in intact plants, but it may be necessary to add them to achieve growth of isolated plant tissue in culture. Cytokinins interact with other plant growth substances, and a proper balance among growth substances is needed to support proper growth. Although animal tissue cultures are not grown on completely chemically defined media, plant tissue cultures can be cultivated indefinitely on completely defined media. By furnishing a proper balance of cytokinin, auxin and other factor, undifferentiated plant tissue can be induced to grow and to produce complete plants capable of flowering and producing viable seeds--this property of plant tissue is designated totipotency. Skoog and colleagues not only isolated and characterized the cytokinins, but they also have been leaders in studying the influence of cytokinins on growth and differentiation.

Kinetin first was isolated by Skoog from heated DNA, but subsequently other cytokinins have been isolated directly from plants and many active compounds of related structure have been synthesized. Skoog has studied these compounds for their activity and has been able to generalize the chemical specifications of physiologically active cytokinins. This also has permitted him to design cytokinin antagonists.

F. Skoog was the discoverer of cytokinins and has been recognized as the leader in their study for years. His work clearly is one of the most important discoveries of the generation in the area of plant sciences.

The following statement covers Skoog's work in somewhat greater detail*.

Skoog has dealt with the biochemistry and physiology of cytokinins. The aim of Skoog's recent work has been to determine the presence, establish the chemical nature and elucidate the modes of action of substances which regulate growth and development in plants.

The present project on the biochemistry and physiology of cytokinins has developed gradually from Skoog's early interest in growth correlations especially the inhibition of lateral buds (apical dominance). Skoog's thesis under Professor K. V. Thimann dealt with the biochemistry of auxin ("growth substance") in beans and peas and its function as the inhibitory agent in apical dominance. Some years later he deduced that the inhibitory action of auxin was exerted in a multi-component regulatory ("auxin reaction") system in which promotion and inhibition of growth would depend on quantitative levels and interactions of the components, and a search was initiated for factors which would interact with auxin in such a system. The strain of tobacco callus tissue first cultured by P. R. White in 1939 proved to be suitable experimental material for this purpose. It was shown that this tissue synthesized more auxin than needed for its growth in vitro. Its growth was slightly repressed and its sporadic capacity to differentiate (form buds) was completely suppressed by moderate concentration of exogenous indoleacetic acid or naphthaleneacetic acid (IAA or NAA). In attempts to overcome this inhibition it was shown that increased levels of Fe, phosphate and carbohydrate in the medium were partially effective, and use of "organic phosphate" (adenosine plus phosphate used in lieu of adenylic acid) showed that both adenosine and adenine under these conditions would in fact promote growth

---

* BAP (6-BAP) 6-Benzylaminopurine
BAPA 6-Benzylamino-9-ß-D-ribofuranosylpurine
2iP 6-(3-methyl-2-butenylamino)purine
6-Δ^2-isopentenylaminopurine
2iPA 6-(3-methyl-2-butenylamino)-9-ß-D-ribofuranosylpurine
zeatin 6-(4-hydroxy-3-methyl-trans-2-butenylamino)purine
cis-zeatin 6-(4-hydroxy-3-methyl-cis-2-butenylamino)purine
iso-zeatin 6-(4-hydroxy-2-methyl-trans-2-butenylamino)purine
ribosyl-zeatin 6-(4-hydroxy-3-methyl-2-butenyl)amino-9-ribofuranosylpurine
ms2iP 6-(methyl-2-butenylamino)-2-methylthiopurine
DPU (N,N'-DPU) N,N'-Diphenylurea
Compound 6 (cytokinin antagonist) 3-methyl-7-(3-methylbutylamino-pyrazolo/4,3-d/pyrimidine

in the presence of IAA. A study of the interaction of IAA, phosphate and adenine in excised stem segments of "normal" tobacco revealed that undifferentiated growth and formation of organs (roots or buds) could be regulated by the IAA/adenine ratio in the medium.

In contrast with stem segments excised pith tissue required a second factor in addition to auxin (which was present in vascular tissue and in various extracts; malt, yeast and coconut milk), for vigorous continuous growth in vitro. This factor in yeast extract was extractable at least in part by organic solvents and was deduced to have properties of a purine. This in turn led to testing of nucleic acid preparations and to the isolation of a crystalline active material from DNA hydrolysate which was identified, by analysis of degradation products and synthesis, as 6-furfurylaminopurine (kinetin) (see F. M. Strong, Topics in Microbial Chemistry, Chapter III).

Although a large number of similarly active N^6-adenine derivatives were synthesized and properties required for biological activity were investigated soon afterwards (see F. M. Strong, Topics in Microbial Chemistry, Chapter III), a more systematic study of structure/activity relations was undertaken jointly by Skoog and N. J. Leonard and his group in 1961 when it was found that triacanthine, an alkaloid identified in locust leaves could be converted by intermolecular rearrangement into highly cytokinin active N^6-isomer. /6-(γ,γ-dimethylallylamino)purine, 6-Δ^2-isopentenylaminopurine, 2iP, or 6-(3-methyl-2-butenylamino)-purine/. This substance seems to be universally present, at least as a constituent of tRNA in all kinds of organisms from mycoplasma to man, and the synthetic compound has facilitated the identification of its naturally occurring derivatives such as zeatin (Letham et al. 1964) and the 2-methylthio-substituted derivatives of 2iP and zeatin which Skoog found.

A requirement for kinetin (a cytokinin) together with IAA (an auxin) for cytokinesis was demonstrated and a regulatory influence of the two substances on DNA and RNA (total tissue content) and on various other cell constituents was established. The striking influence of cytokinins on the biosynthesis of various low-molecular metabolites including pigments, glyosides, and essential growth factors, such as auxin and thiamine, may be basic to their numerous regulatory roles, as in macromolecular biosynthesis (chloroplast formation), morphogenetic processes (tissue differentiation) and organ formation.

Following the isolation of cytokinins from wheat germ tRNA, the same methodology was used to isolate cytokinins from tRNA of 46 kilograms of cytokinin dependent tobacco callus tissue grown on media with 6-benzylaminopurine as the exogenous cytokinin source. Three cytokinin-active ribonucleosides, ribosyl zeatin, 2iP, and ms-ribosyl zeatin (a new species first found in wheat germ) were

isolated and identified by mass spectrometry. A fourth biologically active ribonucleoside was tentatively identified by chromatography as ms2iPA. 6-Benzylamino-9-β-D-ribofuranosylpurine (BAPA) was also identified as a fifth cytokinin active ribonucleoside in this material.

The same cytokinin species found in wheat germ and tobacco callus tRNA (i.e. the ribonucleosides of zeatin, ms-zeatin and 2iP were identified in tRNA from young, green Pisum shoots. The presence of ms2iPA was indicated, but it was not found in sufficient quantity to establish its identity. In Pisum shoots evidence was obtained for the first time of both the trans- and cis-isomers of ribosylzeatin.

Earlier work showed that cytokinins in tRNA of microorganisms appear to be located exclusively in species responding to codons starting with uridine, and in the few cases established, located adjacent to the anticodons. Less evidence is available for this "species specificity" of cytokinins in higher organisms, except that $tRNA^{Ser}$ in beef liver contains 2iPA and work on wheat germ indicates that $tRNA^{Ser}$ and a minor $tRNA^{Leu}$ may be the only cytokinin-containing species. Thus the number of tRNA species may be less than in microorganisms, but the restriction to $tRNA_{U--}$ species still holds.

It is often proposed that "the simple" experiment to test whether or not cytokinins are incorporated into tRNA as a prerequisite to functioning in growth regulation is to determine incorporation of a double labeled synthetic cytokinin. Claims for and against incorporation of 6-benzylaminopurine (with a single label) have been reported, but the evidence cannot be considered conclusive. A major effort in Skoog's laboratory was made to obtain rigorous evidence on this point by determining the incorporation into tRNA of cytokinin dependent tobacco callus of 6-BAP unlabeled and double-labeled with ^{14}C in the adenine ring and ^{3}H in the benzyl group and in different proportions. The isolation and identification of the ribonucleoside (6-BAPA) from the tRNA of tissue grown on medium with 6-BAP have been reported. The ratio of ^{14}C to ^{3}H label remains the same in the isolated BAPA as in the administered BAP. The total 6-BAPA content is estimated as ca 0.01 mole %, which is about one fifth the total cytokinin-containing ribonucleoside content of the tRNA. In view of the low cytokinin-nucleoside content further evidence is needed to show that the 6-BAPA is present in specific tRNA species and is associated with specific oligonucleoside fragments.

Studies of the distribution of 2iPA and ms2iPA in highly purified tRNA species from E. coli showed that both species are in $tRNA^{Cys}$, $tRNA^{Phe}$, $tRNA^{Trp}$ and $tRNA^{Leu}$ but perhaps only ms2iPA is present

in $tRNA^{Tyr}$ and $tRNA^{Ser}$. Furthermore the relative amounts of the different species change with the age of the culture. This may suggest that different species are associated with different organelles and serve different functions. Thus Barnett (1972) has shown that Base Y in $tRNA^{Phe}$ is present only in cytoplasmic $tRNA^{Phe}$ in Euglena and Neurospora; not in the chloroplast $tRNA^{Phe}$ of the former nor in the mitochondrial $tRNA^{Phe}$ of the latter. In work preliminary to testing this possibility three different cytokinins have been found in algal tRNA.

Further studies were made on disubstitution and on modification in the N^6-side chain of adenine derivatives. This included a detailed study of zeatin indoleacetate which serves as a single source of both cytokinin and auxin activity, a comparison of biological activities of a set of 16 synthetic isopentenyl and isopentyl adenine or adenosine derivatives which occur or are likely to be found naturally, and a stereoselective synthesis of cis-zeatin (which has < 1/50 the activity of zeatin (the trans isomer) in the bioassay), and the corresponding ribonucleosides. By this procedure, it was possible to demonstrate the presence of both the latter in tRNA from Pisum shoots; only the cis isomer was found by Morris et al. in Pisum roots and in Skoog's tRNA preparation retained from wheat germ and tobacco callus. Skoog studied iso-, cis- and trans isomers of zeatin and isopentenyl adenine and adenosines.

A systematic approach, based on available knowledge of structure/activity relationships, to organic synthesis of cytokinin antagonists was carried out by Skoog, Hecht, Leonard and Bock. Highly active, and apparently highly specific antagonists were obtained by three modifications in the structure of 2iP (a) exchange of the 8C and 9N atoms in the adenine ring to give 7-isopentenyl-pyrazolo-(3,4-d) pyrimidine; (b) saturation of the double bond in the isopentenyl side chain; and (c) methylation of the 3 position of the pyrozolopyrimidine. Each of these three steps markedly reduced activity in the tobacco bioassay, but none of the three alone or in combinations of two resulted in a powerful antagonist. Further modifications of the side chain provided a two-fold increase in antagonist activity; a normal five carbon side chain provides optimal activity (is lethal at 0.2 µM) and the straight four and 6 carbon chains are also more effective than the branched chains, but the cyclopentyl and cyclohexyl and the dibutyl chains yield inactive compounds.

Skoog's results indicate an extreme dependence on detailed as well as the overall structural configuration for high potency cytokinin and/or antagonist activity. Only the isopentyl derivative has been available for extensive testing so far. Up to 1 or 2 µM concentrations of the antagonist are counteracted by appropriate doses of cytokinins. It is of special interest that the antagonist promotes growth of the tissue when superoptimal concentration of cytokinins are used, indicating a highly specific relationship between the two substances. On the other hand it should be noted that diphenylurea in high concentrations also counteracts the

antagonist. In comparative tests with abscisic acid this natural inhibitor, known to be counteracted by cytokinins in some systems (van Overbeek; Kahn, etc.) is practically without effect in the low concentration range where the antagonists become lethal. Preliminary tests on intact plants, seedlings and seeds so far have been largely negative.

Skoog has studied a number of physiological effects of cytokinins.

1. Effects on auxin biosynthesis. A remarkable effect of cytokinins is the influence on the synthesis of other growth factors. Thus high concentrations of cytokinins eliminate the requirement for exogenous auxin or thiamine in tobacco tissue cultures. Cytokinin also replaces the influence of the roots on the growth of the coleoptile in Avena seedlings. This and an influence on "auxin production" by the coleoptile tip suggest a role of cytokinin in auxin regulated elongation in intact plants.

   Additional evidence has been obtained on the release from apical dominance of lateral buds treated with cytokinins. An effect of cytokinin on the "synthesis" of auxin in the released lateral and stoppage of auxin synthesis in the terminal bud have been demonstrated.

2. Effects on protein biosynthesis. Tissue systems have been developed for determining differential cytokinin effects on uptake of specific amino acids and biosynthesis of protein. Effects of cytokinin on the biosynthesis of specific protein species rather than on bulk synthesis have been obtained.

3. A disease caused by growth factor imbalance. A disease syndrome known as false broom rape (involving prolific bud formation of root systems) which has become prevalent in tobacco fields in recent years has been induced with cytokinin treatments and inhibited by auxin treatments. It thus is diagnosed as being caused by the imbalance in growth factors brought about by excessive lowering of auxin levels following the effective chemical desuckering procedures now employed.

Practical Significance of Skoog's Research on Cytokinins

1. Benzylaminopurine and the nutrient media developed by Skoog have found widespread application for cultivation of numerous species including monocots (rice, wheat and corn) and have been used for cultivation of plant protoplasts and cell suspensions.

   These techniques are becoming increasingly important for the utilization of new procedures gained from microbial genetics in plant breeding. (The development of haploid strains, gene manipulation, etc.)

2. The Murashige-Skoog nutrient medium also has been reported to be superior to standard fertilizer formulas in large scale horticultural practice.

3. The striking action of cytokinins in regulating translocation of metabolites and enhancing resistance to extreme temperatures, drought and other stress conditions may have widespread practical significance.

4. The unique action of cytokinins in inducing cell division and bud-formation has found widespread use in vegetative propagation. It has revolutionized horticultural practices in the production of orchids, carnations and begonias.

5. It is now known that cytokinins may have a growth regulatory function in mammalian systems, as illustrated by regulation of the cell cycle in lymphocytes (Gallo et al.). The relative activities of cytokinins in this function parallels their activities in the tobacco bioassay, except that the hydroxylated derivatives found only in plants are without effect on lymphocytes. Antileukemic action of cytokinins has been reported (Rosswell Park Research Institute).

6. The cytokinin antagonists should find numerous applications in selective regulation of plant growth. Because of their unique action and extreme potency, one might guess that they may find practical uses on a wide scale, perhaps even comparable to that for 2,4-D and related auxin analogues.

Citation

Folke Skoog's discovery of the cytokinins and his demonstration of their mediation of diverse physiological activities in plants has been basic to our modern concepts of plant growth and development.

Skoog, Folke K.

Born July 15, 1908, Halland, Sweden; son of Karl (G.) Skoog and Sigrid (Person) Skoog; immigrated to U.S. 1925; naturalized U. S. Citizen 1935; married Birgit Anna Lisa Bergner 1947; one child; B. S. (Chemistry) Cal. Inst. Tech. 1932, Ph.D. (Biology) 1936, D. Phil. (Hon.) Univ. of Lund, Sweden 1956.

Teaching and Research Fellow, Cal. Inst. Tech. 1934-36; Nat'l. Res. Fellow, Division of Plant Nutrition, U. of Cal., Berkeley 1936-37; Instructor, Tutor and Res. Assoc., Harvard Univ., 1937-41; Ass't. and Assoc. Prof. Biology, John Hopkins Univ. 1941-44; Chemist U. S. Army Trop. Det'n. Lab., Phila. Pa.; and U. S. Army Techn. Rep. in European Theatre, War Dept., Office of Quartermaster General, Military Planning Research and Development Division, Washington, D. C. 1944-46; Assoc. Prof. and Prof. of Botany (1949), Univ. of Wisconsin 1947-present. Temporary positions held during tenure of above: Visiting physiologist, Pineapple Res. Inst., U. of Hawaii (6 months) 1938-39; Assoc. Physiologist (Sp. Res. Assignment) Nat'l. Inst. of Health, U. S. Public Health Service (5 months) 1943; Visiting Lecturer, Wash. Univ., St. Louis, Mo. (3 months) 1946: Visiting Lecturer, Royal Coll. of Agric., Sweden (2 months) 1952. Recipient, Univ. of Wisc. Haight Foreign Travel Fellowship, Dec. 1969 to Sept. 1970 for study in Sweden and Germany. 1975 U. of Calif., Santa Cruz.

Appointed C. Leonard Huskins Professor of Botany in the College of Letters and Science.

Member of the following Professional Societies: Nat'l. Acad. Sci.; Deutsche Akademie der Naturforscher (Leopoldina); Royal Swedish Academy of Sciences; Amer. Acad. of Arts and Sci.; Bot. Soc. Amer. (Chmn. Physiol. Sec. 1955); Amer. Soc. Pl. Physiol. (V. Pres, 1956; Pres. 1957, Elect. Member Exec. Comm. 1959-62, Ed. Bd. 1962-67, 1967-72, 1975-81); Amer. Soc. Gen'l. Physiol. (V. Pres. 1956-57, Pres. 1957-58); Soc. of Develop. Biol. (Pres. Elect 1969, Pres. 1970-71); Scan. Soc. Pl. Physiologists; Amer. Soc. Biol. Chemists; Japanese Society of Plant Physiologists; Corresp. Member Royal Soc. of Sciences, Upsala, Sweden.

Honors: Amer. Soc. of Plant Physiologists Stephen Hales Price Award, 1954; Reid Barnes Life Membership Award, 1970; Bot. Soc. of America Centennial Celebr. Certif. of Merit. 1956.

Three Scientists Acquainted with Folke Skoog's Work

1) Dr. Anton Lang
Michigan State University
MSU-AEC Plant Research Lab
East Lansing, Michigan 48824

2) Dr. Nelson J. Leonard
University of Illinois
School of Chemical Sciences
Department of Chemistry
Urbana, Illinois 61801

3) Dr. K. V. Thimann
University of California
Department of Biology
Santa Cruz, California 95060

Skoog, Folke K.

Bibliography

1. Thimann, K. V. and F. Skoog. 1934. On the inhibition of bud development and other functions of growth substance in Vicia faba. Proc. Roy. Soc. B. 114:317-339.

2. Skoog, F. and K. V. Thimann. 1934. Further experiments on the inhibition of the development of lateral buds by growth hormone. Proc. Nat. Acad. Sci. 20:480-485.

3. Skoog, F. and K. V. Thimann. 1940. Enzymatic liberation of auxin from plant tissues. Science 92:64-65.

4. Skoog, F., Charles Schneider and Peter Malan. 1942. Interaction of auxin in growth and inhibition. Amer. Jour. Bot. 29:568-576.

5. Skoog, F. 1944. Growth and organ formation in tobacco tissue cultures. Amer. Jour. Bot. 31:19-24.

6. Skoog, F. 1947. Growth substances in higher plants. Ann. Rev. Biochem. 16:229-264.

7. Skoog, F. and Cheng Tsui. 1951. Growth substances and bud formation. (Plant Growth Substances, Univ. of Wisc. Press, pp. 263-285).

8. Mauney, J. R., et al. 1952. Bioassay, purification and properties of a growth factor from coconut. Physiol. Plantarum 5: 485-497.

9. Jablonski, John R. and Folke Skoog. 1954. Cell enlargement and cell division in excised tobacco pith tissue. Physiol. Plant. 7:16-24.

10. Skoog, Folke. 1954. Chemical regulation of growth in plants. In: Dynamics of growth processes. Boell Editor, Princeton Univ. Press. pp. 148-182.

11. Skoog, Folke. 1954. Substances involved in normal growth and differentiation of plants. In: "Abnormal and pathological plant growth", Brookhaven National Laboratory Symposia in Biology, 6:1-21.

12. Skoog, Folke. 1955. Growth factors, polarity and morphogenesis. First International Symposium on Plant Tissue Culture, Briancon (1954). L'Anneé Biol. 31:201-223.

13. Miller, C. O., F. Skoog, F. S. Okumura, M. von Saltza and F. M. Strong. 1956. Isolation, structure and synthesis of kinetin, a substance promoting cell division. J.A.C.S. 78: 1375-1380.

14. Das, N. K., K. Patau and F. Skoog. 1956. Initiation of mitosis and cell division by kinetin and indoleacetic acid in excised tobacco pith tissue. Physiol. Plantarum 9:640-651.

15. Skoog, F. and C. O. Miller. 1957. Chemical regulation of growth and organ formation in plant tissues cultured in vitro. Symposium on Biological Action of Growth Substances, Soc. Exptl. Biol. XI. (pp. 118-131; 9 plates) Cambridge Univ. Press. (Republished in Molecular and Cellular Aspects of Biol., E. Bell Ed., Harper and Row Press, 1966, and in Papers on Plant Growth and Development, W. M. Laetsch and R. E. Cleland Eds., Little, Brown and Co., Boston, 1967).

16. Patau, K., N. K. Das and F. Skoog. 1959. Initiation of DNA synthesis by kinetin and indoleacetic acid in excised tobacco pith tissue. Physiol. Plantarum 10:949-966.

17. Skoog, F. and E. Montaldi. 1961. Auxin-kinetin interaction regulating the scopoletin and scopolin levels in tobacco tissue cultures. Proc. Nat'l. Acad. Sci. (Wash.) 47:36-49.

18. Murashige, Toshio and Folke Skoog. 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiologia Plantarum 15:473-497.

19. Hamzi, Hamzi, Q. and Folke Skoog. 1964. Kinetin-like growth-promoting activity of 1-substituted adenines (1-benzyl-6-amino-purine and 1-(γ,γ-dimethylallyl)-6-aminopurine). Proc. Nat'l. Acad. Sci. 51:76-83.

20. Linsmaier, Elfriede M. and Folke Skoog. 1965. Organic growth factor requirements of tobacco tissue cultures. Physiologia Plantarum 18:100-127.

21. Klämbt, D., G. Thies, and F. Skoog. 1966. Isolation of cytokinins from Corynebacterium fascians. Proc. Nat'l. Acad. Sci., U.S. 56:52-59.

22. Skoog, Folke, D. J. Armstrong, J. D. Cherayil, A. E. Hampel, and R. M. Bock. 1966. Cytokinin activity: Localization in transfer RNA preparations. Science 154:1354-1356.

23. Linsmaier-Bednar, Elfriede M. and Folke Skoog. 1967. Thiamine requirement for "normal" and "mutant" strains of tobacco callus. Planta (Berl.) 72:146-154.

24. Skoog, F., H. Q. Hamzi, A. M. Szweykowska, N. J. Leonard, K. L. Carraway, T. Fujii, J. P. Helgeson, and R. N. Loeppky. 1967. Cytokinins: Structure/activity relationships. Phytochemistry 6:1169-1192.

25. Leonard, N. J., S. M. Hecht, F. Skoog and R. Y. Schmitz. 1968. Cytokinins: Synthesis of 6-(3-methyl-3-butenylamino)-9-β-D-ribofuranosylpurine (3iPA), and the effect of side-chain saturation on the biological activity of isopentylaminopurines and their ribosides. PNAS 59:15-21.

26. Matsubara, S., D. J. Armstrong and F. Skoog. 1968. Cytokinins in tRNA of Corynebacterium fascians. Plant Physiology 43:451-453.

27. Szweykowska, A. and F. Skoog. 1968. Development of cytokinin activity by conversion of deoxydenosine. Wissenschaftliche Zeitschrift der Universität Rostock 16: Mathematische-Naturwissenschaftliche Reihe, (4/5) 627-628.

28. Burrows, W. J., D. J. Armstrong, F. Skoog, S. M. Hecht, J. T. A. Boyle, N. J. Leonard, and J. Occolowitz. 1968. Cytokinin from soluble RNA of Escherichia coli: 6-(3-methyl-2-butenylamino)-2-methylthio-9-β-D-ribofuranosylpurine. Science 161:619-623.

29. Leonard, N. J., S. M. Hecht, F. Skoog, and Ruth Y. Schmitz. 1968. Cytokinins: Synthesis and biological activity of related derivatives of 2iP, 3iP, and their ribosides. Israel Journal of Chemistry 6:539-550.

30. Hecht, S. M., N. J. Leonard, J. Occolowitz, W. J. Burrows, D. J. Armstrong, F. Skoog, R. M. Bock, I. Gillam and G. M. Tener. 1969. Cytokinins: Isolation and identification of 6-(methyl-2-butenylamino)-9-β-D-ribofuranosylpurine from yeast cysteine tRNA. Biochem. Biophys. Res. Commun. 35:205-209.

31. Skoog, Folke and N. J. Leonard. 1969. Sources and structure/activity relationships of cytokinins. 6th International Conference on Plant Growth Regulators. Biochemistry and Physiology of Plant Growth Regulators. F. Wightman and G. Setterfield Eds., Runge Press, Ontario, Canada. pp. 1-18.

32. Dravnieks, D. E., F. Skoog and R. H. Burris. 1969. Cytokinin activation of de novo thiamine biosynthesis in tobacco callus cultures. Plant Physiol. 44:866-870.

33. Burrows, W. J., D. J. Armstrong, F. Skoog, S. M. Hecht, J. T. A. Boyle, N. J. Leonard and J. Occolowitz. 1969. Isolation and identification of two cytokinins from Escherichia coli transfer ribonucleic acids. Biochemistry 8:3071-3076.

34. Skoog, Folke, Donald J. Armstrong, W. John Burrows, Peter K. Evans and Ruth Y. Schmitz. 1969. Hormonal regulation of development through modulation of protein biosynthesis. Abstr. Proc. Eleventh Int'l. Botanical Congress, Seattle, Washington, U. S. A.

35. Burrows, W. J., D. J. Armstrong and F. Skoog. 1969. The isolation of two cytokinins from wheat germ sRNA. Plant Physiol. 44:Suppl. 1 #1 (Abstr.).

36. Engelke, Alvin E., Hamzi Q. Hamzi and Folke Skoog. 1969. Gibberellin-cytokinin interactions in the regulation of shoot development and leaf form. Midwest ASPP. Abstr. Plant Physiology 44:Suppl 1 #2 (Abstr.).

37. Wardell, W. and F. Skoog. 1969. Flower formation in excised tobacco stem segments. Midwest ASPP. Abstr. Plant Physiology 44: Suppl. 1 #3 (Abstr.).

38. Armstrong, D. J., F. Skoog, L. H. Kirkegaard, A. E. Hampel, R. M. Bock, I. Gillam and G. M. Tener. 1969. Cytokinins: Distribution in yeast tRNA species. Proc. Nat. Acad. Sci. U.S. 63:504-511.

39. Armstrong, D. J., W. J. Burrows, F. Skoog, K. L. Roy, and D. Söll. 1969. Cytokinins: Distribution in tRNA species of Escherichia coli. Proc. Nat'l. Acad. Sci. U. S. 63:834-841.

40. Leonard, N. J., S. M. Hecht, F. Skoog, and R. Y. Schmitz. 1969. Cytokinins: Synthesis, mass spectra, and biological activity of compounds related to zeatin. Proc. Nat. Acad. Sci. 63:175-182.

41. Schneider, Michael J., Julia C. J. Lin and Folke Skoog. 1969. Nucleic acid metabolism during cytokinin induced cellular differentiation. Plant Physiology 44:1402-1406.

42. Wardell, William L. and Folke Skoog. 1969. Flower formation in excised tobacco stem segments. I. Methodology and effects of plant hormones. Plant Physiology 44:1402-1406.

43. Wardell, William and Folke Skoog. 1969. Flower formation in excised tobacco stem segments. II. Reversible removal of IAA inhibition by RNA base analogues. Plant Physiology 44:1407-1412.

44. Hecht, S. M., N. J. Leonard (U. of Ill.), W. J. Burrows, D. J. Armstrong, F. Skoog (U. of Wis.), and J. Occolowitz (Eli Lilly Res. Lab.). 1969. A cytokinin from the soluble RNA of wheat germ: 6-(4-hydroxy-3-methyl-2-butenylamino)-2-methylthio-2-ß-D-ribofuranosylpurine. Science 166:1272-1274.

45. Armstrong, D. J., W. J. Burrows, P. K. Evans and F. Skoog. 1969. Isolation of cytokinin containing ribosides from tRNA. Biochem. and Biophys. Res. Commun. 37:451-456.

46. Armstrong, D. J., P. K. Evans, W. J. Burrows, F. Skoog, J. F. Petit, T. Stewart, Dahl, J., J. Strominger, N. J. Leonard, S. M. Hecht and J. Occolowitz. 1970. Cytokinins: Activity and identification in Staphylococcus epidermis transfer RNA. J. Biol. Chemistry 245:2922-60.

47. Hecht, Sidney M. and Nelson J. Leonard (U. of Ill.), Ruth Y. Schmitz and Folk Skoog (U. of Wis.). 1970. Cytokinins: Synthesis and growth-promoting activity of 2-substituted compounds in the N^6-isopentenyladenine and zeatin series. Phytochemistry 9:1173-80.

48. Schmitz, R. Y. and F. Skoog. 1970. The use of dimethylsulfoxide as a solvent in the tobacco bioassay for cytokinins. Plant Physiol. 45:537-8.

49. Hecht, S. M., N. J. Leonard (U. of Ill.), R. Y. Schmitz and F. Skoog (U. of Wis.). 1970. Cytokinins: Influence of side chain planarity of N^6-substituted adenines on growth promoting activity. Phytochemistry 9:1907-13.

50. Skoog, F. and Armstrong, D. J. 1970. Cytokinins. Ann. Rev. Pl. Physiol. 21:359-84.

51. Burrows, W. J., D. J. Armstrong, M. Kaminek, F. Skoog, R. M. Bock, S. M. Hecht, L. G. Dammann, N. J. Leonard and J. Occolowitz. 1970. The isolation and identification of four cytokinins in wheat germ tRNA. Biochemistry 9:1867-72.

52. Burrows, W. J., D. J. Armstrong, F. Skoog (U. of Wis.), S. M. Hecht, J. T. A. Boyle, N. J. Leonard (U. of Ill.) and J. Occolowitz (Eli Lilly Res. Lab.). The isolation and identification of two cytokinins, ms2iPA and 2iPA, from E. coli tRNA. Abstr., Proc. Eleventh Int'l. Bot. Congr., Seattle, WAsh. Aug. 1969.

53. Schmitz, R. Y., F. Skoog, S. M. Hecht and N. J. Leonard. 1971. Cytokinins: Synthesis and biological activity of zeatin esters and related compounds. Phytochem. 10:275-280.

54. Hecht, S. M., R. M. Bock, R. Y. Schmitz, F. Skoog, N. J. Leonard, and J. L. Occolowitz. 1971. Question of the ribosyl moiety in the promotion of callus growth by exogenous cytokinins. Biochem. 10:4224-4228.

55. Hecht, S. M., R. M. Bock, R. Y. Schmitz, F. Skoog and N. J. Leonard. 1971. Cytokinins: Development of a potent antagonist. Proc. Nat'l. Acad. Sci., U.S. 68:2608-2610.

56. McDonald, J. J., N. J. Leonard, R. Y. Schmitz and F. Skoog. 1971. Cytokinins: Synthesis and biological activity of ureidopurines. Phytochem. 10:1429-1439.

57. Jordan, W. R. and F. Skoog. 1971. Effects of cytokinins on growth and auxin in coleoptiles of derooted Avena seedlings. Plant Physiol. 48:97-99.

58. Leonard, N. J., A. J. Playtis, F. Skoog and R. Y. Schmitz. 1971. A steroselective synthesis of cis-zeatin. Jour. Amer. Chem. Soc. 93:3056-3058.

59. Burrows, W. J., F. Skoog and N. J. Leonard. 1971. Isolation and identification of cytokinins located in the transfer ribonucleic acid of tobacco callus grown in presence of 6-benzylaminopurine. Biochem. 10:2189-2194.

60. Skoog, F. 1971. Aspects of growth factor interactions in morphogenesis of tobacco tissue cultures. pp. 115-135 in Les Cultures de Tissues de Plantes. (Colloque Internationaux du Centre de Recherche Scientifique, 15 Quai Anatole France, Paris VII^{e}.

61. Leonard, N. J. and F. Skoog. 1971. Mass spectra of some heterocyclics related to N^6-(Δ^2-isopentenyl)adenosine. Analyt. Biochem. 44:262-

62. Skoog, Folke and Ruth Y. Schmitz. 1972. "Cytokinins" in Plant Physiology. A Treatise VIB., F. C. Steward, Ed., Academic Press, N. Y.

63. Schmitz, R. Y., F. Skoog, S. M. Hecht, R. M. Bock and N. J. Leonard. 1972. Comparison of cytokinin activities of naturally occurring ribonucleosides and corresponding bases. Phytochem. 11:1603-1010.

64. Skoog, F., R. Y. Schmitz, R. M. Bock and S. M. Hecht. 1973. Cytokinin antagonists: Synthesis and physiological effects of 7-substituted 3-methylpyrazolo[4,3-d]pyrimidines. Phytochem. 12:25-37.

65. Einset, J. W. and F. Skoog. 1972. Biosynthesis of cytokinins in autonomous tobacco callus strain. Plant Physiol. Suppl 49 (abstr. 345, p. 61).

66. Hamilton, J., R. Lowe and F. Skoog. 1972. False Broom Rape: A physiological disorder caused by growth regulator imbalance. Plant Physiol. 50:303-304. (Also reviewed by correspondent in Nature. 1972) Nov. issue.

67. Schmitz, R. Y., F. Skoog, S. M. Hecht, and N. J. Leonard. 1972. Comparison of zeatin indole acetate with zeatin and indole-acetic acid in the tobacco bioassay. Plant Physiol. 50:114-6.

68. Vreman, J. H., F. Skoog, C. R. Frihart, and N. J. Leonard. 1972. Cytokinins in Pisum transfer ribonucleic acid. Plant Physiol. 49:848-851.

69. Schmitz, R. Y., F. Skoog, A. J. Playtis and N. J. Leonard. 1972. Cytokinins: Synthesis and biological activity of geometric and position isomers of zeatin. Plant Physiol. 50:702-705.

70. Skoog, F. 1973. Cytokinins in regulation of plant growth. Chapter 11, pp. 147-184 in Genes, Enzymes and Populations. A. M. Srb, Ed. Plenum Press, New York.

71. Scarbrough, E., D. J. Armstrong, F. Skoog, C. R. Frihart and N. J. Leonard. 1973. Isolation of cis-zeatin from Corynebacterium fascians cultures. Proc. Nat'l. Acad. Sci. U. S. 70:(Dec. issue, Part II).

72. Einset, J. W. and F. Skoog. 1973. Biosynthesis of cytokinins in cytokinin-autotrophic tobacco callus. Proc. Nat'l. Acad. Sci. U.S. 70:658-660.

73. Engelke, A. L., H. Q. Hamzi and F. Skoog. 1973. Cytokinin-gibberellin regulation of shoot development and leaf form in tobacco plantlets. Amer. Jour. Bot. 60:491-495.

74. Wardell, W. L. and F. Skoog. 1973. Flower formation in excised tobacco stem segments. III. Deoxyribonucleic acid content in stem tissue of vegetative and flowering tobacco plants. Plant Physiol. 52:215-220.

75. Kaminek, M., R. M. Bock and F. Skoog. 1973. The effect of 6-(3-methyl-2-butenylamino)purine on methionine content of protein in tobacco pith explants. Proc. Int'l. Symposium on Plant Growth Regulators, Prague.

76. Kaminek, M., N. Murai, F. Skoog and R. M. Bock. 1973. Comparison of subspecies of $tRNA^{Phe}$ from tobacco callus and intact plants. Proc. Int'l. Symp. on Plant Growth Regulators. Prague.

77. Vreman, H. J., R. Y. Schmitz, F. Skoog, A. J. Playtis, C. R. Frihart, and N. J. Leonard. 1974. Synthesis of 2-methylthio-cis- and trans ribosylzeatin and their isolation from Pisum tRNA. Phytochem. 13:31-37.

78. Dammann, L. G., N. J. Leonard, R. Y. Schmitz and F. Skoog. 1974. Cytokinins: Synthesis of 2-, 8-, and 2,8- substituted 6-(3-methyl-2-butenylaminopurines and their relative activities in promoting cell growth. Phytochemistry 13:329-336.

79. Skoog. F. 1973. A survey of cytokinins and cytokinin antagonists with reference to nucleic acid and protein metabolism. In: Nitrogen Metabolism in Plants. T. W. Goodwin Ed., IUBC + IUB Symposium #38.

80. Skoog, F. and D. J. Armstrong. 1974. Chapter 15 pp. 110-117 in Experimental Plant Physiology. Anthony San Pietro, Ed., Mosby Co., St. Louis, Mo. 176 pp.

81. Walker, G. C., N. J. Leonard, D. J. Armstrong, N. Murai and F. Skoog. 1974. The mode of incorporation of 6-benzylaminopurine into tobacco callus transfer ribonucleic acid. A double labeling determination. Plant Physiol. 54:537-543.

82. Murai, N., D. J. Armstrong, and Folke Skoog. 1975. Incorporation of mevalonic acid into ribosylzeatin in tobacco callus ribonucleic acid preparations. Plant Physiol. 55:853-858.

83. Armstrong, Donald J. and Folke Skoog. 1975. Chromatography of cytokinins on a neutral polystyrene resin. A simple procedure for the separation of the cis- and trans- isomers of zeatin and ribosylzeatin. Plant Physiol. 55:237-239.

84. Schmitz, Ruth Y., Folke Skoog, Adam Vincze, Graham C. Walker, Leslie H. Kirkegaard and Nelson J. Leonard. 1975. Comparison of cytokinin activities of the base, ribonucleoside and 5'- and cyclic-3',5'-monophosphate ribonucleotides of N^6-isopentenyl-N^6-benzyl- or 8-bromo-adenine. Phytochemistry 14:1479-1484.

85. White, B. N., R. Dunn, I. Gillam, G. M. Tener, D. J. Armstrong, F. Skoog, C. R. Frihart and N. J. Nelson. 1975. An analysis of five serine transfer ribonucleic acids from Drosophila. J. Biol. Chem. 250:515-521.

86. Leonard, N. J., John C. Greenfield, Ruth Y. Schmitz and Folke Skoog. 1975. Photoaffinity-labeled auxins. Synthesis and biological activity. Plant Physiol. 55:1057-1061.

87. Henderson, Thomas T., Charles R. Frihart, Nelson J. Leonard, Ruth Y. Schmitz and Folke Skoog. 1975. Cytokinins with different connecting links between purine and isopentenyl or benzyl groups. Physochemistry 14:1687-1690.

88. Hecht, Sidney M., R. Bruce Frye, Dieter Werner, S. D. Hawrelak, Folke Skoog and Ruth Y. Schmitz. 1975. On the "activation" of cytokinins. J. Biol. Chem. 250:7343-7351.

89. Skoog, Folke, Ruth Y. Schmitz, Sidney M. Hecht, and R. Bruce Frye. 1975. Anticytokinin activity of substituted pyrrolo(2,3-d)-pyrimidines. PNAS 72:3508-3512.

90. Armstrong, Donald J., Norimoto Murai, Barbara J. Taller and Folke Skoog. 1976. Incorporation of cytokinin N-benzyladenine into tobacco callus transfer ribonucleic acid and ribosomal ribonucleic acid preparations. Plant Physiol. 57:15-22.

91. Mok, Machteld C., Warren H. Gabelman and Folke Skoog. 1975. Carotenoid synthesis in carrot tissue cultures. Plant Physiol Supplement to 56(2):29.

92. Skoog, Folke. 1975. Relationships between chemical structure and biological activity of cytokinin and cytokinin antagonists. Abstracts Symposium of Function of Plant Growth Hormones. Twelvth International Botanical Congress, Leningrad, July 3-10, 1975.

93. Mok, M. C., W. H. Gabelman and F. Skoog. 1976. Carotinoid synthesis in tissue cultures of Daucus carota L. Proc. Am. Hort Sci. (in press).

94. Spreder, M. A., A. G. Morrice, B. A. Gruber and N. J. Leonard, R. Y. Schmitz and F. Skoog. 1976. Fluorescent Cytokinins: Stretched-out analogs of N^6-benzyladenine and N^6-(Δ^2-isopentenyl)-adenine. Phytochemistry (in press).

95. Einset, John W., Swaminathan and F. Skoog. 1976. Cis-ribosyl-zeatin in a leucyl tRNA species from peas. Plant Physiol (in press).

Monsanto

bc: W. R. Briggs
F. T. Addicott
H. Currier

MONSANTO AGRICULTURAL PRODUCTS CO.
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166
Phone: (314) 694-1000

March 30, 1976

Dr. Robert Burris
Department of Biochemistry
University of Wisconsin
Madison, Wisconsin 53706

Dear Bob:

Thank you for your willingness to assemble the information needed to place Dr. Folke Skoog in nomination for the National Medal of Science.

The information needed is described in the attached document. I shall be happy to handle any clerical work needed if you can get the information. Since the deadline date is June 30, 1976, may I suggest shooting for June 5th at the latest to send me the material.

Incidentally, Nels Leonard at the University of Illinois would be pleased to contribute his name to supporting this nomination.

I shall look forward to helping you in any way I can and to receipt of the information.

With kind regards.

Sincerely yours,

Ernest G. Jaworski, Chairman
Honors and Awards Committee,
American Society of Plant
Physiologists

EGJ:jo

Enclosure

February 6, 1976

Gentlemen:

It is my pleasure as Chairman of the Honors and Awards Committee of the American Society of Plant Physiologists to nominate Dr. Robert H. Burris for the Edward W. Browning Award.

Please let me know if we may be of further assistance.

Sincerely yours,

EGJ

Edward W. Browning Award
American Society of Agronomy
677 S. Segoe Road
Madison, Wisconsin 53711

NOMINATION OF DR. ROBERT HARZA BURRIS

FOR THE

EDWARD W. BROWNING AWARD

NOMINEE

Name:	Dr. Robert Harza Burris
Birthdate:	April 13, 1914
Place of Birth:	Brookings, South Dakota
Mail Address:	Department of Biochemistry University of Wisconsin Madison, Wisconsin 53706
Telephone:	(608) 262-3026

NOMINATOR

Dr. Ernest G. Jaworski

Ernest G. Jaworski

Monsanto Agricultural Products Co.
800 North Lindbergh Blvd.
St. Louis, Missouri 63166

(314) 694-3776

SPONSOR

THE AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS

Dr. Ernest G. Jaworski
Chairman, Honor and Awards Committee
The American Society of Plant Physiologists

QUALIFICATIONS OF NOMINEE

(a) Degrees Received

B.S. (Chemistry), 1936, South Dakota State College

M.S. (Bacteriology), 1938, University of Wisconsin-Madison.

Ph.D. (Bacteriology), 1940, University of Wisconsin-Madison.

(b) Membership in Honorary Academic Societies

National Academy of Sciences (1961)

Fellow of the American Academy of Arts and Sciences (1975)

Sigma Xi (President, 1959)

Gamma Alpha

Phi Sigma

(c) Honors and Awards Received

Honorary D. Sc., South Dakota State University (1966)

Merit Awards of the Botanical Society of America (1966)

Stephen Hales Award of American Society of Plant Physiologists (1968)

(d) Profession Positions Held

1940-41, Postdoctoral National Research Council Fellow, Columbia University, New York.

1941-44, Postdoctoral appointment in Bacteriology, University of Wisconsin, Madison.

1944-46, Assistant Professor of Biochemistry, University of Wisconsin, Madison.

1946-51, Associate Professor of Biochemistry, University of Wisconsin, Madison.

1951-date, Professor of Biochemistry, University of Wisconsin, Madison.

1958-70, Chairman of Department of Biochemistry, University of Wisconsin, Madison.

1946, Argonne National Laboratories

1950-54, Study Section, National Science Foundation.

1954, Guggenheim Fellow in Helsinki, Finland and at Cambridge University.

1960, U. S. State Department representative to evaluate biochemistry in India.

1962-67, Study Section, National Institutes of Health Biochemistry Training Grants (Chairman of panel two years).

1969-71, NIH General Support Advisory Committee.

1973, Prather Lecturer at Harvard University, Cambridge, Mass.

1973, NSF Researcher, Great Barrier Reef, Australia.

(e) Professional Publications (R. H. Burris)

Franke, Kurt W., Robert H. Burris, and Robert S. Hutton. A New Colorimetric Procedure Adapted to Selenium Determination. Ind. Eng. Chem., Analytical Edition, 8, 435 (1936).

Umbreit, W. W., and R. H. Burris. Composition of Soybean Nodules and Root Nodule Bacteria. Soil Sci. 45, 111-126 (1938).

Wyss, Orville, R. H. Burris, and P. W. Wilson. Occurrence and Significance of Oxalacetic Acid in Plant Tissues. Proc. Soc. Exp. Biol. Med. 40, 372-375 (1939).

Burris, R. H., and P. W. Wilson. Respiratory Enzyme Systems in Symbiotic Nitrogen Fixation. Cold Spring Harbor Symposia on Quant. Biol. 7, 349-361 (1939).

Thorne, D. W., and R. H. Burris. Respiratory Enzyme Systems in Symbiotic Nitrogen Fixation. II. The Respiration of Rhizobium from Legume Nodules and Laboratory Cultures. J. Bacteriol. 39, 187-196 (1940).

Burris, R. H., and P. W. Wilson. Measures of Respiratory Activity with Resting Cells. Proc. Soc. Exp. Biol. Med. 45, 721-726 (1940).

Burris, R. H., Chapter 5, p. 93-101, Respiratory Enzymes, Elvehjem and Wilson, et al., 1939, Burgess Publishing Co., Minneapolis, Minn.

Burris, Robert H., and Charles E. Miller. Application of N^{15} to the Study of Biological Nitrogen Fixation. Science 93, 114-115 (1941).

Burk, D., and R. H. Burris. Biochemical Nitrogen Fixation. Annual Review of Biochemistry 10, 587-618 (1941).

Burris, R. H. Failure of Barley to Fix Molecular N^{15}. Science 94, 238-239 (1941).

Burris, R. H., and P. W. Wilson. Liebig and the Microbiologist. Amer. Fertilizer 94, 9-11, 24, 26 (1941).

Burris, R. H. Distribution of Isotopic Nitrogen in Azotobacter vinelandii. J. Biol. Chem. 143, 509-517 (1942).

Burris, R. H., and P. W. Wilson. Oxidation and Assimilation of Glucose by the Root Nodule Bacteria. J. Cell and Comp. Physiol. 19, 361-371 (1942).

Lee, S. B., R. H. Burris, and P. W. Wilson. Cell-free Enzymes of Azotobacter vinelandii. Proc. Soc. Exp. Biol. Med. 50, 96-98 (1942).

Lee, S. B., and R. H. Burris. Large-scale Production of Azotobacter. Ind. Eng. Chem. 35, 354-357 (1943).

Wilson, P. W., R. H. Burris, and W. B. Coffee. Hydrogenase and Symbiotic Nitrogen Fixation. J. Biol. Chem. 147, 475-481 (1943).

Burris, R. F., F. J. Eppling, H. B. Wahlin, and P. W. Wilson. Detection of Nitrogen Fixation with Isotopic Nitrogen. J. Biol. Chem. 148, 349-357 (1943).

Wilson, P. W., J. F. Hull, and R. H. Burris. Competition between Free and Combined Nitrogen in Nutrition of Azotobacter. Proc. Nat. Acad. Sci. 29, 289-294 (1943).

Wilson, P. W., R. H. Burris, and C. J. Lind. The Dissociation Constant in Nitrogen Fixation by Azotobacter. Proc. Nat. Acad. Sci. 28, 243-250 (1942).

Burris, R. H., A. S. Phelps, and J. B. Wilson. Adaptations of Rhizobium and Azotobacter. Soil Sci. Soc. Amer. Proc. 7, 272-275 (1942).

Burris, R. F., F. J. Eppling, H. B. Wahlin, and P. W. Wilson. Studies of Biological Nitrogen Fixation with Isotopic Nitrogen. Soil Sci. Soc. Amer. Proc. 7, 258-262 (1942).

Burris, R. H., and Erwin Haas. The Red Pigment of Leguminous Root Nodules. J. Biol. Chem. 155, 227-229 (1944).

Umbreit, W. W., R. H. Burris, and J. F. Stauffer. Manometric Techniques and Related Methods for the Study of Tissue Metabolism. Burgess Publishing Co., Minneapolis, Minn. (1945).

Burris, R. H., and P. W. Wilson. Biological Nitrogen Fixation. Annual Review of Biochemistry 14, 685-708 (1945).

Koffler, H., R. L. Emerson, D. Perlman, and R. H. Burris. Chemical Changes in Submerged Penicillin Fermentations. J. Bacteriol. 50, 517-548 (1945).

Koffler, H., S. G. Knight, R. L. Emerson, and R. H. Burris. The Effect of Certain Chemicals on Penicillin Production and Mold Metabolism in Shake Flask Fermentations. J. Bacteriol. 50, 549-559 (1945).

Koffler, H., S. G. Knight, W. C. Frazier, and R. H. Burris. Metabolic Changes in Submerged Penicillin Fermentations on Synthetic Media. J. Bacteriol. 51, 385-392 (1946).

Burris, R. H., and P. W. Wilson. Comparison of the Metabolism of Ammonia and Molecular Nitrogen in Azotobacter. J. Biol. Chem. 165, 595-598 (1946).

Burris, R. H., and P. W. Wilson. Ammonia as an Intermediate in Nitrogen Fixation by Azotobacter. J. Bacteriol. 52, 505-512 (1946).

Burris, R. H., and P. W. Wilson. Characteristics of the Nitrogen-fixing Enzyme System in Nostoc muscorum. Bot. Gaz. 108, 254-262 (1946).

Olson, Oscar, E., R. H. Burris, and C. A. Elvehjem. A Preliminary Report of the "Folic Acid" Content of Certain Foods. J. Amer. Dietetic Assn. 23, 200-203 (1947).

Little, Henry N., and R. H. Burris. Activity of the Red Pigment from Leguminous Root Nodules. J. Amer. Chem. Soc. 69, 838-841 (1947).

Wilson, P. W., and R. H. Burris. The Mechanism of Biological Nitrogen Fixation. Bacteriol. Rev. 11, 41-73 (1947).

Leonard, Mary Jane Kreko, and R. H. Burris. A Survey of Transaminases in Plants. J. Biol. Chem. 170, 701-709 (1947).

Machata, Helen A., R. H. Burris, and P. W. Wilson. Fixation of Isotopic Nitrogen by Excised Nodules. J. Biol. Chem. 171, 605-609 (1947).

Powelson, Dorothy M., P. W. Wilson, and R. H. Burris. Oxidation of Glucose, Glycerol, and Acetate by Staphylococcus aureus. Biochem. J. 41, 486-491 (1947).

MacVicar, R., and R. H. Burris. The Relation of Boron to Certain Plant Oxidases. Arch. Biochem. 17, 31-39 (1948).

Olson, O. E., E. E. C. Fager, R. H. Burris, and C. A. Elvehjem. Folic Acid Activity in Homogenates of Rat Liver. J. Biol. Chem. 174, 319-326 (1948).

Molnar, Dorothy M., R. H. Burris, and P. W. Wilson. The Effect of Various Gases on Nitrogen Fixation by Azotobacter. J. Amer. Chem. Soc. 70, 1713-1716 (1948).

Stutz, R. E., and R. H. Burris. Factors Influencing Oil Content of Potato Chips. Food Industries 20, 1146-1149, 1243-1246 (1948) (August).

Olson, O. E., E. E. C. Fager, R. H. Burris, and C. A. Elvehjem. The Use of a Hog Kidney Conjugase in the Assay of Plant Materials for Folic Acid. Arch. Biochem. 18, 261-270 (1948).

MacVicar, R., and R. H. Burris. Translocation Studies in Tomato Using Ammonium Sulfate Labeled with N^{15}. Amer. J. Bot. 35, 567-570 (1948).

MacVicar, R., and R. H. Burris. Studies on Nitrogen Metabolism in Tomato with Use of Isotopically Labeled Ammonium Sulfate. J. Biol. Chem. 176, 511-516 (1948).

Lardy, H. A., W. E. Gilson, J. Hipple, and R. H. Burris. Circular Bath and Shaking Mechanism for Manometric Microapparatus. Anal. Chem. 20, 1100-1102 (1948).

Fager, E. E. C., O. E. Olson, R. H. Burris, and C. A. Elvejhem. Folic Acid in Vegetables and Certain Other Plant Materials. Food Res. 14, 1-8 (1949).

Mitchell, J. E., R. H. Burris, and A. J. Riker. Inhibition of Respiration in Plant Tissues by Callus Stimulating Substances and Related Chemicals. Amer. J. Bot. 36, 368-378 (1949).

Clagett, C. O., N. E. Tolbert, and R. H. Burris. Oxidation of α-Hydroxy Acids by Enzymes from Plants. J. Biol. Chem. 178, 977-987 (1949).

Lardy, H. A., R. L. Potter, and R. H. Burris. Metabolic Functions of Biotin. I. The Role of Biotin in Bicarbonate Utilization by Lactobacillus arabinosus studied with C^{14}. J. Biol. Chem. 179, 721-731 (1949).

Lindstrom, E. S., R. H. Burris, and P. W. Wilson. Nitrogen Fixation by Photosynthetic Bacteria. J. Bacteriol. 58, 313-316 (1949).

Tolbert, N. E., C. O. Clagett, and R. H. Burris. Products of the Oxidation of Glycolic Acid and l-Lactic Acid by Enzymes from Tobacco Leaves. J. Biol. Chem. 181, 905-914 (1949).

Burris, R. H., P. W. Wilson, and R. E. Stutz. Incorporation of Isotopic Carbon into Compounds by Biosynthesis. Bot. Gaz. 111, 63-69 (1949).

Wagenknecht, A. C., and R. H. Burris. Indoleacetic Acid Inactivating Enzymes from Bean Roots and Pea Seedlings. Arch. Biochem. 25, 30-53 (1950).

Burris, R. H. Isotopes as Tracers in Plants. Bot. Rev. 16, 150-180 (1950).

Tolbert, N. E., and R. H. Burris. Light Activation of the Plant Enzyme which Oxidizes Glycolic Acid. J. Biol. Chem. 186, 791-804 (1950).

Ghosh, B. P., and R. H. Burris. Utilization of Nitrogenous Compounds by Plants. Soil Sci. 70, 187-203 (1950).

Stutz, R. E., and R. H. Burris. Photosynthesis and Metabolism of Organic Acids in Higher Plants. Plant Physiol. 26, 226-243 (1951).

Burris, R. H. Radioisotopes in Biology. The Science Counselor 14, 52-53 (1951) (June).

Zelitch, I., E. D. Rosenblum, R. H. Burris, and P. W. Wilson. Isolation of the Key Intermediate in Biological Fixation by Clostridium. J. Biol. Chem. 191, 295-298 (1951).

Burris, R. H. The Study of Growth Substances in Plant Metabolism. Plant Growth Substances, edited by Folke Skoog, Univ. Wis. Press (1951) pp. 93-95.

Grisolia, S., R. H. Burris, and P. P. Cohen. Carbon Dioxide and Ammonia Fixation in the Biosynthesis of Citrulline. J. Biol. Chem. 191, 203-209 (1951).

Miller, I. H., Jr., and R. H. Burris. Effect of Plant Growth Substances upon Oxidation of Ascorbic and Glycolic Acids by Cell-free Enzymes from Barley. Amer. J. Bot. 38, 547-549 (1951).

Wagenknecht, A. C., A. J. Riker, T. C. Allen, and R. H. Burris. Plant Growth Substances and the Activity of Cell-free Respiratory Enzymes. Amer. J. Bot. 38, 550-554 (1951).

Eberts, Floyd S., Jr., R. H. Burris, and A. J. Riker. The Effects of Indole-3-Acetic Acid and Common Organic Acids on the Respiration of Slices from Tomato Stem and Crown Gall Tissue. Amer. J. Bot. 38, 618-621 (1951).

Zelitch, I., E. D. Rosenblum, R. H. Burris, and P. W. Wilson. Comparison of the Metabolism of Ammonia and Molecular Nitrogen in Clostridium. J. Bacteriol. 62, 747-752 (1951).

Zelitch, I., P. W. Wilson, and R. H. Burris. The Amino Acid Composition and Distribution of N^{15} in Soybean Root Nodules Supplied N^{15}-enriched N_2. Plant Physiol. 27, 1-8 (1952).

Zbinovsky, V., and R. H. Burris. Metabolism of Infiltrated Organic Acids by Tobacco Leaves. Plant Physiol. 27, 240-250 (1952).

Burris, R. H. Photosynthesis. Research Reviews, April (1952) pp. 21-25.

Burris, R. H., and P. W. Wilson. Effect of Haemoglobin and Other Nitrogenous Compounds on the Respiration of the Rhizobia. Biochem. J. 51, 90-96 (1952).

Aprison, M. H., and R. H. Burris. Time Course of Fixation of N_2 by Excised Soybean Nodules. Science 115, 264-265 (1952).

Williams, A. E., and R. H. Burris. Nitrogen Fixation by Blue-green Algae and Their Nitrogenous Composition. Amer. J. Bot. 39, 340-342 (1952).

Wall, J. S., A. C. Wagenknecht, J. W. Newton, and R. H. Burris. Comparison of the Metabolism of Ammonia and Molecular Nitrogen in Photosynthesizing Bacteria. J. Bacteriol. 63, 563-573 (1952).

Hyndman, L. A., R. H. Burris, and P. W. Wilson. Properties of Hydrogenase from Azotobacter vinelandii. J. Bacteriol. 65, 522-531 (1953).

Burris, R. H. Organic Acids in Plant Metabolism. Ann. Rev. Plant Physiol. 4, 91-114 (1953). (Ann. Rev., Inc., Stanford. Cal.).

Burris, R. H. Carbon-14 Studies on Organic Acid Metabolism in Plants. Proceedings of the Fourth Annual Oak Ridge Summer Symposium, Aug. 25-30, 1952; p. 342-377. Available from Office of Technical Services, Dept. Commerce, Washington 25, D. C.

Newton, Jack W., P. W. Wilson, and R. H. Burris. Direct Demonstration of Ammonia as an Intermediate in Nitrogen Fixation by Azotobacter. J. Biol. Chem. 204, 445-451 (1953).

Burris, R. H. Studies of Biological Nitrogen Fixation with N^{15}. The Use of Isotopes in Plant and Animal Research. U. S. Atomic Energy Commission, pp. 68-80 in TID 5098, U. S. Gov. Printing Office, Washington, D. C. (1953).

Brummond, D. O., and R. H. Burris. Transfer of C^{14} by Lupine Mitochondria through Reactions of the Tricarboxylic Acid Cycle. Proc. Nat. Acad. Sci. U. S. 39, 754-759 (1953).

Wilson, P. W., and R. H. Burris. Biological Nitrogen Fixation-a Reappraisal. Ann. Rev. Microbiol. 7, 415-432 (1953).

Zbinovsky, Vladimir, and R. H. Burris. New Techniques for Adding Organic Acids to Silicic Acid Columns. Anal. Chem. 26, 208-210 (1954).

Newburgh, R. W., and R. H. Burris. Effect of Inhibitors on the Photosynthetic Fixation of Carbon Dioxide. Arch. Biochem. Biophys. 49, 98-109 (1954).

Aprison, M. H., Wayne E. Magee, and R. H. Burris. Nitrogen Fixation by Excised Soybean Root Nodules. J. Biol. Chem. 208, 29-39 (1954).

Eberts, F. S., Jr., R. H. Burris, and A. J. Riker. The Metabolism of Nitrogenous Compounds by Sunflower Crown Gall Tissue Cultures. Plant Physiol. 29, 1-10 (1954).

Magee, Wayne E., and R. H. Burris. Fixation of $N_2{}^{15}$ by Excised Nodules. Plant Physiol. 29, 199-200 (1954).

Noll, Clifford R., Jr., and R. H. Burris. Nature and Distribution of Glycolic Acid Oxidase in Plants. Plant Physiol. 29, 261-265 (1954).

Wilson, D. G., K. W. King, and R. H. Burris. Transamination Reactions in Plants. J. Biol. Chem. 208, 863-874 (1954).

Grisolia, Santiago, and R. H. Burris. Preparation of Glutamate and Carbamyl Glutamate Selectively Labeled with Deuterium. J. Biol. Chem. 210, 109-117 (1954).

Grisolia, Santiago, R. H. Burris, and P. P. Cohen. Fate of Deutero-labeled Carbamyl Glutamate in Citrulline Biosynthesis. J. Biol. Chem. 210, 761-764 (1954).

Smeby, R. R., V. Zbinovsky, R. H. Burris, and F. M. Strong. The Organic Acids of Narcissus poeticus. J. Amer. Chem. Soc. 76, 6127-6130 (1954).

Mozen, Milton M., and R. H. Burris. The Incorporation of ^{15}N-labeled Nitrous Oxide by Nitrogen Fixing Agents. Biochim. Biophys. Acta 14, 577-578 (1954).

Magee, Wayne E., and R. H. Burris. Fixation of N_2 and Utilization of Combined Nitrogen by Nostoc muscorum. Amer. J. Bot. 41, 777-782 (1954).

Brummond, D. O., and R. H. Burris. Reactions of the Tricarboxylic Acid Cycle in Green Leaves. J. Biol. Chem. 209, 755-765 (1954).

Krall, Albert R., and R. H. Burris. Evidence for the Participation of Cytochrome Oxidase in Photosynthetic Fixation of Carbon Dioxide. Physiologia Plantarum 7, 768-776 (1954).

Virtanen, Artturi I., Tauno Moisio, Russell M. Allison, and R. H. Burris. Fixation of Molecular Nitrogen by Excised Nodules of the Alder. Acta Chem. Scand. 8, 1730-1731 (1954).

Burris, R. H., Wayne E. Magee, and Michael K. Bach. The pN_2 and the pO_2 Function for Nitrogen Fixation by Excised Soybean Nodules. Ann. Acad. Sci. Fennicae., Ser. A, II. Chem. 60. A. I. Virtanen homage vol. 190-199 (1955).

Cohen, J. S., and R. H. Burris. A Method for the Culture of Hydrogen Bacteria. J. Bacteriol. 69, 316-319 (1955).

Mozen, Milton M., and R. H. Burris. Experiments with Nitramide as a Possible Intermediate in Biological Nitrogen Fixation. J. Bacteriol. 70, 127-128 (1955).

Virtanen, Artturi I., Tauno Moisio, and R. H. Burris. Fixation of Nitrogen by Nodules Excised from Illuminated and Darkened Pea Plants. Acta Chem. Scand. 9, 184-186 (1955).

Mozen, Milton M., R. H. Burris, Sinikka Lundbom, and Artturi I. Virtanen. The Effect of Nitrous Oxide on Nitrate Utilization by Azotobacter vinelandii. Acta Chem. Scand. 9, 1232-1234 (1955).

Burris, R. H. Studies on the Mechanism of Biological Nitrogen Fixation. In Inorganic Nitrogen Metabolism, edited by William D. McElroy and Bentley Glass. The Johns Hopkins Press, Baltimore, 1956, pp. 316-343.

Scott, R. W., R. H. Burris, and A. J. Riker. Nonvolatile Organic Acids of Crown Galls, Crown Gall Tissue Cultures and Normal Stem Tissue. Plant Physiol. 30, 355-360 (1955).

Tissieres, A., and R. H. Burris. Purification and Properties of Cytochromes C_4 and C_5 from Azotobacter vinelandii. Biochem. Biophys. Acta 20, 436-437 (1956).

Magee, W. E., and R. H. Burris. Oxidative Activity and Nitrogen Fixation in Cell-free Preparations from Azotobacter. J. Bacteriol. 71, 635-643 (1956).

Allison, R. M., and R. H. Burris. Kinetics of Fixation of Nitrogen by Azotobacter vinelandii. J. Biol. Chem. 224, 351-364 (1957).

Burris, R. H. Nitrogen Fixation. A Conference on Radioactive Isotopes in Agriculture, U. S. Gov. Printing Office, Washington, D. C.; TID 7512, pp. 361-369 (1956).

Hoch, G. E., H. N. Little, and R. H. Burris. Hydrogen Evolution from Soybean Root Nodules. Nature 179, 430-431 (1957).

Burma, D. P., and R. H. Burris. Kinetics of Ammonia Utilization by Azotobacter vinelandii. J. Biol. Chem. 225, 287-295 (1957).

Burma, D. P., and R. H. Burris. Metabolism of Nitrogen by Cell-free Preparations from Azotobacter vinelandii. J. Biol. Chem. 225, 723-733 (1957)

Peterson, William H., Robert H. Burris, Rameshchandra Sant, and Henry N. Little. Production of Toxic Gas (Nitrogen Oxides) in Silage Making. Agr. Food. Chem. 6, 121-126 (1958).

Bergmann, F. H., J. C. Towne, and R. H. Burris. Assimilation of Carbon Dioxide by Hydrogen Bacteria. J. Biol. Chem. 230, 13-24 (1958).

Bach, Michael K., W. E. Magee, and R. H. Burris. Translocation of Photosynthetic Products to Soybean Nodules and Their Role in Nitrogen Fixation. Plant Physiol. 33, 118-124 (1958).

Fritz, G. J., Wilmer G. Miller, R. H. Burris, and Laurens Anderson. Direct Incorporation of Molecular Oxygen into Organic Material by Respiring Corn Seedlings. Plant Physiol. 33, 159-161 (1958).

Raggio, Nora, Raggio, Miguel, and R. H. Burris. Enhancement by Inositol of the Nodulation of Excised Bean Roots. Science 129, 211-212 (1959).

Mudd, J. B., B. G. Johnson, R. H. Burris, and K. P. Buchholtz. Oxidation of Indoleacetic Acid by Quackgrass Rhizomes. Plant Physiol. 34, 144-148 (1959).

Raggio, Nora, Raggio, Miguel, and R. H. Burris. Nitrogen Fixation by Nodules Formed on Isolated Bean Roots. Biochim. Biophys. Acta 32, 274-275 (1959).

Burris, R. H. Nitrogen Nutrition. Ann. Rev. Plant. Physiol. 10, 301-328 (1959).

Mudd, J. B., and R. H. Burris. Participation of Metals in Peroxidase-Catalyzed Oxidations. J. Biol. Chem. 234, 2774-2777 (1959).

Delhumeau-Arreeillas, Graciela, and R. H. Burris. Effects of Azaserine on Azotobacter agilis. J. Bact. 78, 740-741 (1959).

Tamaeki, T., A. C. Hildebrandt, A.J. Riker, R. H. Burris, and Bunji Hagihara. Oxidative and Phosphorylative Activities of Cytoplasmic Particles from Plant Tissue Cultures. Nature 184, 1491-1492 (1959).

Mudd, J. B., and R. H. Burris. Inhibition of Peroxidase-Catalyzed Oxidations. J. Biol. Chem. 234, 3281-3285 (1959).

Neumann, Norbert P., and R. H. Burris. Cytochromes C_4 and C_5 of Azotobacter vinelandii: Chromatographic Purification, Crystallization, and a Study of Their Physical Properties. J. Biol. Chem. 234, 3286-3290 (1959).

Burris, R. H. Hydroperoxidases (Peroxidases and Catalases). Handbuch der Pflanzenphysiologie - Encyclopedia of Plant Physiology, Vol. 12, p. 365, W. Ruhland, editor, 1960.

Hock, G. E., K. C. Schneider, and R. H. Burris. Hydrogen Evolution and Exchange and Conversion of N_2O to N_2 by Soybean Root Nodules. Biochim. Biophys. Acta 37, 273 (1960).

Kurtzman, R. N., Jr., A. C. Hildebrandt, R. H. Burris, and A. J. Riker. Inhibition and Stimulation of Tobacco Mosaic Virus by Purines. Virology 10, 432 (1960).

Schneider, K. C., Clive Bradbeer, R. N. Singh, Li Chuan Wang, P. W. Wilson, and R. H. Burris. Nitrogen Fixation by Cell-free Preparations from Microorganisms. Proc. Nat. Acad. Sci. 46, 726 (1960).

Tamaoki, Taiki, A. C. Hildebrandt, R. H. Burris, A. J. Riker, and B. Hagihara. Respiration and Phosphorylation of Mitochondria from Normal and Crown-Gall Tissue Cultures of Tomato. Plant Physiol. 35, 942 (1960).

Wang, Li Chuan, and R. H. Burris. Mass Spectrometric Study of Nitrogenous Gases Produced by Silage. Ag. and Food Chem. 8, 239 (1960).

Bergersen, F. J., R. H. Burris, and P. W. Wilson. Biochemical Studies on Soybean Nodules. Recent Advances in Botany, pp. 589-593, 1961.

Tamaoki, Taiki, A. C. Hildebrandt, R. H. Burris, and A. J. Riker. Oxidation of Reduced Diphosphopyridine Nucleotide by Mitochondria from Normal and Crown-Gall Tissue Cultures of Tomato. Plant Physiol. 36, 347 (1961).

Wang, Li Chuan, J. Garcia-Rivera, and R. H. Burris. Metabolism of Nitrate by Cattle. Biochem. J. 81, 237 (1961).

McNary, J. E., and R. H. Burris. Energy Requirements for Nitrogen Fixation by Cell-free Preparations from Clostridium pasteurianum. J. Bacteriol. 84, 598 (1962).

Burris, R. H. Discussion of Evolution of Biological Nitrogen-Fixation. Proc. 5th Internat. Cong. Biochemistry Vol. III, A. Oparin, ed., Pergamon Press Ltd., Oxford, England, 1963, p. 173-177.

Dua, Ramji Dass, and R. H. Burris. Stability of Nitrogen-Fixing Enzymes and the Reactivation of a Cold Labile Enzyme. Proc. Nat. Acad. Sci. 50, 169 (1963).

Sund, J. M., R. P. Niedermeier, and R. H. Burris. Watch Out for Silage Gas. Circular 624 Oct. 1963 - U. W. Ag. Exp. Station.

Wang, Dalton, and R. H. Burris. Carbon Metabolism of C^{14}-Labeled Amino Acids in Wheat Leaves. II. Serine and Its Role in Glycine Metabolism. Plant Physiol. 38, 430 (1963).

Wasserman, Aaron R., J. C. Garver, and R. H. Burris. Purification of Cytochrome C and Other Hemoproteins from Wheat Germ. Phytochemistry 2, 7 (1963).

Hamilton, I. R., R. H. Burris, and P. W. Wilson. Hydrogenase and Nitrogenase in a Nitrogen-fixing Bacterium. Proc. Nat. Acad. Sci. 52, 637 (1964).

Burris, R. H. Photosynthesis-Reduction in the Presence of a Strong Oxidant. Vol. V Molecular Structure and Biochem. Reactions: Proc. Robt. A. Welch Found. Conf. on Chem. Res. Dec. 4-6, 1961, pp. 113-116, pub. 1964.

Hamilton, I. R., R. H. Burris, P. W. Wilson, and C. H. Wang. Pyruvate Metabolism, Carbon Dioxide Assimilation, and Nitrogen Fixation by an Archomobacter Species. J. Bacteriol. 89, 647 (1965).

Hamilton, I. R., R. H. Burris, and P. W. Wilson. Pyruvate Metabolism by a Nitrogen-Fixing Bacterium. Biochem. J. 96, 383 (1965).

Munson, T. O., M. J. Dilworth, and R. H. Burris. Method for Demonstrating Cofactor Requirements for Nitrogen Fixation. Biochim. Biophys. Acta 104, 278 (1965).

Dilworth, M. J., D. Subramanian, T. O. Munson and R. H. Burris. The Adenosine Triphosphate Requirement for Nitrogen Fixation in Cell-free Extracts of Clostridium pasteurianum. Biochim. Biophys. Acta 99, 486 (1965).

Dua, R. D., and R. H. Burris. Studies of Cold Lability and Purification of a Nitrogen-Activating Enzyme. Biochim. Biophys. Acta 99, 504 (1965).

Burris, R. H., H. C. Winter, T. O. Munson, and J. Garcia-Riveria. Intermediates and Cofactors in Nitrogen Fixation. In Non-Heme Iron Protein: Role in Energy Conversion, A symposium sponsored by the Chas. F. Kettering Research Laboratory, The Antioch Press, Yellow Springs, Ohio 1965, pp. 315-321.

Lockshin, A., and R. H. Burris. Inhibitors of Nitrogen Fixation in Extracts from Clostridium pasteurianum. Biochim. Biophys. Acta 111, 1 (1965).

Burris, R. H. Nitrogen Fixation. Plant Biochemistry, edited by James Bonner and J. E. Varner, Academic Press, New York, pp. 961-979 (1965).

Schöllhorn, R., and R. H. Burris. Study of Intermediates in Nitrogen Fixation. Federation Proc. 25, 710 (1966) Abstract.

Burris, R. H. Biological Nitrogen Fixation. Ann. Rev. Plant Physiol. 17, 155 (1966).

Klucas, R. V., and R. H. Burris. Locus of Nitrogen Fixation in Soybean Nodules. Fixation by Crushed Nodules. Biochim. Biophys. Acta 136, 399 (1967).

Garcia, Rivera, J., and R. H. Burris. Hydrazine and Hydroxylamine as Possible Intermediates in the Biological Fixation of Nitrogen. Arch. Biochem. Biophys. 119, 167 (1967).

Schöllhorn, R., and R. H. Burris. Reduction of Azide by the N_2-Fixing Enzyme System. Proc. Natl. Acad. Sci. 57, 1317 (1967).

Schöllhorn, R., and R. H. Burris. Acetylene as a Competitive Inhibitor of N_2 Fixation. Proc. Natl. Acad. Sci. 58, 213 (1967).

Kelley, M., R. V. Klucas, and R. H. Burris. Fractionation and Storage of Nitrogenase from Azotobacter vinelandii. Biochem. J. 105, 3c (1967).

Fang, Florence S., and R. H. Burris. Cytochrome c in Hydrogenomonas eutropha. J. Bacteriol. 96, 298-305 (1968).

Stewart, W. D. P., G. P. Fitzgerald, and R. H. Burris. Acetylene Reduction by Nitrogen-Fixing Blue-Green Algae. Arch. für Mikrobiologie 62, 336-348 (1968).

Winter, Harry C., and R. H. Burris. Stoichiometry of the Adenosin Triphosphate Requirement for N_2 Fixation and H_2 Evolution by a Partially Purified Preparation of Clostridium pasteurianum. J. Biol. Chem. 243, 940-944 (1968).

Burris, R. H. Progress in the Biochemistry of Nitrogen Fixation. Proc. Roy. Soc. B. 172, 339-354 (1969).

Dravnieks, Dzintar E., Folke Skoog, and R. H. Burris. Cytokinin Activation of de novo Thiamine Biosynthesis in Tobacco Callus Cultures. Plant Physiology 44, 866-870 (1969).

Munson, T. O., and R. H. Burris. Nitrogen Fixation by Rhodospirillum rubrum Grown in Nitrogen-Limited Continuous Culture. J. Bacteriol. 97, 1093-1098 (1969).

Ouelette, C. A., R. H. Burris, and P. W. Wilson. Deoxyribonucleic Acid Base Composition of Species of Klebsiella, Azotobacter and Bacillus. Antonie van Leeuwenhoek, J. Microbiol. and Serol. 35, 275-286 (1969).

Swank, Richard T., and R. H. Burris. Purification and Properties of Cytochromes c of Azotobacter vinelandii. Biochim. Biophys. Acta 180, 473-489 (1969).

Swank, R. T., and R. H. Burris. Restoration by Ubiquinone of Azotobacter vinelandii Reduced Nicotinamide Adenine Dinucleotide Oxidase Activity. J. Bacteriol. 98, 311-313 (1969).

Kleiner, D., and R. H. Burris. The Hydrogenase of Clostridium pasteurianum Kinetic Studies and the Role of Molybdenum. Biochim. Biophys. Acta 212, 417-427 (1970).

Rusness, Donald and R. H. Burris. Acetylene Reduction (Nitrogen Fixation) in Wisconsin Lakes. Limnology and Oceanography 15, 808-813 (1970).

Stewart, W. D. P., G. P. Fitzgerald, and R. H. Burris. Acetylene Reduction Assay for Determination of Phosphorus Availability in Wisconsin Lakes. Proc. Natl. Acad. Sci. 66, 1104-1111 (1970).

Sundquist, J. E., and R. H. Burris. Light-Dependent Structural Changes in the Lamellar Membranes of Isolated Spinach Chloroplasts: Measurement by Electron Microscopy. Biochim. Biophys. Acta 223, 115-121 (1970).

Vandecasteele, Jean-Paul, and R. H. Burris. Purification and Properties of the Constituents of the Nitrogenase Complex from Clostridium pasteurianum. J. Bacteriol. 101, 794-801 (1970).

Shethna, Y. I., N. A. Stombaugh, and R. H. Burris. Ferredoxin from Bacillus polymyxa. Biochem. Biophys. Res. Commun. 42, 1108-1116 (1971).

Stewart, W. D. P., T. Mague, G. P. Fitzgerald, and R. H. Burris. Nitrogenase Activity in Wisconsin Lakes of Differing Degrees of Eutrophication. New Phytol. 70, 497-509 (1971).

Hwang, J. C., and R. H. Burris. Nitrogenase-Catalyzed Reactions. Biochimica et Biophysica Acta 283, 339 (1972).

Ljones, T., and R. H. Burris. ATP Hydrolysis and Electron Transfer in the Nitrogenase Reaction with Different Combinations of the Iron Protein and the Molybdenum-Iron Protein. Biochimica et Biophysica Acta 275, 93 (1972).

Ljones, T., and R. H. Burris. Continuous Spectrophotometric Assay for Nitrogenase. Analytical Biochemistry 45, 488 (1972).

Mague, T. H., and R. H. Burris. Reduction of Acetylene and Nitrogen by Field-Grown Soybeans. New Phytol. 71, 275 (1972).

Orme-Johnson, W. H., W. D. Hamilton, T. Ljones, M.-Y. Tso, R. H. Burris, V. K. Shah, and W. J. Brill. Electron Paramagnetic Resonance of Nitrogenase and Nitrogenase Components from Clostridium pasteurianum W5 and Azotobacter vinelandii OP. Proc. Natl. Acad. Sci. U.S.A. 69, 3142 (1972).

Tso, M. -Y., T. Ljones, and R. H. Burris. Purification of the Nitrogenase Proteins from Clostridium pasteurianum. Biochim. Biophys. Acta 267, 600 (1972).

Vanderhoef, L. N., B. Dana, D. Emerich, and R. H. Burris. Acetylene Reduction in Relation to Levels of Phosphate and Fixed Nitrogen in Green Bay. New Phytol. 71, 1097 (1972).

Wong, P. P., and R. H. Burris. Nature of Oxygen Inhibition of Nitrogenase from Azotobacter vinelandii. Proc. Nat. Acad. Sci. U.S.A. 69, 672 (1972).

Tso, M. -Y., and R. H. Burris. The Binding of ATP and ADP by Nitrogenase Components from Clostridium pasteurianum. Biochim. Biophys. Acta 309, 263 (1973).

Mague, T. H., and R. H. Burris. Biological Nitrogen Fixation in the Great Lakes. BioScience 23, 236 (1973).

Campbell, W. H., Orme-Johnson, W. H., and R. H. Burris. A Comparison of the Physical and Chemical Properties of Four Cytochromes c from Azotobacter vinelandii. Biochem. J. 135, 617 (1973).

Burris, R. H. Nitrogen Fixation - Assay Methods and Techniques. In Methods in Enzymology 24B, edited by A. San Pietro, Editors-in-Chief S. P. Colowick and N. O. Kaplan, Academic Press, New York and London.

Murphy, Patrick M., and Burton L. Koch. Compatability of the Components of Nitrogenase from Soybean Bacteroids and Free-living Nitrogen-fixing Bacteria. Biochim. Biophys. Acta 253, 295-297 (1971).

Kratochvil, J. F., R. H. Burris, Margaret K. Seikel, and John M. Harkin. Isolation and Characterization of α-Guaiaconic Acid and the Nature of Guaiacum Blue. Phytochem. 10, 2529-2531 (1971).

Hwang, J. C., C. H. Chen, and R. H. Burris. Inhibition of Nitrogenase-Catalyzed Reductions. Biochim. Biophys. Acta 292, 256-270 (1973).

Stombaugh, N. A., R. H. Burris, and W. H. Orme-Johnson. Ferredoxins from Bacillus polymyxa. Low Potential Iron-Sulfur Proteins which Appear to Contain Single Four Iron, Four Sulfur Centers Accepting a Single Electron on Reduction. J. Biol. Chem. 248, 7951-7956 (1973).

Ljones, Torbjørn. Nitrogenase from Clostridium pasteurianum. Changes in Optical Absorption Spectra during Electron Transfer and Effects of ATP, Inhibitors and Alternative Substrates. Biochim. Biophys. Acta 321, 103-113 (1973).

Tso, Man - Yin W. Some Properties of the Nitrogenase Proteins from Clostridium pasteurianum. Arch. Microbiol. 99, 71-80 (1974).

Ljones, Torbjørn. The Enzyme System. pp. 617-638. In The Biology of Nitrogen Fixation. A. Quispel, editor; North-Holland Publishing Company, Amsterdam-Oxford, 1974.

Burris, R. H. Methodology. pp. 9-33. In The Biology of Nitrogen Fixation. A. Quispel, editor; North Holland Publishing Company, Amsterdam-Oxford, 1974.

Burris, R. H., and W. H. Orme-Johnson. pp. 187-209. In Microbial Iron Metabolism, A Comprehensive Treatise; J. B. Neilands, editor; Academic Press, Inc., New York, 1974.

Burris, Robert H. Biological Nitrogen Fixation, 1924-1974. Plant Physiol. 54, 443-449 (1974).

Vanderhoef, Larry N., Chi-Ying Huang, Robert Musil, and Jeffrey Williams. Nitrogen Fixation (Acetylene Reduction) by Phytoplankton in Green Bay, Lake Michigan, in Relation to Nutrient Concentrations. Limnology and Oceanography 19, 119-125 (1974).

Phillips, William D., C. C. McDonald, N. A. Stombaugh, and W. H. Orme-Johnson. Proton Magnetic Resonance and Magnetic Susceptibility Characterization of Ferredoxin I from Bacillus polymyxa. Proc. Nat. Acad. Sci. U.S.A. 71, 140-143 (1974).

Kleiner, D., and C. H. Chen. Physical and Chemical Properties of the Nitrogenase Proteins from Azotobacter vinelandii. Arch. Microbiol. 98, 93-100 (1974).

Silver, W. S., and Mague, Timothy. Assessment of Nitrogen Fixation in Terrestrial Environments in Field Conditions. Nature 227, 378-379 (1970).

Shethna, Y. I. Non-heme Iron (Iron-Sulfur) Proteins of Azotobacter vinelandii. Biochim. Biophys. Acta 205, 58-62 (1970).

Burris, R. H. Fixation by Free-living Micro-organisms: Enzymology. In The Chemistry and Biochemistry of Nitrogen Fixation. Edited by J. R. Postgate, Plenum Press, London. pp. 105-160 (1971).

Rivera-Ortiz, J. M., and R. H. Burris. Interactions among Substrates and Inhibitors of Nitrogenase. J. Bacteriol. 123, 537-545 (1975).

Publications in Process:

Barrier Reef

Bonner and Varner - Chapter

Ann. Rev. Biochem. (1975) with H. Winter

ASPP - History of N_2 Fixation - Plant Physiol.

Burris, R. H., and W. H. Orme-Johnson - Introduction to Symposium on N_2 Fixation, Pullman - submitted.

Burris - IBP - Edinburgh - submitted.

Burris - Hardy monograph - Chapter 1 - Introduction and Chapter 5 - Inhibition - submitted.

Kleiner and Chen - Arch. Microbiol. - A. vinelandii Nitrogenase Properties.

Ljones - Chapter in Quispel book - In press.

BBA - Nitrogenase from Clostridium pasteurianum, Changes in optical absorption spectra system during electron transfer and effects of ATP, inhibitors and alternative substrates, BBA 321, 103 (1973).

Burris, R. H., and W. H. Orme-Johnson - Neiland's book - In press.

Stombaugh - NMR - W. D. Phillips, C. C. McDonald, N. A. Stombaugh and W. H. Orme-Johnson, PNAS.

Stombaugh, Sundquist, etc., Fd. potentials - JBC - In press.

Stombaugh, Missbauer (Chapter 4 of thesis).

Stombaugh - Biological activities of ferredoxins I and II from B. polymyxa (Chapter 5 of thesis).

Burris - Quispel book chapter - In press.

Tso - Arch. Mikrobiol. - In press.

Vanderhoef - Plant Physiology - In press (Vanderhoef, Liebson, Musel, Huena, Fiehweg, Willing, Wackivitz, Marc).

Vanderhoef - Limnology and Oceanography.

(f) Educational Contributions other than Publications

University Faculty Biotron Committee

Graduate School Administrative Committee

Honorary Degrees Committee

Faculty Senate Departmental Representative

Sea Grant Advisory Committee

College Academic Planning Council

Committee on Molecular Biology and Biophysics

Chairman, Course Committee

Director, Training Grant Committee

(g) Development or Improvement of Programs, Practices and Products for the Improvement of Food Sources

1. First to use ^{15}N for study of biological nitrogen fixation.
2. Established importance of glutamate dehydrogenase in conversion of ammonia into amino acids.
3. Discovered the requirement of adenosine triphosphate as an energy source in the reduction of atmospheric nitrogen.
4. Discovered the importance of glycolic acid pathway in green plants.
5. Discovered the reduction of acetylene by nitrogen-fixing blue-green algae.

(h) Other Professional Contributions

Service on Editoral Boards: Phytochemistry, Plant Physiology, Physiological Reviews, Analytical Biochemistry, Chemistry Biology Interface Series, Biological Handbook Series (FASEB).

(i) Services to Organized Groups or Professions

Departmental Committees for Buildings and Space, Staffing, Contemporary Biochemistry, Harry and Evelyn Steenbock Career Award, Radiation Safety.

President of the American Society of Plant Physiologists.

President of Sigma Xi.

Canvassing committee for Eli Lilly Award by American Chemical Society.

Executive Committee, Assembly of Life Sciences.

Chairman, Department of Biochemistry.

Chairman, Search Committee for president of University of Wisconsin.

Chairman, National Institutes of Health Biochemistry Training Grants Study Section.

EVALUATION

Dr. Burris has been involved in the field of nitrogen fixation for more than three decades. His graduate work at the University of Wisconsin dealt with the basic chemistry and physiology of organisms that fix nitrogen in the soil. Following a period of postdoctoral training at Columbia University, in which he became proficient in the handling of isotopes for biological experiments, he joined the staff of the Department of Biochemistry at the University of Wisconsin.

In this department, he and his students broadened their program in plant biochemistry to include not only nitrogen fixation but also many other aspects of plant growth and productivity. He was the first to use the isotope ^{15}N to study the mechanism of biological nitrogen fixation; he established that ammonia is an intermediate in the fixation of atmospheric nitrogen by microbes that live freely as well as those that live in symbiosis with leguminous plants. He established the importance of glutamate dehydrogenase in the conversion of fixed nitrogen (ammonia) into amino acids; he discovered the requirement of adenosine triphosphate as an energy source in the reduction of atmospheric nitrogen; he discovered the reduction of acetylene by nitrogen-fixing blue-green algae and has made this into a highly useful test in the study of eutrophication of lakes, and has demonstrated that the limiting factor in the growth of algae in lake waters is the availability of phosphorus. He has purified many of the electron transport enzymes from nitrogen-fixing species such as Azotobacter, has purified the enzyme nitrogenase and some of its accompanying enzymes and has studied in exact detail the binding of adenine nucleotides and the transfer of electrons in the process of nitrogen reduction. He discovered the importance of the glycolic acid pathway in green plants, and he has investigated the influence of plant growth regulators on plant metabolism in a series of papers scattered over a period of years.

Burris's preeminent place in the field of nitrogen fixation is attested to by the many reviews that he has been requested to prepare for a wide variety of publications, both in this country and abroad. One of the most important contributions of Dr. Burris to the field of food production was to organize the 5th Annual Steenbock Symposium held in the summer of 1975 which dealt with "CO_2 Metabolism and Productivity in Plants". This was a highly successful meeting, dealing with both the fundamental aspects of plant metabolism and many aspects that are directly applicable to plant growth and food production. Outstanding authorities from all over the world presented papers during the three-day symposium, and some of the best presented were by former students of Professor Burris.

Perhaps the two most significant firsts for Dr. Burris were the preparation of cell free extracts capable of fixing nitrogen (1956) and the demonstration of acetylene reduction by nitrogenase (1966). The former discovery opened up the field to more critical studies of the mechanisms involved in this highly important area of biology, and the latter led to the development of a simple assay for nitrogenase. This assay has been used throughout the world to study nitrogen fixation under laboratory, greenhouse and field conditions. The resultant effect has led to a much greater understanding of factors influencing the chemistry and biology of nitrogen fixation in plants and microorganisms.

Biological nitrogen fixation is the only energy-cheap way available to obtain urgently needed fertilizer and must inevitably play an increasingly dominant role in agriculture. Dr. Burris's research work in this area has laid a scientific foundation upon which agricultural applications can be developed.

LETTERS SUPPORTING THE NOMINATION OF

DR. ROBERT H. BURRIS

TO THE

EDWARD W. BROWNING AWARD

The American Society of Plant Physiologists

Office of the President

January 28, 1976

Dr. Ernest G. Jaworski, Chairman
Honors and Awards Committee
Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, MO 63166

Dear Dr. Jaworski:

It is a real pleasure to write a letter in support of your nomination of Dr. Robert H. Burris for the Edward W. Browning Award of the American Society of Agronomy. From the very first demonstration of nitrogen fixation in vitro, he has made continued important contributions to our knowledge of nitrogen metabolism and fixation in plants and procaryotes. His continued productivity is revealed in one way by inspecting Dilworth's 1974 review of nitrogen fixation. Burris is cited in the context of the biochemical details of the process no less than ten separate times. A few years back, he was the unanimous choice of the faculty of the Harvard Biology Department to deliver the distinguished Prather lecture series, which this writer had the privilege of hearing. It was clear that Burris's own contributions over the years have been major ones, and that they have been sustained for over twenty five years.

I gather that a letter such as this one should mention the relevancy of the nominee's work to agriculture, but I think this sufficiently obvious in the case of nitrogen fixation as to need little documentation. Biological nitrogen fixation is the only energy-cheap way available to obtain urgently needed fertilizers, and must inevitably play an increasingly dominant role in agriculture.

I hope that these rather brief remarks are of assistance to you. Burris is clearly an outstandingly strong candidate for the Society to nominate.

Sincerely yours,

Winslow R. Briggs

Winslow R. Briggs
President

WRB:kk

UNIVERSITY OF WISCONSIN-MADISON

COLLEGE OF AGRICULTURAL AND LIFE SCIENCES

Department of Biochemistry
420 Henry Mall
Madison, Wisconsin 53706 USA
Telephone: 608/262-3026/262-3040

January 21, 1976

Dr. Ernest Jaworski
Monsanto Company
800 North Lindberg Boulevard
St. Louis, MO 63166

Dear Dr. Jaworski:

I am pleased to learn that you are nominating Professor Robert Burris for the Edward Browning Award administered by the American Agronomy Society. On behalf of the many colleagues of Professor Burris in this Department of Biochemistry, I am submitting an appraisal of Dr. Burris's qualifications for this Award.

The scientific career of Robert Burris has been devoted entirely to efforts to increase the basic understanding of factors that are important in the production of food. His own research has been directed toward that goal, and he has trained many outstanding graduate students who have, in their own careers, contributed importantly to it. It is especially appropriate that you are nominating Professor Burris at this time, when our dwindling supplies of natural gas will make the biological fixation of nitrogen a very important factor in maintaining food production in the future.

Dr. Burris grew up and received his early education in South Dakota. His graduate work at the University of Wisconsin Department of Bacteriology dealt with the basic chemistry and physiology of organisms that fix nitrogen in the soil. Following a period of postdoctoral training, in which he became proficient in the handling of isotopes for biological experiments at Columbia University, he joined the staff of the Department of Biochemistry on this campus where he advanced rapidly in rank and where he served as Chairman of the Department from 1958 to 1970.

In this department, he and his students broadened their program in plant biochemistry to include not only nitrogen fixation but also many other aspects of plant growth and productivity. He was the first to use the isotope ^{15}N to study the mechanism of biological nitrogen fixation; he established that ammonia is an intermediate in the fixation of atmospheric nitrogen by microbes that live freely as well as those that live in symbiosis with leguminous plants. He established the importance of glutamate dehydrogenase in the conversion of fixed nitrogen (ammonia) into amino acids; he discovered the requirement of adenosine triphosphate as an energy source in the reduction of atmospheric nitrogen; he discovered the reduction of acetylene by nitrogen-fixing blue-green algae and has made this into a highly useful test in the study of eutrophication of lakes, and has demonstrated that the limiting factor in the growth of algae in lake waters is the availability of phosphorus. He has purified many of the electron transport enzymes from nitrogen-fixing species such as Azotobacter, has purified the enzyme nitrogenase and some of its accompanying enzymes and has studied in exact detail the binding of adenine

nucleotides and the transfer of electrons in the process of nitrogen reduction. He discovered the importance of the glycolic acid pathway in green plants, and he has investigated the influence of plant growth regulators on plant metabolism in a series of papers scattered over a period of several years.

Burris's preeminent place in the field of nitrogen fixation is attested to by the many reviews that he has been requested to prepare for a wide variety of publications, both in this country and abroad. One of the most important contributions of Dr. Burris to the field of food production was to organize the 5th Annual Steenbock Symposium held in the summer of 1975 which dealt with "CO_2 Metabolism and Productivity in Plants." This was a highly successful meeting, dealing with both the fundamental aspects of plant metabolism and many aspects that are directly applicable to plant growth and food production. Outstanding authorities from all over the world presented papers during the three-day symposium, and some of the best presented were by former students of Professor Burris.

On coming to this department, Professor Burris initiated a modern course in plant biochemistry which he has continued to teach and to keep up to date ever since. He is recognized by both faculty and students as an exceptionally good teacher, both of basic information and of concepts that are relevant to plant food production.

In addition to his teaching and research responsibilities, Professor Burris has served his university well in a number of other capacities. He was an excellent departmental chairman for as long as we could persuade him to retain the post. He initiated many new procedures, obtained department-wide support for students in the form of training grants, and improved the facilities of the department for both teaching and research. He has served on many very important committees, of which I shall mention only a few. He was Chairman of the Search Committee to seek a president of the University of Wisconsin in 1970. He was Chairman of the National Institutes of Health Biochemistry Training Grants Study Section for two years, and served for a total of five years. He served on the Editorial Boards of Phytochemistry, Plant Physiology, Physiological Reviews, Analytical Biochemistry, the Monograph Series of the American Society of Plant Physiology, the Chemistry-Biology Interface Series, and the Biological Handbook Series of the Federated Societies of Experimental Biology. In addition to his more than 200 research publications, he is a coauthor of the book Manometric Techniques, which is now in its fifth edition and which serves to guide new students as well as old professors in laboratory techniques in almost every biochemistry department in this country and in many abroad.

Many honors have come to Professor Burris. His alma mater, South Dakota State University, conferred the honorary D.Sc. on him in 1966. He received the Merit Award of the Botanical Society of America in the same year, was elected President of the American Society of Plant Physiologists in 1960, received the Stephen Hales Award of the American Society of Plant Physiology in 1968, and has been elected to the National Academy of Sciences and the American Academy of Arts and Sciences.

I am enclosing a detailed curriculum vitae which lists several of Professor Burris's accomplishments not included in this letter. I endorse your nomination of Professor Burris for the Edward Browning Award with enthusiasm and with the concurrence of his colleagues at this university.

Sincerely yours,

Hector DeLuca
Harry Steenbock Professor
and
Chairman, Department of Biochemistry

mjt
Enclosure

WASHINGTON UNIVERSITY

ST. LOUIS, MISSOURI 63130

DEPARTMENT OF BIOLOGY

February 4, 1976

Dr. E. G. Jaworski
The Monsanto Company
800 North Lindbergh Blvd.
St. Louis, Missouri 63036

Dear Ernie:

I enthusiastically support the nomination of Prof. Robert Burris for the Edward Browning Award of the American Society of Agronomy.

Since he began his career as a graduate student with Perry Wilson, Burris has had a remarkable influence on the development of the present knowledge of nitrogen fixation. Much of the important work on nitrogen fixation since the 1940's has been done in Burris' laboratory. Much has been done by students of Burris after their training with him. And many others have asked Burris to check their own exciting new results for confirmation.

Burris established ammonia as the key intermediate in nitrogen fixation and work by Dilworth in Burris' lab led to the development of the acetylene assay for nitrogenase. The first consistent cell-free nitrogen fixation was obtained in Burris' lab. The beautifully precise work of Bulen was inspired by Burris and Bulen freely acknowledged the value of Burris' advice and consultation. In short, Burris has almost certainly been more effective in increasing and encouraging the increase in our understanding of nitrogen fixation than any other single person. This has already led to improved crop production in several parts of the world and there is now widespread confidence that application of the present knowledge of nitrogen fixation to crop production problems will bring about further improvements in the quantity and quality of food production. It is generally agreed that this will occasion no further damage to the environment in contrast to doubts and controversy in connection with additional usage of nitrogen fertilizers.

Thus we are seeing within the lifetime of one man the realization of widespread agricultural and ecological benefits from the application of knowledge derived from his laboratory research.

Sincerely,

J. E. Varner

JEV/lls