Proceedings of the Iowa Academy of Science

Volume 43 | Annual Issue | Article 6

1936

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Recommended Citation

Buchanan, R. E. (1936) "The Address of the President: Paul Bunyan Turns Scientist," *Proceedings of the Iowa Academy of Science, 43(1),* 47-58.
Available at: https://scholarworks.uni.edu/pias/vol43/iss1/6

THE ADDRESS OF THE PRESIDENT

PAUL BUNYAN TURNS SCIENTIST

R. E. Buchanan

Paul Bunyan, the legendary hero of the north woods has in recent years developed far toward becoming the Baron Munchausen of America. In fact, his feats of strength and cleverness quite surpass those of the Baron himself. The tales of the lakes that were gouged out of the earth by the pawing of his giant blue oxen, the magnitude of the tasks that he undertook and accomplished, his enormous griddle, his skill with the ax, these and many other tales have been told and retold in the lumber camps and about the camp fires; great celebrations are held annually in his honor. But Paul Bunyan in recent years has wearied of his tales of the forests and lakes; he has taken note that we now live in a more sophisticated era, and has turned scientist. He is flooding anew our literature with his feats and has even abandoned recounting his labors of the past in order to indulge in prophecies of the future. For a time he contented himself with putting his material into the standard literature of the news stand in "Amazing Stories" and in the comic supplement of the Sunday papers where as "Popeye, the Sailor" he extols the virtues of spinach. Then he ventured into the more serious literature and we have "The Farm Chemurgic." He appears in Harpers, where, writing under the *nom de plume* of Parrish and Clark, and under the title of "Chemistry wrecks the farm," he relates a wonderful tale of the might of his modern blue ox named "Chemistry," which, he insists through its pawings and insatiable appetite, is rapidly returning our cultivated fields to useless wilderness. He has come to claim not only chemistry but the whole realm of science as his domain. He is in turn bacteriologist, geologist, zoologist, botanist, physicist, historian, and above all, economist.

In our limited time it is obviously quite impossible adequately to review and evaluate Paul Bunyan's writings in all the fields of science. Perhaps his preachments and prophesies in the field of chemistry and in the economic utilization of chemistry in replacement of agriculture may sufficiently occupy us. May we therefore peruse together some of the chemical, rhetorical gems that have within the year appeared from his everflowing pen.

Paul writes cleverly and convincingly. He is prone to startle us with his predictions; his reasonings from cause to effect leave one gasping. For example, in one of his effusions he states:

> "In the sense that we have known it in the past, American agriculture is a dying industry. The nation's largest single business . . . is in the midst of a scientific revolution, and the farm as an individual production unit . . . is seeing its last days. For chemistry and technology are bringing agriculture under control."

and again he states that the chemist will transfer

> "the whole agricultural enterprise to the factory, eliminating seeds, plant, sun, winds and rain. He (that is, the chemist) finds out what a plant is made of, duplicates or imitates it, and provides unlimited production of a uniform product by automatic processes."

If these statements, apparently put forth seriously, are true, it behooves us to face the facts squarely and attempt to control the changes in the largest industry of America so that they will be accomplished with the least possible damage to our social structure. If these statements are not true, editors should be cautioned that yarns of this type should be relegated to the official publication agencies of Paul Bunyan and not masquerade as serious literature.

II

Let us examine first the claims and then the evidence relative to the dangers threatening agriculture through the machinations of the chemist.

Agriculture, it is claimed, or rather farming, is to be transformed gradually in four stages from an enterprise based on tillage of the soil into a strictly chemical enterprise of the laboratory and factory. The stages prophesied are as follows:

1. *Primitive* stage, the present agricultural practice of "soil and seed" and of "the whole business left to nature." Some unscientific fertilization of soil may be used.
2. *Intensive* stage. Chemistry will produce "synthetic" fertilizers to increase crop yields enormously and make possible the growth of all needed crops on a small fraction of the land now cultivated, and by the use of a small proportion of the population now engaged in agriculture.
3. *Control* stage. Plants will not be grown on farms, but "in trays or cabinets, with a new crop every few weeks." "Agri-

culture" in this stage moves into factories with plants under strict control.

4. *Synthetic* stage. All agriculture is to be replaced by chemical synthesis of all needed materials for food, clothing and shelter.

It is urged that we are rapidly entering into the intensive stage in which not to exceed 5% of the population of the United States can easily raise all the agricultural products needed on a total area of land not greater than that of Kansas. Furthermore, we are told that some phases of the third and fourth stages are already upon us; with the advance of chemistry the entire present agriculture is becoming rapidly and completely mechanized in factories. So claims Paul Bunyan.

There is, of course, some basis of fact in this reasoning. What part, if any, is fiction?

III

The most startling pronouncement in the whole argument is that agriculture is about to be replaced by a complete series of syntheses in "the factory, eliminating seeds, plant, sun, winds and rain," all, of course, in the interest of efficiency. The farm must go because the factory to replace it of necessity under the direction of Paul's chemists will be more efficient and turn out products better standardized.

An interesting definition of the farm is given to support this contention:

> "What is a farm, after all, but a little factory, a factory that uses an inordinate amount of space and lies idle a good many months out of the year; or to put it another way, a simple and extremely inefficient chemical laboratory which converts certain organic elements that man can't use into those elements he can use."

One may question the chemical terminology used (as "organic elements"), but the idea seems to be clear. The farm must go because Paul's chemists have shown it to be inefficient. But not without protest, for our agriculturists have been taught quite another definition of a farm, a definition wholly at variance with the one just quoted. The farmer says:

> "A farm is a little factory which has proved to be by far the most efficient device discovered for synthesizing from rela-

> tively unavailable inorganic materials those organic compounds for which man has the greatest need for food, clothing, and shelter."

Note carefully Paul's insistence that the factory is to be much more efficient as an agency for the synthesis of useful materials than is the farm.

Let it be known that no chemist has thus far made any substantial advance in any real synthesis of any food or textile fiber which is now produced on the farm. Given the raw materials used on the farm, it may be repeated, no chemist, at present, with all of the chemical knowledge that he has accumulated, can synthesize any one of the hundreds and thousands of chemical entities elaborated so readily on every farm. To be completely explicit, no chemist has ever manufactured an ounce of any edible sugar, or edible fat, or edible protein, or any fiber having the characteristics of cotton. Yet any good farmer can produce these materials by the ton. Is not Paul rather premature in heralding chemistry or rather the chemists as wrecking the farm, when no chemist can duplicate in his laboratory a single one of the compounds produced so readily by the original organic chemist, the farmer?

But surely, you may argue, our great Paul Bunyan, even though he marshals his chemists as farm wreckers, must have *some* basis for his deductions. Yes, he has, but like so many others of us, when we venture from the narrow fields of our specialization, he has unfortunately become confused in certain definitions and their implications, most important the definition of the term *synthesis*. The definition implicit in the quotations given above is "the production of more complex and perhaps more useful compounds out of simpler." The farmer synthesizes complex organic substances as starch, sugar, fats, vitamines, proteins, etc., from very simple inorganic elements and compounds, such as water, carbon dioxide, nitrogen gas, phosphates, magnesium, sulphates and iron. It is this fundamental type of synthesis that Paul's chemists in the laboratory must accomplish more efficiently if they are to establish factories that can compete with the farmer.

Another definition of synthesis, the one apparently used by Paul, is "the preparation of one chemical compound from another." This is quite different in its implications from the previous definition. The making of a rayon fiber is the result of certain chemical and mechanical treatment of cellulose, the transformation of one organic material into another. In such a transformation there may be no more complex molecule eventuate than that of the compound used in manufacture. Not infrequently, it is even simpler.

The farmer synthesizes his organic compounds from the inorganic materials of air and soil. The laboratory chemist in practically all cases (though not in all) starts his synthesis of an organic compound from some pre-existing organic compound. This differentiation is important and should be kept in mind for the further discussion.

IV

Can the organic chemist synthesize organic compounds from inorganic more efficiently than the farmer? Our protagonists of the chemical revolution say yes. It has been emphasized that in America alone twelve million dollars are annually spent on research in synthetic chemistry alone, and from such research and expenditures inevitably there must flow rapid progress. Yet there is probably not an organic chemist in America who, given complete control of the expenditure of the entire twelve million dollars, could in the course of a single year manufacture one pound of the cane sugar such as we use daily in food. But the farmer produces and sells at a profit the raw sugar which he has synthesized on his farm when the selling price of refined cane sugar on the market is perhaps five cents a pound. The ratio of efficiency would seem to be represented fairly by the ratio — twelve million dollars to five cents. It would seem that thus far the farmer has been at least two hundred million times as efficient as the organic chemist. If the farm is to be characterized as an inefficient factory, what must be the verdict relative to the laboratories of Paul's chemists. But, it may be argued, perhaps the laboratory chemist will be able to increase his efficiency several billion times, when the tables will be turned and we can proceed with abolition of the farm as a sugar factory. It is not at all impossible that the chemist may develop methods of synthesizing cane sugar. We may even grant that this will quite certainly happen. The next question, can he do it more efficiently than the farmer? Can we agree to measure efficiency in terms of labor required and costs? We may get some conception of comparative efficiency by studying comparative costs of raw materials, of power or energy required to synthesize, of catalysts, factory, machinery and labor. A complete analysis would take us too far afield, but fortunately in many cases disparity in costs is so great as to make refinement of methods of analysis unnecessary.

First, what about the cost of raw materials? If there is to be a true synthesis of a farm product the farmer and the laboratory chemist must each start with inorganic carbon (practically, this means elementary carbon or carbon dioxide), water, nitrogen gas and certain salts. The farmer uses the inexhaustible supply of carbon dioxide present in the air. It is constantly replenished on his farm by the winds. It costs him nothing. If necessary the farmer can use nitrogen gas, or he may use a nitrogenous fertilizer, perhaps synthetic. The former (i.e., the nitrogen gas) is the principal component of an ocean of atmosphere which completely and permanently inundates his farm, and costs him nothing. In general, he depends upon rain for his water supply, but in some localities he supplies water by irrigation. For the other elements he may depend upon the soil in whole or in part, in the latter case supplementing with fertilizers.

And what of the laboratory chemist? He might get his carbon dioxide as does the farmer, directly from the atmosphere, but no practicable method of concentrating this very dilute solution has been perfected. He may choose to purify and concentrate the carbon dioxide from flue gases, or from the great deposits of calcium or magnesium carbonates which may be calcined. It is quite apparent that the chemist is at a disadvantage. He must gather, purify and concentrate the carbon he wishes to use. The farmer does not.

The disparity in favor of the farmer is almost as great when other basic needs as for nitrogen, phosphorus and potasium are considered. From the standpoint of cost of raw materials the farmer with his technique in synthesis has advantages which the laboratory chemist must overcome if he is to be as efficient as the farmer. The gathering and purification of raw materials require the use of power and labor, both of which cost money.

Second, organic syntheses such as we are discussing require the use of great amounts of power or energy. If we burn a pound of sugar, a considerable amount of energy is released as heat and light. The reaction produces carbon dioxide and water, frees energy and uses oxygen. In order to make the pound of sugar from carbon dioxide and water, more energy must be used than was released by the burning. As a very minimum to produce a pound of sugar it would be necessary to supply as much energy as would be required (in the form of heat) to raise forty pounds of water from the freezing point to the boiling point. How does the farmer get his power to synthesize sugar and other materials? From the rays of the sun, in the form of light. The energy required costs him nothing. And Paul's chemist? Theoretically he might also use the direct sunlight as does the farmer. He doesn't for two reasons. He hasn't yet learned how, which would seem to be sufficient reason. And he has defined a farm as a factory that "uses an inordinate amount of space"; if he uses sunlight he too will be compelled to use a great amount of space. He may and does use water power. Most probably he will use power produced as a result of the combustion (destruction) of coal or petroleum. In the latter case, much more organic material is destroyed to secure energy than is produced in the synthetic process. The question at once arises, why destroy one organic compound completely in order to synthesize another, when, in general, it is more economical to transform the one compound into the other? The cheapness of coal or petroleum and the availability of by-products for use may make the synthesis of certain alcohols and related simple organic compounds commercially feasible, but the evidence thus far is that the power costs for true synthesis of complex organic compounds from inorganic may well prove prohibitive.

One other important comparison is to be made. The chemist produces some of his changes by very direct chemical additions and subtractions. But in general he has discovered that to get the products desired it is necessary to bring the raw materials together under exactly the right conditions, and frequently he finds it also necessary or expedient to use a *catalyst*. This word, catalyst, is one which finds its way more and more into our technical literature. It signifies some material that assists in some way in producing a desirable chemical change without itself being used up. For example, cotton seed oil can be improved in its qualities as a cooking fat by having its melting point increased and its other physical qualities improved by the addition of hydrogen. But in a simple mixture cotton seed and hydrogen do not combine readily. The chemist discovered that the addition of very finely divided nickel very greatly speeded up the process and made it commercially feasible. The nickel is not used up by being used, and is removed from the fat before it is marketed. The nickel is a *catalyst*. Sometimes noble metals as platinum are used as catalysts, at other times iron, or less expensive materials. Wherever and whenever the chemist uses catalysts in his syntheses, as he very frequently must, he adds to the cost and to his difficulties.

As for the farmer, his catalysts are developed quite automatically by growing crops. Catalysts elaborated by the green leaf are the only ones as yet known which can facilitate the transformation of carbon dioxide and water into starch. Further, the plant produces a great variety of catalysts, and in consequence a great variety of products. The cost of seed is the entire cost of these catalysts. Here again the farmer apparently has a cost advantage over the chemist.

So the farmer has free, or very cheap, raw materials, free power and cheap catalysts for his organic syntheses. Paul's chemist must pay for these at prices that would seem in most cases to be prohibitive. Are there other items which are so definitely in favor of the laboratory chemist as to throw the balance in his favor? What can they be? Initial plant cost? Labor cost? Depreciation? Interest on investment? Quality of product? Operating risks? Labor difficulties? There seems to be none of these which *a priori* are definitely to the disadvantage of the farmer. His prices for the things the consumer needs in the long run will be more definitely determined by his competition with other farmers than by competition with organic chemists engaged in synthesis.

For years to come the farmer has little to fear from the chemist in his attempt to synthesize food and textiles from inorganic materials. The chemist cannot readily overcome his handicap of high power costs, high cost of raw material, high cost of catalysts and his lack of experience. The fundamental laws of chemical thermodynamics still hold, even in Paul's laboratories.

And what is the conclusion of the whole matter? Simply that the proposal to transfer agriculture to the factory "eliminating seeds, plant, soil, sun, winds and rain" is so fantastic as to make it a genuine Paul Bunyan classic.

V

But we must not forget our second definition of synthesis, the making of a more valuable product from a less valuable material. This is the meaning implicit in much of the writing of our "farm wreckers." Here indeed there are possibilities and potentialities that may eventuate in certain agricultural readjustments. It is possible that there may be some wrecking of farms due to the advances of chemistry in this field, but for the most part *readjustments* can be effected and agriculture placed on a better and more secure basis as a result of the chemical findings.

The chemist has developed considerable facility in the transformation of one type of organic material into another. There are considerable possibilities of substitution and conversion. If the chemist can secure a cheap source of organic material, hold down his conversion cost, and produce something to compete with a food or fiber now on the market he may indeed influence agriculture and require its reorganization. But note that the raw material of the chemist must be cheap in order to compete with the products of agriculture. What are the sources of such cheap, raw material to which the chemist has access? But first a word as to the nature of organic compounds and their transformation in nature.

Organic chemistry is the chemistry of carbon. In inorganic nature carbon is found almost entirely as carbon dioxide and carbonates. The great function of plants is the synthesis of complex organic compounds from water, carbon dioxide and nitrogen. All animal food comes directly or indirectly from plants. Though respiration, fermentation and decay the organic carbon compounds are again converted to carbon dioxide and water. This is the great constantly recurring chemical cycle of nature, inorganic carbon to organic to inorganic. And thus far, Paul Bunyan to the contrary notwithstanding, the building up process, the synthesis, has been accomplished for all practical purposes only by living plants.

Mankind has devised ways and means of storing and preserving the organic compounds produced by plants so that the eventual disintegration with production of carbon dioxide may be indefinitely postponed. The farmer dries great quantities of seed and food to prevent deterioration and allow storage until needed for use. He may also place many tons of forage in silos where the material undergoes a certain amount of useful chemical (fermentative) change and is thus preserved for future use as feed.

Nature, during past geologic ages, has also constructed and filled several types of silos and storehouses in which the organic compounds synthesized by plants have been preserved. Among these are the great beds of coal and lignite in which plant materials from moses to trees have been collected, fermented, compressed and placed under conditions for preservation. Another type of silo has been filled with the fermented remains of plants and animals under such conditions that petroleum has been developed and stored in various porous strata of the earth.

Nature is constantly, through the agency of the plant world, continuing the synthesis of organic compounds. The farm is the laboratory in which these synthetic efforts of nature are guided into their most productive channels, though the process is going on wherever on land or in the sea there are plants growing. The compounds thus developed are to be numbered literally by the thousands, possibly by the tens or hundreds of thousands.

When the organic chemist, therefore, looks for cheap organic compounds from which to prepare his cheaper foods and textiles, there are (for all practical purposes) only the three sources to which he can turn, the coal beds, the petroleum deposits, and the products of farm and forest. The chemical potentialities of these three are worthy of our examination.

Coal is relatively abundant, and while not inexhaustible, will last at least for centuries. Coal tar chemistry has become so important that for many years it threatened to dominate the whole field of organic chemistry. The discovery of the benzene ring and the principles of organic transformations and synthesis made possible the production of thousands of new compounds, many of which have proved highly useful. Dyes, drugs, flavoring substances, perfumes, phenols for plastic production, all have been produced in profusion. In a few cases this development has impinged upon agriculture. The examples quoted most frequently are the substitution of aniline dyes for plant and animal dyes such as indigo, madder and cochineal. Tropical and subtropical agriculture were particularly affected. Certain drugs and flavoring materials of plant and animal origin have been displaced by coal tar products, and some land in consequence released from cultivation, but the total change in agriculture has been compartively insignificant. Practically no food is prepared from coal, nor is there any indication that such will be produced. Nor is there any evidence that textiles will be developed from coal or coal derivatives. It is difficult, if not impossible, to see how the chemical utilization of coal can be of any serious detriment to American agriculture. In fact, the agriculturist, along with all other individuals, will continue to profit greatly by the advances in this field. It is possible that the development of plastics made in part from coal products may displace some wood from the forest, but the repercussions on forestry will probably not be serious. Coal, as a serious competitor of the farm can be quite definitely ruled out in that probably major adjustments required have already been made.

Petroleum is rather more of an unknown quantity. Modern methods of cracking have made available great quantities of gases which (together with natural gas) have real potentialities in organic chemistry. Here can be secured an abundance of straight chained and branched chained carbon compounds relatively free from cyclic compounds. From them alcohols, aldehydes and organic acids may be produced. Insofar as these compounds are also products of the farm or of the fermentation of farm products there may be some repercussions upon agriculture. One development that might at least temporarily adversely affect agriculture is the possible production of long chain alcohols from petroleum, and from these in turn sulphonated to compounds which make satisfactory substitutes for fatty acids in the production of soaps and other detergents. Agriculture in the United States through its lard, tallow, cottonseed oil, soybean oil and peanut oil is already seriously threatened with chronic over-production. Large quantities of present surpluses are now used in soap making. But even the substitution of petroleum in soap making would not wipe out agriculture, nor necessitate any impossible readjustment. In fact, the hydrogenation of cotton seed oil forced a more serious realignment in agriculture than seems probable will result from petroleum competition. In the long run the question of relative costs will determine whether farm products or petroleum will be used. The evidence as yet is not at all clear that farm products, or farm byproducts may not be able to compete successfully. While the cry of "wolf, wolf" has been heard so frequently with reference to the imminence of the exhaustion of our American petroleum supplies, there can be little doubt that in the not distant future all of the petroleum available will be needed for power production. Then, too, it should be noted that no one has even seriously proposed the conversion of petroleum into carbohydrates, fats, proteins or textiles. The farm need not anticipate serious competition with petroleum in food production. The competition comes about through the fact that farm products and petroleum may each be used for the manufacture of the same compounds useful in industry, such as alcohol and acetic acid.

So coal and petroleum are ruled out as serious competitors of farm products for foods and textiles. This leaves to the chemist the products of forest and farm with which to work if he is going to "wreck agriculture." In other words, if agriculture is to be wrecked it must come about largely through competition among agriculturists themselves. If a more cheaply grown agricultural commodity can be cheaply transformed into another agricultural product or a satisfactory substitute for it, the more costly will be forced out of the picture. This is exactly the type of competition which results from the introduction of better mechanized methods of tillage, or the opening up of new areas of new agricultural land.

It is the same type of competition that results from the introduction of superior varieties of plants, or better methods of control of fungus diseases or insect pests, or better fertilizers.

VI

Will Paul Bunyan's chemists wreck the farm?

Twenty-five years ago I heard Dr. Nef, then head of the Department of Chemistry at the University of Chicago and one of the world's most famous and brilliant carbohydrate chemists, prophesy that within a decade the artificial synthesis of the important carbohydrates would be effected. It has not yet been accomplished and the difficulties are now known to be far greater than Nef could have known.

No, chemistry and chemists will not wreck the farm. In the long run the chemist will raise the standards of living of all our people, including those on the farm. The tales of those who contend otherwise upon analysis are found to be contributions to the great and growing literature flowing from the pen of Paul Bunyan, the charlatan.

We have been discussing Paul Bunyan's chemists. May I assure you that chemists were chosen for illustrative purposes only. Paul claims to be an all round scientist, as versatile in your field and mine as he is in chemistry. The whole tale here unfolded might be retold and as appropriately for any field of science. Particularly interesting are those instances in which Paul's henchmen boldly invade the field of economics. And now may we offer up a final petition. "From Paul Bunyan, the scientist, may the good Lord deliver us. And so say we all of us."

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