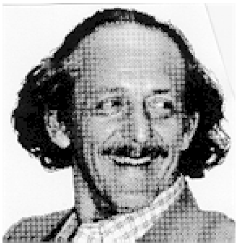
Essays of an Information Scientist, Vol:5, p.279-287, 1981-82 Current Contents, #42, [/5-13, October 19, 1981



Current Comments

Introducing the *ISI Atlas of Science: Biochemistry and Molecular Biology, 1978/80*

Number 42 October 19, 1981

For years, I've been promising readers of *Current Contents*® *(CC*®) that ISI® would someday produce an atlas of science.[1] Such an atlas would depict the discipline structure of science by mapping the citation linkages among highly cited papers. It would show, among other things, how closely or distantly various subfields are related to each other. I am now pleased to announce that we have taken a giant step toward reaching our goal. ISI will soon publish a prototype section of the atlas of science, called the *ISI Atlas of Science: Biochemistry and Molecular Biology, 1978/80.* This initial volume is the precursor to other atlases or sections for other fields, depending upon the reaction of the scientific community.

The new *Atlas* was compiled from data contained in *Science Citation Index*® (*SCI*®) from 1978 and 1980. Based on information obtained by cluster analysis, the *Atlas* will provide concise, factual presentations of 102 subspecialties in biochemistry and molecular biology. Our clustering techniques have been described in previous essays.[2,3]

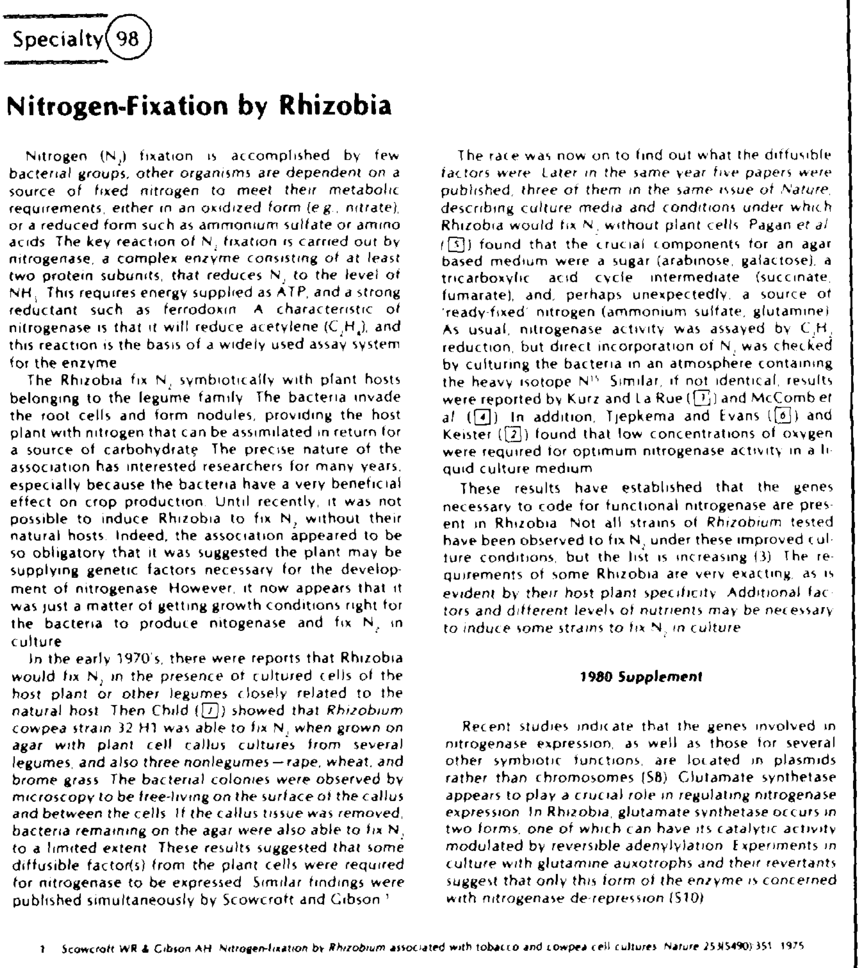
Each "chapter" of the *Atlas* covers a distinct subspecialty, or research front, and consists of four components: a minireview of the subject, a cluster map showing the "connectedness" among the core documents of the subspecialty, a bibliography of the core documents which establish the cluster, and a list of the key current papers which cite the core papers.

The figures presented here show each *Atlas* component for the chapter entitled "Nitrogen-Fixation by Rhizobia." This specialty, like the others in the *Atlas*, has been identified through our 1978 cluster data. Figure 1 presents the essay which accompanies the cluster map. Since our experiment with this *Atlas* extended over two years, we prepared supplements to each essay to bring the specialties up to date for 1980.

All of the essays in the *Atlas* were written by scientists who hold PhDs in the biochemical sciences. Moreover, these essays were reviewed by one or more experts whose names appear in the appropriate cluster. Each essay is about 750 words long and amounts to a minireview tracing the historical development of the subject area. It provides users with a quick orientation to each topic.

The essays, I believe, give the *Atlas* the flavor of an "encyclopedia of biochemistry." The importance of authoritative reviews to the advancement of science cannot be overstated. But as I and others have repeatedly noted, there is a chronic shortage of review writers.[4,5] To collect and digest all the literature in a field is a time-consuming task. Perhaps these *Atlas* minireviews, written from ISI's cluster data, can help fill the gap.

Figure 1: Sample minireview, with supplement, which accompanies each map in the *Atlas*.



Specialty ⑱

Nitrogen-Fixation by Rhizobia

Nitrogen (N$_2$) fixation is accomplished by few *bacterial groups, other organisms are dependent on a source of fixed nitrogen to meet their metabolic requirements, either in an oxidized form (e.g., nitrate),* or a reduced form such as ammonium sulfate or amino acids. The key reaction of N$_2$ fixation is carried out by *nitrogenase, a complex enzyme consisting of at least two protein subunits, that reduces N$_2$ to the level of NH$_3$. This requires energy supplied as ATP, and a strong reductant such as ferrodoxin.* A characteristic of nitrogenase is that it will reduce acetylene (C$_2$H$_2$), and this reaction is the basis of a widely used assay system for the enzyme.

The Rhizobia fix N$_2$ symbiotically with plant hosts belonging to the legume family. The bacteria invade the root cells and form nodules, providing the host plant with nitrogen that can be assimilated in return for a source of carbohydrate. The precise nature of the association has interested researchers for many years, especially because the bacteria have a very beneficial effect on crop production. Until recently, it was not possible to induce Rhizobia to fix N$_2$ without their natural hosts. Indeed, the association appeared to be so obligatory that it was suggested the plant may be supplying genetic factors necessary for the development of nitrogenase. However, it now appears that it was just a matter of getting growth conditions right for the bacteria to produce nitogenase and fix N$_2$ in culture.

In the early 1970's, there were reports that Rhizobia *would fix N$_2$ in the presence of cultured cells of the host plant or other legumes closely related to the natural host. Then Child ($\boxed{1}$) showed that Rhizobium cowpea strain 32 H1 was able to fix N$_2$ when grown on agar with plant cell callus cultures from several legumes, and also three nonlegumes—rape, wheat, and brome grass. The bacterial colonies were observed by microscopy to be free-living on the surface of the callus and between the cells. If the callus tissue was removed, bacteria remaining on the agar were also able to fix N$_2$ to a limited extent. These results suggested that some diffusible factor(s) from the plant cells were required for nitrogenase to be expressed. Similar findings were* published simultaneously by Scowcroft and Gibson.[1]

The race was now on to find out what the diffusible *factors were. Later in the same year five papers were published, three of them in the same issue of* Nature, *describing culture media and conditions under which* Rhizobia would fix N$_2$ without plant cells. Pagan *et al* ($\boxed{5}$) found that the crucial components for an agar based medium were a sugar (arabinose, galactose), a tricarboxylic acid cycle intermediate (succinate, fumarate), and, perhaps unexpectedly, a source of 'ready-fixed' nitrogen (ammonium sulfate, glutamine). As usual, nitrogenase activity was assayed by C$_2$H$_2$ reduction, but direct incorporation of N$_2$ was checked by culturing the bacteria in an atmosphere containing the heavy isotope N^{15}. Similar, if not identical, results were reported by Kurz and La Rue ($\boxed{3}$) and McComb *et al* ($\boxed{4}$). In addition, Tjepkema and Evans ($\boxed{6}$) and Keister ($\boxed{2}$) found that low concentrations of oxygen were required for optimum nitrogenase activity in a liquid culture medium.

These results have established that the genes necessary to code for functional nitrogenase are present in Rhizobia. Not all strains of *Rhizobium* tested have been observed to fix N$_2$ under these improved culture conditions, but the list is increasing (3). The requirements of some Rhizobia are very exacting, as is *evident by their host plant specificity. Additional factors and different levels of nutrients may be necessary to induce some strains to fix N$_2$ in culture.*

1980 Supplement

Recent studies indicate that the genes involved in nitrogenase expression, as well as those for several other symbiotic functions, are located in plasmids *rather than chromosomes (S8). Glutamate synthetase appears to play a crucial role in regulating nitrogenase expression. In Rhizobia, glutamate synthetase occurs in two forms, one of which can have its catalytic activity modulated by reversible adenylylation. Experiments in culture with glutamine auxotrophs and their revertants suggest that only this form of the enzyme is concerned with nitrogenase de-repression (S10).*

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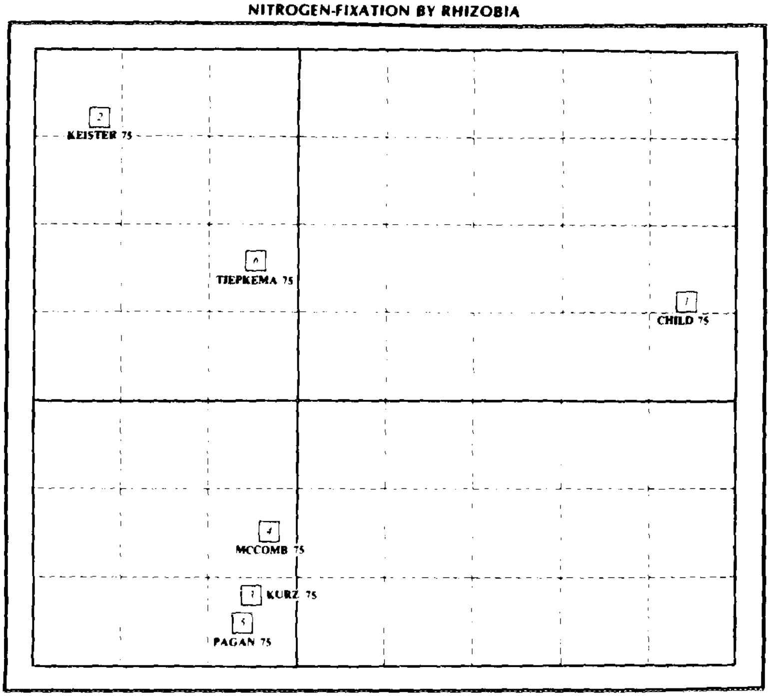
[1] *Scowcroft WR & Gibson AH. Nitrogen-fixation by Rhizobium associated with tobacco and cowpea cell cultures. Nature 253(5490):351. 1975.*

Figure 2 shows the cluster map of core documents in research on nitrogen-fixation by rhizobia. The numbers in boxes representing each paper are merely for identification, and are assigned alphabetically by first author. Looking at the map, one can observe the degree of subject similarity among the core papers. For example, the papers by J.D. Pagan and W.G.W. Kurz appear close together on the grid. This means they have been heavily co-cited, and probably discuss very similar topics or frequently used methods. The papers by J.J. Child and D.L. Keister, on the other hand, are farther apart and are probably related in a more peripheral fashion.

The bibliography for the core papers appears on the same page as the map for easy reference. The numbers in the CF (citation frequency) column indicate the number of times the core documents were cited in 1978. In this example, a

Figure 2: Sample *Atlas* cluster map, with bibliography of core documents. Numbers in boxes identify core papers in the bibliography. Proximity of boxes in the map is an indication of subject similarity. The grid provides orientation.

Specialty 98



☐ represents a core document Axes provide orientation
Proximity of ☐ 's defines subject similarity

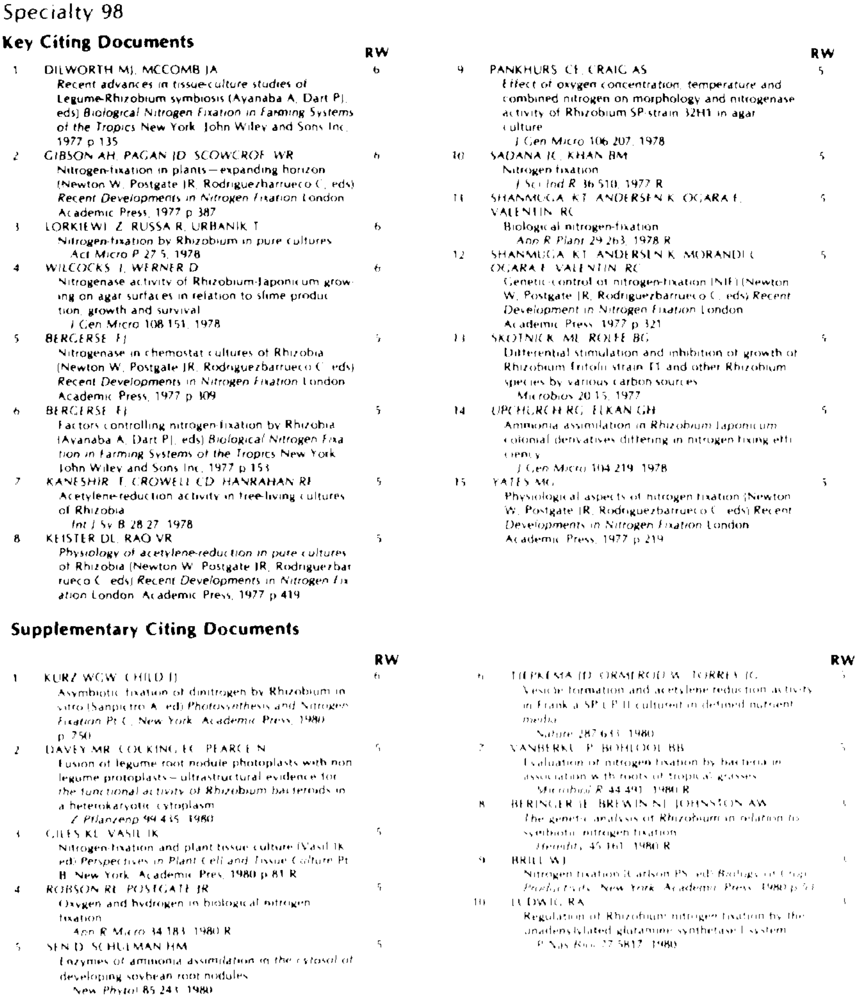
Cited Core Documents

		CF
1	CHILD JJ Nitrogen-fixation by a Rhizobium SP in association with non-leguminous plant-cell cultures *Nature* 253(5490) 350, 1975	18
2	KEISTER DL Acetylene-reduction by pure cultures of Rhizobia *J Bact* 123(3) 1265-1268, 1975 N	19
3	KURZ WGW, LARUE TA Nitrogenase activity in Rhizobia in absence of plant host *Nature* 256(5516) 407-409, 1975	30
4	MCCOMB JA, ELLIOTT J, DILWORTH MJ Acetylene-reduction by Rhizobium in pure culture *Nature* 256(5516) 409-410, 1975	26
5	PAGAN JD, CHILD JJ, SCOWCROF WR, GIBSON AH Nitrogen-fixation by Rizobium cultured on a defined medium *Nature* 256(5516) 406-407, 1975	28
6	TJEPKEMA J, EVANS HJ Nitrogen-fixation by free-living Rhizobium in a defined liquid-medium *Bioc Biop R* 65(2):625-628, 1975	22

1978 citation threshold of 17 was established.

Figure 3 lists the papers published during 1978/1980 that have cited the core. The RW heading stands for relevance weight. Relevance is measured by counting how many core documents have been cited. The first entry on the list, M.J. Dilworth and J.A. McComb, cited all six of the core papers, showing a high degree of relevance to the cluster. It is not unusual for review papers to rank highest in relevance, since they usually cite many relevant papers. The list of supplementary citing documents includes the most relevant papers published in 1980. These supplementary documents indicate where the research front now stands. They lend timeliness to the *Atlas* chapter.

Figure 3: Sample bibliography of key documents and supplementary documents that cite an *Atlas* cluster.



Specialty 98

Key Citing Documents

RW

1 DILWORTH MJ, MCCOMB JA 6
Recent advances in tissue-culture studies of Legume-Rhizobium symbiosis (Ayanaba A, Dart PJ, eds) *Biological Nitrogen Fixation in Farming Systems of the Tropics* New York John Wiley and Sons Inc, 1977 p 135

2 GIBSON AH, PAGAN JD, SCOWCROF WR 6
Nitrogen-fixation in plants—expanding horizon (Newton W, Postgate JR, Rodriguezbarrueco C, eds) *Recent Developments in Nitrogen Fixation* London Academic Press, 1977 p 387

3 LORKIEWI Z, RUSSA R, URBANIK T 6
Nitrogen-fixation by Rhizobium in pure cultures
Act Micro P 27 5, 1978

4 WILCOCKS J, WERNER D 6
Nitrogenase activity of Rhizobium-Japonicum growing on agar surfaces in relation to slime production, growth and survival
J Gen Micro 108 151, 1978

5 BERGERSE FJ 5
Nitrogenase in chemostat cultures of Rhizobia (Newton W, Postgate JR, Rodriguezbarrueco C, eds) *Recent Developments in Nitrogen Fixation* London Academic Press, 1977 p 309

6 BERGERSE FJ 5
Factors controlling nitrogen-fixation by Rhizobia (Ayanaba A, Dart PJ, eds) *Biological Nitrogen Fixation in Farming Systems of the Tropics* New York John Wiley and Sons Inc, 1977 p 153

7 KANESHIR T, CROWELL CD, HANRAHAN RF 5
Acetylene-reduction activity in free-living cultures of Rhizobia
Int J Sy B 28 27, 1978

8 KEISTER DL, RAO VR 5
Physiology of acetylene-reduction in pure cultures of Rhizobia (Newton W, Postgate JR, Rodriguezbarrueco C, eds) *Recent Developments in Nitrogen Fixation* London Academic Press, 1977 p 419

RW

9 PANKHURS CE, CRAIG AS 5
Effect of oxygen concentration, temperature and combined nitrogen on morphology and nitrogenase activity of Rhizobium SP-strain 32H1 in agar culture
J Gen Micro 106 207, 1978

10 SADANA JC, KHAN BM 5
Nitrogen fixation
J Sci Ind R 36 510, 1977 R

11 SHANMUGA KT, ANDERSEN K, OGARA F, VALENTIN RC 5
Biological nitrogen-fixation
Ann R Plant 29 263, 1978 R

12 SHANMUGA KT, ANDERSEN K, MORANDI C, OGARA F, VALENTIN RC 5
Genetic-control of nitrogen-fixation (NIF) (Newton W, Postgate JR, Rodriguezbarrueco C, eds) *Recent Development in Nitrogen Fixation* London Academic Press, 1977 p 321

13 SKOTNICK ML, ROLFE BG 5
Differential stimulation and inhibition of growth of Rhizobium Trifolii strain T1 and other Rhizobium species by various carbon sources
Microbios 20 15, 1977

14 UPCHURCH RG, ELKAN GH 5
Ammonia assimilation in *Rhizobium Japonicum* colonial derivatives differing in nitrogen fixing efficiency
J Gen Micro 104 219, 1978

15 YATES MG 5
Physiological aspects of nitrogen fixation (Newton W, Postgate JR, Rodriguezbarrueco C, eds) Recent *Developments in Nitrogen Fixation* London Academic Press, 1977 p 219

Supplementary Citing Documents

RW

1 KURZ WGW, CHILD JJ 6
Asymbiotic fixation of dinitrogen by Rhizobium in vitro (Sanpietro A, ed) *Photosynthesis and Nitrogen Fixation Pt C*, New York Academic Press, 1980 p 750

2 DAVEY MR, COCKING EC, PEARCE N 5
Fusion of legume root nodule photoplasts with non legume protoplasts—ultrastructural evidence for *the functional activity of Rhizobium bacteroids in* a heterokaryotic cytoplasm
Z Pflanzenp 99 435, 1980

3 GILES KL, VASIL IK 5
Nitrogen-fixation and plant tissue culture (Vasil IK ed) *Perspectives in Plant Cell and Tissue Culture Pt* B, New York Academic Pres, 1980 p 81 R

4 ROBSON RL, POSTGATE JR 5
Oxygen and hydrogen in biological nitrogen fixation
Ann R Micro 34 183, 1980 R

5 SEN D, SCHULMAN HM 5
Enzymes of ammonia assimilation in the cytosol of developing soybean root nodules
New *Phytol* 85 243, 1980

RW

6 TJEPKEMA JD, ORMEROD W, TORREY JG 5
Vesicle formation and acetylene reduction activity in Frankia SP CPI1 cultured in defined nutrient *media*
Nature 287 633, 1980

7 VANBERKU P, BOHLOOL BB 5
Evaluation of nitrogen fixation by bacteria in association with roots of tropical grasses
Microbiol R 44 491, 1980 R

8 BERINGER JE, BREWIN NJ, JOHNSTON AW 5
The genetic analysis of Rhizobium in relation to symbiotic nitrogen fixation
Heredity 45 161, 1980 R

9 BRILL WJ 5
Nitrogen fixation (Carlson PS, ed) *Biology of Crop Productivity*, New York Academic Press, 1980 p 53

10 LUDWIG RA 5
Regulation of Rhizobium nitrogen fixation by the unadenylylated glutamine synthetase I system
P Nas *Bio* 77 5817, 1980

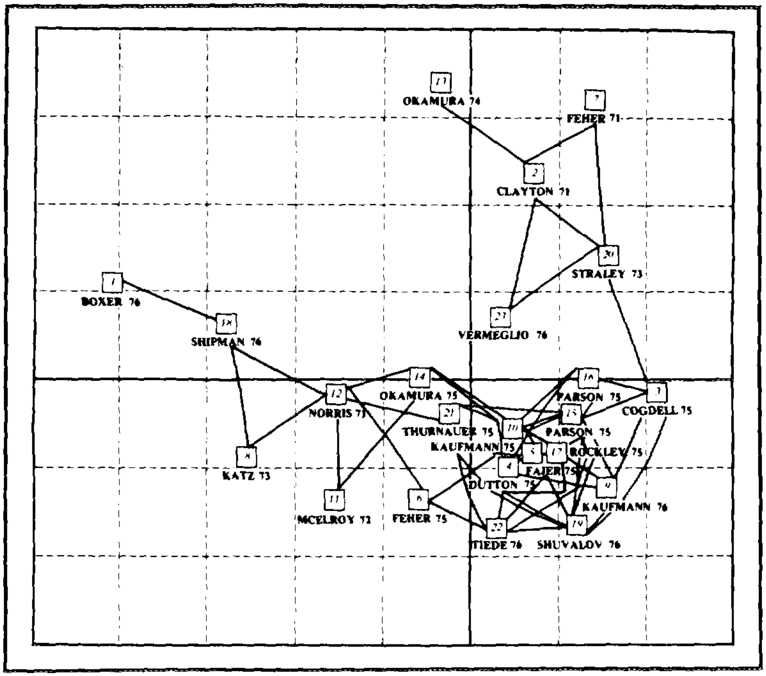
However, in the future the material will be even more timely since the clusters will be formed from 1979 data. For rapidly changing fields, the core will change each year.

Figure 4 presents a cluster map from another *Atlas* chapter entitled "Reaction Center of Photosynthetic Bacteria." For this and other more highly populated maps, we have added connecting lines showing co-citation linkages among documents. The distance between papers is inversely proportional to their co-citation strength. We think this provides an added dimension and clarity to the map. User reactions to these and other features are eagerly awaited. If you have any thoughts about this, or about anything else connected with the *Atlas*, please write to me directly. User feedback has always played an important role in the

Figure 4: **Sample *Atlas* cluster map showing co-citation linkages. Numbers in boxes identify core papers in the bibliography. Proximity of boxes in the map is an indication of subject similarity. The grid provides orientation.**

Specialty 46

REACTION CENTER OF PHOTOSYNTHETIC BACTERIA



☐ represents a core document Axes provide orientation
Proximity of ☐'s defines subject similarity

Cited Core Documents

		CF
1	BOXER SG, CLOSS GL Covalently bound dimeric derivative of pyrochlorophyllide A—possible model for reaction center chlorophyll *J Am Chem S* 98(17):5406-5408, 1976 L	19
2	CLAYTON RK, WANG RT Photochemical reaction centers from Rhodopseudomonas-spheroides *Meth Enzym* 23:696, 1921	22
3	COGDELL RJ, MONGER TG, PARSON WW Carotenoid triplet-states in reaction centers from Rhodopseudomonas-sphaeroides and Rhodospirillum-rubrum *Bioc Biop A* 408(3):189-199, 1975	23
4	DUTTON PL, KAUFMANN KJ, CHANCE B, RENTZEPI PM Picosecond kinetics of 1250 NM band of RPS-sphaeroides reaction center—nature of primary photochemical intermediary state *FEBS Letter* 60(2):275-280, 1975	35
5	FAJER J, BRUNE DC, DAVIS MS, FORMAN A, SPAULDIN LD Primary charge separation in bacterial photosynthesis—oxidized chlorophylls and reduced pheophytin *P NAS US* 72(12):4956-4960, 1975	41
6	FEHER G, HOFF AJ, ISAACSON RA, ACKERSON LC Endor experiments on chlorophyll and bacteriochlorophyl invitro and in photosynthetic unit *Ann NY Acad* 244(Apr15):239-259, 1975	24
7	FEHER G Some chemical and physical properties of a bacterial reaction center particle and its primary photochemical reactants *Photochem P* 14(3):373, 1971	23
8	KATZ JJ, NORRIS JR Chlorophyll and light energy transduction in photosynthesis *Curr T Bio* 5:41, 1973	25
9	KAUFMANN KJ, PETTY KM, DUTTON PL, RENTZEPI PM Picosecond kinetics in reaction centers of RPS-sphaeroides and effects of ubiquinone extraction and reconstitution *Bioc Biop R* 70(3):829-845, 1976	17
10	KAUFMANN KJ, DUTTON PL, NETZEL TL, LEIGH JS, RENTZEPI PM Picosecond kinetics of events leading to reaction center bacteriochlorophyll oxidation *Science* 188(4195):1301-1304, 1975	39
11	MCELROY JD, FEHER G, MAUZERAL DC Characterization of primary reactants in bacterial photosynthesis 1 Comparison of light-induced EPR signal (g = 2.0026) with that of a bacteriochlorophyll radical *Bioc Biop A* 267(2):363, 1972	18
12	NORRIS JR, UPHAUS RA, CRESPI HL, KATZ J Electron-spin resonance of chlorophyll and origin of signal-I in photosynthesis *P NAS US* 68(3):625, 1971	28
13	OKAMURA MY, STEINER LA, FEHER G Characterization of reaction centers from photosynthetic bacteria 1 Subunit-structure of protein mediating primary photochemistry in Rhodopseudomonas-spheroides R-26 *Biochem* 13(7):1394, 1974	22
14	OKAMURA MY, ISAACSON RA, FEHER G Primary acceptor in bacterial photosynthesis—obligatory role of ubiquinone in photoactive reaction centers of Rhodopseudomonas-spheroides *P NAS US* 72(9):3491-3495, 1975	24

Cited Core Documents *(cont.)*

		CF
15	PARSON WW, CLAYTON RK, COGDELL RJ Excited-states of photosynthetic reaction centers at low redox potentials *Bioc Biop A* 387(2) 265-278, 1975	27
16	PARSON WW, COGDELL RJ Primary photochemical reaction of bacterial photosynthesis *Bioc Biop A* 416(1) 105-149, 1975	47
17	ROCKLEY MG, WINDSOR MW, COGDELL RJ, PARSON WW Picosecond detection of an intermediate in photochemical reaction of bacterial photosynthesis *P NAS US* 72(6) 2251-2255, 1975	47
18	SHIPMAN LL, COTTON TM, NORRIS JR, KATZ JJ New proposal for structure of special-pair chlorophyll *P NAS US* 73(6) 1791-1794, 1976	25
19	SHUVALOV VA, KLIMOV VV Primary photoreactions in complex cytochrome-P-890, P-760 (bacteriopheophytin-760) of Chromatium-minutissimum at low redox potentials *Bioc Biop A* 440(3) 587-599, 1976	24
20	STRALEY SC Content and molar extinction coefficients of photochemical reaction centers from Rhodopseudomonas spheroides *Bioc Biop A* 305(3) 597-609, 1973	20
21	THURNAUER MC, KATZ JJ, NORRIS JR Triplet-state in bacterial photosynthesis – possible mechanisms of primary photo-act *P NAS US* 72(9) 3270-3274, 1975	21
22	TIEDE DM, PRINCE RC, DUTTON PL EPR and optical spectroscopic properties of electron carrier intermediate between reaction center bacteriochlorophylls and primary acceptor in Chromatium-vinosum *Bioc Biop A* 449(3) 447-467, 1976	18
23	VERMEGLIO A, CLAYTON RK Orientation of chromophores in reaction centers of Rhodopseudomonas-sphaerodies – evidence for 2 absorption-bands of dimeric primary electron-donor *Bioc Biop A* 449(3) 500-515, 1976	17

design of ISI products. Having just completed a lecture tour in which I discussed these same ideas, I know that we were remiss in leaving out the names of the institutions associated with each group of authors. However, it was also evident that this was not critical for those working in the field.

One innovative feature of the *Atlas* can be found in the very first pages. There's the usual table of contents to provide the user with page numbers for any research front covered in the volume. But accompanying the table is a foldout map of all 102 clusters, depicting the degree of "connectedness" between them. Each subspecialty on the map is identified by both its name and the cluster number assigned to it in the *Atlas*. The map presents a "global" view of biochemistry and molecular biology. I would not be surprised if it becomes a standard laboratory wall poster, much like those posters depicting the Krebs cycle.

These have been busy times for us here at ISI. The *Atlas* is part of a spate of new and innovative information tools. Recently, I described our new *ISI/BIOMED*™,[6] the online service that uses clustering techniques to provide researchers and physicians with a new way to access the biomedical literature. We have also announced that a new generation of citation indexes will soon be available for specific disciplines.[7] Although targeted at researchers in specialized branches of science, they will have multidisciplinary input, so that users can find articles of interest to them, even if they appear in nonspecialist journals. Our new *ISI/CompuMath*™ information system, which I will describe in a future essay, has as one of its components a discipline-oriented citation index. The other components are a *CC/CompuMath* edition, and an online *CompuMath* search service similar to *ISI/BIOMED*.

It is worth recounting the history of events in the development of the *Atlas*. For me, the story begins long before the creation of *SCI*. It goes back to the days when I was writing my first paper on the concept of citation indexing.[8] At that time, I was a graduate student at Columbia University School of Library Service. I had just completed two years of research at Johns Hopkins University. Thanks to the help of Dean Carl White, I became the first Grolier Fellow sponsored by the *Encyclopedia Americana*. Shortly afterward, I even served as a consultant to the *Encyclopedia Americana* on methods of mechanizing their indexing procedures. It was there that I realized the intimate connection between scientific indexing and encyclopedism. That's when I first thought about an encyclopedia of science based on a new approach to classification, and a new approach to essay compilation.

Any practical application of these ideas had to await the development and implementation of *SCI*. This multidisciplinary tool freed researchers from the arbitrary classification schemes of traditional subject indexes.[9] The first *SCI* became commercially available in 1964, but it had been apparent long before then that the data base we were compiling could and would be used for much more than producing indexes.

For one thing, the information contained in *SCI* allowed us to use citation frequency as a method of identifying the significant papers of science. This is important, for if one is to describe a given research specialty "structurally," one must first identify key papers that contributed to its development.

But also residing in the design of *SCI* were the seeds for developing large-scale, computer-mediated classifications of "knowledge." As early as 1963, I asserted that citation indexing provided an objective method for defining a field of inquiry.[9] That same year, Derek Price declared that the study of citation relationships among documents might allow us to view the structure of science in geographic terms, "in which the parts of science are conceived as mapped like a territory."[10] It is ironic that *SCI*, a tool that broke down disciplinary barriers to information retrieval, would now be used to objectively identify and isolate specific research disciplines.

In 1964, I, along with Irv Sher and Richard Torpie, authored a study which showed the citation linkages within the cumulative research that led to the discovery of the DNA code.[11] It was our purpose to demonstrate how citation analysis can be useful in studying the history of science, which is why we called our diagram of DNA research an "historigraph." But while the methodologies may be different, there is essentially no conceptual difference between diagraming the long-term history of a scientific field such as molecular biology, and producing current maps of the different research fronts which, at any given moment, now make up the broad area of molecular biology.

In 1963, Michael Kessler described his technique of bibliographic coupling for identifying areas of scientific inquiry.[12] It was his view that the number of references a given pair of documents have in common is a measure of the similarity of their subject matter. Papers strongly associated in this way are likely to fall within the same "discipline." The problem with bibliographic coupling, however, is that it is a fixed measure—a paper's references do not change. But the structure of science is dynamic over time.

The measure of co-citation strength used in our *Atlas* is a creative reversal of Kessler's bibliographic coupling. It was first described in papers by ISI's Henry Small and Belver Griffith, Drexel University.[13-15] That work showed that the structure of science can indeed be objectively described. It should be mentioned that the Soviet researcher I.V. Marshakova later independently arrived at co-citation clustering to describe the laser literature.[16] The work by Small and Griffith was the last theoretical rivet needed to get our flying machine off the ground. It was from that point on that I began promising *CC* readers that an atlas of science would someday become a reality.

Before that could happen, we had to learn a great deal more about techniques for naming clusters and mapping them. We had to observe how maps change from year to year and to test whether they did in fact reflect the reality of ongoing research. Even now, there are many who question the validity of these techniques. This is partly why we looked for specialist reviewers to help validate our data. But Small and others have found a remarkable correlation between the core papers in chemistry and other fields identified by co-citation analysis and subjective accounts of the important papers in the field from researchers.

The *Atlas* will be the end result of years of research and development here at ISI. For most of this time, its development was the responsibility of Anthony Cawkell, ISI's former vice president for research. The task of naming the clusters for each new year of data was performed primarily by Beta Starchild, former research associate. Her intimate involvement with, and wild enthusiasm for, the project made her a key figure in its development. Starchild received assistance from a number of people, including my son Joshua. Working on the *Atlas* was Joshua's first project at ISI.

It is important to note here that from the first, the *Atlas* was visualized both as a tool in its own right and also as an adjunct to *SCI.* The *Atlas* will provide the librarian and others with a way to identify the key papers for entry into the citation index. Since it includes our newly-named clusters for each year, it becomes a classified directory to supplement the alphabetical arrangement of the same citation indexes. While the library profession has yet to recognize the significance of these methods for automated ongoing classification, it will become increasingly apparent. The online version of the *Atlas,* minus the essays and maps, is implicit in *ISI/BIOMED.* In later versions of our online systems, we expect to include the minireviews. There is no technical reason why we could not include the maps as well.

Everyone involved in the production of the *Atlas* was excited by the incredible accuracy of the data and by the rapidity of retrieval this product offers. In many ways, the *Atlas* combines some of the best features of several ISI products. It offers the depth and flexibility of *SCI.* While it may never be as current as *CC,* the essays that accompany the cluster maps provide a current and comprehensive view of each field. When the number of essays reaches a critical mass, it will indeed become the "Encyclopedic Atlas of Science." This is only a matter of time. With a minimum of luck and lots of education, I believe that the *Atlas* will prove especially useful to students and experts alike. While I do not view it as an ending, it is for me a culmination of my chief vision for the World Brain.[17]

I refer to this *Atlas* as a prototype. As such it is lacking in certain respects that will be overcome once the production of minireviews has become a routine procedure. These "experimental" essays were written under different conditions and time restraints than will apply when we are producing the service regularly.

Any reader who has followed the various descriptions of our clustering procedures may wonder why we didn't use the 1980 *SCI* to create our file of research fronts. There is no question that important changes in biochemistry have taken place in the period 1978 to 1980. For example, if you look for the research front on nitrogen-fixation by rhizobia in Figure 2, you may not find it as such in *ISI/BIOMED* for 1980. There are, however, several newly named and closely related research fronts involving nitrogen-fixation and rhizobia. The same is true for the cluster on photosynthetic bacteria.

Had we been able to produce the *Atlas* in the spring of 1979, the list of core papers would have been identical to the core you now see, but the list of current citing papers would have been limited to 1978 papers. Since we were unable to produce these essays so promptly, we realized that the *Atlas* would not have as much impact unless citing papers from 1980 were included. So we decided to bring the data for these specialties up to date, without reclustering.

If this sounds like an apology it is not. The specialties are certainly legitimate and current for 1981. All that has changed is the degree of specialization or branching that occurs in the fastest moving fields.

The *Atlas* will become available this month. It will cost $45.00 for individuals, and $90.00 for institutions. Those interested in purchasing a copy should contact Marketing Services, ISI, 3501 Market Street, University City Science Center, Philadelphia, Pennsylvania 19104.

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My thanks to Thomas Di Julia for his help in the preparation of this essay.

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*Reprinted in: **Garfield E.** *Essays of an information scientist.* Philadelphia: ISI Press, 1980. 3 vols.