R. B. Woodward

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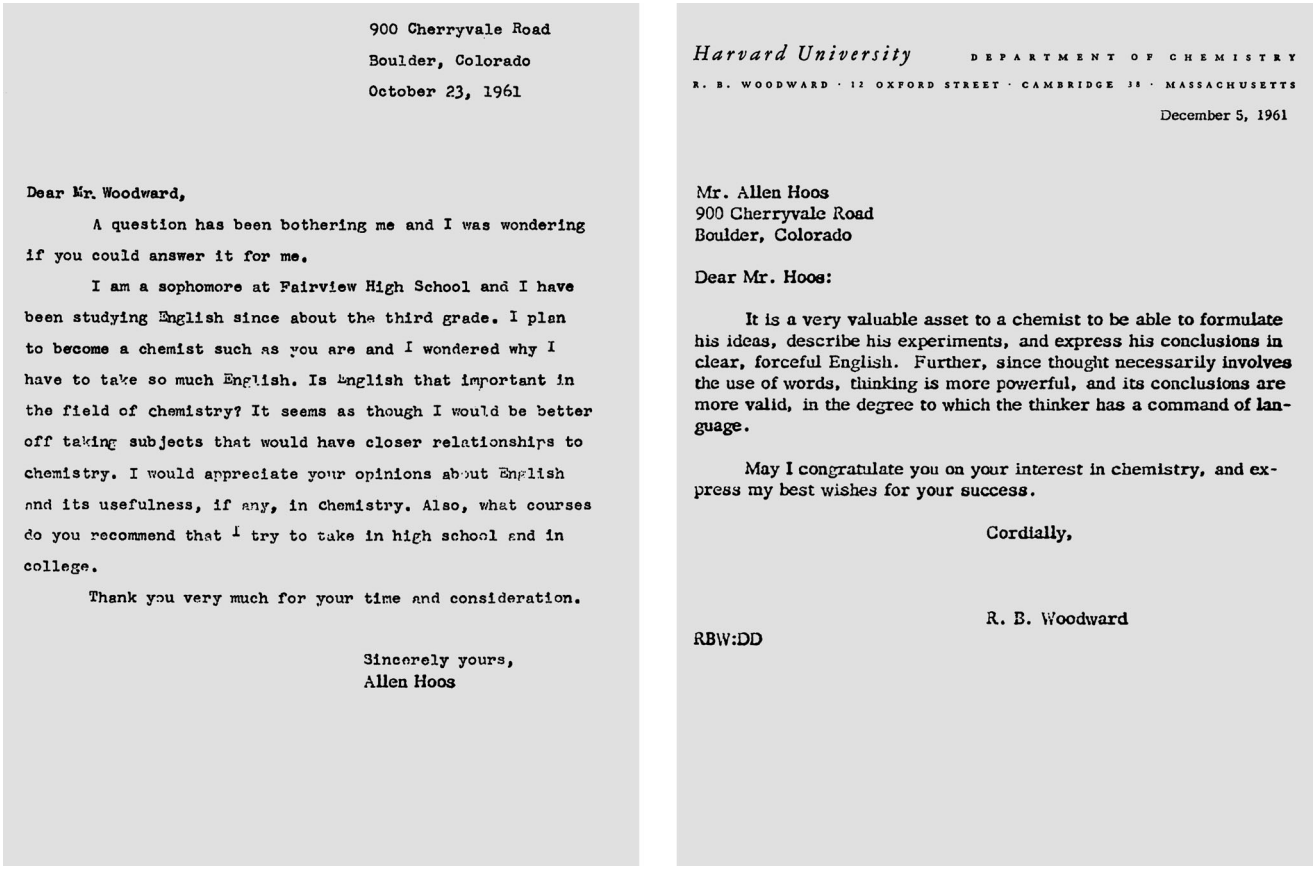
# Woodward's Words: Elegant and Commanding

*Jeffrey I. Seeman**

*Dedicated to O. Theodor Benfey and Peter Morris on the occasion of Benfey's 90th birthday and Morris's retirement from the Science Museum (London)*



900 Cherryvale Road
Boulder, Colorado
October 23, 1961

Dear Mr. Woodward,

A question has been bothering me and I was wondering if you could answer it for me.

I am a sophomore at Fairview High School and I have been studying English since about the third grade. I plan to become a chemist such as you are and I wondered why I have to take so much English. Is English that important in the field of chemistry? It seems as though I would be better off taking subjects that would have closer relationships to chemistry. I would appreciate your opinions about English and its usefulness, if any, in chemistry. Also, what courses do you recommend that I try to take in high school and in college.

Thank you very much for your time and consideration.

Sincerely yours,
Allen Hoos

*Harvard University* DEPARTMENT OF CHEMISTRY
R. B. WOODWARD · 12 OXFORD STREET · CAMBRIDGE 38 · MASSACHUSETTS

December 5, 1961

Mr. Allen Hoos
900 Cherryvale Road
Boulder, Colorado

Dear Mr. Hoos:

It is a very valuable asset to a chemist to be able to formulate his ideas, describe his experiments, and express his conclusions in clear, forceful English. Further, since thought necessarily involves the use of words, thinking is more powerful, and its conclusions are more valid, in the degree to which the thinker has a command of language.

May I congratulate you on your interest in chemistry, and express my best wishes for your success.

Cordially,

R. B. Woodward

RBW:DD

***Figure 1.*** Letters[1,2] courtesy of Harvard University Archives and the family of R. B. Woodward.

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This paper is a sequel to my three previously published papers in the "Words" series: "Gilbert Stork: In his Own Words and in the Musings of His Friends";[3] "Carl Djerassi: In His Own Words";[4] and "John D. Roberts: In His Own Words and Those of His Friends."[5] Those papers celebrated Stork's and Djerassi's 90th birthdays and Roberts's 97th birthday. This paper celebrates the literature of R. B. Woodward, over and above his intellectual and chemical contributions to science.

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## Introduction

Writing a scientific paper involves a process that is inherently paradoxical.

On the one hand, each publication is inherently unique. Authors want to display their own research achievements, differentiate themselves from their peers, and seek distinction and identification. On the other hand, many influences funnel the style of scientific publications into a similar pattern,[6] though calls for more diversity and personality in scientific writing have been made.[7–9] In many disciplines, authors are discouraged from writing papers that go beyond information transfer so as not to include beauty and wit in their text.[10]

Books have been written to guide publication style for almost 50 years.[11,12] The American Chemical Society, the world's largest scientific society and publisher of numerous journals, has published *The ACS Style Guide* in several editions since the 1990s.[13] Journals promulgate standards that are policed by reviewers, editors, and journal production staff. Journal editors quietly but powerfully act behind the scenes to control content and style in contrast to their (the editors) being visible in the pages of their journals as they were in the 19th century.[14] Researchers imitate what they see in journals, especially mirroring the styles of their role models. Scientists also assume the styles of their Ph.D. and postdoctoral advisors with whom they first published.

In 1960, Louis F. Fieser and his wife Mary Fieser—the famous "Fieser and Fieser" team, both from Harvard—published a *Style Guide for Chemists*.[12] Given the large number of textbooks published by the Fiesers as well as the series of *Fieser and Fieser's Reagents for Organic Synthesis* now having 28 volumes, it is not surprising that they would be considered experts in style. Among their most poignant recommendations were:

- "Use short words and simple sentences."
- "We chemists are not concerned with creative writing, nor do we aspire to any real artistry."
- "One approach which is to be avoided is narration of the whole chronology of work on a problem."
- "A paper should review the work as it appears in retrospect, and not as it appeared at various stages of completion."
- "Any simplification that can be achieved will certainly increase clarity…"
- "Inclusion in a paper of an abundance of lengthy footnotes is probably a mistake…"
- "E. B. White's 'first piece of advice is this: to achieve style, begin by affecting none—that is, place yourself in the background.' Most writers of scientific papers will do well to follow this advice not only at the beginning but for keeps. We do not want our personality to emerge in our writing …"[12]

On rare occasions, a scientist comes along whose personality, status within the relevant community, knowledge base, and communication skills result in publications that stand apart from the normal scientific style. Robert Burns Woodward (April 10, 1917–July 8, 1979, Figure 2) was such a person. Woodward's chemical legacy (see Figures 3 and 4 and a previously published discussion of his contributions to physical organic chemistry[15]) is memorialized by his publications. In his published papers, Woodward divorced himself from the science and styles of his predecessors, that is, pre-1940s. Indeed, Woodward often displayed the opposite of Fieser and Fieser's edicts. It may amaze many of the younger generations of chemists that the renowned Woodward actually published less than 200 scientific papers, far fewer than many of his contemporaries and a fraction compared to the numerical output of today's most prolific chemists.

***Figure 2.*** Woodward at the Woodward Research Institute, Basel, Switzerland, 1972. Photograph courtesy of Novartis.

Woodward wrote in the "grand or high style," a form of writing that is classical in its rhetorical style. This style is figurative, emblematic, and highly ornate with a heightened emotional tone evoking strong feelings in the reader. This style often is characterized by its nobility and poetic nature. The grand style is intended to convey information, to persuade by its expressiveness and spirit, and to entertain and impress the reader, especially the scholar.

Why did Woodward write in the grand style? The evidence—that he wrote spontaneously; drafts were often final versions—indicates that he simply wrote in the style that was natural for him. I do not believe that he worked hard to adopt a style that he admired but that was foreign to him. Nor do I believe he expected others to emulate his style of writing, any more than he expected others to adopt his style of research or research management or his sense of humor. Further, I don't think he thought about his writing style, one way or the other, though he certainly planned in great detail other aspects of his scientific communications (e.g., the graphics and his lectures) and his public persona.

Woodward's mother, Margaret née Burns Woodward, was a native of Glasgow. His father Arthur Woodward was of English antecedents. Woodward was likely named after Robert Burns, the Scottish poet and lyricist. Four of Woodward's closest friends, Derek Barton, Jeremy Knowles, William Moffitt, and Alexander Todd, were British. And Woodward visited England quite frequently. According to the

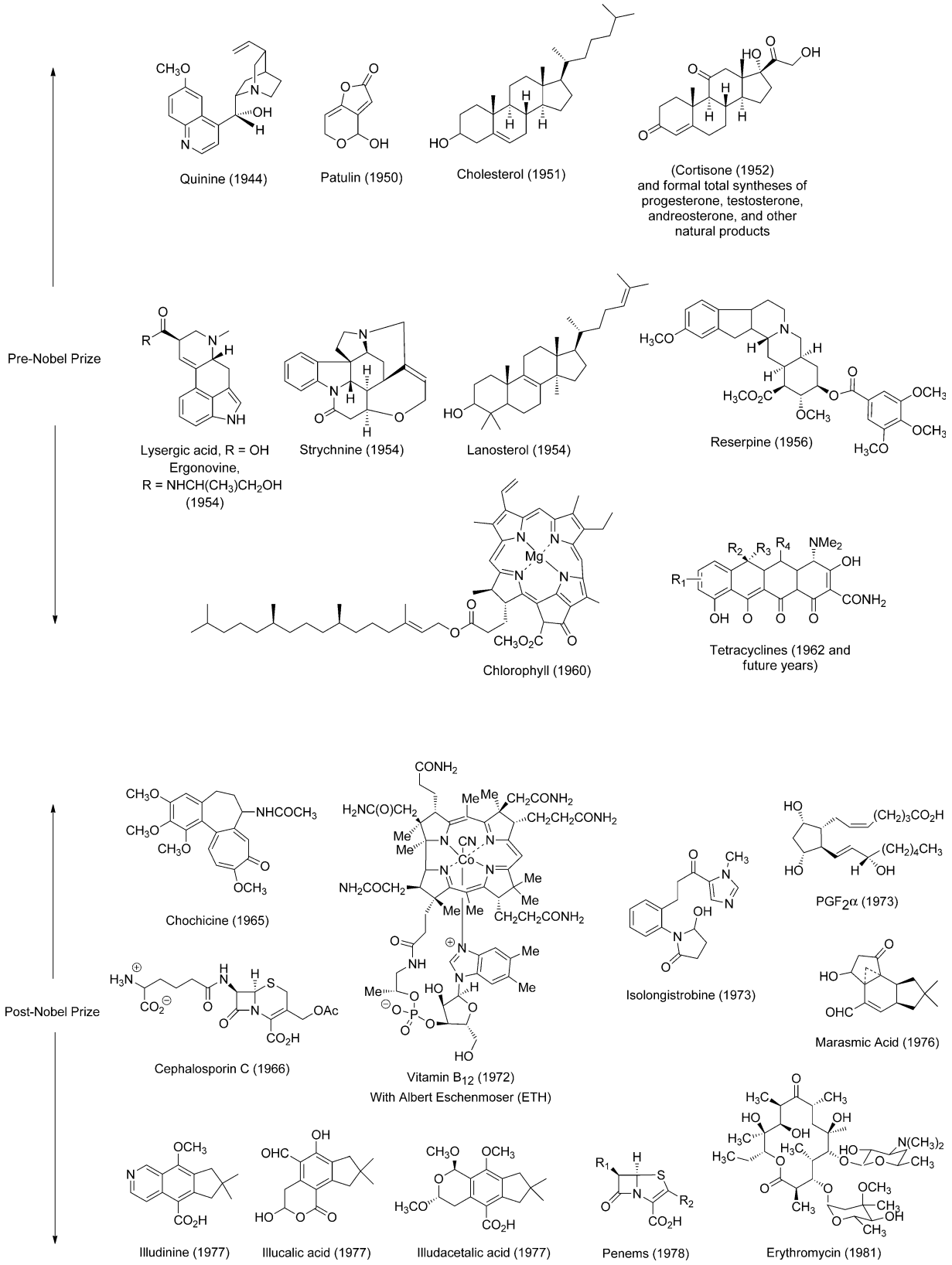



***Figure 3.*** Selected total syntheses reported in the literature by R. B. Woodward with colleagues at Harvard; at the Woodward Research Institute in Basel, Switzerland; with Albert Eschenmoser and his group at the ETH in Zürich; and in industry.

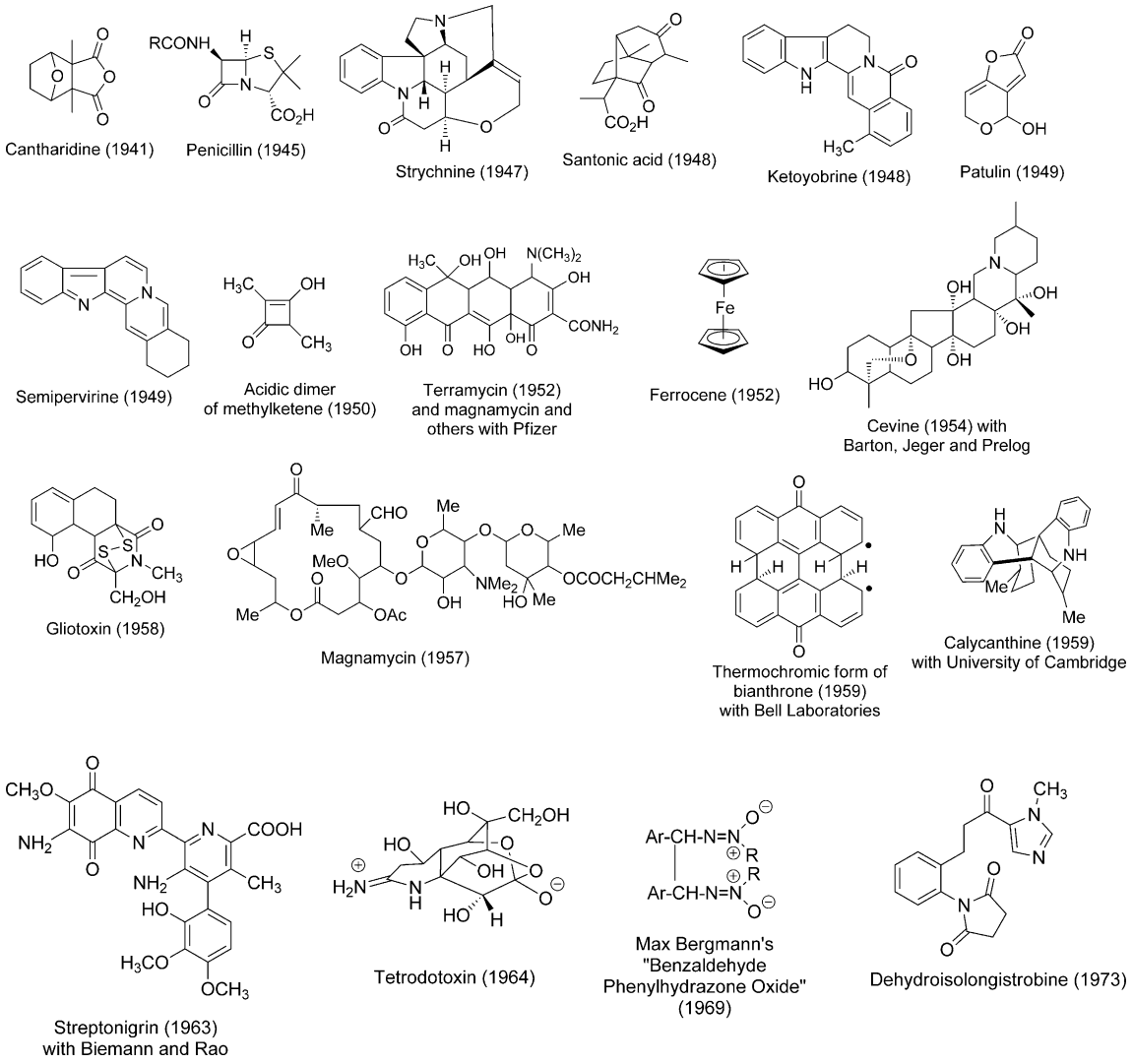



***Figure 4.*** Selected natural product structure determinations reported in the literature by R. B. Woodward with colleagues at Harvard; at the Woodward Research Institute in Basel; Switzerland; and in industry.

British historian of chemistry Peter Morris, "Woodward cherished what he as an American of British descent considered to be time-honored (if perhaps quaint) British traits such as the yard being the length of the King's arm, classical honorary degree ceremonies, and using Latin phrases in one's own lectures."[16] Woodward's writing clearly reveals him as a romantic and an Anglophile.

Likely, few chemists not of Woodward's generation have read his papers and thus experienced his writings. What follows herein is a treat: a smörgåsbord of the scientific words of R. B. Woodward.[17] Perhaps this paper will serve as a teaser, to entice the reader to experience more of Woodward's words firsthand.

*In the text that follows, narration by the chemist historian [JIS] is presented in italics.*

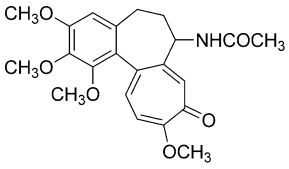
## Woodward's Love of Chemistry and Molecules

*Woodward's love of chemistry translated directly to his love for many of the molecules he studied. Woodward built a relationship with many of his molecules, and in doing so, he personalized them, using anthropomorphic expressions. This is perhaps best illustrated by his relationship with the isothiazole ring which played a critical role in Woodward's total synthesis of colchicine.[18] In this excerpt, Woodward speaks of the isothiazole ring as if it were one of his closest and dearest friends who passed away after a too-short but rich life, an anthropomorphic moment of high drama and touching sincerity.*

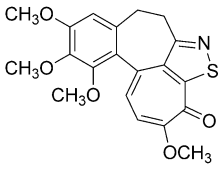
Isothiazole

[1965] "Our investigation now entered a phase which was tinged with melancholy. Our isothiazole ring [in **1**] had served admirably in every anticipated capacity, and some others as well. … [I]t had enabled us to construct the entire colchicine skeleton, with almost all of the needed features properly in place, and throughout the process, it and its concealed nitrogen atom had withstood chemical operations, variegated in nature, and in some instances of no little severity. It had mobilized its special directive and reactive capacities duti-

fully, and had not once obtruded a willful and diverting reactivity of its own. Now, it must discharge but one more responsibility—to permit itself gracefully to be dismantled, not to be used again until someone might see another opportunity to adopt so useful a companion on another synthetic adventure. And perform this final act with grace it did."[18]




Colchicine

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"I actually remember that paragraph from reading the paper when I was an undergrad. It is partly why I switched my major from biology to chemistry. Organic chemistry seems to be alive when described so poetically!"
—Anonymous academic chemist (2016).

*For Woodward, chemistry was his life. His writings reflect his joys and his frustrations. Sharing his chemistry was deeply personal. Woodward allowed his personal views and his personal enthusiasms (for compounds, crystals, and beauty) to infuse his writings. To Woodward, crystallization was a magical chemical process and crystals were beauty and joy.[19] No doubt this is reflected by the name of his third child, Crystal.*

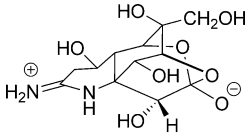
[1963] "Not infrequently it is possible to introduce delightful elements of surprise into synthetic work. An apparently rather dull grouping of atoms suddenly, under the impact of especially chosen reactants, undergoes unusual transformations which are of great utility in progress toward the objective. The impact on an observer may perhaps be compared with that on the traveler down an uninteresting street, who turns through a small hidden doorway into a delightful and charming garden. This kind of satisfaction in chemical synthesis is by its nature suited only for the special delectation of the initiated, and its pleasures are, alas, not transferable to those not fortunate in the possession of detailed chemical knowledge. I am confident that the chemists who read this will share my regret that non-chemists who may venture this far cannot savour with me anew the delights of this short sequence of operations…"[20]

[1965] "Crystallization is one of the most beautiful processes known, and no true chemist fails to experience a thrill when he brings a new form of matter into the crystalline state for the first time."[20]

[1965] "Each of the intermediates along our progression to the colchicine molecule is a beautifully crystalline substance, an entirely new form of matter, persuaded into being in response to the challenge of an often remote objective. It is delightful to work with such things, and the delight which the experimenter experiences in his manipulation contributes in no small measure to the skill required to create them."[18]

*To receive praise from one's Ph.D. advisor, especially if that advisor was R. B. Woodward, is a marvelous gift. To have your professor name an intermediate in a total synthesis after you is novel and momentous, especially since "compounds are seldom named after a person."[21] "The naming of compounds after his students touches on another aspect of Woodward, a sly playfulness," comments Hoffmann.*

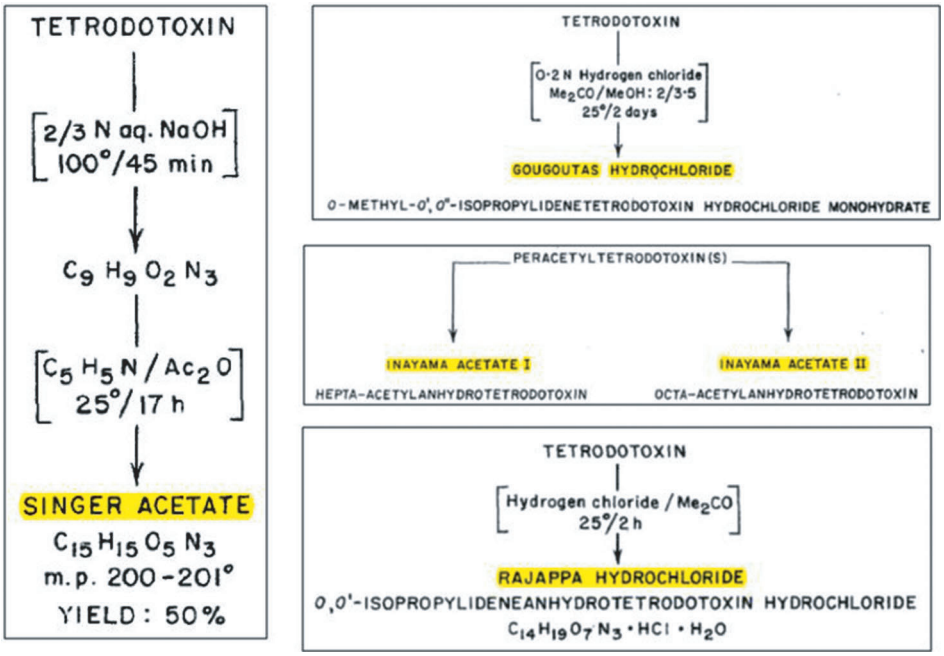
[1964] "Tetrodotoxin is not a substance which yielded easily the crystalline derivatives which were the indispensable cornerstones of our work. From time-to-time in this lecture I have given these latter eponymous designations which permitted me to express in a concise way my affection both for the compounds, and for the men who played the major rôles in the adventure I have described here—Mr Jack Gougoutas, Dr Seiichi Inayama, and Dr Srinivasachari Rajappa. The very valuable early work of Mr Abraham Singer has also very deservedly been eponymized…"[22] [The yellow highlights within the boxed graphics have been added for emphasis.]




Tetrodotoxin

"I think it was around the middle of December 1963 that I succeeded in getting this crystalline hydrochloride; I was elated, but I repeated the experiment a second time to make sure of my result, collected the crystals and kept them under the microscope before informing RBW. He was skeptical at first because he had encountered several such claims for crystalline derivatives earlier, but one look at the microscope, and he was so happy!

The first intimation I got about naming the substance after me was when RB gave me a copy of the lecture he was planning to give at the Kyoto IUPAC meeting. Naturally, I turned to the acknowledgement page first, and came across the words 'eponymous designations.' I had no clue what eponymous meant! So, that evening I quietly went to the Converse library and was trying to locate the word in the dictionary. Just as I




found what I wanted, I heard a faint rustle behind me, turned and to my great embarrassment, found RBW standing there watching me!!!

RBW, of course, never published this work; so this association of my name with the 'anhydro hydrochloride' serves as the only way by which other scientists would get to know of my contribution to this problem."
—Srinivasachari Rajappa (2015)

*Slurvian: "Speech characterized by slurring."* (Merriam–Webster)

[1968] "… compound [**1**], which we have more-or-less jocularly dubbed 'α-corrnorsterone'. The 'corr' in this appellation represents our hope that the substance is destined one day to be transformed into a corrin; the 'norsterone' devolves from the fact that [**2**] is a ketone whose skeleton is that of a norsteroid if the nitrogens be ignored; and finally, if the name be pronounced in Slurvian, it becomes 'cornerstone'!"[23] (Figure 5).

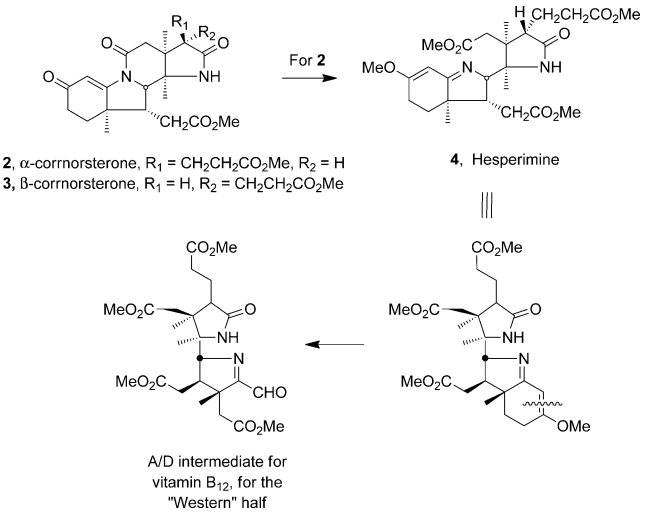


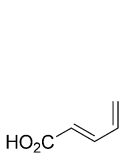

***Figure 5.*** Structures from Woodward's 1968 *Pure and Applied Chemistry* article on the synthesis of vitamin $B_{12}$. Of particular interest is Woodward's naming of the newly synthesized compounds. "Hesper \he(s)-per\ is pronounced HESS-per. It is of Greek and then Latin origin, meaning "western."

[1969] "When β-corrnorsterone [**3**] is treated with methanolic hydrogen chloride, the ring is cleaved and [**4**] hesperimine is produced. … I may perhaps interject a few comments upon our adoption of the name 'hesperimine'[Figure 5] … It has been a loose but fairly consistent practice of the Zürich group [Eschenmoser, et al.] to refer to the B/C moiety of the vitamin $B_{12}$ molecule as the 'eastern' half, and the A/D area as the 'western' part. By contrast, Cambridge custom has tended to utilize the terms 'right' and 'left'. In such trivial affairs consistency is hardly a matter of moment, and we need not cavil at the action of the Zürich group in adopting the name 'dextrolin' for the B/C building block which they first succeeded in constructing. When in Cambridge, more tardily, the A/D intermediate [**4**] became available, the prior onomastic action of the Zürich group suggested some such designation as 'sinistraline' for the new intermediate. But reference to the Oxford English Dictionary gave reason for pause; listed under 'sinister' and 'sinistral' was a most formidable array of ominous correlatives: prejudicial, unfavorable, evil, bad, base, pertaining to misfortune or disaster, adverse, unlucky, unsound, and many others. Some bolder spirits would not have hesitated to attach a name with such inauspicious connotations to our previous and hard-won substance, upon which much in the way of hope still needed to be placed, but more superstitious counsel prevailed and the

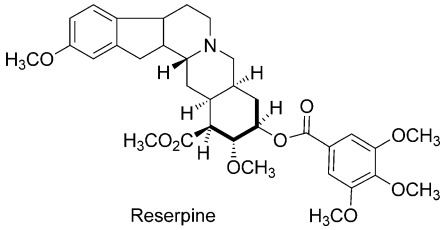
  

designation 'hesperimine' was adopted. So, in a way each of the groups paid a subtle compliment to the other."[23]

[1963] "I myself take special pleasure in a particular architectural aspect of chemical synthesis which is rather hard to name and define, but which might be loosely designated as the systematic aggrandizement of asymmetry. Most of the molecules of complicated naturally occurring substances represent highly asymmetric arrays, whereas the simpler starting materials which form the basic building blocs for their synthesis are much less obviously disordered in structure. None the less, any degree of asymmetry, however small, may be used to direct a chemical combination in one, rather than another, of two possible directions. The problem of synthesis then is often to multiply this directional function, making it more cogent with each succeeding step, until the small geometic differences which existed at the outset have been developed into the greatly unsymmetrical situations represented by the final product. The situation may be illustrated, if perhaps not easily apprehended, by noting that all of the highly asymmetrical elements of the complicated reserpine molecule were brought into their ultimate fixed special [sic] orientations by the gradual development and aggrandizement of the very small element of asymmetry present in only one simple building block—the *trans* vinylacrylic acid whose atoms occupy, in the final reserpine structure, the positions shown by the heavy lines."[20]

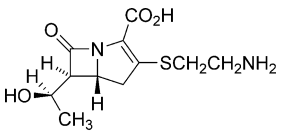


*trans*-Vinyl acrylic acid



Reserpine

[1980] "In constructing thienamycin, has Nature utilized the millions of years available to her, to endow the carbapenem nucleus with substituents which modulate the inherent activity of the nucleus in a manner upon which we cannot improve? We may doubt it. But we may not doubt that the chemist will accept the challenge provided by these fascinating new nuclei, and explore the opportunity to prepare new and perhaps superior antibiotics." [24]

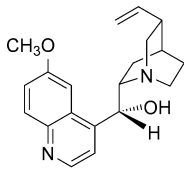


Thienamycin

## *Differences between the Reality of Chemistry and Uninformed Views of How Science Is Done*

*"The adjective* 'Brobdingnagian' *has come to describe anything of colossal size" after the fictional land Brobdingnag occupied by giants. From* Gulliver's Travels *(1726) by Jonathan Swift. (Wikipedia)*

[1963] "Why can the chemist not take the requisite numbers of atoms and simply put them together? The answer is that the chemist never has atoms at his disposal, and if he had, the direct combination of the appropriate numbers of atoms would lead only to a Brobdingnagian potpourri of different kinds of molecules, having a vast array of different structures. … [C]hemical syntheses, at least if the target is at all complicated, never conform to the popular picture, which has it that though the chemist may have to perform many hundreds of experiments before he finds the magic formula, he finally discovers that if he mixes the right things together, in the right kind of pot, he succeeds in producing, say, synthetic quinine." [20]

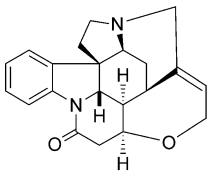


Quinine

## *The Use of Rhetoric*

*Woodward's longest and closest collaborator, due to their years together on vitamin $B_{12}$, was Albert Eschenmoser, who recalls the first sentence in Woodward's total synthesis of strychnine,*

"The exclamation mark. Not 'STRYCHNINE.' But rather 'STRYCHNINE!' I remember the effect of that exclamation mark when I read that paper for the first time in 1963: it was the most extreme deviation from convention in Woodward's scientific writing. There is hardly any other example in the chemical literature, where joy, pathos and emotion of the author reveals and expresses itself so openly and so dramatically by a single little mark. This was Woodward pure."[25] —Albert Eschenmoser (2015)

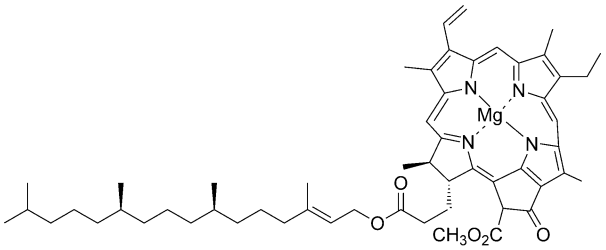


Strychnine

[1963] "STRYCHNINE! The fearsome poisonous properties of this notorious substance attracted the attention of XVIth century Europe to the *Strychnos* species which grow in the rain forests of the Southeast Asian Archipelagos and the Coromandel Coast of India, and gained for the seeds and bark of those plants a widespread use for the extermination of rodents, and other undesirables, as well as a certain vogue in medical practice—now known to be largely unjustified by any utility. The isolation of the pure alkaloid from the beans of *Strychnos ignatu* in 1818 by Pelletier and Caventou was an event of some historical importance, in that it provided

a convincing and elegant demonstration of the correctness of the then only recently proposed and revolutionary suggestion that acid-fixing substances are produced in the vegetable kingdom. Thus did circumstance early place ready at the hand of any interested chemist an abundant supply of a pure crystalline compound whose constitution and construction could hardly fail to excite curiosity. But organic chemistry, in its first hundred years, was scarcely equipped for the attack on so formidable an objective. …"[26]

[1961] "Chlorophyll *a*, the major green pigment of the plant world, is certainly the most widespread and conspicuous of organic natural products. Few can be unaware of its decorative function, and all are beneficiaries of its central role in transforming sunlight into substance and sustenance. Yet the fruitful chemical study of this green badge of life did not commence until fairly recent times. For chlorophyll *a* is a very reactive, sensitive, and complicated substance…. Neither was succor or control sought in chemical principle, nor was any attempt made to place the often striking observations in any generalized framework. Would the conclusions from such a study stand scrutiny from the viewpoint of the present day? Was the structure proposed for chlorophyll correct? When we embarked upon the examination of these questions, we entered a chemical fairyland, replete with remarkable transformations which provide unusual opportunities for the testing and further development of principle, and we cannot but urge others to follow us in penetrating what must have seemed to many the monolithic wall of a finished body of chemistry."[27]




Chlorophyll

## Woodward's Philosophical and Historical Writings

[1956] "In the century that has passed since Berthelot's words were uttered, organic chemistry has literally placed a new Nature beside the old. And not only for the delectation and information of its devotees; the whole face and manner of society has been altered by its products. We are clothed, ornamented, and protected by forms of matter foreign to Nature; we travel and are propelled in, on, and by them. Their conquest of our powerful insect enemies, their capacity to modify the soil and control its microscopic flora, their ability to purify and protect our water, have increased the habitable surface of the earth and multiplied our food supply; and the dramatic advances in synthetic medicinal chemistry comfort and maintain us, and create unparalleled social opportunities (and problems). We do not propose to examine this vast domain in detail, or to prognosticate the direction of its advance, in response to the need, desire, and fancy of man. We shall leave it that the evidence is overwhelming that the creative function of organic chemistry will continue to augment Nature, with great rewards, for mankind and the chemist in equal measure."[28]

## Military Metaphors

*K. C. Nicolaou referred to Woodward as "General."[29] Woodward was also a romantic, a scholar in military history[30] and an admirer of the classics. It is logical that Woodward would use military language often, as part of his grand style. He presided over armies of students, colleagues, and admirers. Two examples of "General" Woodward follow (Figure 6). By way of background, the Battle of Berezina (or Beresina) took place from 26 to 29 November 1812 between the French army of Napoleon and the Russian army. The battle ended with a mixed outcome. The French suffered very heavy losses but managed to cross the Berezina River (near Borisov, Belarus) and avoid being trapped. Since then "Bérézina" has been used in French as a synonym for "disaster." (From Wikipedia)*

***Figure 6.*** R. B. Woodward, in his standard dress of blue suit and tie, with Vladimir Prelog (left) and Carl Djerassi, Riga, June 1970. Photograph courtesy Carl Djerassi. The author has also seen this photograph in the Woodward archives at Harvard and in Prelog's photograph collection in Zürich.

[1955] "Modern organic chemistry possesses a splendid and powerful armamentarium for the attack on the problems which excite the attention of its devotees. From time to time here mention has been made of some of these weapons, and it is certainly worth emphasizing that this campaign could not have been concluded without constant use of the very great body of principle and mechanism which our theorists have placed at our disposal, and without the beautiful physical tools which we now have. But in one respect, organic chemistry has not changed, nor is it likely to. Its successes depend in the first instance upon the experimental skill and devotion of the men who do the work. DR. MICHAEL P. CAVA spent the better part of a year in the exploratory phases of this

work, and was then joined in an intensive effort of another year's duration by DR. W. DAVID OLLIS and DR. ALFRED HUNGER … DR. KARL SCHENKER and DR. HANS DAENIKER—the Beresina group; for it was of this gallant band of Swiss, thrown into the breach of a famous and desperate occasion, that DR. SCHENKER thought, when, arriving in the midst of the difficult campaign against Ring VI, he learned his fate for the months ahead. All of these men worked indefatigably, with great skill, and forbearance of a hard taskmaster. It is a very great pleasure to have the opportunity here to point out that the merit in this work is theirs in large measure, and to acknowledge my immeasurable debt to them."[31]

[1961] "Fresh from his dramatic conquest of the blood pigment, [Hans] Fischer hurled his legions into the attack on chlorophyll, and during a period of approximately fifteen years, built a monumental corpus of fact. As this chemical record, almost unique in its scope and depth, was constructed, the molecule was transformed and rent asunder in innumerable directions, and the fascination and intricacy of the chemistry of chlorophyll and its congeners was fully revealed."[27]

## A Herd of Words

*Some chemists, admirers of Woodward's syntheses, would say of his writings, "Too much". Some would just smile and say, "So Woodwardian." But it was clear to absolutely everyone that the quality of his science was such that his linguistic excesses, if perceived as such, were viewed with admiration. Only Woodward could get away with it.*

[1954] "Strychnine… The tangled skein of atoms which constitutes its molecule… "[32]

[1965] "… an exciting and significant aspect of synthetic activity… one which is more readily—and I dare say more effectively—exemplified and epitomized than it is articulated and summarized."[33]

[1973] "a felicitously placed carboxyl group, a double bond of good augury for the introduction of oxygen atoms… "[34]

[1963] "The next stage in our work represented a welcome relaxation from the strenuous efforts required to master the intricacies attendant upon the construction of our fourth ring, and a useful respite before a further phase of our investigation which would again put our experimental capacity to a severe test. … This easy statement should not be allowed to conceal the formidable effort which was required to bring us to a favourable outcome."[35]

[1964] "While our measurements must be interpreted with the reserve which respect for the long arm of coincidence should always engender, they provide at present no evidence of delocalization among the π-electron systems of the double bonds of triquinacene in the ground state."[36]

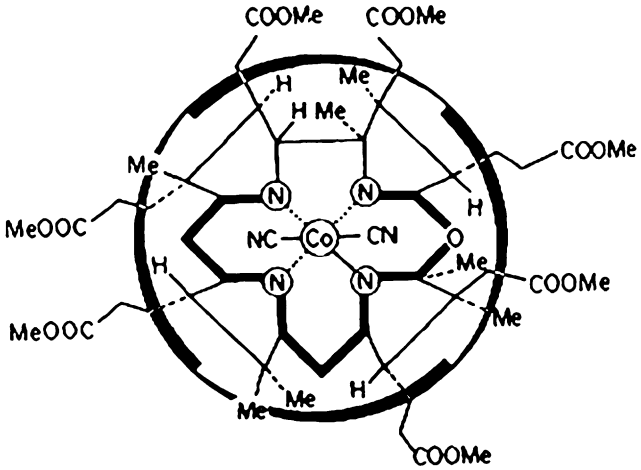
Triquinacene

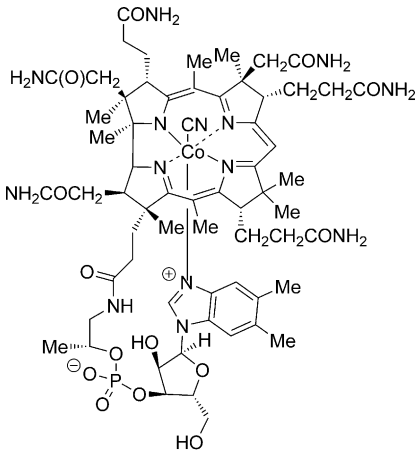
[1964] "The appearance of the array in the tetrodotoxin molecule presents a clear lesson for the future in its intimation that if normally non-interacting groups are appositely attached to a rigid skeleton, or otherwise brought into forced proximity, they may be expected to co-operate in the formation of structural groupings which are not observed in simpler systems."[22]

[1965] "While we make pretense to no virtue beyond that of serendipity in relation to this most amiable accident, it is quite clear what had happened."[18]

[1971] "The next previous [sic] International Symposium on the Chemistry of Natural Products, held in London in 1968, adopted as its symbol a device [see immediately below] which we could not but regard as exhortatory [in our synthesis with Albert Eschenmoser of vitamin $B_{12}$]; as we may see we were able to return the compliment, perhaps in measure less than we might have desired, but certainly no less than we could have hoped."[37]

[1971] "… a substance precariously balanced on a precipice, off of which all of our efforts pushed it into the valley represented by the dormant thioether… Needless to say, innumerable early efforts to effect the desulphurization of the latter were made—alas, with anything but encouraging results."[37]






Vitamin $B_{12}$

## Realism and Disappointment and the Way of Science

*Like any scientist, Woodward faced obstacles in his research and he had disagreements. Romantic that he was, he generally constructed heroic narratives, masterfully, of obstacles and dead ends, barriers all overcome by his heroic band (army?) of chemists from around the globe. And like Nero Wolfe (one of his heroes), Woodward liked cogitation (Figure 7). Some examples of this aspect of his writing follow.*

***Figure 7.*** Woodward, with pencil in hand. His offices, at Harvard and the Woodward Research Institute in Basel, were often decorated with colorful flowers and cigarette-containing ashtrays. Photograph courtesy Chemical Heritage Foundation.

[1961] "[These] are diabolically sensitive compounds. They are torn to shreds and otherwise disastrously transmogrified in the presence of acidic reagents—even under the mildest conditions which we were able to define as necessary for Schiff-base formation. These circumstances conspired to yield a very clear-cut result in all of our early (and not so early) attempts to bring about our directed two-stage porphyrin synthesis—namely, not the slightest trace of porphyrin was obtained!" [27]

[1980] "We have alluded to and described briefly elsewhere some of the false paths down which we trod, and will describe here only the exceptionally simple method which ultimately proved successful." [26]

*In general, he pointed out errors, for instance, incorrect structure assignments, in a forgiving, one could say gentlemanly, way unless he didn't like someone (as you will also see); then his words could pierce like stilettos.*

[1956] "It is our feeling that the fugitive nature of intermediates in chemical reactions does not confer upon them license with respect to molecular dimensions and characteristics. Rather is it likely that a given intermediate is as much an assemblage of atoms characterized by precise bond distances and bond angles as are the molecules from which it is obtained, and into which it is transformed. Consequently, we deplore the tendency to accept as an intermediate any species solely on the ground that it can be conceptualized, and that it is not implausible." [28]

[1959] "Repetition of Beesley and Thorpe's work [on tricyclobutane, also known as tetrahedrane; Figure 8] has given totally different results from the original findings. Decomposition and unknown transformations preclude the presentation of satisfactory material balances, but the proliferation of references to the publications of Beesley and Thorpe prompts this report which concludes our interest in the problem." [38]

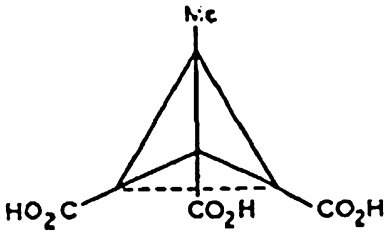



***Figure 8.*** A tricyclobutane (tetrahedrane). Graphic from Larson and Woodward.[40]

[1959] "DEWAR'S observation that maleic anhydride reacts with isoprene seventy-one times faster than acrolein in anisole solution at 100° adds a potentially useful punctilio [a petty point of conduct or procedure] to the body of qualitative evidence which long since showed that maleic anhydride is an exceptionally reactive participant in the Diels–Alder reaction. … We would hardly cavil at the essential distinction drawn in Dewar's succinct transliteration of a central point made in our paper. … There remains the assertion, unadorned by experiment or argument. … We can only regard as bizarre, that view which holds that a process involving the cleavage of one bond of a molecule is unrelated to a process which

involves the breaking of that same bond and one other. In our work it was established experimentally beyond question…"[39]

## Woodward's Philosophy of Science

*Woodward was consistently reflective, thinking about the broader meaning of what he did and its connections. He also was unafraid to generalize from chemistry to all science.*

[1963] "The structure known, but not yet accessible by synthesis, is to the chemist what the unclimbed mountain, the uncharted sea, the untilled field, the unreached planet, are to other men. The achievement of the objective in itself cannot but thrill all chemists, who even before they know the details of the journey can apprehend from their own experience the joys and elations, the disappointments and false hopes, the obstacles overcome, the frustrations subdued, which they experienced who traversed a road to the goal. The unique challenge which chemical synthesis provides for the creative imagination and the skilled hand ensures that it will endure as long as men write books, paint pictures, and fashion things which are beautiful, or practical, or both."[20]

[1963] "Not infrequently, Nature is more knowledgeable and artful than the chemist, and devises combinations between, or transformations of, reacting molecules which the designer had not anticipated at all. Some such surprises may be unpleasant ones, in that the unanticipated course of events may require serious modification of the synthetic plan, or even its abandonment. But in other cases, such happenstances may facilitate the work, and render easier than had been expected some difficult passage. In either event, the unexpected is always important, and its study should be welcomed, since it is likely to lead to further understanding, sharpening of the tools of chemical principle, and new ways to accomplish hitherto unknown transformations which may well be of far wider applicability than merely to the particular synthetic task at hand."[20]

## Collaborations: Who wrote what?

*Woodward was accepting of the text written by his collaborators, even at the height of his career when his writing style was at its peak. Referring to the first Woodward–Hoffmann communication in January 1965,[40,41] Hoffmann reflected,*

> "To me, the interesting question is why Woodward, very much the senior author, conscious and aware of the importance of style in writing, the master of flowing chemical prose, does not take my 'workmanlike' calculator's prose and rewrite it? I would not have objected."[42]
> —Roald Hoffmann (2015)

*During the 1970s, the last decade of Woodward's life, his graduate students and postdoctorals typically designed their own research projects, saw Woodward infrequently, and authored their joint papers. Woodward was able to attenuate his perfectionism. Woodward would review the advanced drafts of these papers and place his own "mark" in them. That Woodward spontaneously wrote in the high style is illustrated by William Greenlee's confirmation that Woodward wrote some of the text in his 1976 paper on the Total Synthesis of Marasmic Acid[43] including the following (the original handwritten text is shown in Figure 9) spontaneously during their meeting to discuss the revision.*

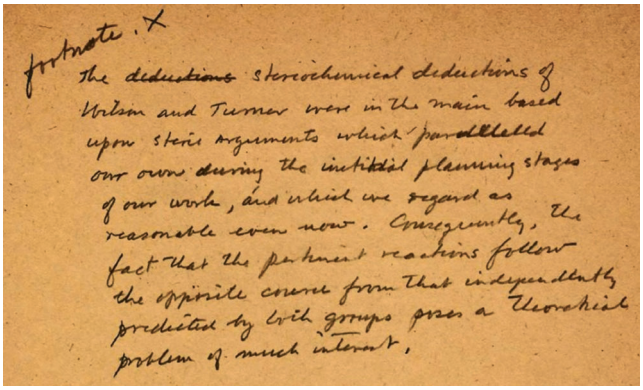
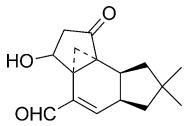



***Figure 9.*** Woodward's handwritten insert into William Greenlee's draft manuscript, where "footnote X" became footnote 4 in their 1976 paper,[43] written spontaneously "during our meeting to discuss the revision," according to Greenlee.[44] This is a further demonstration of Woodward's ability to write, in a first draft, a finished text in the grand style.




Marasmic Acid

[1976] Footnote "(4) The stereochemical deductions of Wilson and Turner were in the main based upon steric arguments which parallel our own during the planning stages of our work, and which we regard as reasonable even now. Consequently, the fact that the pertinent reactions follow the opposite course from that independently predicted by both groups poses a theoretical problem of much interest" (see Figure 9).[43]

## Impact on Chemists (and Readers) and the Style of the Literature

*Woodward served as a role model for many chemists, though he was an unfair exemplar. Few had Woodward's chemical brilliance or writing capabilities. As Eschenmoser recalled,*

> "Needless to say that I belong to the large group of chemists who tried to 'copy' RBW. I would prefer to say: who were 'influenced' by him. What is the difference? Up to other people to decide."[25]
> —Albert Eschenmoser (2015)

*Indeed, in one of his papers on the total synthesis of vitamin $B_{12}$, Albert Eschenmoser used Woodward's words, not as a quote from Woodward but as text within his (Eschenmoser's) own article, though crediting Woodward as the author of that text:*

> "Far from discouraged—indeed, inspired by the untoward events of 'black Friday', Peter Schneider, Hans Maag, Walter Fuhrer, Walter Schilling and Naruyoshi Obata, in a magnificent burst of energy and skill, improved the few remaining shining moments, and succeeded essentially in accomplishing the desired goal, utilizing the almost pitifully small quantities of material which could be scavenged from the disaster'. (The author is pleased to acknowledge this [literary] contribution of R. B. Woodward to the manuscript.)"[45]

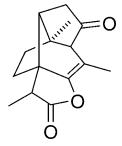
## Woodward's Words Were Not Always Greeted Warmly

*Woodward often used atypical words, in lieu of pedestrian ones, to describe exactly his meaning. The reader's understanding was not Woodward's responsibility any more than it was his responsibility to explain his chemistry to an unsophisticated audience.*

*Woodward certainly included uncommon if not eccentric words in his writings. Early in his career, his use of such words was challenged by journal referees. For example, in Woodward's 1945 full paper on the total synthesis of quinine, one referee twice negatively characterized Woodward's style as "fine writing" but criticized his use of words such as "moiety", "adumbrated", and "apposite" among others (Figure 10). Woodward ignored this criticism and retained his language, not only in the quinine paper but in many subsequent publications. Ironically, "moiety" has become a standard word in the lexicon of organic chemists.*

*Woodward was fond of Latin expressions, using Latin phrases not typically found in scientific texts:*

[1950] "The ultraviolet spectrum of parasantonide is *sui generis* [unique]."[46]



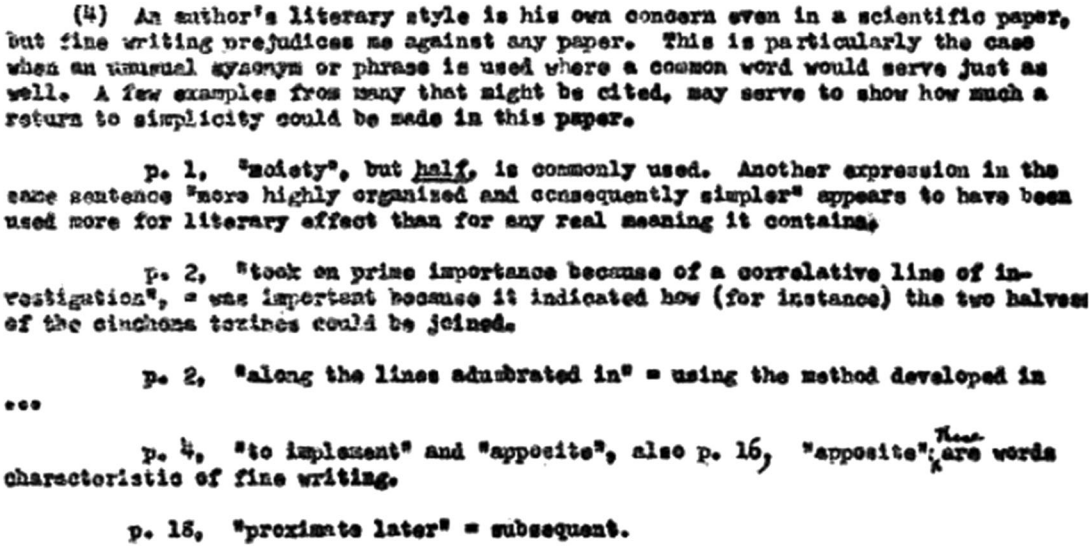
Parasantonide

[1950] "… so far as we are aware, no proof of the identity of the liquid dimer… has been brought forward, and for the present the matter is *sub judice*."[49] ["under judicial consideration and therefore prohibited from public discussion elsewhere"]

[1969]"High energy levels in the transition state may arise *pari passu* [on an equal footing] from real crossing or from intended but avoided ones."[50]

## Discussion

Woodward's words are elegant and powerful. He had an extraordinary command of language, not only of English, but also of French[51] and German.[52] He had an enormous vocabulary and was a polished crafter of language. That he



(4) An author's literary style is his own concern even in a scientific paper, but fine writing prejudices me against any paper. This is particularly the case when an unusual synonym or phrase is used where a common word would serve just as well. A few examples from many that might be cited, may serve to show how much a return to simplicity could be made in this paper.

p. 1, "moiety", but half, is commonly used. Another expression in the same sentence "more highly organized and consequently simpler" appears to have been used more for literary effect than for any real meaning it contains.

p. 2, "took on prime importance because of a correlative line of investigation", = was important because it indicated how (for instance) the two halves of the cinchona toxines could be joined.

p. 2, "along the lines adumbrated in" = using the method developed in ...

p. 4, "to implement" and "apposite", also p. 16, "apposite": these are words characteristic of fine writing.

p. 16, "proximate later" = subsequent.

***Figure 10.*** Excerpt from the referee's comments[47] on Woodward and William von E. Doering's submission of *The Total Synthesis of Quinine* in 1945.[48]

was a chemist, not a person of letters, makes his writings all the more impressive.

Ironically, Woodward's vocabulary, combined with the complexity of the message he had to relate, could result in ponderous prose. He seemed intoxicated with his ability to string words together in a complex fashion, simply for the joy of it. Some of his sentences, even some paragraphs, are nearly impossible to understand without repeated readings. Nonetheless, even those are both artful and captivating. Perhaps this is due to Woodward's love of puzzles and complex structures, whether chemical or verbal.

As can be seen from the dates of the excerpts contained herein, the flowing, flamboyant, grand Woodwardian style was exhibited early in his career and reached its zenith in the publication of a series of sole-authored papers based on plenary lectures. Woodward's extensive reading habits—"averaging a book a day for most of his life,"[52]surely provided inspiration and acquisition for his own writing. Hoffmann concludes, "Among his reading influences, I would include Churchill's *The Second World War*. I also think he liked P. G. Wodehouse."[53]

"When I began writing my first publications, I purposely went and read some of Woodward's papers and tried to use his phrases and style in my writing. Both my undergraduate and postdoc advisors spoke very highly of Woodward's prose…" —Anonymous academic chemist (2015)

## Conclusions

One of the reviewers of this paper concluded that this article

> "basically serves a personality cult. It was perhaps yet another ramification of Woodward's intellect, how masterfully he shaped his own legacy in a pretty Machiavellian attitude."

Another reviewer wrote,

> "I was invited to comment on this essay, and I am so glad that I was! In my formative years as a student of organic chemistry, I enjoyed the depth and color of Woodard's writings more than I can say. In fact, over the years, I read many of his papers multiple times in my efforts to convey his unusually deep chemical insights to the students in my courses (I don't even know how many times I've reread his Harvey Lecture on the Colchicine synthesis). While I never knew Woodward, I am among the generation of chemist who was not only aware of Woodward's style but also highly influenced by it."

It is not unusual to have divergent reviews of a manuscript. In this instance, deeply personal feelings about Woodward appear to sway the reviewers strongly, both negatively and positively. Perhaps such personal feelings toward authors improperly influence reviewers' opinions on matters of substance, consciously or otherwise in other instances.

Did Woodward intentionally adopt a writing style to further his image, as asserted by the first reviewer (immediately above)? There is little doubt that Woodward carefully engineered his public persona: his love of blue, his multi-hour lectures with special colored chalk, his legendary drinking (especially during lectures), to name a few. But a comparison of his handwritten first drafts with the published papers strongly indicates uniformity consistent with a natural flow of words rather than a false front.

Nonetheless, the first reviewer's comments suggest disapproval if not rejection of Woodward—the person. Woodward was not universally admired[54–56] and surely there were some jealousies and rivalries. One wonders how Woodward would have reacted to the descriptors "a personality cult… a pretty Machiavellian attitude." Woodward surely was gathering attention and stimulating passions, one of his goals and one of the goals of this paper.

Woodward's science changed organic chemistry.[29] If any of Woodward's style took hold, it is in the amplification of the historical and even medical context found in the introductions to many of today's chemical publications.

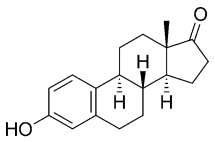
Woodward's words demonstrate the possibility for more humanistic writing in the chemical literature, allowing for publications that go beyond the homogeneity of some scientific writing norm.[6–9] Can one learn from the Fiesers[12] and Schoenfeld[11]? Absolutely, as those style guides are pedagogical instruments which encourage the succinct, conservative journal style. We may learn language and rhetoric (from Woodward) and of mechanics (from Fieser and Fieser,[12] Schoenfeld,[11] and *The ACS Style Guide*[13]). Given that English has become the *lingua franca* (the bridge language) in scientific communications,[51,57] for those whose native language is not English, trying to emulate Woodward's grand style may be inadvisable.

In Woodward's writing, as in that of other great writers including other chemists,[3–5,58,59] the story is well told. And some very good organic chemistry is learned, too. It's good that Woodward carved out for himself, through great science, a wonderful style. He also took the opportunity and the space to tell a good story, and tell it well—over and over again. From Woodward's words to your ears—if only more chemists could relate their work as well, using their own language and style.

## Coda

*The last paragraph of the introduction to Woodward's 1937 Ph.D. thesis is a fitting quote to bookend this article.*

[1937] "This investigation was concerned with an attack on the problem of the total synthesis of oestrone. Although the final goal was by no means reached, a good deal of information has been accumulated, and a path has been beaten for some distance into the untracked forest which surrounds the objective."[60]



Estrone

## Coda to a Coda

[1969] "Violations.

There are none!

Nor can violations be expected of so fundamental a principle of maximum bonding. All the more is it then important to give consideration to some reactions which might appear on casual inspection to contravene orbital symmetry consideration."[50]

## Acknowledgements

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**Keywords:** history of chemistry · language · synthesis · vocabulary · Woodward, Robert Burns

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# And Finally

## R. B. Woodward

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Woodward's Words: Elegant and Commanding

**Robert Burns Woodward's** publications exhibit a beauty and majesty infrequently seen in the scientific literature. Excerpts from Woodward's publications are presented along with a discussion of his literary personality and the effect of his writings on his contemporaries and on the style of the chemical literature that followed.