Connections in Science: implications on idea generation and career development

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U of T Chapter Lecture
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http://www.careerchem.com

OUTLINE

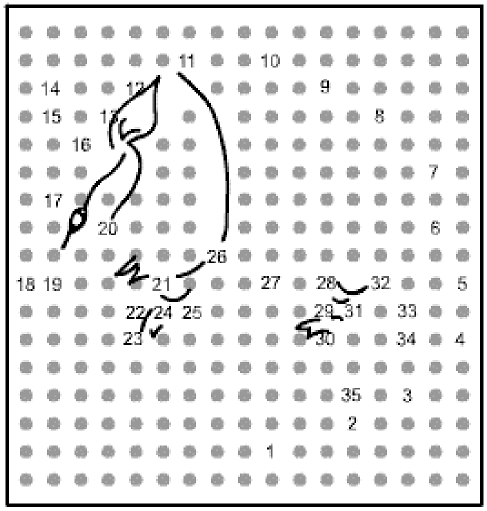
Part 1: Getting the "big picture"
Developments in chemistry and other sciences impacting on chemistry

Part 2: Life of a Scientist
Biographical references on scientists
Patterns of success
Culture of "academia"
Comments from scientists about doing good science

Part 3: Connections between people and ideas
Brief survey of examples from scientific genealogy trees

Part 4: Contributions from Canadian scientists
Surprises: "unknown" people
Development of chemistry knowledge in Canada

Getting the “Big Picture”



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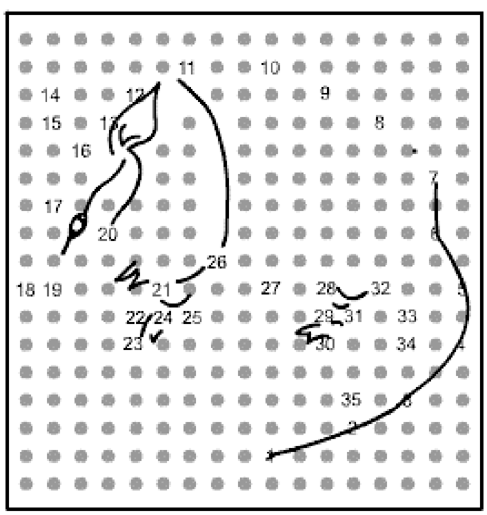
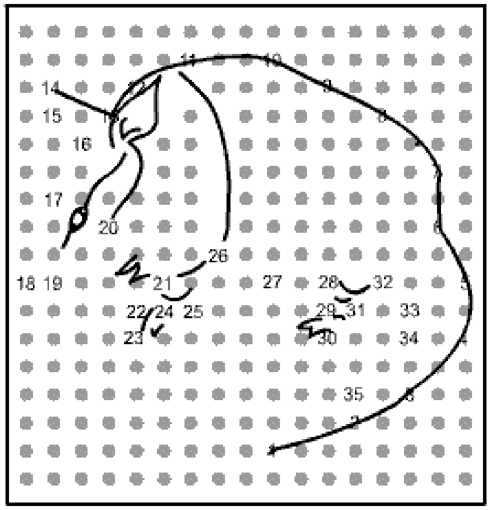


Getting the "Big Picture"



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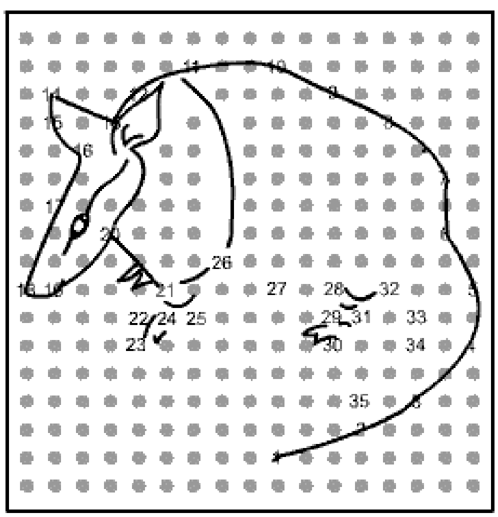

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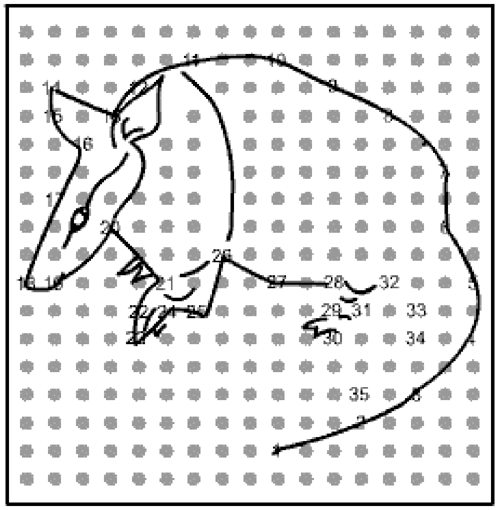

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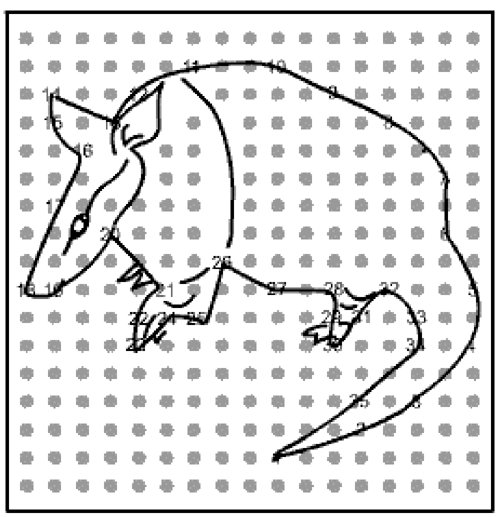
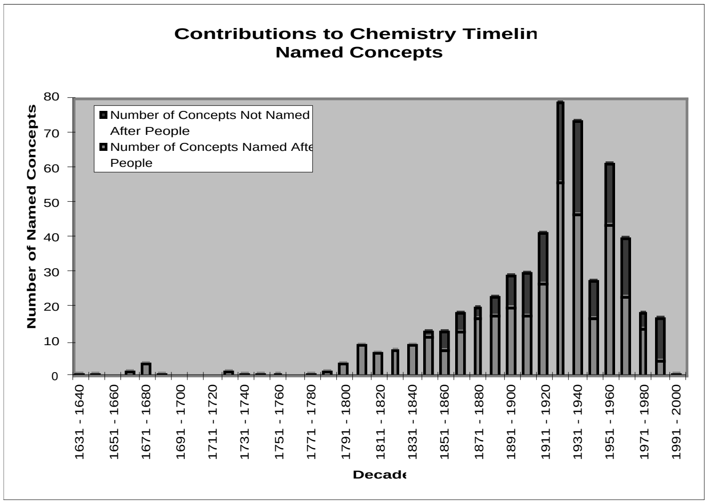


"Named" things: signposts of what ideas are important and which stand the tests of experimentation, verification, and reproducibility over time

Good nomenclature elicits images and aids reasoning by analogy; it is the organic chemists 'best friend'. -- Donald J. Cram



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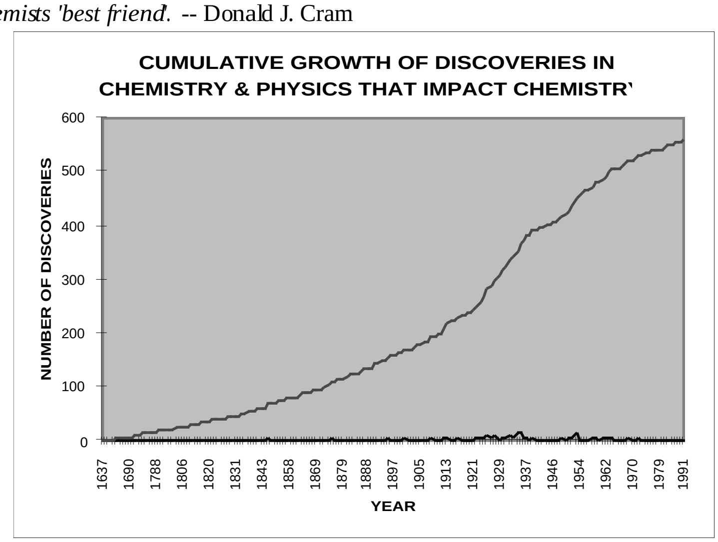

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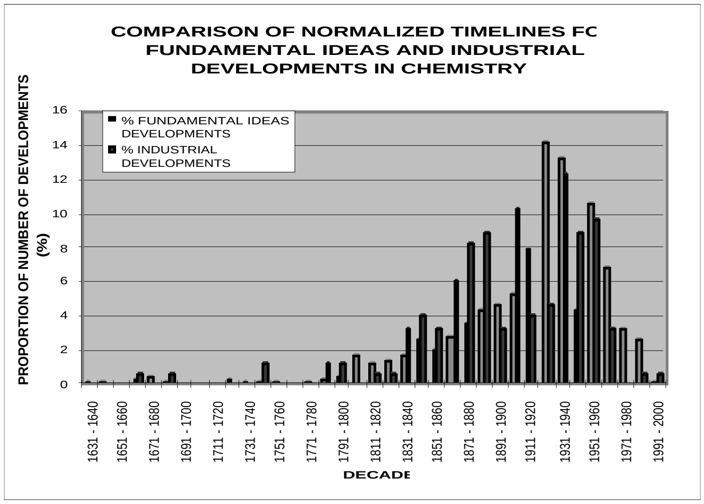

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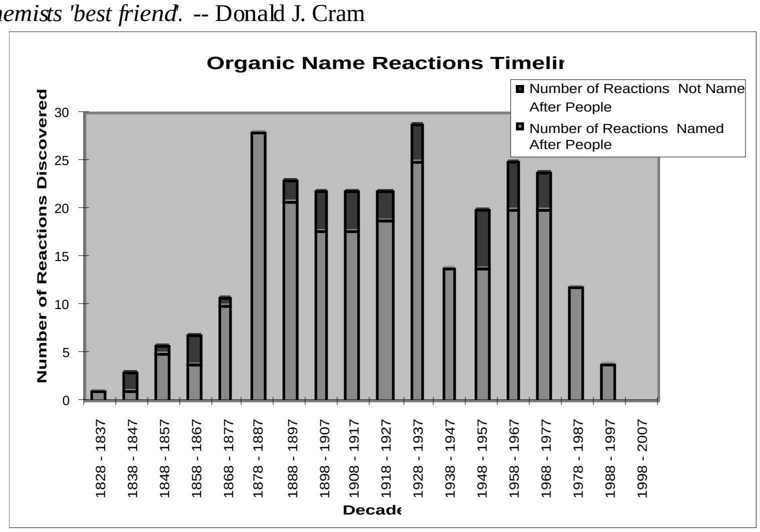

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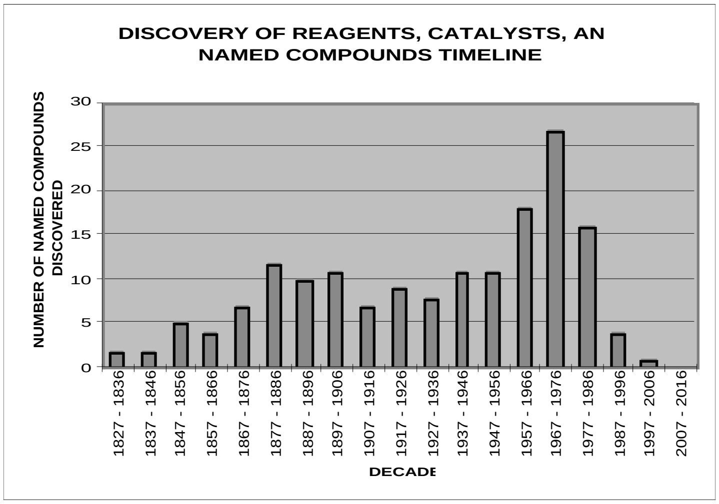

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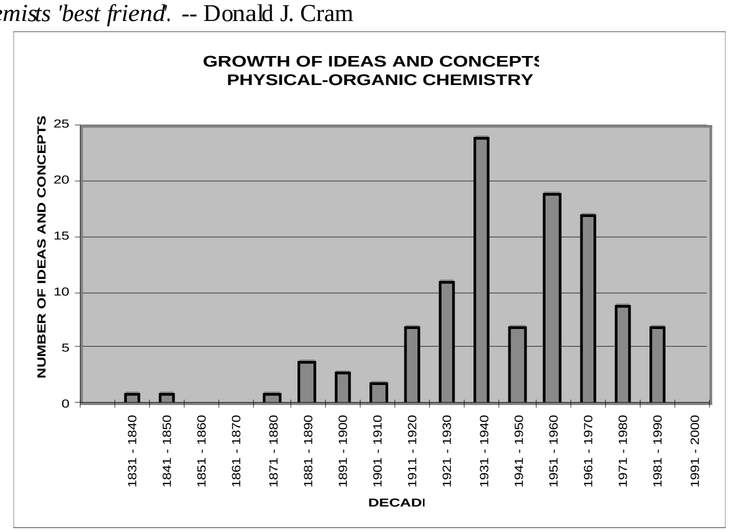

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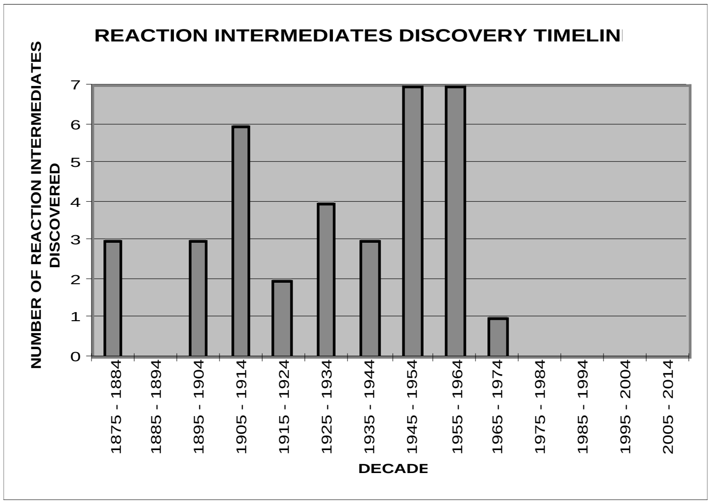
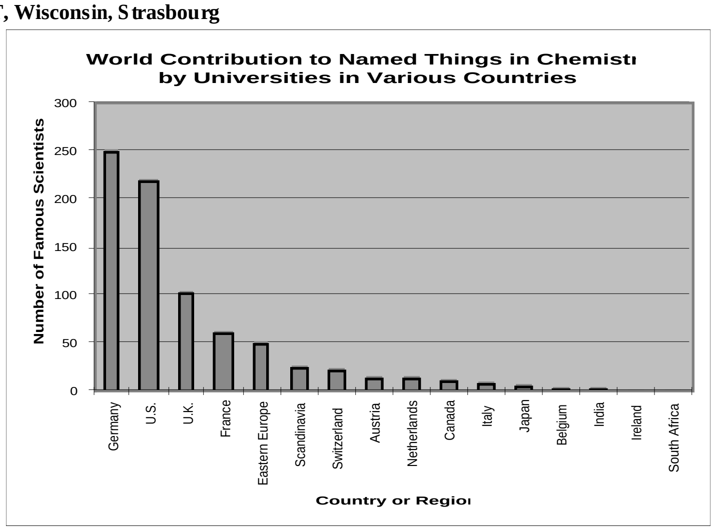
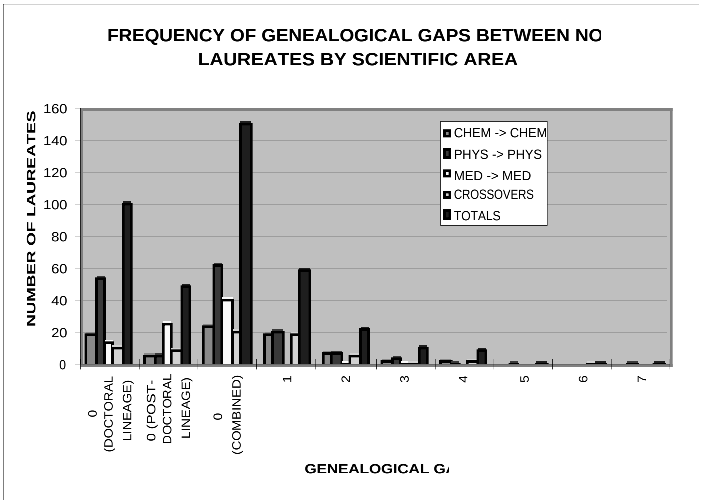


<u>**Universities where famous scientists studied:**</u>

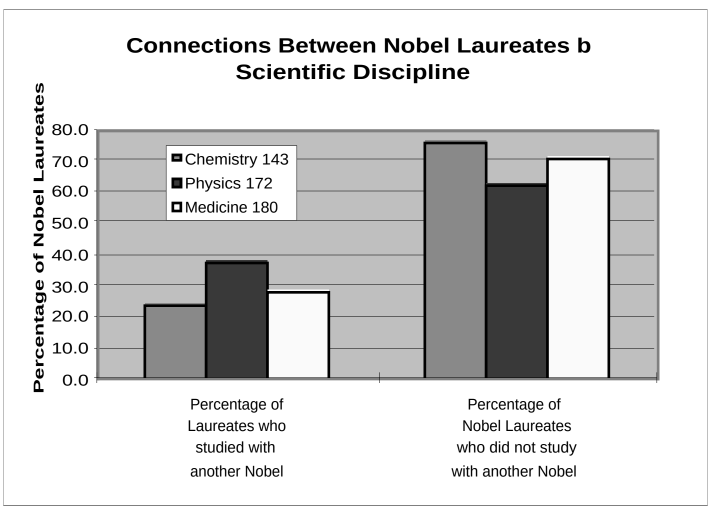
Cambridge, Harvard, Berlin, Göttingen, Munich, Leipzig, London, Heidelberg, St. Petersburg, UC Berkeley, Paris, Columbia, École Polytechnique, Oxford, Cal Tech, MIT, Wisconsin, Strasbourg



Nobel Prizes



Nobel Prizes



Universities where Nobel Laureates obtained their doctoral degrees

Number of Chemistry Prizes	University	Number of Physics Prizes	University	Number of Physiology & Medicine Prizes	University
14	**Cambridge**	19	**Cambridge**	19	**Harvard**
10	**UC Berkeley**	12	**Columbia**	17	**Cambridge**
5	**Harvard**	8	**Chicago**	12	**Johns Hopkins**
5	Munich	7	Berlin	10	**Columbia Coll. Phys. Surg.**
4	Berlin	7	**Harvard**	7	Berlin
4	Göttingen	7	Princeton	7	Munich
4	Marburg	7	MIT	7	Vienna
3	MIT	6	Cal Tech	7	Washington (at St. Louis)
3	Uppsala	6	Munich	6	Cal Tech Copenhagen

Where to find biographical information about scientists?

Gillispie, Charles (ed.) *Dictionary of Scientific Biography*
Obit. Not. Fellows Roy. Soc.; Biog. Mem. Fellows Roy. Soc.
Biog. Mem. Natl. Acad. Sci. USA; Current Biography
***Profiles, Pathways, and Dreams* Series, ACS: Washington, D.C.**
Candid Science series, The Road To Stockholm
Ogilvie, M.; Harvey, J. (eds.) *The Biographical Dictionary of Women in Science*
Websites: Nobel Academy, Named Things in Chemistry & Physics

General: *The Chemical Intelligencer* (1995-2000) *Eur. J. Org. Chem.* (1998)	Swiss: *Helvetica Chimica Acta* (1918+)
British: *Chemical Society Reviews* (1972+), *Journal of the Chemical Society* (1849), *Green Chemistry* profiles (1999+), *Organic and Biomolecular Chemistry* profiles (2003+)	American: *Chemical Reviews* (1980+), *Accounts of Chemical Research* (1972+), *Journal of Physical Chemistry* Festschrift issues, *Chemical & Engineering News* obituaries and profiles
German: *Chemische Berichte* (1868 - 1997), *Angewandte Chemie* (1888+)	Canadian: *Canadian Journal of Chemistry* dedication issues (1988+)
French: *Bulletin de la Société de Chimie de France* (1889+)	Japanese: *Bulletin of the Chemical Society of Japan* (Accounts)

Key patterns of successful academics:

4 Were inspired at a young age about science

4 Learned by example; emulated past advisors => notion of "apprenticeship"

4 Sought people of influence who promoted their scientific efforts and ideas
4 Sought people who steered them in the path of other "good connections"
4 Sought professional allies from within and outside their area of science as early as possible (peers and higher ranking people) => scientific pedigrees
4 Sought mentors who made no distinction between excellence in research and excellence in teaching

4 Were aware of "local nodes" of scientific genealogy trees; were able to distinguish "diggers" (innovators) from "drillers" (followers)

4 Were proficient in using the scientific literature; clarified their scientific ideas, maintained focus on those ideas, and pursued them tenaciously and in many instances rather selfishly

4 Actively participated in the whole research/teaching enterprise: initiated their own ideas, asked important questions, developed a research plan, wrote their own scientific papers and proposals, announced their findings by giving talks at conferences

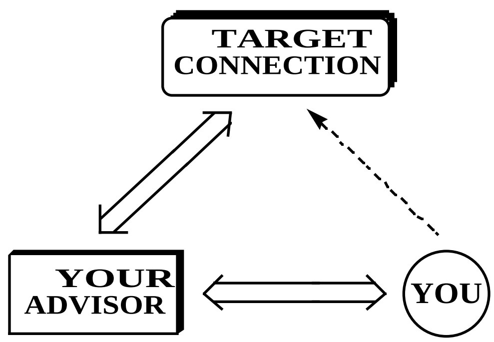
4 Willingly opened themselves up to criticism from others and showed resilience, stamina, and belief in their academic goals

Culture of "Academia"

Professional goals of academicians:

(1) To be recognized for their contributions to a field of study
(2) To propagate and perpetuate those contributions through their students

Triangulation Principle and Rank-to-Rank Flow
Selling yourself versus someone else selling you



Comments from Scientists

A decisive influence for a research career is for it to be launched in a strong environment. The adviser counts the most, but the whole atmosphere is important, the other professors and fellow students, the technological level of the institution, the visitors, and so on. The research seminar is probably the single most critical ingredient in shaping the young researcher's career. It broadens his horizon, introduces him to new fields and outside scientists, with different styles and approaches, and teaches him how to conduct scientific discussions. The beginner sees how questions are asked and answered, witnesses the debates, and gradually becomes part of the process. - Istvan Hargittai

Avoid dumb people…always turn to people who are brighter than yourself.
- James Watson

Most of what he [Michael Polanyi] taught me about physical chemistry I learned…from him. I was a student for six years in the department that he shaped in Manchester. The professor Meredith Evans was one of his favourite students and my PhD supervisor was another of his, Ernest Warhurst. What I learned from [my father's] students gave me a sense of scientific values -- where the field was going, what were the important questions to tackle, and, to a degree, how to tackle them. Without those things I would have been lost. But it happens that I didn't get them directly from him, but from people who owed a lot to him. - John C. Polanyi

There is a greater chance of making significant discoveries at universities that have an intellectual ferment of people who exchange ideas and who have great skill in generating ideas. One needs to learn the "style" of producing great ideas by apprenticing with such people. Good teachers tell students what to pay attention to, what to accept, what to reject, what to retain, what to discard. - John Polanyi (York University invited address, 2000)

From [Hans] Fischer I learnt the trade secrets of being a research chemist; I learnt from him how to pose a research problem, what one may and what one may not investigate, where to start and where to stop. I learnt the tenacity which must accompany a research work. I learnt that one must have the audacity to attack difficult problems, even when they will take a long time and will require a substantial effort.
- Costin Nenitzescu in *The Chemical Intelligencer*, April 1999, 36.

Comments from Scientists

An appropriate answer to the right problem is worth a good deal more than an exact answer to an approximate problem.
- John W. Tukey

In science you sometimes find the solution to a problem from another field. - Aaron Klug

There is nothing more rewarding than linking two quite different subjects.
- Lord George Porter

It is essential in scientific research to make decisions on the basis of incomplete information.
- Istvan Hargittai

It's no trick to get the right answer about some scientific question when you have got all the data. A computer can do that. A real trick is to get the right answer when you've only got half the data and half of what you have is wrong, and you don't know which half is wrong. Then when you get the right answer you're doing something creative…That philosophy can lead you also into great troubles, and it frequently does but you can make advances that way because then you won't be bothered too much by the dogma of the day. - Melvin Calvin

It is not easy to get money for a thing which is wild -- where you cannot say this is going to have results.
- Peter Debye

Research is not just going from mountain top to mountain top, you also have to work in the valleys, and that takes time and freedom. - Aaron Klug

A discovery is getting a counter-intuitive result that can't be explained. - John Polanyi

Good areas of science are selected on the basis of whether the ideas matter, whether they will change people's thinking rather than if the ideas will generate wealth. - John Polanyi

Comments from Scientists

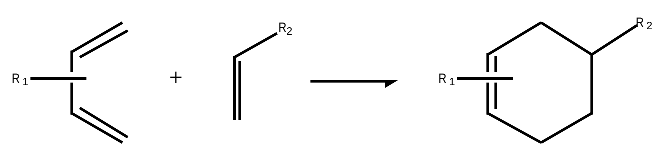
A scientific career is peculiar in many ways. Its *raison d'etre* is the increase of natural knowledge. Occasionally, therefore, an increase of natural knowledge occurs. But this is tactless, and feelings are hurt. For in some small degree it is inevitable that views previously expounded are shown to be either obsolete or false. Most people, I think, can recognize this and take it in good part if what they have been teaching for ten years or so comes to need a little revision; but some undoubtedly take it hard, as a blow to their *amour propre*, or even as an invasion of the territory they have come to think as exclusively their own, and they must react with the same ferocity as we can see in the robins and chaffinches these spring days when they resent an intrusion into their little territories. I do not think anything can be done about it. It is inherent in the nature of our profession; but a young scientist may be warned and advised that when he has a jewel to offer for the enrichment of mankind some certainly will wish to turn and rend him.

- Sir Ronald A. Fisher, BBC interview 1947

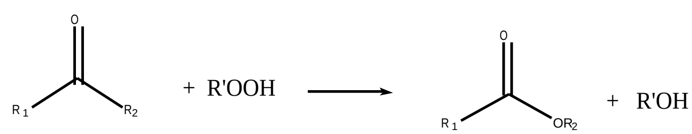
Survey of Connections Between People and Ideas

Type 1: Named thing shared between student and advisor

Diels-Alder reaction (O. Diels, K. Alder, 1928)



Baeyer-Villiger oxidation (A. von Baeyer, V. Villiger, 1899)



Survey of Connections Between People and Ideas

Born-Oppenheimer approximation
(M.Born, J.R. Oppenheimer, 1927)

Electronic motion and nuclear motion in molecules can be separated. Nuclear motions are considered fixed relative to electron motions. Hence, energy of electrons may be calculated for a fixed position of nuclei.

$$\Psi_{molecule} = \Psi_{electrons} * \Psi_{nuclei}$$

$$\Psi_{electrons} = \Psi_{electronic} * \Psi_{rotational} * \Psi_{vibrational}$$

$$E_{electrons} = E_{electronic} + E_{rotational} + E_{vibrational}$$

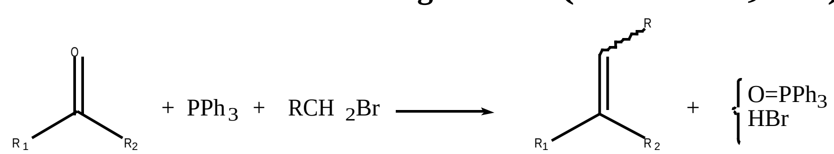
Michaelis-Menten kinetic scheme and equation
(L. Michaelis, M. Menten, 1913)

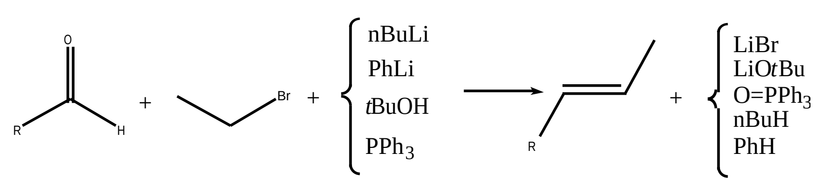
$$\mathbf{E} + \mathbf{S} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \mathbf{ES} \xrightarrow{k_3} \mathbf{P}$$

$$\frac{d[P]}{dt} = \frac{k_3[E]_o[S]}{K_m + [S]}$$

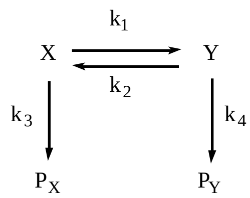
Survey of Connections Between People and Ideas
Type 2 Evolution of ideas from advisor to student (innovator-follower)

Wittig reaction (G. Wittig, 1954) ->
Schlosser modification of Wittig reaction (M. Schlosser, 1971)





Conformational theory (Sir D.H.R. Barton, 1950+) -> Winstein-Holness equation (S.Winstein, N. Holness, 1955)



$$[S] = \left([X]_o + [Y]_o\right)\exp[-k_{obs}t]$$

$$[P] = \left([X]_o + [Y]_o\right)\left(1 - \exp[-k_{obs}t]\right)$$

$$k_{obs} = \left(\frac{[X]_o}{[X]_o + [Y]_o}\right)k_3 + \left(\frac{[Y]_o}{[X]_o + [Y]_o}\right)k_4$$

$$= \left(\frac{1}{1+K}\right)k_3 + \left(\frac{K}{1+K}\right)k_4$$

Stefan-Boltzmann constant and law (J.Stefan, L. Boltzmann, 1879) -> Boltzmann constant (L. Boltzmann, 1877)

σ = 5.669 X 10^{-8} J m^{-2} s^{-1} K^{-4} k_B = 1.380 X 10^{-23} J K^{-1}

Linear combination of atomic orbitals (LCAO) (J. Lennard-Jones, 1929) -> Pariser-Parr-Pople theory (J. Pople, 1953) -> Magnetic resonance imaging (MRI) (P.C. Lauterbur, 1970s)

Karl Pearson

Pearson system for characteriz distributions:
=> mean, standard deviation,
=> symmetry, skewness, kurtosis (1893)
skew distributions (1895)
chi-square test for goodness of fit and degrees of freedom (1900)

William S. Gosset

student t-test and probable error of the mean (1908)

Sir Ronald A. Fisher

distribution of correlation coefficient (1915), concept of maximum likelihood (1921), analysis of variance (1923), analysis of co-variance (1922), concept of degrees of freedom (1924), theory of statistical estimation (1925), general theory of natural selection (1930)

Chester I. Bliss

probit analysis and determination of LD50 (1935)

Jacobian matrix and determinant (C.G.J. Jacobi, 1841) ->
Hessian matrix and determinant (L.O. Hesse, 1842)

Jacobian matrix is first-derivative of a vector-valued function of a vector variable.
Hessian matrix is second-derivative of a scalar-valued function of a vector variable.
Hessian matrix is the Jacobian matrix of the gradient.

Given scalar-valued function of a vector-variable $f(x_1, x_2, ..., x_n)$

Gradient is $\nabla f = \left(\frac{\partial f}{\partial x_1}, \frac{\partial f}{\partial x_2}, ..., \frac{\partial f}{\partial x_n} \right)$

Jacobian matrix element is $J_{ij} = \frac{\partial f_i}{\partial x_j}$

Hessian matrix element is $H_{ij} = \frac{\partial^2 f}{\partial x_i \partial x_j}$

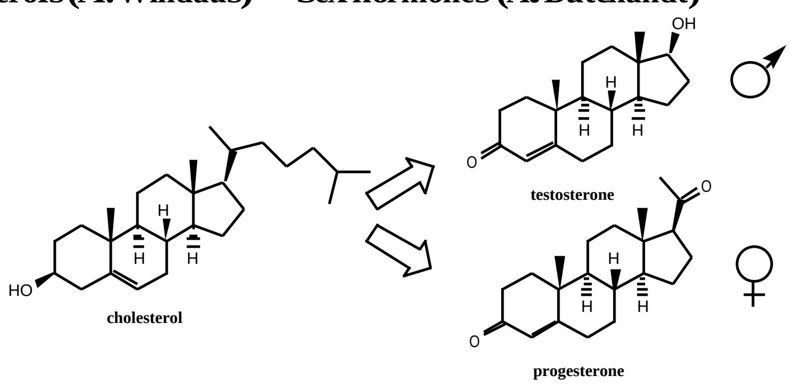
Eigenvalues of Hessian matrix	Determinant of Hessian matrix	Character of critical point
All positive	Positive	Local minimum
One negative, rest positive	Negative	First-order saddle point (transition state)

Hessian matrix = force constant matrix
Eigenvalues of diagonalized Hessian matrix = vibrational energies

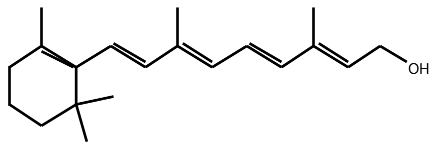
Kasha's rule (M. Kasha, 1950) -> El-Sayed's rule (M. El-Sayed, 1968)

Kasha: Luminescence is the emission of light from an excited state to a ground state of the same multiplicity.
El-Sayed: Intersystem crossing from lowest singlet state to lowest triplet state is a fast process.

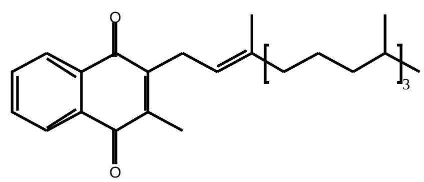
Sterols (A. Windaus) -> Sex hormones (A. Butenandt)



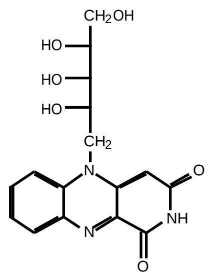
Synthesis of vitamins A and B2 (P. Karrer, 1931 and 1935) -> Discovery of vitamin K (H. Dam, 1939)



vitamin A

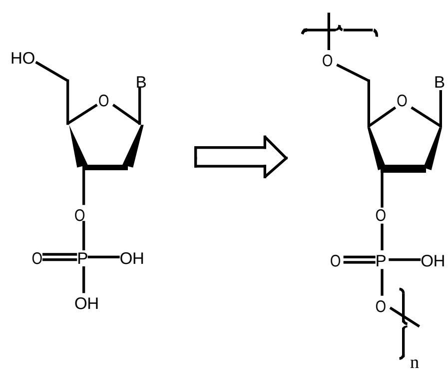


vitamin K



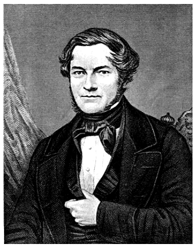
vitamin B2 (riboflavin)

Synthesis of nucleotides (Lord A. Todd, 1947+) -> Synthesis of genes (H.G. Khorana, 1979)



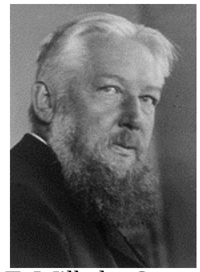
Macromolecular/polymer chemistry (H. Staudinger, 1922+) -> Ziegler-Natta catalyst (K. Ziegler, G. Natta, 1955/6)

Example Genealogy Trees


Robert Bunsen


Antoine Balard


H. v. Helmholtz


F. Wilhelm Ostwald


Adolf v. Baeyer


Emil Fischer


Sir J.J. Thomson

Example Genealogy Trees

Type 3 Novel ideas and discoveries through generations

BUNSEN

Bunsen burner, actinometry **(1855)** (with **Sir Henry Roscoe**)
elemental spectrum analysis **(1860)** (with **Gustav R. Kirchhoff**)
Discovery of element 37, rubidium **(1861)** (with **Gustav R. Kirchhoff**)
Discovery of element 55, cesium **(1860)** (with **Gustav R. Kirchhoff**)

Ludwig Mond
Discovery of metal carbonyls ($Ni(CO)_4$) **(1890)**

Viktor Meyer method
(1876 - 1878)

Wurster dyes **(1879)** , **Wurster's** reagent **(1879)**

Michler's ketone **(1879)**

Bodenstein
steady state approximation
(1913)

Paul Harteck
(Berlin, 1926)
Discovery of parahydrogen **(1929)**

Sir Edward Frankland
Concept of valence **(1852)**

Ladenburg benzene **(1869)**

Philipp E.A. Lenard
Investigation of cathode rays
Physics Nobel 1905

Karl Heumann
(Heidelberg, 1878)
industrial process to produce indigo
(1890)

Wilkinson's catalyst
(1965) ; organometallic chemistry; metallocenes
Chemistry Nobel 1973

Schrock carbenes
(1974)

Hempel column
Hempel pipette

Louis M. Dennis
(Michigan, 1886)

Eugene G. Rochow
silicone polymer **(1941)**
Corey-Pauling-Koltun
space filling model **(1959)**

Heiki Kamerlingh-Onnes
properties of matter at low temperatures, superconductivity **(1911)** ; liquid helium
(1906) Physics Nobel 1913

Penning vacuum gauge **(1937)**
Zeeman effect
(1896 - 1897)
Physics Nobel 1902

Adolf Hermann Kolbe
(Marburg, 1843)
synthesis of salicylates
(1874)

Henry E. Armstrong
(Leipzig, 1869)
discovery of 1,3-butadiene in cracked petroleum (with A.K. Miller) **(1886)**
origin of colour **(1888 - 93)**

Bronsted-Lowry definition of an acid and a base **(1923)**
Armstrong and Wynne's acids (1890's)
Sir William J. Pope
Discovery of asymmetric N, S, Sn, Se compounds **(1899+)**

Beckmann rearrangement
(1886)

Constantin Fahlberg
(Leipzig, 1873)
discovery of sweetener saccharin (with Ira Remsen)
(1878)
Walter Reppe
(Munich, 1920)
Reppe process to make vinyl ethers and acetylenes **(1928)**

BALARD TREE

Antoine J. Balard
Discovery of element 35 bromine **(1826)**

Maurice Hanriot
(Paris, 1880)

Bouveault-Blanc reaction **(1903)**
Acyloin condensation **(1905)**

Grignard reaction
Grignard reagent **(1900)**
organomagnesium halides in organic synthesis
Chemistry Nobel 1912

Gilman organometallic reagents **(1936)**

Barbier-Wieland reaction **(1912 - 1913)**

Berthelot equation **(1875)**

Delepine reaction **(1895)**

Gibbs-Duhem equation **(1886)**

Paul Sabatier
Hydrogenations of unsaturated organic compounds
Chemistry Nobel 1912
Antoine Villiers-Moriame
(College de France, 1880)
Discovery of cyclodextrins **(1891)**

Paul E.L. de Boisbaudran
Discovery of element 31, gallium **(1875)**
Discovery of element 62, samarium **(1879)**
Discovery of element 66, dysprosium **(1886)**
Lobry de Bruyn-van Eckenstein transformation **(1895)**

Pasteur pipet; stereochemistry (definition of enantiomers; R/S tartrates) **(1848)**;
alcohol fermentation; germ theory of disease **(1861)**;
pasteurization (1867); vaccines for rabbies; anthrax

Wurtz coupling reaction **(1855)**
Wurtz-Fittig reaction **(1864)**

Pierre E. Duclaux
(Ecole Norm. Sup., 1865)

Emile Roux
(Paris, MD 1881)

Charles J.H. Nicolle
Investigation of typhus
Physiology & Medicine Nobel 1928

Friedel-Crafts alkylation and acylation reactions **(1877)**

Georges Urbain
Discovery of element 71, lutetium **(1907)**
Bouveault-Blanc reaction **(1903)**
Acyloin condensation **(1905)**
Lobry de Bruyn-van Eckenstein transformation **(1895)**

Louis E. Grimaux
(Sorbonne, 1877)

Darzens condensation **(1904)**

HELMHOLTZ

Helmholtz equation, energy **(1882)**
Concept of conservation of energy **(1847)**
invented ophthalmoscope **(1851)**

Wien displacement law **(1896)**
Physics Nobel 1911

Hans Rau
(Wuerzburg, 1906)

Gerhard Herzberg
electronic structure and geometry of free radicals
Chemistry Nobel 1971

Hertz unit of frequency **(1888)**

Hudson's rules **(1924+)**
Mutarotation of sugars **(1903+)**
William W.Coblentz
Development of IR spectroscopy **(1905)**

Michael I. Pupin
(Berlin, 1889)

Millikan oil drop experiment **(1913)**
Physics Nobel 1923

Hubble constant, law **(1929)**

Philipp E.A. Lenard
Investigation of cathode rays
Physics Nobel 1905

Gibbs free energy
Gibbs equation
Gibbs-Duhem equation **(1876/8)**, **Gibbs** phase rule **(1875/6)**, **Gibbs** vector analysis **(1881)**

Henry A. Bumstead
(Yale, 1897)

Nyquist stability theorem **(1928)**

Johnson noise **(1928)**

Roland Eotvos
(Heidelberg, 1870)

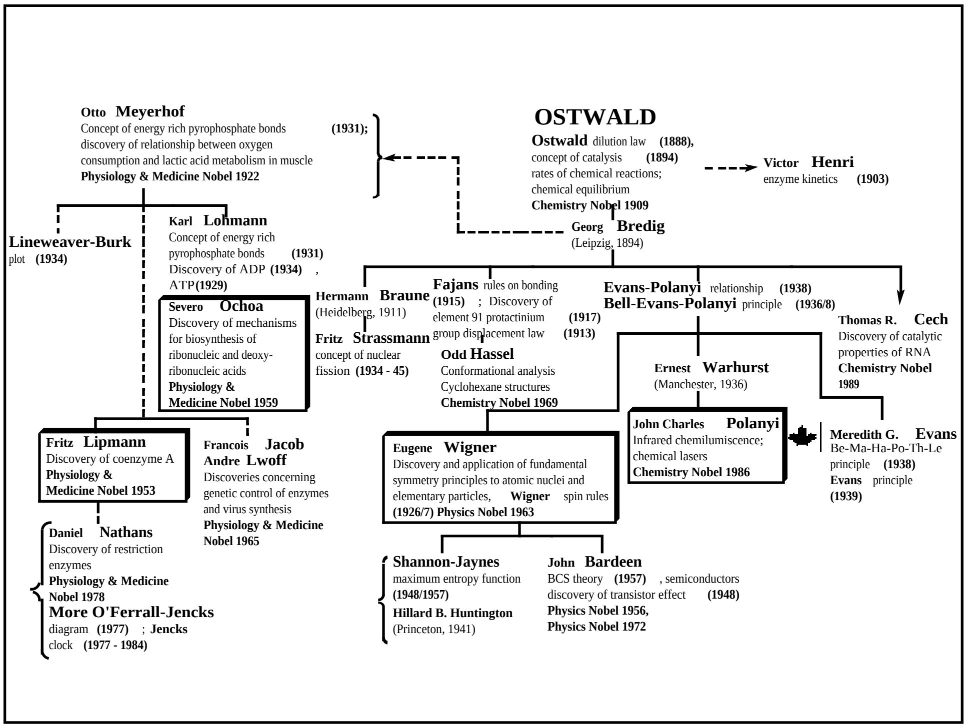
Karl Tangl
(Budapest, 1895)

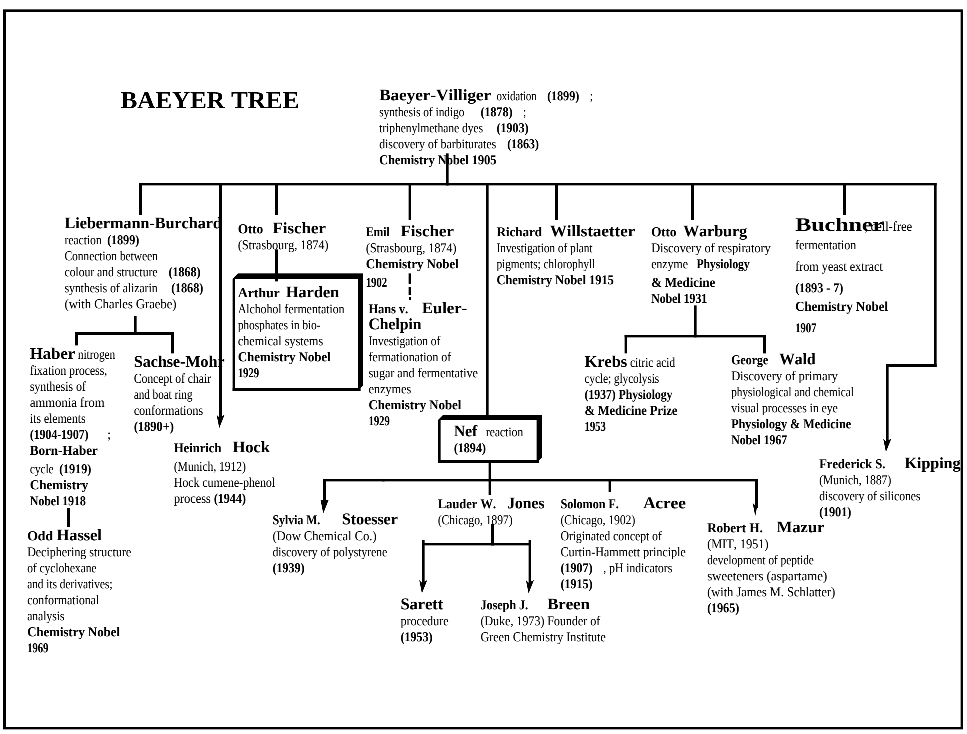
Georg von Bekesy
Discovery of physical mechanism of stimulation of cochlea **Physiology & Medicine Nobel 1961**

Planck's constant,
Planck's radiation law **(1900)**,
Concept of blackbody radiation **(1901)**
Physics Nobel 1918

Laue symmetry groups
Laue equations **(1912)**
discovery of X-ray diffraction by crystals
Physics Nobel 1914

Schottky barrier; diode; noise **(1939)**


OSTWALD
Ostwald dilution law (1888), concept of catalysis (1894) rates of chemical reactions; chemical equilibrium Chemistry Nobel 1909
Victor Henri enzyme kinetics (1903)
Otto Meyerhof Concept of energy rich pyrophosphate bonds (1931); discovery of relationship between oxygen consumption and lactic acid metabolism in muscle Physiology & Medicine Nobel 1922
Georg Bredig (Leipzig, 1894)
Lineweaver-Burk plot (1934)
Karl Lohmann Concept of energy rich pyrophosphate bonds (1931) Discovery of ADP (1934), ATP(1929)
Severo Ochoa Discovery of mechanisms for biosynthesis of ribonucleic and deoxy-ribonucleic acids Physiology & Medicine Nobel 1959
Hermann Braune (Heidelberg, 1911)
Fritz Strassmann concept of nuclear fission (1934 - 45)
Fajans rules on bonding (1915); Discovery of element 91 protactinium (1917) group displacement law (1913)
Odd Hassel Conformational analysis Cyclohexane structures Chemistry Nobel 1969
Evans-Polanyi relationship (1938)
Bell-Evans-Polanyi principle (1936/8)
Thomas R. Cech Discovery of catalytic properties of RNA Chemistry Nobel 1989
Ernest Warhurst (Manchester, 1936)
John Charles Polanyi Infrared chemiluminscence; chemical lasers Chemistry Nobel 1986
Meredith G. Evans Be-Ma-Ha-Po-Th-Le principle (1938) Evans principle (1939)
Fritz Lipmann Discovery of coenzyme A Physiology & Medicine Nobel 1953
Francois Jacob Andre Lwoff Discoveries concerning genetic control of enzymes and virus synthesis Physiology & Medicine Nobel 1965
Eugene Wigner Discovery and application of fundamental symmetry principles to atomic nuclei and elementary particles, Wigner spin rules (1926/7) Physics Nobel 1963
Daniel Nathans Discovery of restriction enzymes Physiology & Medicine Nobel 1978
More O'Ferrall-Jencks diagram (1977); Jencks clock (1977 - 1984)
Shannon-Jaynes maximum entropy function (1948/1957)
Hillard B. Huntington (Princeton, 1941)
John Bardeen BCS theory (1957), semiconductors discovery of transistor effect (1948) Physics Nobel 1956, Physics Nobel 1972


BAEYER TREE
Baeyer-Villiger oxidation (1899); synthesis of indigo (1878); triphenylmethane dyes (1903) discovery of barbiturates (1863) Chemistry Nobel 1905
Liebermann-Burchard reaction (1899) Connection between colour and structure (1868) synthesis of alizarin (1868) (with Charles Graebe)
Otto Fischer (Strasbourg, 1874)
Emil Fischer (Strasbourg, 1874) Chemistry Nobel 1902
Richard Willstaetter Investigation of plant pigments; chlorophyll Chemistry Nobel 1915
Otto Warburg Discovery of respiratory enzyme Physiology & Medicine Nobel 1931
Buchner cell-free fermentation from yeast extract (1893 - 7) Chemistry Nobel 1907
Arthur Harden Alchohol fermentation phosphates in bio-chemical systems Chemistry Nobel 1929
Hans v. Euler-Chelpin Investigation of fermationation of sugar and fermentative enzymes Chemistry Nobel 1929
Haber nitrogen fixation process, synthesis of ammonia from its elements (1904-1907); Born-Haber cycle (1919) Chemistry Nobel 1918
Sachse-Mohr Concept of chair and boat ring conformations (1890+)
Heinrich Hock (Munich, 1912) Hock cumene-phenol process (1944)
Nef reaction (1894)
Krebs citric acid cycle; glycolysis (1937) Physiology & Medicine Prize 1953
George Wald Discovery of primary physiological and chemical visual processes in eye Physiology & Medicine Nobel 1967
Frederick S. Kipping (Munich, 1887) discovery of silicones (1901)
Odd Hassel Deciphering structure of cyclohexane and its derivatives; conformational analysis Chemistry Nobel 1969
Sylvia M. Stoesser (Dow Chemical Co.) discovery of polystyrene (1939)
Lauder W. Jones (Chicago, 1897)
Solomon F. Acree (Chicago, 1902) Originated concept of Curtin-Hammett principle (1907), pH indicators (1915)
Robert H. Mazur (MIT, 1951) development of peptide sweeteners (aspartame) (with James M. Schlatter) (1965)
Sarett procedure (1953)
Joseph J. Breen (Duke, 1973) Founder of Green Chemistry Institute

EMIL FISCHER

Fischer indole synthesis **(1883)**
Fischer projection **(1891)**
Kiliani-Fischer synthesis **(1885/1889)**
Fischer esterification **(1895),** protein peptide structure **(1901)**
carbohydrate chemistry; purine chemistry
Chemistry Nobel 1902

Fritz Pregl
(Graz, MD 1894; Berlin)
Development of microanalysis methods
Chemistry Nobel 1923

Bergmann-Zervas carbobenzoxy method **(1932)**

Burkhardt Helferich tetrahedral intermediate **(1930)**

Zemplen's saponification **(1924)**
Zemplen degradation of sugars **(1926)**

magic or superacid (1968)
Olah's reagent **(1973)**
Investigation of carbocations, new uses of hydrocarbons in petroleum industry, cage molecules
Chemistry Nobel 1994

Piloty's acid **(1896)**

Schlenk tube
Schlenk equilibrium **(1929)**

Feigl spot tests **(1958)**
Herman F. Mark
(Vienna, 1920)
x-ray structures of hexamethylenetetramine **(1923)**, graphite **(1924)**, oxalic acid **(1924)**, calomel **(1926)**, solid CO2 **(1925 - 6)**, ethane and borane **(1925)**, cellulose **(1928)**, organic compounds **(1930)**, polymer structures **(1930s)**, first electron diffraction studies of gases, determination of bond lengths and angles **(1930s)**

Rudolf J. Anderson
(Berlin, 1911)

Newman projection **(1955)**

Taft equation **(1952)**
Kamlet-Taft solvent parameters **(1976)**

Diels-Alder reaction **(1928)**
Chemistry Nobel 1950

Rosenmund reduction **(1918)**
Alder rule **(1960)**

Karl Landsteiner
(Vienna, MD 1891; Wuerzburg)
Discovery of blood groups **(1920s)**
Physiology & Medicine Prize 1930
Michaelis-Menten equation and constant **(1913)**

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36 Physics Nobel Prizes

1915 Sir William H. Bragg
1915 Sir William L. Bragg
1917 Charles G. Barkla
1927 Arthur Compton
1927 Charles T.R. Wilson
1928 Owen W. Richardson
1935 Sir James Chadwick
1937 Clinton J. Davisson
1937 Sir George P. Thomson
1939 Ernest O. Lawrence
1947 Sir Edward V. Appleton
1948 Lord Patrick Blackett
1950 Cecil F. Powell
1951 Ernest T.S. Walton
1952 Edward M. Purcell
1956 Clifford G. Shull
1968 Luis W. Alvarez
1970 Hannes O.G. Alfven
1973 Brian D. Josephson
1974 Sir Martin Ryle
1974 Antony Hewish
1977 Sir Nevill F. Mott
1978 Pyotr L. Kapitsa
1979 Steven Weinberg
1981 Arthur L. Schawlow
1981 Nicolas Bloembergen
1990 Richard E. Taylor
1991 Pierre G. de Gennes
1994 Bertram N. Brockhouse
1995 Frederick Reines
1996 David M. Lee
1996 Douglas D. Oesherhoff
1998 Daniel C. Tsiu
1998 Robert B. Laughlin
1999 Martinus J.G. Veltman
1999 Geraldus 'T. Hooft

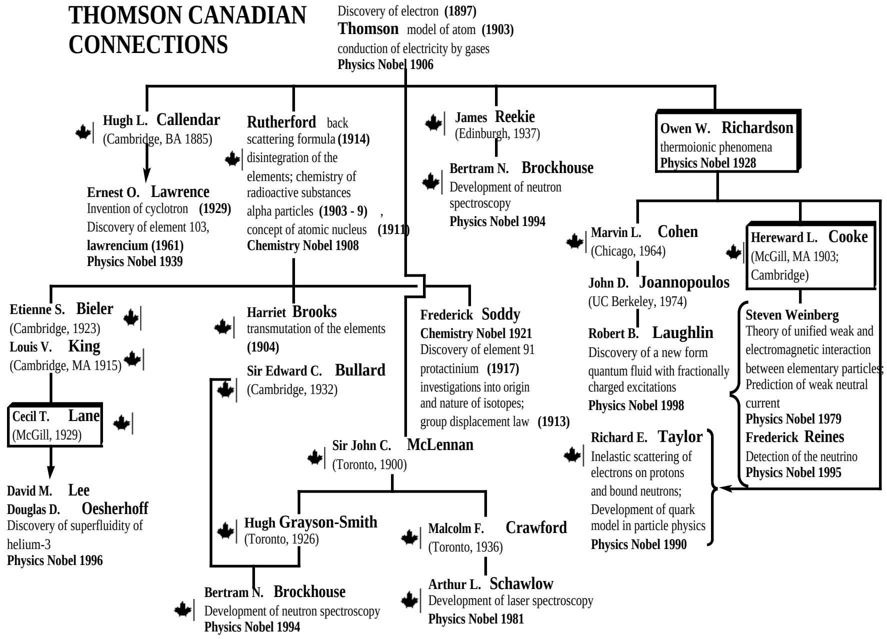
Sir Joseph J. THOMSON Nobel Legacy
Physics Nobel 1906

8 Chemistry Nobel Prizes ⇒
1908 Lord Ernest Rutherford
1921 Frederick Soddy
1921 John A. Cranson
1921 Sir Alexander Fleck
1943 Georg de Hevesy
1962 John Kendrew
1962 Max Perutz
1964 Dorothy C. Hodgkin

3 Physiology & Medicine Nobel Prizes ⇒
1962 Francis Crick
1962 James Watson
1962 Maurice Wilkins

1 Peace Nobel Prize ⇒
1995 Joseph Rotblat

THOMSON CANADIAN CONNECTIONS



"Unknown" Canadian Scientists

SCIENTIST	DATES	BIRTHPLACE	SCIENTIFIC ACHIEVEMENT
Avery, Oswald Theodore MD 1904 Columbia	1877 - 1955	b. Halifax, Nova Scotia	DNA as source of heredity **(1944)**
Brooks, Harriet T. MA 1901 McGill (Lord Ernest Rutherford)	1876 - 1933	b. Exeter, Ontario	Transmutation of the elements **(1904)**
Eadie, George Sharp Ph.D. 1927 Cambridge (J.B.S. Haldane)	1895 - 1976	b. Toronto, Ontario	Eadie plot **(1942)**
Giauque, William Francis **Chemistry Nobel 1949** Ph.D. 1922 UC Berkeley (George E. Gibson)	1895 - 1982	b. Niagara Falls, Ontario	Absolute zero temperature **(1927+)**, partition functions **(1930)**
Good, Norman Everett Ph.D. 1951 Cal Tech (Hershel K. Mitchell)	1917 -	b. Brantford, Ontario	Good buffer solutions **(1966)**

SCIENTIST	DATES	BIRTHPLACE	SCIENTIFIC ACHIEVEMENT
Kamen, Martin Ph.D. 1937 Chicago (William D. Harkins)	1913 -	b. Toronto, Ontario	Discovery of carbon-14 isotope **(1941)**
Menten, Maud Leonora Ph.D. 1916 Chicago (Albert P. Mathews)	1879 - 1960	b. Port Lambton, Ontario	Michaelis-Menten kinetics **(1913)**
Moffatt, John Gilbert Ph.D. 1956 UBC (Har G. Khorana)	1930 -	b. Victoria, British Columbia	Pfitzner-Moffatt reagent **(1963)** (DMSO-dicyclohexylcarbodiimide)
Patterson, Arthur Lindo Ph.D. 1928 McGill (Arthur S. Eve)	1902 - 1966	b. Nelson, New Zealand	Patterson functions **(1934)**
Saunders, Frederick A. Ph.D. 1899 Johns Hopkins (Henry A. Rowland)	1875 - 1963	b. London, Ontario	Russell-Saunders spin-orbit coupling **(1925)**
Winstein, Saul Ph.D. 1938 Cal Tech (Howard J. Lucas)	1912 - 1969	b. Montreal, Quebec	Anchimeric assistance **(1939)**; Normal salt effect **(1940)** with C.K. Ingold; Winstein equation; Grunwald-Winstein equation **(1948)**; intimate and solvent separated ion pairs **(1952)** with D.J. Cram; special salt effect **(1954)**; Winstein-Holness equation **(1955)**

Leaders in Canadian Chemistry Over the Years

1900 - 1949

Otto MAAS
Frederick M.G. JOHNSON
Robert F. RUTTAN
Harold HIBBERT
Clifford B. PURVES

William Lash MILLER
Andrew R. GORDON
George F. WRIGHT
Fred E. BEAMISH

1950 - 1969

Carl A. WINKLER
Raymond U. LEMIEUX
Edgar W.R. STEACIE
Robert L. MCINTOSH

Clara BENSON
Donald J. LEROY
Harry E. GUNNING
Adrian BROOK

England:
Ronald J. GILLESPIE
Theodore P. SCHAEFER
Albert D. ALLEN
Charles A. MCDOWELL
Keith J. LAIDLER
Howard C. CLARK
Gerald W. KING
Brian E. CONWAY

Europe:
Zdenek VALENTA
Karel WIESNER
Paul A. GIGUERE
Henri FAVRE
Paul E. GAGNON
Marcel RINFRET
Gerhard HERZBERG

1970 - 1989

50+ professors from MAAS-WINKLER lineage!

England:
Bryan JONES
Christopher J. WILLIS
Barry LEVER
Geoffrey OZIN
Nicolas C. PAYNE
Donald C. BRADLEY
Michael A. WHITEHEAD
Paul DE MAYO
John C. POLANYI
Chris E. BRION
Stanley J.W. PRICE
G. Michael BANCROFT
Ian S. BUTLER

United States:
Ronald KLUGER
Stephen HANESSIAN
Paul W. BRUMER
William A. AYER
Richard F.W. BADER
John A. PAGE
Robert F. SNIDER
Peter YATES
Keith YATES

Pierre DESLONGCHAMPS
Walter A. SZAREK
Imre G. CSIZMADIA
Bernard BELLEAU

Europe:
George JUST
Charles R. ENGEL
Walter A. AUE
Camille SANDORFY
Robert L. BENOIT