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Concept of R&D

Research and development: how the 'D' got into R&D

Benoît Godin

This paper traces the history of the concept of research and development (R&D) through 70 years of work on taxonomies and statistics on research. It identifies three stages in the construction of development as a category. First, development was only a series or list of activities without a label, but identified for inclusion in questionnaire responses. Second, development came to be identified as such by way of creating a subcategory of research, alongside basic and applied research. Third, development became a separate category, alongside research. It gave us the acronym we now know and use: R&D. Although it is a category of industrial origins, three factors contributed to the inclusion of development in official definitions of research: organizational, analytical, and political.

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IN MID-1952, the Research and Development Board of the US Department of Defense conducted a survey of industrial research in the United States. It was the most recent of a series of measurements of research conducted over the previous decades, increasingly so after World War II. The Department of Defense (DoD, created in 1948) and its predecessors have been involved in several data collections on research since the beginning of this century: the Naval Consulting Board and the Council of National Defense, for example, developed inventories of industrial researchers and scientific personnel as early as 1910 (Noble, 1977: 149–150).

After World War II, the Department and its bodies started conducting regular measurements. First, since its creation in 1946, the Office of Naval Research joined in the systematic collection of data on American men of science, first issued in 1906 (Cattell, 1906a; 1906b) and then in its eighth edition. Second, the Department contracted inventories and surveys of scientists to various institutions (US Bureau of Labor Statistics, 1951; Engineering College Research Council, 1951). Third, it estimated the national resources invested in science and technology (S&T) using concepts that would soon come to define measurements worldwide (US Department of Defense, 1953).

Its major output, however, was the survey on industrial research, the first of its kind in the United States. This would be influential, both in the United States and in other industrialized countries. The survey was part of a larger study aiming to examine management practices at the DoD, and was contracted out to the Division of Research of the Harvard Business School.[1] The purpose of the survey was (Whitman, 1953):

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> To obtain statistics on the research and development practices and potential of American industry. In the course of the current defense effort, we have all observed that increasing demands for technical manpower and facilities create difficult problems. If we know more about the nation’s research and development capacity and the effect of military calls on it, we can perhaps help ease some of these problems. We should be able to plan military research and development more intelligently … Should a greater national emergency suddenly be forced on us, we will need to know more than we do now about the location of specific research resources. In the course of the project, we may locate some facilities which even now are available and needed for military research and development projects.

Briefly stated, the survey was conducted to assist the military departments in locating possible contractors for research projects. This was only one of the motives of the study, however. In fact, the costs were defrayed by several organizations in addition to the Research and Development Board, organizations that were contemplating separate surveys for their own purposes: the Office of Naval Research, the National Association of Manufacturers, the Industrial Research Institute, the Associates of the Harvard Business School.

After exploratory meetings, they agreed to combine their efforts. Three separate but coordinated surveys were conducted. First, the Department of Defense contracted with the Bureau of Labor Statistics to conduct a survey among all companies believed to do research. Although in time the National Science Foundation (NSF) would become the main producer of statistics on S&T in the United States, in the 1950s, the Bureau was the most appropriate organization for such surveys, and it would continue to conduct the survey for the NSF in the following years.

Second, the Division of Research of the Harvard Business School was asked to undertake the other two surveys: one of a large cross-section of companies, and the other of a selected group known to have relatively large research laboratories. R N Anthony, from Harvard Business School, conducted the two surveys, assisted by D C Dearborn and R W Kneznek.

Anthony got interested in statistics on research as an accountant. He earned an MBA from Harvard University in 1940, and his doctoral degree in 1952 with a dissertation on the management of industrial research. He joined the Harvard Business School staff in 1940 and, except for leaves of absence from 1965 to 1968 as Assistant Secretary of Defense, Controller, was a faculty member until retirement in 1983.

In the early 1950s, Anthony was one of the few academics at Harvard interested in industrial research, and this explains why he was asked to participate in the Division of Research project. However, he conducted research on this topic for only a very short period of time. His main output was on accounting: he published 27 books, which have been translated into 13 languages, as well as over 100 articles.

Anthony’s first publication on industrial research was a spin-off from his doctoral dissertation, which examined administrative control of research. In 1952, he published a book with research associate J S Day on management controls in industrial research laboratories, a book financially supported by the Office of Naval Research in collaboration with the corporate associates of the Harvard Business School (Anthony and Day, 1952). By control, Anthony meant the need for firms to manage their research laboratories, relatively new creatures that were not yet well understood. “To some people, the word control has an unpleasant, or even a sinister, connotation: indeed, some of the synonyms given in Webster’s dictionary — to dominate, to subject, to overpower — support such an interpretation. As used here, control has no such meaning”, he wrote (Anthony and Day, 1952: 3).

Anthony was interested rather in the administrative aspects of industrial research: technical programs, service and support activities, funding, facilities, organization and personnel, basic policy decisions, short-range planning, operation decisions and actions, and evaluation. Anthony’s study concluded that: “there seems to be no way of measuring quantitatively the performance of a research laboratory”. To him, only “a comparison of figures for one laboratory with figures for some other laboratory … may lead the laboratory administrator to ask questions about his own laboratory” (Anthony and Day, 1952: 288).

Armed with such a rationale, Anthony was the most appropriate expert to conduct the Department of Defense survey. This was his second and last, but most influential, work on industrial research.

The results of the Department’s surveys were published in two parts in 1953 (Dearborn *et al*, 1953; US Bureau of Labor Statistics, 1953). The Bureau of Labor Statistics’ report looked at industrial research from a broad perspective, measuring research as an entity, without detailed statistics on types of research such as basic and applied.

The originality of Anthony’s investigation was twofold: he looked at precise and well-defined dimensions of research, and collected detailed statistics. First, his survey included precise definitions that would have a major influence on measurement

The originality of Anthony's investigation was twofold: his survey included precise definitions that would have a major influence on measurement worldwide; and he collected statistics on all three terms of the taxonomy of research

worldwide. Anthony's taxonomy of research had three items or categories instead of one (research) or two (basic research and applied research), as was the practice of the time in statistics on research:

- Uncommitted research: pursues a planned search for new knowledge whether or not the search has reference to a specific application.
- Applied research: applies existing knowledge to problems involved in the creation of a new product or process, including work required to evaluate possible uses.
- Development: applies existing knowledge to problems involved in the improvement of a present product or process.

Along with the definitions, Anthony specified precisely the activities that should be included in development (scale activity, pilot plants and design) and those that should be excluded (market and economic or social research, legal work, technical services like control tests and trouble-shooting, and production). This too was a departure from the way most surveys were conducted before then.

The second original aspect of Anthony's report was that he collected statistics on all three terms of the taxonomy of research. The survey revealed that industry spent 8% of its research budget on basic (or uncommitted) research, 42% on new products (applied research) and 50% on product improvement (development). This was the first of a regular series of measurements of development in the history of S&T statistics. It soon became the norm.

This paper is concerned with how and why development, as a category, got into research and development and gave us the acronym known as R&D. How it became a category alongside research is a purely conceptual construction, since development could have been kept as a subcategory of research, as with basic research and applied research. We would then have continued to talk of research instead of R&D, as was the case at the beginning of the 20th century.

Things began to change when development came to be defined as a category with a precise definition, and with a justification provided. It is the thesis of this paper that statistics and its methodology are a valuable source of information in looking for definitions of S&T, since collecting data and producing tables require precise definitions of the object to be measured: measurement usually starts with naming the concept to be measured, followed by defining this concept, and then by classifying its elements into dimensions.

The period covered here is from 1920, when the first statistics on research expenditure appeared in western countries, to 1960, when these statistics were conventionalized at the world level. The paper concentrates on the official (government) literature, that is, the efforts of governments in constructing definitions and statistics. We owe a large part of the early statistical developments and measurements, as well as standardized definitions of S&T, to governments and their organizations (Godin, 2005a; 2002). This work was conducted with the support of influential academics, who will be discussed in the light of their contribution to official efforts.

The first part introduces the reader to the history of statistics on S&T from 1920 to 1960, concentrating on three pioneering countries: the United States, Canada and Great Britain. The second part concentrates on the development of taxonomies of research for statistical purposes, which culminated in the current classification: basic research/applied research/development. The third part explains why development was included alongside research in official definitions of S&T. The last part identifies one more factor in this innovation, examining an institution that was responsible for the worldwide use of the acronym R&D: the US Office of Scientific Research and Development.

Statistics on science and technology

We owe a large part of the development of official measurement of S&T in western countries to the United States. It was there that the first experiments emerged in the 1920s. Two factors were at work that explained this phenomenon: the need to manage industrial laboratories; and the need to plan government scientific and technological activities, particularly in the event that they might be needed for war (mobilization of scientists).[2] Canada followed a decade later, with the same objectives, and Great Britain in the decade after that. It seems that, before the 1960s, the collection of S&T statistics was mainly an Anglo-Saxon phenomenon (Godin, 2005a).

The very first measurement of research activities in the United States came from the US National Research Council (NRC). During World War I, the US National Academy of Sciences convinced the Federal Government to give scientists a voice in the war effort. The NRC was thus created in 1916 as an advisory body to the Government. Rapidly, a research information committee, then a Research Information Service, was put into place. The Service was concerned with the inter-allied exchange of scientific information (Cochrane, 1978: 240–241). After the war, these activities were closed, and the Service reoriented its work toward other ends. It became (Cochrane, 1978: 240–241):

> a national center of information concerning American research work and research workers, engaged in preparing a series of comprehensive card catalogs of research laboratories in this country, of current investigations, research personnel, sources of research information, scientific and technical societies, and of data in the foreign reports it received.

It was as part of these activities that the Service developed directories on research in the United States. Beginning in 1920, it regularly compiled four types of directory, the raw data of which were published extensively in the Bulletin of the NRC, sometimes accompanied by statistical tables. One directory was concerned with industrial laboratories (NRC, 1920a). The first edition listed approximately 300 laboratories, and contained information on fields of work and research personnel. A second was devoted to sources of funds available for research (NRC, 1921), a third dealt with fellowships and scholarships (NRC, 1923), and a fourth with societies, associations and universities, covering both the United States and Canada (NRC, 1927).[3]

The Council directories were used to conduct the first official statistical analyses of research, particularly industrial research. The Council itself conducted two such surveys. One in 1933, by the Division of Engineering and Industrial Research, tried to assess the effect of the Great Depression on industrial laboratories (Holland and Spraragen, 1933). The other was conducted in 1941 for the NRC (1941). Besides the Council itself, Government departments and institutions also used the Council's industrial directories to survey research, among them the Works Progress Administration, which looked at the impact of new industrial technologies on employment (Perazich and Field, 1940).

It was not long before the Federal Government started conducting its own surveys. It began in 1938, when the National Resources Committee published the first systematic analysis of Government research, intended to document how to plan and coordinate Government scientific activities (National Resources Committee, 1938).

The report, concluding that research, particularly of an academic nature, could help the nation emerge from the depression, was based on a survey of Government research, including universities. For the first time, a survey of research included the social sciences, and this would later become the practice for surveys of government research in Organization for Economic Development (OECD) countries (two years later, the National Resources Planning Board published a study by the Social Science Research Council (SSRC) that looked at social research in industry, but without statistics (SSRC, 1941)).

We had to wait until 1945 to see new measurements of research appear in the United States. Two of these deserve special mention. First, V Bush offered some data on research in *Science: The Endless Frontier*, the blueprint for science policy in the United States (Bush, [1945] 1995: 85–89). However, the data were either based on previously published numbers, like those from the National Research Council, or of dubious quality, like the estimates on basic research.

Slightly better were the numbers included in a second experiment, the so-called Steelman report (Steelman, [1947] 1980). The President's adviser tried, to some extent, to measure research in every sector of the economy: industry, government and university. To estimate the importance of research in the economy at large, he collected statistics wherever he could find them, and whatever their quality, adding very few numbers of his own (in the same way as Bush).[4]

There was no time for an original survey since the report had to be delivered to the President ten months after the executive order. The report innovated, however, on several fronts: definition of research categories; research expenditure as a percentage of gross domestic product (GDP) as an indicator of R&D effort; and original estimates on manpower for discussing shortages. It also suggested numerical targets for science policy for the next ten years.

Other compilations were of better quality, but limited to Government research. Senator H M Kilgore estimated the wartime effort (1940–1944) in research for a Committee of Congress (Kilgore, 1945), and the Office of Scientific Research and Development (OSRD) measured its own activities for the period 1940–1946 (OSRD, 1947). Finally, the Bureau of Budget started compiling a Government "research and development budget" in 1950 (US Bureau of Budget, 1950).[5]

From then on, the locale for official S&T measurement came to be the NSF. This was the result of a compromise for the Bureau of Budget. The Bureau had always been skeptical of research funding by the Federal Government, particularly for basic research (England, 1982: 82; Sapolsky, 1990: 43, 52; Owens, 1994: 533–537; National Resources Committee, 1938: 18, 74). President Truman's adviser and director of the Bureau, Harold Smith, once argued that the real title of *Science: The Endless Frontier* should be *Science: The Endless Expenditure* (Barfield, 1997: 4).

To accept the degree of autonomy asked by the NSF, the Bureau required that the organization produce regular evaluations of the money spent. According to the Bureau's W H Shapley, the Bureau was mainly interested in identifying overlap among agencies and programs (Shapley, 1959: 8). In 1950, therefore, the law creating the NSF charged the organization with funding basic research, but it also gave it a role in science measurement. The NSF was directed to “evaluate scientific research programs undertaken by the Federal Government … [and] to maintain a current register of scientific and technical personnel, and in other ways provide a central clearinghouse for the collection, interpretation, and analysis of data on scientific and technical resources in the United States”.[6]

In 1954, the President specified in an executive order that the NSF should “make comprehensive studies and recommendations regarding the Nation’s scientific research effort and its resources for scientific activities” and “study the effects upon educational institutions of Federal policies and administration of contracts and grants for scientific R&D”.[7]

When the NSF entered the scene in the early 50s, difficulties were increasingly encountered when one wanted to compare the data from different sources, or to develop a historical series (US Department of Commerce and Bureau of Census, 1957). Definitions of research differed, as did methodologies for collecting data. According to Anthony (1951: 3), accounting practices could result in variations of up to 20% in numbers on industrial research.

The NSF standardized the research surveys by monopolizing official measurement and imposing its own criteria. The Harvard Business School survey was influential here. It developed concepts and definitions that the NSF reproduced — such as those of research, basic research, and non-research activities — as well as methodologies. By 1956, the NSF had surveyed all sectors of the economy: government, industry, university and non-profit.

By 1960, several industrialized countries had more-or-less similar definitions and methodologies for surveying R&D. Canada had conducted its first survey of industrial research in 1939 (Dominion Bureau of Statistics, 1941) with the declared aim “to mobilize the resources of the Dominion for the prosecution of the war”, that is, to build a directory of potential contractors. This was followed by a Department of Reconstruction and Supply survey on Government research in 1947 (DRS, 1947). Regular and periodic surveys on industrial research by the Dominion Bureau of Statistics resumed in 1955 (Dominion Bureau of Statistics, 1956). The systematic survey of Government research followed in 1960 (Dominion Bureau of Statistics, 1960).

For its part, the British Government had been involved from the start in estimating total research expenditure for the country. From 1953–54, the Advisory Council on Science Policy published annual data on Government funding of civilian research, and, from 1956–57, it undertook triennial surveys of national research expenditure.[8] These measurements were preceded by those of the Federation of British Industries (FBI), which surveyed industries in 1947 (FBI, 1947).

In the light of these experiences, particularly that of the NSF, in the early 1960s, the OECD gave itself the task of conventionalizing existing statistical practices. Member countries adopted what came to be known as the *Frascati Manual*, a methodological manual concerned with conventions to follow in conducting surveys of R&D (OECD, 1962a). The manual proposed precise definitions of concepts to be measured; it suggested classifications of the activities measured; and it made recommendations on numbers and indicators to be produced.

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Development of a taxonomy

An important measurement issue before the standardization of statistics in the 1960s concerned the demarcation of research and non-research activities. Anthony *et al* identified two problems: there were too many variations on what constituted research, and too many differences among firms on which expenses to include in research (Dearborn *et al*, 1953: 91). Although routine work was almost always excluded, there were wide discrepancies at the frontier between development and production, and between scientific and non-scientific activities: testing, pilot plants, design, and market studies were sometimes included in research and at other times not. To Anthony, the main purpose of a survey was to propose a definition of research and then to measure it.

It took several decades before research came to be defined precisely for statistical purposes. Yet this did not prevent measurement. In fact, statistics contributed considerably to the construction of the official definition of research. Although it had been measured since the early 1920s, the question “what is research?” was originally left to the questionnaire respondent to decide.

The first edition of the US National Research Council directory of industrial research laboratories reported using a “liberal interpretation” that let each firm decide which activities counted as research: “all laboratories have been included which have supplied information and which by a liberal interpretation do any research work” (NRC, 1920a: 45). Consequently, any studies that used National Research Council numbers, like those by Holland and Spraragen (1933) and the US Works Projects Administration (Perazich and Field, 1940) were of questionable quality: “the use of this information [National Research Council data] for statistical analysis has therefore presented several difficult problems and has necessarily placed some limitations on the accuracy of the tabulated material" (Perazich and Field, 1940: 52).

Again in 1941, in its study on industrial research conducted for the US National Resources Planning Board, the National Research Council used a similar practice: the task of defining the scope of activities to be included under research was left to the respondent (NRC, 1941: 173). In Canada as well, the first study by the Dominion Bureau of Statistics contained no definition of research (Dominion Bureau of Statistics, 1941).

As we shall see below, a standard definition of research appeared in the 1950s and 1960s thanks wholly to the NSF and the OECD. In the meantime, however, that is between 1930 and 1960, two situations came to prevail. First, research was defined either by simply excluding routine activities or by using a list of activities designed only to help respondents decide what to include in their responses to the questionnaires. Among these were basic and applied research, but also engineering, testing, prototypes, and design, which would later come to be called development. No disaggregated data were available for calculating statistical breakdowns, however. In fact,

> in these early efforts, the primary interest was not so much in the magnitude of the dollars going into scientific research and development, either in total or for particular agencies and programs, but in identifying the many places where research and development of some sort or other was going on." (Shapley, 1959: 8)

Although no definition of research *per se* existed, analysts and official statisticians soon started defining research by way of categories. This was the second situation. The most basic taxonomy relied on an age-old dichotomy: pure vs applied research (Kline, 1995; Godin, 2003).[9] Three typical cases prevailed with regard to the measurement of these two categories. The first was an absence of statistics because of the difficulty of producing any numbers that met the terms of the taxonomy. The British and left-wing scientist J D Bernal, for example, was one of the first academics to conduct measurement of research expenditure in a western country, although he used available statistics and did not conduct his own survey.

Bernal is best known today for his plea for state planning of scientific and technological activities, and for the debates on the freedom of science with J R Baker and M Polanyi (Congress for Cultural Freedom, 1955). Bernal had a big influence on science policy, identifying fundamental issues in the economics of science (Freeman, 1992: 3–30; Werskey, 1971)). He also had a big influence on statistics on science. For example, he suggested a statistic that would become a cherished indicator in science policy: the expenditure devoted to research as a percentage of GDP.

With regard to taxonomies of research, Bernal did not break his statistics on the research budget down by type of research or 'character of work' — such statistics were not available. "The real difficulty … in economic assessment of science is to draw the line between expenditures on pure and on applied science", Bernal ([1939] 1973: 62) said. He could only present total numbers, sometimes broken down by economic sector according to the System of National Accounts, but he could not figure out how much was allocated to basic research and how much to applied research.

The second case with regard to the pure vs applied taxonomy was the use of proxies. For example, in his well-known report, *Science: The Endless Frontier*, Bush elected to use the term basic research, and defined it as "research performed without thought of practical ends" (Bush, [1945] 1995: 18). He estimated for the first time in history that the nation invested nearly six times as much in applied research as in basic research (Bush, [1945] 1995: 20). The numbers were derived by equating college and university research with basic research, and industrial and government research with applied research. More precise numbers appeared in appendices, such as ratios of pure research in different sectors — 5% in industry, 15% in government, and 70% in colleges and universities (Bush, [1945] 1995: 85) — but the sources and methodology behind these figures were totally absent from the report.

The third case was skepticism about the utility of the taxonomy, to the point that authors rejected it outright. For example, *Research: A National Resource*, one of the first measurements of science in government in America, explicitly refused to use any categories but research: "There is a disposition in many quarters to draw a distinction between pure, or fundamental, research and practical research … It did not seem wise in making this survey to draw this distinction" (National Resources Committee, 1938: 6). The reasons offered were that fundamental and applied research interact, and that both lead to practical and fundamental results. This was just the beginning of a long series of debates on the classification of research according to whether it is pure or applied.

First taxonomy of research

We owe to another British and left-wing scientist, J S Huxley, the introduction of new terms and the first formal taxonomy of research (Table 1). The taxonomy had four categories: background, basic, *ad hoc* and development (Huxley, 1934). The first two categories defined pure research: as background research has "no practical objective consciously in view", while basic research is "quite fundamental, but has some distant practical objective … Those two categories make up what is usually called pure

Table 1. Taxonomies of research

J. Huxley (1934)	background/basic/ad hoc/development
J. D. Bernal (1939)	pure (and fundamental)/applied
V. Bush (1945)	basic/applied
Bowman (in Bush, 1945)	pure/background/applied and development
US PSRB (1947)	fundamental/background/applied/development
Canadian DRS (1947)	pure/background/applied/development/analysis & testing
R. N. Anthony	uncommitted/applied/development
US NSF (1953)	basic/applied/development
British DSIR (1958)	basic/applied and development/prototype
OECD (1963)	fundamental/applied/development

science” (Huxley, 1934: 253). To Huxley, *ad hoc* meant applied research, and development meant more or less what we still mean by the term today: “work needed to translate laboratory findings into full-scale commercial practice”.

Despite having these definitions in mind, however, Huxley did not conduct any measurements. Nevertheless, his taxonomy and definitions had several influences. Bush used the same newly-coined term “basic research” as Huxley for talking of pure research. The concept of “oriented basic research”, later adopted by the OECD, comes from Huxley’s definition of basic research (OECD, 1970: 10). Above all, the taxonomy soon came to be widely used for measurement. We owe to the US President’s Scientific Research Board the first such use.

In 1947, president H Truman, not satisfied with the Bush report, asked the economist J R Steelman, then director of the Office of War Mobilization and Reconstruction, as science advisor, to prepare a report on what the Government should do for science. The report used, for the first time in the history of science policy, the statistic first suggested by Bernal: research expenditure as a percentage of GDP. The report suggested that the nation should invest 1% of its GDP in science activities (Truman, 1948).[10] It also proposed to redress the balance between fundamental research and applied research by quadrupling funds devoted to the former.

Adapting Huxley’s taxonomy, the President’s Scientific Research Board conducted the first measurement of national resources devoted to “research and development” (the first time the term appeared in a statistical report) using precise categories, although these did not make it “possible to arrive at precisely accurate research expenditures” because of the different definitions and accounting practices employed by institutions (PSRB, [1947] 1980: 73). In the questionnaire it sent to Government departments (other sectors such as industry were estimated using existing sources of data), it included a taxonomy of research that was inspired directly by Huxley’s four categories: fundamental, background, applied and development (PSRB, [1947] 1980: 299–314).

Using these definitions, the Board estimated that basic research accounted for about 4% of total research expenditure in the United States in 1947 (PSRB, [1947] 1980: 12), and showed that university research expenditure was far lower than Government or industry expenditure, that is, lower than applied research expenditure, which amounted to 90% of total research (PSRB, [1947] 1980: 21). Despite the Board’s precise definitions, however, development was not measured separately, but was included in applied research, as it had in Bush’s analysis.

First measurement of development

We owe to the Canadian Department of Reconstruction and Supply the first measurement of development *per se* (DRS, 1947). In the survey it conducted on Government research in 1947, it distinguished research, defined as composed of pure, background[11] and applied research (but without separating the three items “because of the close inter-relationships of the various types of research”), from development and analysis and testing. Development was defined as “all work required, after the initial research on the laboratory (or comparable) level has been completed, in order to develop new methods and products to the point of practical application or commercial production”.

The inclusion of development was (probably) motivated by the importance of military procurement in the Government’s budget on science (contracts to industry for developing war technologies). Indeed, most of the data were broken down into military and non-military expenditure. Overall, the Department estimated that 40% of the Can$34 million spent on federal scientific activities went to research, 48% to development, and 12% to analysis and testing.

Although innovative with regard to the measurement of development in government research,[12] Canada would not repeat such a measurement for years, and never did measure development in industry before the advent of the OECD recommendations contained in the *Frascati Manual* published in 1962. It is, in fact, to Anthony that we owe the first of a series of systematic measurements of all the terms in

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the taxonomy. By that time, however, the taxonomy was reduced to three terms, as it continues to this day: basic research, applied research, and development.

Measurement of all terms

How did Anthony construct his taxonomy and definitions? The inspiration probably came from different sources, among them C C Furnas, Director, Cornell Aeronautical Laboratory, and later US Assistant Secretary of Defense (Research and Development) under president Eisenhower. Furnas' definition was used by Anthony in *Management Controls in Industrial Research Organizations* (Anthony and Day, 1952: 58). In an influential book prepared and published by the US Industrial Research Institute in 1948,[13] Furnas (1948: 2) defined research as "the observation and study of the laws and phenomena of nature and/or the application of these findings to new devices, materials, or processes, or to the improvement of those which already exist". According to Furnas, research is composed of several activities, among them:

- Fundamental research: investigation of the fundamental laws and phenomena of nature and the compilation and interpretation of information on their operation.
- Applied research: pursuit of a planned program toward a definite practical objective — a preconceived end result. It takes the results of fundamental or exploratory research and tries to apply them to a specific process, material, or device.
- Development: application of technology to the improvement, testing, and evaluation of a process, material, or device resulting from applied research. It includes engineering, design and pilot plants, tests, and market research.

The book devoted a whole chapter to development, and discussed the different steps that defined the activity: pilot-scale work, product evaluation, utilization studies, economic studies, process design, market research, and market development.

Whatever the sources of Anthony's definitions, the NSF extended the definitions to all sectors of the economy — industry, government, and university — and produced the first national numbers on research so broken down. It took about a decade, however, for standards to appear at the NSF. Until 1957, for example, development was merged with applied research in the case of Government research, with no breakdown. Similarly, until 1959, statistics on development were not presented and discussed at all in reports on industrial research.[14] Thereafter, though, the three components of research were separated, and a national total was calculated for each based on the following definitions:

- Basic or fundamental research: research projects that represent original investigation for the advancement of scientific knowledge and do not have specific commercial objectives, although they may be in the fields of present or potential interest to the reporting company.[15]
- Applied research: research projects that represent investigation directed to discovery of new scientific knowledge and that have specific commercial objectives with respect to either products or processes.
- Development: technical activity concerned with non-routine problems that are encountered in translating research findings or other general scientific knowledge into products or processes.

The NSF surveys showed once more the importance of development in the research budget: over 60% in the case of Government research (NSF, 1957a: 10), and 76.9% for industrial research (NSF, 1959: 49). For the nation as a whole, the numbers were 9.1% of the research budget for basic research, 22.6% for applied research, and 68.3% for development (NSF, 1962: 5). The numbers indicated without doubt the importance of development in the budget of S&T, and the relevance of the category for analytical and policy purposes.

By the early 1960s, most countries had more-or-less similar definitions of research and its components (Gerritsen, 1961; 1963). The OECD gave itself the task of conventionalizing these definitions. In 1962, OECD member countries adopted a methodological manual for conducting R&D surveys. To the organization, R&D was a driver of economic growth, and one way to demonstrate this was to measure it (OECD, 1962b). The *Frascati Manual* included precise instructions for separating research from related scientific activities[16] and non-research activities,[17] and development from production. The manual also recommended collecting and tabulating data according to the three components of research, defined as (OECD, 1962a: 12):

- Fundamental research: work undertaken primarily for the advancement of scientific knowledge, without a specific practical application in view.
- Applied research: work undertaken primarily for the advancement of scientific knowledge, with a specific practical aim in view.
- Development: the use of the results of fundamental and applied research directed to the introduction of useful materials, devices, products, systems, and processes, or the improvement of existing ones.

Most importantly, the manual, from its second edition, suggested a definition of research as "creative work undertaken on a systematic basis to increase the stock of scientific and technical knowledge and to use this stock of knowledge to devise new applications" (OECD, 1970: 8). This definition, with its emphasis on systematic research, would have a strong influence in the following decades on R&D surveys, questionnaires and the numbers produced (Godin, 2005b).

A multipurpose category

In the 1960s, in the light of increasing expenditure on research as reported in official statistics, particularly military research, several analysts began questioning what really goes into statistics on research. David Novick (1965), from RAND Corporation, suggested: "we should stop talking about research and development as though they were an entity and examine research on its own and development as a separate and distinct activity" (see also Novick, 1960) The rationale for this suggestion was provided by economists S Kuznets and J Schmookler a few years earlier: "development is a job of adjustment …; it is not original invention" (Kuznets, 1962: 35); "while the problems dealt with in development are non-routine, their solution often does not demand the creative faculty which the term invention implies" (Schmookler, 1962: 45).

All three authors lost this argument. Why did the 'D' get into R&D?

An organizational category

Before the beginning of the 20th century, scientists simply spoke of science or knowledge, sometimes of invention, inquiry or investigation.[18] Research was a term that became generalized in the 20th century, and became used regularly by industry, where science was often a contested term when applied to firms: industrial research included several activities such as engineering, testing and design. The term research was rapidly incorporated, however, into the names of public institutions such as the Department of Scientific and Industrial Research (UK 1916) and the National Research Council (USA 1916 and Canada 1917), and the term came to define S&T policy after World War II (Godin, 2005b).

Development is also a term that came from industry. At the origins of industrial research, in the 1900s, the term meant the evolution of the firm, which could be accomplished through research. The term was also used somewhat ambiguously to mean both a new thing and the latter stage of a project. It got its current meaning after 1920, when large firms separated fundamental research and other activities in laboratories.

There is now a relatively large volume of literature on the history of industrial laboratories, with systematic analyses of the administrative organization of development activities in firms and its relationship to research (NRC, 1941; Wise, 1985; Reich, 1985; Hounshell and Smith, 1988; Heerding, 1986; Schopman, 1989; Graham and Pruitt, 1991; Smith, 1990; Homburg, 1992; Meyer-Thurow, 1982; Dennis, 1987; Mowery, 1984; Shinn, 1980; for statistical analyses, see Mowery and Rosenberg, 1989; Mowery, 1983; Edgerton and Horrocks, 1994; Horrocks, 1999; Mowery, 1986; Edgerton, 1993; 1987; Sanderson, 1972).

An important finding of this literature, as well as that on the administration of research (see, for example, Bichowsky, 1942; Zieber, 1948; Mees and Leermakers, 1950), is the problem of the boundary between research and production activities, that is, the separation of research from (development and) production facilities. To industrialists, research was entirely aimed at developing new products for commercialization, or what we now call innovation, and development was an integral part of (applied) research.[19]

The organization of research in firms reflected this interpretation: until the 1920s, there were very few separate departments for research on the one hand, or development on the other. Both activities were carried out in the same department, usually called experimental laboratory (Bell), technical laboratory (Bayer) or, increasingly, development laboratory (DuPont). It was also the same kind of people (engineers) who carried out both types of task (Wise, 1980; Reich, 1983). All in all, most of the laboratories "were, in fact, testing or engineering labs, where scientists and engineers labored to assure consistency and efficiency in production" (Reich, 1985: 2), a fact admitted by most industrialists and analysts of the time,[20] but obscured by the increased use, in the 1920s, of both terms, research and development, together as a concept.

Equally, the early public discourses of the National Research Council and its industrial members, since they were aimed at persuading firms to get involved in research, mainly talked of research or science, ignoring development.[21] Within firms, though, the reality was different: there was little basic research, some applied research, and a lot of development. It was not long before the organization of research reflected this. As mentioned above, the two activities first split when a few companies began to do 'fundamental' research. Several large laboratories began to develop separate divisions for the two functions: research and (product) development. By 1945, most large companies conducting research had two types of laboratory or division.

An analytical category

Development as a category gained more autonomy and visibility when industrialists, consultants and academics in business schools, long before the economists,[22] began to study industrial research. In the 1940s and 1950s, these individuals began developing conceptual frameworks, or what would later be called models of innovation. The models, usually illustrated with diagrams, portrayed research as a linear process starting with basic research, then moving on to applied research, and then development.

Already in 1920, in a book that would remain a classic for decades, C E K Mees, director of the research laboratory at Eastman Kodak, described the development laboratory as a small-scale manufacturing department devoted to developing "a new process or product to the stage where it is ready for

Development as a category gained more autonomy and visibility when industrialists, consultants and academics in business schools, long before the economists, began to study industrial research: they began developing models of innovation

manufacture on a large scale" (Mees, 1920: 79). The work of this department was portrayed as a sequential process: development work is (Mees, 1920: 79):

> founded upon pure research done in the scientific department, which undertakes the necessary practical research on new products or processes as long as they are on the laboratory scale, and then transfers the work to special development departments which form an intermediate stage between the laboratory and the manufacturing department.

To the best of my knowledge, however, the first and most complete description of such a model came from R Stevens, vice-president at Arthur D Little, and published in the US NRC report entitled *Research: A National Resource* in 1941.[23] Stevens (1941: 6–7) identified several "stages through which research travels on its way toward adoption of results in industry", the third to fifth stages corresponding more or less to what we now call development:

- Fundamental research
- Applied research
- Test-tube or bench research
- Pilot plant
- Improvement
- Trouble shooting
- Technical control of process and quality.

Later models would often be simpler and restricted to fewer stages (see, for example, Bichowsky, 1942: 81; Furnas, 1948: 4), culminating in the well-known three-stage model or taxonomy. It was Anthony and the NSF who first suggested this simple model and objectified it with statistics as we saw above.[24] Anthony talked of (Anthony and Day, 1952: 58–59):

> a spectrum, with basic research at one end, with development activities closely related to production or sale of existing products at the other end, and with other types of research and development spread between these two extremes.

The NSF, for its part, suggested that: "the technological sequence consists of basic research, applied research, and development", where "each of the successive stages depends upon the preceding" (NSF, 1952: 11–12). In the following decades, the literature on innovation would be full of such models,[25] despite the numerous criticisms concerning their linearity.[26]

In a sense, we owe this continuity to the very simplicity of the model. However, official statistics are actually more important in explaining its continued use. By collecting numbers on research as defined by three components, and presenting and discussing them one after the other within a linear framework, statisticians helped crystallize the model as early as the 1950s (Godin, 2006).

In fact, statistics on the three components of research were for a long time (and still are, to many) the only available statistics allowing us to 'understand' the internal organization of research, particularly in firms.[27] As innovation came to define the science-policy agenda, statistics on R&D were seen as a legitimate proxy for measuring technological innovation because they included development (of new products and processes).[28]

A political category

A third factor behind the widespread acceptance and use of development as a category was an eminently political one. It had two variants. The first was a will for purification. Measuring development activities allowed these activities to be subtracted from R&D and a category arrive at concerned only with research proper. This was the rationale offered at the NSF, an organization entirely devoted to funding (academic) research. Distinguishing between applied research and development "is one of our most difficult problem areas", stated K Sanow from the NSF at the meeting that launched the OECD *Frascati Manual*.

> In almost every meeting that we have with the Advisory Council on Federal Reports, a few of the industrial representatives have emphasized the difficulties associated with distinguishing between applied research and development. These representatives argue that the dividing line here is so difficult to determine that they would prefer that the NSF not request two separate figures but rather a combined total for applied research and development expenditures.

However,

> regardless of the relative lack of high statistical reliability, the Foundation considers it to be extremely important to obtain a separate measure of the dollar volume of applied research which can be added to basic research to obtain a

> statistical total for industrial research expenditures (basic and applied research). Development activities account for such a large proportion of total research and development in the United States that it is necessary to obtain some indication of the portion of R&D resources that are devoted to research *per se*. (Sanow, 1963: 13–14)

Indeed, the NSF would lobby during the 1960s for increased funding to academic research, using statistics on R&D as its basis. Following the practice of both the Bush report and the President’s Scientific Research Board, the NSF, in a manifesto published in 1957, contrasted funds going into basic research to those spent on applied research and development. It showed that only a small percentage of R&D in the country was devoted to basic research (NSF, 1957b).

The second political use of the category was the complete opposite of the first. In our modern era, characterized by science, there are reasons for showing a large expenditure on research. It brings prestige to the performers. Governments are the most illustrious examples of such practices, using the gross expenditure on R&D (GERD) to GDP ratio to compare their performance with that of other countries. It is usually the United States’ ratio of 3% that has served as the norm since the 1960s.

In the case of companies, the political (or policy) aspect of the category of development is a result of economic considerations. Adding development to research allows a larger share of activities to be considered for direct public support or as exempt from taxation. The debates between government officials and industrialists on defining R&D for contracts and grants (Asner, 2004) or for tax purposes (Hertzfield, 1988; Poterba, 1997; Warda, 2003) are testimony to the politics behind the definitions and the statistics.

Overall, development was an appropriate category for the S&T policy agenda of the 20th century. At the outset of World War II, US Government funding of R&D was definitely oriented towards developing new technologies for defense, and development became an important economic issue (costs, efficiency) for the Department of Defense (Klein and Meckling, 1958; Klein, 1962; Hitch and McKean, 1965). From the 1960s onwards, technological innovation would again be the main goal of S&T policies, this time for economic purposes: economic competitiveness and the development of what came to be called high technologies were priorities of governments (Godin, 2004).

This interest in technology in S&T policy partly explains the acceptance of the coupling of development with research, above all in statistics. As G Glockler, chief scientist at the Office of Ordnance Research, US Army, once suggested: “The broadening or, one might say, debasement of the meaning of the term research has occurred gradually while the nation has become more and more interested in the advancement of its technology” (Glockler, 1957: 269).

Office of Scientific R&D

Development as a category in taxonomies of research and statistics, and R&D as an acronym, came to be widely used in all sectors of the economy, including universities, in the mid-1940s. It is to the US Office of Scientific Research and Development (OSRD), created in 1941 to contribute to the war research efforts, that we owe the wide diffusion of the acronym R&D. At the OSRD, development activities were coupled to those of research, above all in the organization’s name, for operational reasons. There were problems during the war getting technologies rapidly into production (Pursell, 1979: 363). As I Stewart noted (Stewart, [1948] 1980: 35):

> Between the completion of research and the initiation of a procurement program there was a substantial gap that the armed services were slow to fill. It was becoming increasingly apparent that for the research sponsored by NDRC [OSRD’s predecessor] to become most effective, it was essential that the research group carry its projects through the intermediate phase represented by engineering development.

In fact, firms experienced a lot of problems with production, and universities were often called on to help with development (pilot plants, large-scale testing) (Owens, 1994: 553–555). Adding development to research at OSRD was the solution to these problems. In 1943, the OSRD created the Office of Field Service to bring research closer to its military users (Stewart, [1948] 1980: 128). “Military dissatisfaction with the performance of new weapons in combat, although it might result from improper use in the hands of personnel without technical knowledge, could delay an entire program of research and development” (Stewart, [1948] 1980: 128).

The services rendered by the Office of Field Service were, among other things, “analysis of the performance of new weapons and devices under field combat condition, which might result in

It is to the US Office of Scientific Research and Development, created in 1941 to contribute to the war research efforts, that we owe the wide diffusion of the acronym R&D

modifications back to the laboratories; assistance in promoting the flow of technical information between laboratories and production plants and the field users" (Stewart, [1948] 1980: 131).

With the OSRD, Bush succeeded in obtaining greater responsibilities than he had with its predecessor, the National Defense Research Committee (NDRC), namely for development, procurement and liaison with the Army, and research activities (Owens, 1994: 527), without getting involved in production *per se*, that is, with respect for the frontiers between research and production.

Thanks to the OSRD, among others, the R&D acronym spread to other public organizations, first the Department of Defense: the Research and Development Board (1946); the RAND project (1948), which gave the current organization its name;[29] the Air Force R&D Command (1950); and the position of Assistant Secretary of Defense for R&D (1953). In the private sector, firms such as American R&D (a venture capital firm) and Evans R&D (a consulting firm) were set up after the war.

Measurements too began to carry the acronym: statistical reports from the President's Scientific Advisory Board (Steelman, [1947] 1980), the OSRD (1947)[30] and the Department of Defense itself used it,[31] but so did Congress (Kilgore, 1945) and statistical offices: the Bureau of Labor Statistics integrated the acronym into its surveys in 1953 (US Bureau of Labor Statistics, 1953), as did the National Science Foundation in the same year.[32] The concept then spread rapidly to other countries' statistical offices (Dominion Bureau of Statistics, 1956; DSIR, 1958),[33] international organizations (OECD, 1962a; UNESCO, 1968), and the academic world.

Conclusion

R&D is a central component of official definitions of S&T. Decades of work on taxonomies and statistics on research are testimony to the construction behind the definition. We can identify three stages in the construction of development as a category for statistical purposes. First, development was only a series or list of activities without a label, but identified for inclusion in questionnaire responses. Second, development came to be identified as such by way of creating a subcategory of research, alongside basic and applied research. This was Huxley's innovation, and Anthony was influential in its measurement. Third, development became a separate category, alongside research. It gave us the acronym we now know and use: R&D.[34] Figure 1 gives a representation of how the use of the term diffused in the literature.

The category had three main purposes. The first was organizational. It corresponded to the type of research conducted in industry, to research divisions in firms, and to entire organizations that defined themselves according to both research and development. The second was analytical. Here, it was industrialists, consultants and academics in business schools who developed models identifying development as a separate and decisive step in the innovation process. Third, the category served political ends, among them the greater amount of money firms could obtain from public funds by including development in research expenditure.

Despite its widespread use, the category was not without its methodological problems. Early on, these problems were discussed at a meeting organized by the NSF in 1959, and at the OECD meeting that launched the *Frascati Manual* in 1963. Most of the problems concerned the demarcation between development and other activities, and the absence of precise accounting practices to distinguish types of activity properly. This was an additional factor explaining the inclusion of development in statistics on research.

Methodological difficulties also explain the exclusion of development from more recent statistics on S&T. Development as an activity is in fact located somewhere between two other activities: research and production. We have already alluded to

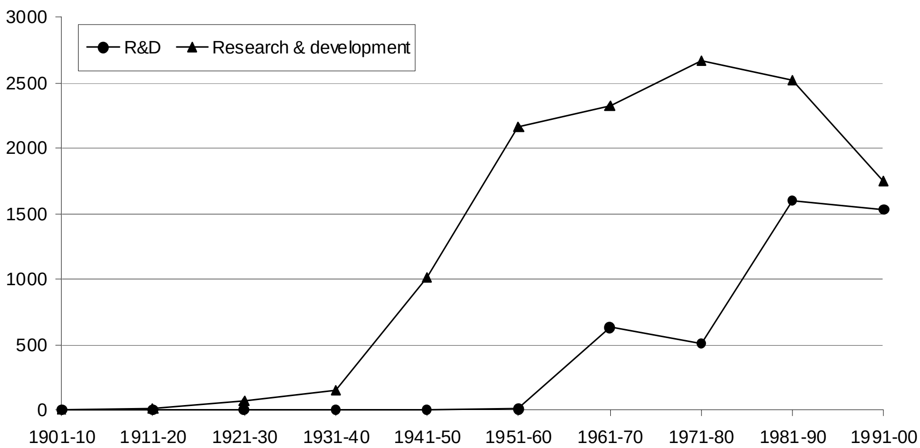

Figure 1. Occurrences of R&D in *Science*
Source: JSTOR (The Scholarly Journal Archives)

the difficulty of separating applied research from development. This became even more pronounced when the category was used for research other than industrial research. As W H Shapley from the US Bureau of Budget commented at the NSF meeting in 1959 (Shapley, 1959: 12):

> The practical problem results chiefly from the fact that a distinction between research and development is not recognized in the way Government does its business … Projects and contracts cover both research and development, and the distinction is usually not made even in the financial records at the local operating level … because of the large number of projects.

The other demarcation problem concerned development and production. Since, for example, minor developments can also occur during this later stage, "the main difficulty arises in determining the point at which development work ceases and production begins" (OECD, 1962a: 17; see also OECD, 1993: appendix 12). This is particularly important in the case of military research, because R&D is not a separate entity, but part of general expense appropriations or procurement contracts.[35] This practice has enormous consequences on statistics: many different statistical estimates frequently coexist for measuring the same phenomenon. As a National Research Council report (known as the Frank Press report) argued in the mid-1990s (Committee on Criteria for Federal Support of Research and Development, 1995: 52):

> Nearly half of traditional federal research and development spending involves initial production, maintenance, and upgrading of large-scale weapons and space systems … Those activities are neither long-term investments in new knowledge nor investments in creating substantially new applications. If they were excluded, the research and development investment budget — called the federal S&T (FS&T) budget in this report — would be between $35 billion and $40 billion annually.

As a consequence, and in line with the Frank Press report, the US Government started compiling a Federal Science and Technology Budget in 1999, different from Federal Research and Development Spending. The two now appear in the Budget (OMB, 2005). Federal Research and Development Spending, on one hand, is the conventional way of counting R&D expenditure, and amounted to over US$117 billion in 2003. Here, expenditure is broken down according to the standard three categories — basic research, applied research, and development — to which 'facilities and equipment' is added.

The Federal Science and Technology Budget,[36] on the other hand, is a collection of federal programs designed to be easy to track in the budget process, rather than constituting a comprehensive inventory of federal S&T investments. The budget for these programs amounted to nearly US$60 billion in 2003. The main difference between this and the Federal Research and Development Spending budget is that it excludes most development, such as Department of Defense weapons systems development, and includes some scientific and technical education and training activities (AAAS, 2005).

The Federal Science and Technology Budget presents a new concept in measuring S&T, and allows no comparisons with other countries' statistics. It differs from both the OECD definitions and the Press report suggestion. Since its first introduction in 1999, the definition has also changed regularly. It is the most recent official response to the statistical challenges of measuring development: not abandoning the historical and traditional methodology, but adding a second series of numbers. At the same time, it is a (timid) acceptance of the decades-old complaint, initially offered by Bernal: the statistics on money spent on research "is delusive because it includes money spent on non-profit making plant on a semi-industrial scale, an expense far greater than that of scientific research proper" (Bernal, [1939] 1973: 56).

Appendix 1. Official taxonomies of research

US National Research Council (R Stevens, C M A Stine)

- Fundamental research: quest for facts about the properties and behavior of matter, without regard to a specific application of the facts discovered.
- Pioneering applied research: research aimed at the development of new processes and their application to manufactured products.
- Development: this category is defined via specific activities, that is, test-tube or bench research; pilot plant; improvement; trouble shooting; technical control of process and quality.

V Bush (and the Bowman Committee)

- Pure research: research without specific practical ends. It results in general knowledge and understanding of nature and its laws.
- Background research: provides essential data for advances in both pure and applied research; the objective and methods are reasonably clear before an investigation is undertaken.
- Applied research and development: the objective can often be definitely mapped out beforehand; results are of a definitely practical and commercial value.

(*continued*)

Appendix 1 (*continued*)

US President's Scientific Advisory Board

- Fundamental research: theoretical analysis, exploration, or experimentation directed to the extension of knowledge of the general principles governing natural or social phenomena.
- Background research: systematic observation, collection, organization, and presentation of facts, using known principles to reach objectives that are clearly defined before the research is undertaken, to provide a foundation for subsequent research or to provide reference data.
- Applied research: extension of basic research to the determination of the combined effects of physical laws or generally accepted principles with a view to specific applications, generally involving the devising of a specified novel product, process technique, or device.
- Development: adaptation of research findings to experimental, demonstration, or clinical purposes, including the experimental production and testing of models, devices, equipment, materials, procedures, and processes.

US Institute for Industrial Research (C C Furnas)

- Exploratory research: exploration (the realm of try and see) pursued with or without preconceived objectives.
- Fundamental research: investigation of the fundamental laws and phenomena of nature and the compilation and interpretation of information on their operation.
- Applied research: pursuit of a planned program toward a definite practical objective — a preconceived end result; it takes the results of fundamental or exploratory research and tries to apply them to a specific process, material, or device.
- Development: application of technology to the improvement, testing, and evaluation of a process, material, or device resulting from applied research; it includes engineering, design and pilot plants, tests, market research.

US Department of Defense (R N Anthony)

- Uncommitted research: pursue a planned search for new knowledge whether or not the search has reference to a specific application.
- Applied research: apply existing knowledge to problems involved in the creation of a new product or process, including work required to evaluate possible uses.
- Development: apply existing knowledge to problems involved in the improvement of a present product or process.

US National Science Foundation

- Basic or fundamental research: research projects that represent original investigation for the advancement of scientific knowledge and do not have specific commercial objectives, although they may be in the fields of present or potential interest to the reporting company.
- Applied research: research projects that represent investigation directed to discovery of new scientific knowledge and have specific commercial objectives with respect to either products or processes.
- Development: technical activity concerned with non-routine problems that are encountered in translating research findings or other general scientific knowledge into products or processes.

OECD

- Fundamental research: work undertaken primarily for the advancement of scientific knowledge, without a specific practical application in view.
- Applied research: work undertaken primarily for the advancement of scientific knowledge, with a specific practical aim in view.
- Development: the use of the results of fundamental and applied research directed to the introduction of useful materials, devices, products, systems, and processes, or the improvement of existing ones.

Appendix 2. Official definitions of research

US National Resources Committee (1938)
Investigations in both the natural and social sciences, and their applications, including the collection, compilation, and analysis of statistical, mapping, and other data that will probably result in new knowledge of wider usefulness that aid in one administrative decision applying to a single case.

US National Research Council (1941)
Organized and systematic search for new scientific facts and principles that may be applicable to the creation of new wealth, and presupposes the employment of men educated in the various scientific disciplines.

Canadian Department of Reconstruction and Supply (1947)
Purposeful seeking of knowledge or new ways of applying knowledge, through careful consideration, experimentation and study.

Federation of British Industries (1947)
Organized experimental investigations into materials, processes and products, and scientific principles in connection to industry, and also development work, but excluding purely routine testing.

US Institute for Industrial Research (C C Furnas) (1948)
Observation and study of the laws and phenomena of nature and/or the application of these findings to new devices, materials, or processes, or to the improvement of those that already exist.

US Department of Defense (R N Anthony) (1953)
Activities carried on by persons trained, either formally or by experience, in the disciplines and techniques of the physical sciences including related engineering, and the biological sciences including medicine but excluding psychology, if the purpose of such activity is to do one or more of the following things: 1) pursue a planned search for new knowledge, whether or not the search has reference to a specific application; 2) apply existing knowledge to problems involved in the creation of a new product or process, including work required to evaluate possible uses; 3) apply existing knowledge to problems involved in the improvement of a present product or process.

US National Science Foundation (1953)
Systematic, intensive study directed toward fuller knowledge of the subject studied and the systematic use of that knowledge for the production of useful materials, systems, methods, or processes.

(*continued*)

Appendix 2 (*continued*)

OECD (1970)
Creative work undertaken on a systematic basis to increase the stock of scientific and technical knowledge[37] and to use this stock of knowledge to devise new applications.

UNESCO (1978)
Any systematic and creative work undertaken to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications.

Notes

1. Interview with R N Anthony, author of the main report on the survey, 20 December 2004.
2. On the early efforts at planning in science, see Dupree (1957: 344ff).
3. NRC also reproduced lists from *Science* and *School and Society* on doctorates conferred (NRC, 1920b).
4. Most of the new numbers concern university research. See also: Bush [1945] 1995: 122–134.
5. Data from 1940 through 1949 can also be found in *The Annual Report of the Secretary on the State of the Finances for the Fiscal Year ended June 30, 1951*, Washington, p. 687.
6. Public Law 507 (1950).
7. Executive Order 19521 (1954).
8. Appeared in the *Annual Reports of the ACSP* from 1956–57 to 1963–64. London: HMSO.
9. For recent discussions of the dichotomy in history, see Kline (1995); Godin (2003)
10. US President H S Truman would subsequently adopt the target in his first discourse on science policy in 1948 (see Truman, 1948).
11. Here, the term background has changed meaning, as in Bush, and means collection and analysis of data.
12. The report of the US National Resources Committee on Government research published in 1938 made no use of the category development (see National Resources Committee, 1938).
13. The Institute was launched in 1938 as the National Industrial Research Laboratories Institute, renamed the next year as the Industrial Research Institute. It became an independent organization in 1945.
14. The situation was similar in other countries, see, for example, DSIR (1958).
15. The last part of the definition was, and still is, used for the industrial survey only.
16. Scientific information, training and education, data collection, testing and standardization.
17. Legal administrative work for patents, routine testing and analysis, technical services.
18. An exception was Price (1879)
19. For an excellent discussion of the confusion between research and other activities in analyses of industrial research, see Bichowsky (1942)
20. US National Research Council (1920: 1–2): "Research is sometimes differentiated into scientific and industrial. Scientific research comprises investigations directed toward the discovery of new truths for the sake of increasing human knowledge. Industrial research is the endeavor to learn how to apply scientific facts to the service of mankind. Many laboratories are engaged in both industrial research and industrial development. These two classes of investigation commonly merge so that no sharp boundary can be traced between them. Indeed, the term research is frequently applied to work which is nothing else than development of industrial processes, methods, equipments, production or by-products". J D Bernal ([1939] 1973: 55): there is a "difficulty of distinguishing between scientists and technicians in industrial service. Many mechanical engineers, and still more electrical and chemical engineers, are necessarily in part scientists, but their work on the whole cannot be classified as scientific research as it mostly consists of translating into practical and economic terms already established scientific results".
21. See, for example, the discourses of industrialists published in the *Reprint and Circular Series* of the National Research Council.
22. With the exception of J Schumpeter.
23. Some authors often go back to J Schumpeter to model the process of innovation. Certainly, we owe to Schumpeter the distinction among invention, (initial) innovation, and (innovation by) imitation. However, Schumpeter "professed little dependence of innovation on invention", as J Schmookler (1966: 108) commented. The formalization of Schumpeter's ideas into a sequential model is due to interpreters of Schumpeter, see, for example, MacLaurin (1953).
24. A precursor to this model can be found in the Bush ([1945] 1995; 81) report. Here, the Bowman committee suggested a taxonomy of three components (pure research/background research/applied research and development) and argued that "the development of important new industries depends primarily on a continuing vigorous progress of pure science". However, neither the argument nor the components of R&D were discussed in terms of sequence, see Godin (2005b).
25. For reviews, see Roberts and Romine (1974: 20–29); Saren (1984: 11–24); Forrest (1991: 439–452).
26. For the first such criticisms, see Schmookler (1966); Price and Bass (1969: 802–806); Myers and Marquis (1969); US Department of Defense (1969).
27. For early uses of the categories and the construction of tables of categories by economists, see Carter and Williams (1957); Scherer (1959); Ames (1961: 370–381); Machlup (1962: 178ff).
28. Early on, policy-makers adopted a definition of innovation as a process consisting of three phases, as suggested by J Schumpeter: generation of an idea; problem-solving or development; and implementation and diffusion: see Utterback (1974: 621).
29. RAND means R and D.
30. Interestingly enough, the OSRD report does not break down R&D by types of activity.
31. The Department of Defense made wide use of taxonomies on R&D in the 1950s and after, and developed its own definitions for measuring its activities, see Godin (2005b).
32. The acronym was so new that the NSF felt obliged to specify, in its first survey of industrial R&D: "The abbreviation 'R&D' is frequently used in this report to denote research and development" (NSF, 1956: 1).
33. For an analysis of current taxonomies, although centered on the basic/applied dichotomy and not on development, see Averch (1991)
34. Since the 1970 edition of the *Frascati Manual*, the OECD suggests adding the adjective 'experimental' to 'development' to avoid, so it is argued, a confusion between development, a phase of R&D, and the same term in economics, and to use the same term as Eastern European countries and UNESCO. Today, experimentation even sometimes replaces the 'D' of R&D. This is the case for tax legislation in Canada and the United States. For the latter, see Hertzfeld (1988).
35. For an historical point of view on this problem, see Shapley (1959: 9–19). For legal aspects, see Lazure (1957: 255–264).
36. First entitled Research Fund for America, then 21st Century Research Fund.
37. "including knowledge of man, culture and society " was added in 1976.

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