2.

Manuscripts

36.

Manuscripts - by title

Jeans & Eddington.

Nov 1930

Shelley, describes the same, not uncommon, type of man thus:– "To whose passive ken those mighty spheres that gem infinity were only specks of tinsel, fixed in Heaven To light the midnights of his native town"!

Robert Browning in one of his poems refers to the very limited type of mind of those who "see in the stars mere garnishry of heaven" –

It is not thus that knowledge of the true nature of the Universe about us has been won.

Tonight it is my task to introduce to you two of the most outstanding men of science of the present day – Professor A S Eddington and Sir J. H. Jeans.

Both of them have made notable contributions to the edifice of knowledge – both are endowed with winged imaginations and they have speculated (not in stocks but in stellar theories) with a daring akin to audacity – but they are both men of deep honesty of thought with well balanced critical judgment and neither the one nor the other would wish to confuse established facts with the results of pure speculation.

Imagination has its place & a very essential place in the process of advancing knowledge. It is like the eagle that flies with undazzled vision towards the full blaze of the sunlight, pointing the way along which careful painstaking research must strive to make headway – But unaccompanied by sound honest judgment, imagination can be misleading and harmful.

Slide

J.H.J.

Jeans & Eddington.

During the past nine weeks you have listened to accounts of the lives & achievements of fourteen of the greatest British men of science from the 17th century to the present time

This evening it is my task to introduce to you two of the most outstanding men of science of our own day and generation.

They are men who have made notable contributions to the ediface of knowledge — they are also men endowed with winged imaginations and they have speculated (not in stocks – but in theories) with a daring akin to audacity — but they are men of deep honesty of thought and of well balanced judgment and they never confuse established facts with the results of their speculations. Furthermore they are both masters of popular exposition and their writings are high watermark English prose.

Slide

b. 1877 2.

James Hopwood Jeans (52) 66 in 1943

physicist
astrophysicist
cosmologist

d. Sept 16 1946 69 years

Sec. R.S.
one-time president Roy. Astr. Soc.
Author of the books you see before you
and of many important papers that
appear from time to time in Sci. journals

b. 1882

Arthur Stanley Eddington (47) 60 in 1943

d. 1944 Nov 21

Mathematician
Astronomer
astrophysicist
philosopher

Plumian professor of astron in Univ. of Cambridge
One-time assist. to the Astr Royal at Greenwich
F.R.S.
one time Pres. R.A.S.
Author of many scientific papers, memoirs
+ books as well as of several expositions
of modern scientific theories + discoveries.
His influence on the thought of our day is very
great

J. H. J.

b. Sept 1877 London.

Educated. Trin. Col. Camb.
2nd Wrangler 1898
Smiths Prizeman 1900
Fellow of Trin 1901
Univ. Lecturer in Math 1904
Prof App. Math. Princeton 1905-9.
Stokes Lecturer in App. Math Camb. 1910-12

Halley lecturer Oxford 1922
Research Assoc Mt. W. 1923 -

Lives in Dorking

Published Books:—
1 Dynamical Theory of Gases 1904
2. Theoretical Mechanics 1906
3. Math Theory of Electricity + Magnetism 1911
5 Problems of Cosmogony and Stellar Dynamics 1919.
(Adams Prize Essay 1917)
4 Report on Radiation and Quantum Theory 1914
6 Atomicity and Quanta 1926.
7. Eos (Today + Tomorrow Series) 1928
Kegan Paul, London.
8 The Universe Around us C.U.P. 1929.
9 The Mysterious Universe 1929
10 The Stars in their Courses 1929
11 New Bkgd of Science 1933
12 Through Space + Time 1934
13 Science + Music 1937
14 Physics + Philosophy 1942

added 1947

A. S. Eddington.

b. Kendal Dec. 1882 [d. 1944 Nov. 21 in Cambridge.]

Educ. Owens Col. Manchester
Trinity " Camb.
Senior Wrangler 1904
Smiths Prizeman 1907
Fellow Trinity 1907

Chief Asst. Greenwich 1906-13.

Plumian Prof. Camb. 1913. 31 yrs old.

FRS 1914

Pres. R.A.S. 1921-23.

Romanes Lecturer 1922.
Gifford " 1927.
→ OM 1938. (only 24 at any time)

Published Books. 1 Stellar Movements & the Structure of the Universe 1914
2 Report on Relativity Theory of Gravitation 1920
3 The Mathematical Theory of Relativity 1923
4 Space Time & Gravitation 1920
5 The Internal Constitution of the Stars 1926.
6 Stars and Atoms (Clarendon Press Oxford) 1927.
7 The Nature of the Physical World (C.U.P.) 1928
8 Science and the Unseen World (Allen & Unwin Co) 1929.
added. 9 Exp. Univ.
10 New Pathways of Sci.
11 Philos. of Phys. Sci.
12 Fundamental Theory.

Lights.

J. H. J.

The first time that I saw Dr Jeans —
Roy. Chem. Soc. 1918-19?
Quantum theory.

second time R.A.S.C. 1922

First astronomical work.
Sir Geo Darwin } Phil Trans 1901
Poincaré }
2-dimensional model - cylinder of liquid
→ Read p. 280. (MNRAS) ① What year?
16 yrs work
The way to truth is a zig zag road.

Slide: ⬭ and Roche
binary stars

Nebular hypothesis of Laplace
Not solar system
but star galaxy.

→ p. 284 ①

Slides: nebulae
Stars in galaxy
posn of sun.
Aquila Milky Way

7 n. eye stars. 4h exp.
Chance of collision 10^9 yrs. Solar System
Packing
→ Read p. 284. ①

→ Scattering of Moving Clusters. p. 287.

→ Subsequent work stimulated by and in antagonism to Eddingtons - p. 285.

A.S.E.

Slide

Personality – gentle – almost timid

Lecturer – contrast J. J. T.

In his study.

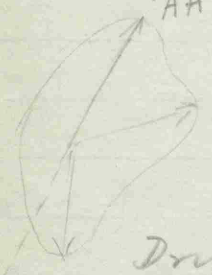
Light

1st work Star Streaming.

1904 Sept. Kapteyn. 2 favoured directions

1906 – 1914 Edd

AA



Drift I near Sirius
32 Km/sec.

Drift II below Sagittarius
18 Km/sec

Apex
Hercules
20 Km/sec.

I : II :: 3 : 2

+ Drift O Eddington's Contribn.
see MNRAS. LXXXIV, 8.
p. 552
June 1924.

2nd. Radiation Pressure.

Range in luminos. small range in mass.

→ Read Stars & atoms p 24 (2)

Slide Slide 2×10^{27} tons

3rd Internal Constitution of Stars.

→ Temp at centre Read (2) p. 12
14-15
20, 21.
26, 27

4th March 1924 Mass Luminosity Law.

Slide Hertzsprung & Russell Giants & Dwarfs.

Read p 176 The Universe around us.

Conflict with Jeans. gas or liquid core!

United in belief of

mass → radiation – irreversible.

Jeans

Annihilation of mass.

Age of Stars.

Binary Orbits

Equipartition of Energy.

mass $\propto \frac{1}{vel^2}$

Sirius → Sun 10^{13} years.

Evolution of Universe - Running down

→ Read Univ. around us. p. 190✓
p. 331
& p. 342

Eddington.

2 Sample Questions.

Slides

Why is Sirius B so faint?

Why is Betelgeuse so bright?

radius 290 × Sun's radius

ρ 6×10^{-7}

Nov 1930 I pass over E's work on the calculations of the diams of stars - brilliantly carried through & gloriously confirmed by Mt Wilson astronomers

Also E's remarkable calculations on the fundamental electrical unit - the charge on an electron - still a matter of theoretical speculation on the part of physicists -

Eddington:

Exponent of Relativity - Read Space T & G. Preface

Verification by Eclipse JH

Read: Whitehead p.14-15.

Einsteins formal world.

mass momentum, stress, gravitation

CURVATURE

Eddingtons criticism.

Weyls world building grav. + el-mag.

Eddingtons " " generalized Weyl's theory.

Einsteins " "

Nov. 1930. → Eddingtons + Lemaitres Expanding Space

Eddingtons criticism

* Map. Graph.

not MODEL.

See Summary p.2.

Beginnings of his philosophy.

Read Space Time & Grav.

p. 200-201

It is a common mistake p.23.

Nat. Phys. World.

Eddington's Philosophy

Platonic in his insistence upon the part played by mind.

p. 276. E's Harmony

228

Nov 1930 Mth

Symbolic + intimate knowledge.

Read Summary

Eddington is a Quaker with deep + sincere mystical trend of mind

→ 327-28 if time read Rainbow paragraph also

Sci. & Unseen World. p. 50

p. 53, 4

55, 6.

THE LITERATURE OF SCIENCE

The subject matter of his choice is not the determining factor as to whether ~~what a scholar writes~~ a scholar's writing will or will not have literary merit, perhaps even literary excellence. The useful classification of knowledge into divisions and subdivisions has been done by erecting arbitrary walls where no intrinsic boundaries exist. All branches of knowledge interpenetrate one another, hence to affirm the oneness of all knowledge is no meaningless assertion. It was therefore essential to include a chapter on the literature of science in the present volume. To have done otherwise would have been to neglect a rich field of Canadian scholarship, a field which for more than a century can claim among its expositers men who have handled the English language with distinction and discrimination.

"We approach Nature in the same spirit as we are bidden to approach the Kingdom of Heaven, that is, as little children, and patiently strive by observation and experiment to find out what she is"......"the scientific idea of truth is a principle which brings order and harmony into phenomena... not arrived at by any mechanical stringing together of facts but by a flash of insight which may be compared to inspiration" - so wrote Professor E. W. McBride in the University Magazine in 1908 in an essay on The Criterion of Truth. The words "not arrived at by any mechanical stringing together of facts" deserve to be repeated with emphasis since many scholars trained too exclusively in the classical, literary and social studies fall into the grievous error of imagining that science is in fact no more than just that. "The dramatic fancy which creates myths," wrote Dean W. R. Inge with an all too rare insight, "is the raw material of both poetry and science".

Unavoidable curtailment of space alloted to this chapter necessitated drastic and arbitrary limitation of the scope and depth of the survey and of the interpretation of the phrase 'literature of science'. The survey is restricted to books and articles of literary merit which are designed to expound and interpret science to the general reader. This rules out all technical papers and reports, and the many catalogues of fish, birds, animals, plants and rocks, no matter how important these have been in the history of scientific achievement. Hence the names of most of Canada's outstanding scientists do not appear in the pages that follow.

References will be found to astronomy and physics, chemistry and geology, the biological, medical and applied sciences; but no attempt has been made to cover agricultural science (with the exception of reference to one famous book) or anything pertaining to the arctic regions. Where there are hundreds of books and essays to be considered, the selection of a few is obviously a very personal choice. In the bibliographies from 1751 - 1867 alone, some 108 authors are listed. After this date, the volume of scientific writing increases, and with striking acceleration in this century. The attempt is here made to select some typical and some of the most outstanding contributions made by native Canadians and by residents of Canada, whether their stay in this country was of long or short duration. The survey is confined to writings in the English language.

- I -

Prior to 1800 very little if any literature of science seems to have appeared in Canada. One finds references to almanacs and to practical instructions relating to husbandry, health, the practice of dentistry, and so forth. As R. O. Earl has pointed out in The Culture of Contemporary Canada (1957) "the early days of pioneer settlement were not appropriate for the development of scientists nor were scientists likely to come to a country in this stage."

But by the nineteenth century many well educated professional men were coming out as officers in the army, as surveyors, teachers medical men, or ministers of religion. In the old Scottish universities, particularly, many of them had acquired considerable knowledge of geology and natural history and they were keenly observant of nature. Scholarly articles and a few books on scientific topics began to be written in Canada.

In Nova Scotia as early as 1818, the Letters of Agricola appeared weekly in the Halifax Recorder. Their author, John Young, not only stimulated farmers of the Maritimes to improve their methods and to form groups for the discussion of general and local problems, but he gave them food for thought in a variety of ways. Good examples are Letters 6 and 7 on climate,
In this latter category he included lime. The
and Letters 27-32 on manures. ~~wherein the author first discoursed~~
discursive nature of his writing is illustrated by his digression to recall a visit to the last
~~on the poet Burns, then described a visit to his grave and a~~
resting place of Burns where an old gardener talked with him about the poet and then
~~conversation with an old man in the graveyard who told him of~~
remarked upon the greatly increased fertility of Ayrshire since the poet's day,
~~the immense improvement of the land since Burns's day. On inquiry~~
ascribing this to the ~~addition~~ application of lime to the fields.
~~he learned that fertility had been brought about by the application of lime to the fields.~~ Young then advocated this treatment and described the various types of occurrence of lime in Nova

Scotia and how best to prepare it for spreading. So highly were these letters regarded and so great was their influence that they were published as a book under the same title in Halifax in 1822.

In 1847 Abraham Gesner, M.D., who became a surveyor in New Brunswick, geologist, investigator of fisheries, pioneer in extracting kerosene and oils from bituminous substances, published in London New Brunswick; with Notes for Emigrants, a book which contains chapters on natural history, climate, soils and wild life.

One manifestation of growing intellectual activity was the formation by groups of enquiring spirits in Montreal, Quebec and the Maritimes of Natural History Societies or Literary and Scientific Societies. The Montreal Natural History Society was founded in 1827, shortly after the Literary and Historical Society of Quebec; a museum was established and the papers read at its meetings were published subsequently in the Canadian Naturalist. This magazine undoubtedly helped to form the intellectual atmosphere of those early years.

In Upper Canada a similar function was performed by the Canadian Journal, organ of the Royal Canadian Institute which was established in Toronto in 1849. Through its public lectures, its Journal (1852-78), and its subsequent Proceedings and Transactions, the Institute has richly contributed to the intellectual growth of this country. In its Centennial Volume (1949) are found ten essays on One Hundred Years of Science in Canada.

The Nova Scotia Literary and Scientific Society was established in January 1859 " for the reading and discussion of original communications... in Literature, Science, Political Economy, Commerce, Statistics and the Arts... to foster a spirit of enquiry and enterprise and generally promote the advancement of science, learning and the useful arts." Many of the papers are of high quality, couched in the dignified, often somewhat ponderous style of the period. In one of the first papers read before the Society, on the Fossiliferous Rocks of Arisaig, the

Rev. David Honeyman wrote "we see nature, by chemical constituents of these rocks, often times embalming their entombed inhabitants as no Egyptian physician could embalm, not to present, after a few thousand years, a dry and withered mummy, but, after years whose numbers we cannot imagine, to present them almost, if not altogether, as lovely as when they were first entombed."

This somewhat too all-embra~~ss~~cive society was modified in 1863 when the Institute of Natural Science was founded and ~~commenced~~ began publication in its Transactions of the papers read at its meetings. The seventh paper for that year was by R. G. Haliburton, F.S.A., (son of Judge Haliburton, satirist) on "The Festival of the Dead", afterwards published in Halifax as the first part of his book New Materials for the History of Man (1863). In this he showed that ancient and more recent inhabitants of four continents regulated their Festival of the Dead and their date of the beginning of the new year from the heliacal rising or the midnight culmination of the Pleiades. Haliburton communicated these ideas to Professor Piazzi Smith which led the latter to base one of his dates for the construction of the Great Pyramid on the present altitude of the Pleiades at culmination relative to the inclination of a passage to the south face, up which, due to the precession of the equinoxes, the Pleiades ~~might~~ could have been seen in B.C. 2170.

In the previous year, 1862, the Principal of Queen's University, Rev. Dr. William Leitch, published in London, a ~~charming~~ little book ~~giving~~ which gave a good account of the astronomical knowledge of the day with reproductions of the Earl of Rosse's drawings of galactic, elliptical and spiral nebulae. The tone of the book is set by its title, God's Glory in the Heavens. Published also in New York, it ran to a third edition in 1866.

H. Beaumont Small was the author of <u>The Animals of North America</u> (Montreal 1864) illustrated with many attractive woodcuts and written to meet "a growing desire for further acquaintance with... the pleasing study of Natural History... felt among a large and increasing class of intelligent readers". Of this little book the Montreal <u>Gazette</u> wrote " we can almost imagine 'old Isaak' recommending it to his pupil Venator," and the <u>Athenaeum</u> praised it as "well worth perusal, written in a style seldom met with in a concise handbook."

- II -

A striking feature in our development is the early interest in Canada in the repercussions of advancing scientific knowledge upon religious beliefs. One evidence of this is the work of Henry Taylor which seems to have had considerable influence in Great Britain. Published by Coates in Toronto 1836, it bears the title " <u>An Attempt to Form a System of the Creation of our Globe, of the Planets and the Sun of our System</u>." It is founded on the first chapter of Genesis, on the geology of the earth, and" on the modern discoveries in that science and the known operations of the laws of Nature, as evinced by the discoveries of Lavoisier and others in pneumatic chemistry." The author set out "to reconcile the present Geological appearances of our Earth with the Mosaic account of creation" by taking literally "the waters" of the second, sixth and seventh verses of Genesis and explaining them in the light of "the wonderful discoveries in pneumatic chemistry, of the gaseous bodies and... the component principles of water." Out of this "Universal ocean" sun, moon, planets are born, the "days of creation" being successive cycles of time. His manuscript, composed between 1819 and 1825, was shown to Archdeacon Mountain, and the Bishop of Quebec, who encouraged him to take it to England where he gave a copy to the Lord Bishop of London, to a theologian named Fairholme, and in 1833, to the Royal Institution in London. When he learned in 1836 that Professor Buckland and the theologians Pusey, Chalmers and Gleig were advocating these very ideas, he hastened to publish his work, fully believing that he was the originator of the ideas.

The same serious motive led Thomas Trotter, Minister of the Presbyterian Church of Antigonish, to publish in 1845 in Pictou his Treatise on Geology, "in which the discoveries of that science are reconciled with the Scriptures, and ancient revolutions of the earth are shown to be of benefit to man." This book was written in the belief that "a comprehensive, connected and scientific view of these events would render an important service to Religion by silencing many of the cavils of the infidel, and solving some of the greatest difficulties which perplex the mind of the inquisitive Christian."

"It is utterly unworthy of the cause of our holy religion, which professes to rest on truth... to shrink from confronting any of the established truths of science," wrote Rev. Moses Harvey of St. John's Newfoundland, and with eloquence and many poetic references he reviewed current advances in geology and astronomy in The Harmony of Science and Revelation, Halifax and St. John's, 1856. In this book he upheld the speculative musings of Sir David Brewster on the plurality of inhabited planets in the universe. A different treatment of this theme was T. W. Goldie's Mosaic Account of Creation of the World and the Noachian Deluge geologically explained, which ran to two editions in Quebec in 1856.

Thoughtful and scholarly men in Canada viewed with the same deep interest and grave concern, the great wave of new biological knowledge and speculation which swirled around the words Evolution and Natural Selection throughout the latter half of the nineteenth century and far into the twentieth. The names of Lyell, Darwin, Lamarck, Spencer, Huxley, Haeckel, produced feelings of hopeful exhilaration or of dismay according to the reader's knowledge and temperament. The concern was of two kinds - unreasoned opposition to the new knowledge on the assumption that it was undermining spiritual faith; and honest acceptance leading to earnest and often ingenious efforts to reconcile new scientific knowledge with biblical cosmology. In 1859, the same year in which The Origin of Species appeared in London, Dr. James Bovell, M.D. published in Toronto Outlines of Natural Theology of which Professor Chapman wrote in the Canadian Journal "It deserves the attention of all interested in the progress of Canadian Literature." In this book the author, who believed "that a Being exists, who through his works reveals himself, as an author in his volume," proceeded to outline the current state of knowledge in geology, zoology, physiology, quoting numerous authorities such as Lyell, Humboldt, Darwin, Murchison, Huxley, Solly and Agassiz, stating unequivocably where he agreed or differed with their metaphysical or theological deductions. The influence of Dr. Bovell on the thinking and activities of the youthful William Osler (afterwards Sir William Osler, M.D.) continued to be a potent factor throughout Osler's life.

In the opposite camp was a Nova Scotian author, Hon. John G. Marshall, whose letters published in 1863 in the Christian World (London) opposed Sir Charles Lyell's views as to the age of the earth, transmutation of species and gradual development in the natural world. Also among the reactionaries was a school master, Ezekiel S. Wiggins, whose book published in Montreal in 1864 carried the title and explanation, The Architecture of the Heavens: "containing a new theory of the Universe, the extent of the Deluge, the testimony of the Bible and Geology in opposition to the views of Dr. Colenso." Dr. Colenso, be it recalled, was an anglican ecclesiastic and mathematician, a pioneer in the Higher Criticism who became Bishop of Natal, but was excommunicated for his liberal views by the Bishop of Capetown.

The proponents of reconciliation of science and religion had an eloquent champion in that distinguished and prolific Canadian scholar, Sir John William Dawson. Only five of his books will be mentioned here. His classical Acadian Geology, Edinburgh and London, 1855, of which Hugh Miller wrote in the Edinburgh Witness, " high scientific merit, very considerable literary merit," is far from being in the category of an ordinary textbook, vide his beautiful and dramatic description of the incoming tide in the Cobequid and Chiegnecto Bays and his pages on the history of the name Acadia. Dawson's Archaia (Studies of the Cosmogony and Natural History of the Hebrew Scriptures) Montreal and London 1860, was so widely read and valued that he revised it in 1877 and it reappeared under the title The Origin of the World according to Revelation and Science. His prestige both in Canada and in Great Britain is further indicated by the reception accorded to two later books. The Chain of Life in Geological Time, was published in London in 1880, 2nd. edition 1885, 3rd. edition 1888. From this little book is taken a passage from the final chapter, " What general conclusions can we reach as to this long and strange history of the progress of life on our planet? Perhaps the most comprehensive of these is that the links in the chain of life or rather its many chains are not scattered and disunited things but members of a great and complex plan... It must also appear that the original plan of nature both in the animal and vegetable worlds, was too vast to be realized at one time on a globe as limited as ours, but had to be distributed in time as well as in space... successive aeons in which, one after the other, the work of creation could rise to successive stages of perfection and completeness till it culminated in man." Modern Ideas of Evolution as related to Revelation and Science, London 18[illegible] provided, amongst other topics, a critical examination of the views of Haeckel and Huxley. A tenth impression appeared in 1910.

— III —

During the latter half of last century, the scientific magazines like the Canadian Naturalist, the Canadian Journal, the Anglo-American Magazine were providing well written articles on a wide range of scientific topics: T. Sterry Hunt on Lithology, good writing and imaginative thinking; John Matthew Jones, F. L. S., on Ocean Drifts and Currents; Sir William Dawson's Presidential address, 1864, to the Natural History Society, in light whimsical vein and his tribute to Sir William Logan's Report of the Geological Survey; Sir Sandford Fleming's tribute to Logan 1856; Rev. A. De Sola's address in 1868 when he said, "Possibly Robinson Crusoe himself was not so much astonished at the footprints on the sands of his desolate island as the naturalist who first saw the footmark of birds on a slab of sandstone which was turned up by the plow...in 1802 at South Hadley in the valley of the Connecticut River."; papers on the great Niagara suspension bridge (1853), on the wave principle in marine architecture (1852), on Dew (1853), on the Victoria Bridge (1855); John Langton, Auditor-General and Vice-Chancellor of the University of Toronto on the Age of Timber Trees (1862) and Ethnological Investigations (1866). A list of such papers in the semi-popular journals could cover many pages.

The British American Journal (Montreal 1845, with a new series beginning in 1860) contained articles and reviews on medical subjects both general and specific. The report on Quackery, Imposition and Deception by Dr. William Marsden (1860) reads like a chapter from a modern detective tale.

The growth of productive scholarship in Canada was greatly stimulated by the increase in the number of universities across the country in the latter part of the 19th century. These with their faculties of letters, social, and scientific studies attracted and encouraged able, ambitious scholars. To provide new outlets for the publication of their ideas the Queen's Quarterly [Q] was founded in 1893, The University Magazine [M] 1901 and The Dalhousie Review [Dal] and University of Toronto Quarterly [T] twenty years later, as well as the Canadian Forum [F]. True, high quality journals like the Atlantic Monthly [A] (1857) from the U.S.A. and the Hibbert Journal [H] (1902) and Discovery [Disc] (1920) from Great Britain had found some devoted readers among thoughtful Canadians, but very few Canadian scientists have published in their pages. Canadian periodicals were therefore very necessary and in them much excellent writing is to be found including expositions of scientific ideas and achievements designed for the enlightenment of general readers, articles on the overlapping fields of science, philosophy and religion, and a large number of able reviews of scientific books. That even the Canadian Forum should carry so many such reviews is convincing evidence of the widespread interest in science during the last forty years.

The following names recur time and again in one or in several of these periodicals; by the initials following each name, identification of the periodicals to which each contributed may be made.

Frank Allen (T), W. C. Baker (Q), S. Basterfield (T,F), N.J. Berrill (A), G. S. Brett (T,F), N.R. Carmichael (Q), A.L. Clark (Q), C.K. Clarke (Q), A. P. Coleman (T,F), A.V. Douglas (Q,T,H,A,Disc), N.F. Dupuis (Q), R. O. Earl (Q), Sandford Fleming (Q), W.L. Goodwin (Q), D. Fraser Harris (Dal, H), A. P. Knight (Q), A. Macphail (U,Q,), W. T. McClement (Q), E.W. McBride (U,H), J. Markowitz (F), R.E.K. Pemberton (F), J.K. Robertson (Q).

With the increasing emphasis on scientific research since the close of the first world war, university research laboratories and federal, provincial and industrial laboratories have proliferated, one result being an ever increasing flow of published papers, reports and surveys. While one does not turn to such sources primarily for the delight of finding literary quality, such writing is not absent. It is important to note that the Society of Technical Writers and Publishers is actively promoting higher standards for their work. Many of these writers realize that scientific accuracy, clarity and succinctness are not incompatible with a good style of expression and a discriminating choice of words.

Some 75 Canadian Scientific Journals and Publications are listed in <u>The Culture of Contemporary Canada</u> (pp 327-366). Mention will only be made here of the annual <u>Proceedings and Transactions</u> of the Royal Society of Canada, and attention drawn to some of the presidential addresses delivered to the Society or to one of the science sections. It may appear invidious to single out a few from so many, nevertheless mention may be made of The Progress of Biology, R. Ramsay Wright, 1911; The National Domain in Canada and its proper conservation, Frank D. Adams, 1914; The "Miraculous" Micro-organism, F. C. Harrison, 1924 (Sect. V); Time and Life, W. A. Parks, 1926; Continuity and Discontinuity, J. K. Robertson, 1945; Mutations, W. P. Thompson, 1948; Microbes and Men, G.B.Reid, 1953: Micheli and the Discovery of Fungi, A. H. Reginald Buller, 1915 (Sect. V), and by the same author as President of the Society in 1928, The Plants of Canada Past and Present, from which address three passages follow: "Among the great generalizations of science not one seems more secure than that of organic evolution".... "What are the first traces of plant life within the boundaries of this broad Dominion? For an answer to this question we must go with the palaeontologist to the oldest rocks of our country and with hammer and chisel extract from them their fossil remains. 'In the never-idle workshop of nature,' as Mathew Arnold has called it, many strange plants have been woven on the looms of time and have left the traceries of their stems and leaves and the beautiful hexagonal pattern of their internal tissues in the sedimentary rocks, but the first products of the loom were doubtless too delicate and too frail for proper preservation."..... "It is possible that Eozoon [J. W. Dawson's discovery in the Pre-Cambrian] is one of the rocks that owe their origin to the activity of Blue-green Algae."

- IV -

When we come to consider the books written at the close of the last century and during six decades of this century, we note the wide range of subject matter, the almost complete absence of sermonizing, the rarity of adventuring into metaphysical regions, the rich sense of history and an evident pride in solid scientific achievement by men, many of whom have been inspiring teachers and citizens as well as able researchers.

In the broad field of natural science the books of Ernest Thompson Seton have been very widely read by three generations. Seton's keen observation of wild life in Ontario and Manitoba between the ages of four and twenty-four provided the material for his life stories of foxes, rabbits, wolves, grouse, prairie chicken, etc. published in the Canadian Journal, St. Nicholas, Scribners and other magazines. Later sojourns in New York, London, Paris and eventually New Mexico, added their quota. - His books include Wild Animals I have Known (1898), and in rapid succession Lives of the Hunted, Biography of a Grizzly, Animal Heroes, The Trail of the Sandhill Stag, Monarch the Big Bear of Tallac. Later came his Life Histories of Northern Animals in two volumes, Lives of Game Animals in four volumes, and at the age of 80 in 1940 came the charming autobiography Trails of an Artist - Naturalist.

A Canadian born naturalist whose life was lived chiefly in England and Europe was Grant Allen, (1848-1899). Some ten books became well known in the ~~1880's~~ last two decades of the century. The Story of Plants (1895) was reprinted in London in 1927. His observations and conclusions as a field botanist won praise from Darwin and Spencer, while T. H. Huxley complimented him on his ability to achieve in his writings "precision with popularity". He termed himself "a scientific middle-man", but he was much more.

A friend of Seton's, ~~was~~ William Perkins Bull, ~~who~~ wrote the beautiful books From Humming Bird to Eagle (1936), From Amphibians to Reptiles (1937) and From Medicine Man to Medical Man (1934), in ~~the last of~~ which he traced "the efforts of men of science through the past century and a half, not only to increase the pleasure of living, but also to lengthen the span of human life." Sir W. Arbuthnot Lane considered it "an important contribution to the literature of public health, particularly for the closely defined area of one Canadian County [Peel Co.]".

From the prolific pen of a contemporary zoologist, N. J. Berrill, have come a series of books for the lay reader: The Living Tide (1951), Journey into Wonder (1952), Sex and the Nature of Things (1954), The Origin of Vertebrates (1956), You and the Universe (1958), Man's Emerging Mind (1961).

To A. G. Huntsman we owe Life and the Universe (1959), a veteran biologist's examination of thought, science, will, faith and purpose. A question of perennial importance is ably discussed by Robert McRae, philosopher, in The Problem of the Unity of the Sciences (1961).

Textbooks are not often remarkable for their literary value, but in the eyes of his contemporaries those of Dr. William Clauser Boyd are in this category: Surgical Pathology (1925) ran to a 6th edition in 1947 and a Text-book of Pathology (1933) to a 6th edition in 1953; An Introduction to Medical Science (1937); Fundamentals of Immunology (1943) with a 3rd edition in 1956; Pathology for the Physician (1958).

The history of science has claimed the interest of not a few Canadian scientists, among whom are F. D. Adams, whose erudite Birth and Development of the Geological Sciences (1938) is a classic; Sir William Osler in his learned and wholly delightful Evolution of Modern Medicine (1921) and Incunabula Medica 1467-1480 (1922); Walter Libby, A History of Medicine in its Salient Features (1921); Maude E. Abbott, History of Medicine in the Province of Quebec (1931); J. J. Heagerty, Four Centuries of Medical History in Canada and Newfoundland (1928) and The Romance of Medicine in Canada (1940); Frank Allen, The Universe, from Crystal Spheres to Relativity (1931); Lloyd G. Stevenson, The Meaning of Poison (1959); C. J. S. Warrington and R. V. V. Nicholls, A History of Chemistry in Canada (1949), which opens thus - "A thread of metal runs through the whole fabric of Canadian history. The period spans the epoch between the last years of alchemy and the beginning of the atomic era."

Some biographies of men of science are enriched by informative accounts of scientific work and discoveries: Loring Woart Bailey by Joseph Whitman Bailey (1925) containing many quotations from L. W. Bailey's notes, letters and his Reminiscences; Thomas Sterry Hunt by F. D. Adams (1933); The Life of Sir Thomas Roddick (1938) and Maude Abbott; a Memoir (1941) by H. E. MacDermot; Sir Frederick Banting by Lloyd Stevenson (1946); Arthur Stanley Eddington by A. Vibert Douglas (1956); Sir William Osler, a memorial volume of 119 articles edited by Maude E. Abbott (1920) whose expressed aim was to supply "the unsmelted ore from which the future historian may extract that firsthand evidence which may enable him rightly to estimate the service which William Osler rendered to his day and generation..."; Young Endeavour (1958) by William C. Gibson summarizes the "contributions to science by medical students of the Past Four Centuries"; Medicine in the Making (1960) by Gordon Murray and Amid Masters of Twentieth Century Medicine (1958) by Leonard G. Rowntree both contain vivid descriptions of the fight against disease and of the developments in surgical practice made by these masters and their medical contemporaries. The Chord of Steel by Thomas B. Costain (1960) portrays the early years of Alexander Graham Bell and his discoveries culminating in the telephone. Leopold Infeld, for many years a professor in Toronto, wrote an inspiring biography, Albert Einstein - His work and its influence on our world (1950); and an autobiography, Quest (1941) recounting not only his life in Europe and America but his intellectual quest in the realm of mathematical physics wherein we read, "The transition from particle physics to field physics is undoubtedly one of the greatest, and as Einstein believes, the greatest step accomplished in the history of human thought. Great courage and imagination were needed to shift the responsibility for physical phenomena from particles into the previously empty space and to formulate mathematical equations describing the changes in space and time." Thanks to the Engineering Institute of Canada some important books have been produced. One entitled Daylight through the Mountain - The Letters and Labours of Civil Engineers Walter and Francis Shanly (1957) is edited by Frank Norman Walker. Another is the life of one of the founders of the Institute Sir Casimir Stanislaus Gzowski (1959) by Ludwik Rabcewicz-Zubkowski and William Edward Greening.

In the field of Applied Science R. F. Legget's ~~has written~~ The Rideau Waterway (1955) recounts ~~ing~~ a great achievement of historic significance to Canada, and his Geology and Engineering (1939) is a stimulating book. So too is ~~and likewise~~ Modern Railroad Structures (1949) by C. P. Disney and R. F. Legget. D. M. LeBourdais in his Sudbury Basin - The Story of Nickel (1953) and G. B. Langford in Out of the Earth - The Mineral Industry in Canada (1954) have produced books of extreme interest about mineral deposits in Canada and the problems and achievements of mining engineers.

The year 1960 saw the publication of three ~~two~~ books on evolution, Evolution - Its Science and Doctrine, edited by T. W. M. Cameron, Darwin in Retrospect edited by H. H. J. Nesbitt, and The Ascent of Life by T. A. Goudge, indicating the widened scientific, philosophical, and social significance of the theory a century after Darwin's Origin of the Species. Goudge has contributed essays in this field to various journals including Mind (1954) and British Journal for the Philosophy of Science (1955, 1958-59).

Special mention should be made to J. Tuzo Wilson's I.G.Y., the Year of the New Moons (1961) where chapters on his journeys and observations from Arctic to Antarctic and to every continent are interspersed with clear informative chapters on the discoveries and new problems confronting science as a result of researches in which men of 67 nations cooperated.

Bare mention of many books of high quality could run to an undue length for this limited chapter; hence only a few more are selected for inclusion. ~~Although many readers will notice what will seem to them unforgivable omissions.~~ Nerves and Personal Power (1922) by Dougall MacDougall King (brother of W. L. Mackenzie King), an eloquent book by a physician who knew his days were few; <u>On Understanding Physics</u> (1938) by W. H. Watson, one of the few philosophical books written by a physicist in Canada; <u>Our Mobile Earth</u> (1926) by Reginald A. Daly; <u>Ice Ages, Recent and Ancient</u> (1926) and <u>The Last Million Years</u> (1941) by Arthur P. Coleman; <u>Our Wonderful Universe</u> (1928) by C. A. Chant; <u>The Stress of Life</u> (1956) by Hans Selye; <u>Memory, Learning and Language</u>; <u>The Physical Basis of Mind</u> (1960) edited by William Feindel with contributions by A. Hoffer, J. W. T. Spinks, Arthur Porter and Wilder Penfield, O.M., and his own chapter on "The Brain considered as a Thinking Machine", containing the following paragraph: "each of us has in his possession the most remarkable of galaxies - twelve billion nerve cells with their myriads of subconstellations in the compact universe of the brain. It is this inner space of the mind which surely, of all our natural resources, offers the most exciting potentialities. Consideration makes us realize that we are far from exploiting this thinking machine as efficiently as we might in the broad field of creative learning. To paraphrase Cassius, 'The fault, dear Brutus, lies not in our brains, but in ourselves, that we are underlings.'"

The concluding word must be an exhortation to scientists to take time to interpret science to non-scientists, to bridge the chasm which too often exists between the disciplines. Men with a flair for literary expression, whose interests embrace the exposition of scientific ideas and achievements, are needed in our country. When their 'apples' of pure scientific 'gold' are given to a hungry reading public in 'baskets' of literary 'silver' these writers are making an important contribution to the literary history of Canada.

THE LURE OF MYSTERY

I.

Out of the depths of a far distant past there has come down to us the record of the unceasing efforts of men to dispel the mists of ignorance, to penetrate further and further into the hidden places of nature, "to sail beyond the sunset" into that mysterious, shadowy borderland between the known and the unknown.

"Behold I shew you a mystery!" Nature has been proclaiming these words unceasingly since first man as a conscious, thinking being appeared upon the earth, and throughout all the ages the lure of mystery has been unfailing. It is more than a lure, it is a challenge - a challenge that has led the deepest thinkers of every age, the philosophers and men of science, with adventurous enthusiasm to engage upon the exploration of and the quest after truth. What is truth? Like Pilate of old we may be unable to define it, but it is a high ideal towards which it is our faith that human knowledge is gradually approaching.

Mystery in nature! It is omnipresent and it is universal in its appeal. The child in the nursery whose little mind is just commencing to grapple with some of the problems of the universe, the youth rejoicing in prowess of mind and body, the man with four score years of rich and varied experience behind him, the scholar with trained intellect, and the unlettered peasant - all are alike attracted by mystery because curiosity is one of the most fundamental and universal characteristics with which the mind of man is endowed. In the minds of the greatest thinkers and investigators this curiosity is accompanied by a ________________________________ powerful, vivid, adventurous imagination, a sane, honest, logical, and critical insight and a profound faith that beneath and behind the apparently mysterious phenomena of nature there is law and order and reason. Seek and ye shall find, knock and it shall be opened! But what do we find, and what does the opening of the door reveal? - Further mystery, and a wider horizon with a panorama of new marvels to excite the wonder and the admiration of the explorer. And even while he pauses a moment in wonder, he feels anew the challenge of the unknown. What lies just beyond the new horizon? Thus has knowledge advanced with the passing of the years.

This is true of every branch of human knowledge and it is particularly evident in the history of the sciences - biology, the mystery of life in all its various forms, animal and vegetable, visible and microscopic; chemistry, providing an inexhaustible revelation of atomic and molecular affinities; geology, with its marvellous record of the history of the earth, movements, convulsions and crumplings, uplifts and subsidences, the forces of erosion, climatic changes, the dawn of life and the development of forms of life both extinct and extant; physics, the study of energy in all its manifestations, radiant energy, and bound energy as in the ultimate constituents of matter, the electron and the proton; astronomy, the study of the stars and the starlight, of the solar system with its planets and satellites, of the immense regions of gaseous nebulosity, of the myriad star galaxies sprinkled throughout this vast universe, and of the fundamental mystery of space and time.

II

From earliest times the heavens must have excited the wonder and the admiration of men. In the stars they found two very important things - time and direction. The movements, or apparent movements, of the stars, the sun, the moon, provide the time-pieces by which man has always regulated his life. The relative positions of the stars provide the direction signs by which men shape their course on sea or on land. But curiosity was challenged by the mystery of the universe and in every community no doubt there were men set apart and entrusted with the task of observing the sky with care and precision. The western world owes a tremendous debt to the thinkers and star gazers of the Euphrates valley.

For many centuries before the rise of Greece, the heavens had been studied with much diligence by the Chaldeans and the other wise men of Babylonia. Three or four thousand years before the time of Christ, they had mapped the heavens and plotted the apparent motions of the sun, the moon and the five planets visible to the naked eye, Mercury, Venus, Mars, Jupiter and Saturn, against the background of the seemingly fixed stars. With amazingly vivid imaginations these ancient star gazers had identified various groups of stars or constellations with animals, birds, dragons, fish, giants, and other mythical figures. One group of these constellations was of special interest and importance because it covered the broad belt around the sky in which the seven exceptional heavenly bodies (sun, moon and five planets) were always to be found. This great belt is called the Zodiac. So exact were the Babylonian observations of the apparent motions of the sun and moon and planets against the background of the star groups of the Zodiac that they could predict such events as eclipses of sun or moon, times of high or low tide, with some degree of accuracy; and due to the computations of such men of high scientific attainment as Naburiannu and Kidinu it was known that the cycle of lunar phenomena repeated itself every fifty-four years and one month.

All this knowledge as well as a great mass of unexplained observations of planetary positions came into the hands of Aristotle about 300 B.C., and the keen Greek minds at once began to construct a geometrical model of the universe to account for these motions. Even a casual observation of the heavens shows that the sun and moon move eastward relative to the almost unchanging background of the stars, but the planets move with less apparent regularity - sometimes eastward and sometimes westward. To portray these motions the early Greek astronomers had imagined the sun, the moon, and each of the planets to be imbedded in a crystal sphere, one sphere for each. The outermost sphere was supposed to be the one in which all the stars were fixed, and as each of these eight spheres had to rotate about the earth at a different speed, and not always at a constant speed, there was inevitably a friction between their surfaces which was the cause of a mythical "music of the spheres," so delicate, so exquisite that the ear of the ordinary mortal man could not detect it.

The later Greek astronomers elaborated the geometrical model by introducing epicycles and placing the earth slightly away from the centre of the revolving spheres. These conceptions dominated thought for over seventeen centuries and though they were ultimately shown to be fallacious, nevertheless, this belief in the rythmic, harmonious movements of the heavenly bodies, giving rise as it did to the idea of the music of the spheres was no idle fancy. After Copernicus had propounded the theory that the sun was the centre of the planetary system, the earth being simply one of the minor planets; and after Galileo, about the year 1610, had made observations strongly supporting this heliocentric theory, John Kepler established for all time the rythmic harmony of the solar system. As a result of his almost superhuman efforts in examining the observations of the times and positions of the planets, (made and collected during the long life of that picturesque astronomer, Tycho Brahe), it was given to Kepler to discover three remarkable laws, the mathematical simplicity of which [redacted] astonishes and delights the mind of man even as does some unexpected sequence of simple chords which may be found to form the basis of an elaborate and complex symphony.

Kepler's first law states that the orbit of every planet is an ellipse, the sun being at one of the foci. Now the conic sections - circle, ellipse, parabola, hyperbola - had been thoroughly studied in Greek times long before it was known that not only the first but all four of these would be found essential in the investigation of the motions of the celestial bodies. This is but one of many instances where progress made in one realm of thought for its own sake alone has later proved to be the sine qua non in the development of some entirely different branch of knowledge.

Kepler's second law showed that while the planets do not move with uniform speed in their orbits, there is nothing uncertain or haphazard about their motions; the radius vector, or line joining sun to planet, sweeps over equal areas in equal times. This means that every planet increases its speed [redacted] as it passes nearest to the sun and gradually slows down as it recedes from perihelion towards the more remote part of its orbit. So, too, the comets moving slowly on the outskirts of the solar system are obedient to the same fundamental law, their velocities increasing as they approach the sun round which they pass at their maximum speeds again to withdraw at lesser and lesser velocities.

The third law discovered by Kepler is often referred to in terms strongly suggestive of music - the harmonic law:- the squares of the periodic times of the planets vary as the cubes of their average distances from the sun. And then as the crowning glory of celestial mechanics, the Newtonian law of gravitation supplied the missing factor of proportionality, namely, the sum of the masses of sun and planet. Here, truly, is a~~n~~ heavenly lyric of surpassing beauty, and universal in its applicability, for whether it be Earth and Moon, or Earth and Sun, or Mars, or Jupiter, or Neptune, or the multiple stars like Algol and Mizar far off in the sky, or even twin galaxies in the remotest depths of space - all revolving systems are radiant embodiments of this celestial lyric.

III.

Without the harmonic law, astronomical knowledge would be very limited. Even within our own solar system we ~~would~~ should be unable to measure the masses of the planets, while the masses of the stars would be an insoluble mystery. With the aid of this law, astronomers have weighed the stars, placed our sun as ~~a very~~ an average dwarf star, found very few stars as much as one hundred times more massive and not one star as little as one tenth the mass of the sun. Here was a problem which aroused the curiosity of the astronomers. Supposing there were a time when all the matter of the entire galaxy was more or less evenly spread out as a vast gaseous nebula, then with the random movements of the individual molecules or atoms there would inevitably be formed places of greater concentration and these would act as gravitating centres of attraction. Thus stars would be gradually formed from the chaos of nebulosity, but it appears that there are upper and lower limits to the mass of the stars thus formed. How ~~is this accomplished~~ are these limits set? By what system of weights and measures does Nature apportion out her clouds of gases to form each star - the old problem of Shylock, a pound of flesh, no more, no less - or to be more correct, not very many times more nor very much less.

Spurred on by the challenge of this problem, Sir A. S. Eddington pursued a series [redacted] of theoretical investigations, and when dawn came he had before him a beautiful [redacted] example of the harmonious balance of natural forces. [redacted] In the growing star three forces are making a bid for supremacy. Gravitation tends to augment the mass of the star and increase its density indefinitely, by attracting more and more matter to the star and drawing it nearer and nearer to the centre. But the more gravitation succeeds, the hotter grows the interior of the star, like the air compressed into a bicycle tire; and the higher the temperature, the greater the kinetic energy of the atoms, hence the faster they move and the greater becomes the second force, the gas pressure, tending to expand the star against gravitation. A third force likewise comes into play more and more vigorously as temperature increases, the pressure of the radiation generated within the star. This radiation is of the nature of heat when the temperature in the star is low, but as temperature rises the star will begin to glow, radiations of the wavelengths of visible light being generated within it. At still higher temperatures more and more penetrating radiations, like X-rays, are generated within, and all these radiations rushing outwards towards the surface of the star, ultimately to escape into outer space, exert an outward pressure buoying up the gases composing the star.

The pressure of light! Not many years ago the most learned man of science would have said that the pressure of light was as unreal, illusory, and fantastic as was the music of the spheres - an intangible figment of the imagination. But today the pressure of light is recognized as one of the major forces of nature. It preserves the equilibrium of the stars by balancing gravitational force; it prevents the stars from growing to abnormal size by blowing off [redacted] with a mighty outrushing hurricane of energy [redacted] the excess gases that the rival force of gravitation would embrace and enfold with an ınsatiable hunger; it tosses up clouds of atoms of hydrogen and helium and calcium like spray from the surface of our sun, to heights of half a million miles, and radiating their distinctive lights of red and violet, these lofty clouds excite the wonder and the curiosity of the astronomer. Pressure of radiation is responsible, in part at least, for one of the phenomena which through all the ages has awakened the emotions and imaginations of men, the beautiful spectacle of the long, luminous tail of a comet. Pressure of radiation, acting with explosive violence, is probably the cause of the rejuvenation of a faint star, a phenomenon which occurs in the heavens from time to time and is [redacted]usually referred to as the appearance of a "new star", or nova. What the astronomer observes is the rapid brightening of a star never previously recorded as being other than steadily faint. In the course of a few hours or days its brightness may increase many thousand-fold, after which it slowly and fluctuatingly loses its brilliance again. This is in reality a cataclysm of nature of a magnitude unparalled in the whole range of scientific knowledge. We know not how or why, but in such a star there has evidently occurred a sudden liberation of vast stores of hitherto locked-up energy, and this energy being released as radiation exerts [redacted] a pressure so tremendous that it lifts layer upon layer of the star's substance and hurls it outward in all directions with terrific velocity, and the light of the star breaking from its surface and rushing headlong through the turbulent luminous clouds of ejected gases wings its way outward into the vast regions of interstellar space, - ever outward, never slowing down, on and on, year after year, century after century - until in the fulness of time perchance a minute fraction of that out-streaming light falls upon the lens or the mirror of a telescope set up by man on the surface of a very small planet which revolves around one somewhat insignificant star. From lens or mirror this little glimmer of light finds itself hurtling through the prisms of a spectrograph which causes its component rays to spread out in order of wave length like the notes of a musical scale. There, in ordered array, it falls upon the emulsion of the photographic plate. Here its long journeyings come to an end for the radiant energy becomes transformed into chemical energy - the molecular readjustments in the emulsion which develop out as the photographic image of star light. But the transformation of energy takes place in such a way that every detail of the incoming light is retained and preserved in the photographic record. Thus it is possible for the astrophysicist to unravel the majestic story of such a star from the image of its light, just as a musician contemplating a printed score can reconstruct the full grandeur and solemnity of an immortal oratorio.

IV.

In a very beautiful sixteenth century example of the art of wood-cut, there is represented the earth with its hills and valleys, its towns, and its country side, with trees, plants and animals; and over it the spherical dome of heaven containing symbolic representations of sun, moon, comets, and stars. The dome of heaven rests upon a rim of high mountains, which the ancient cosmologists imagined to extend all around the earth. In the foreground the artist has portrayed a shepherd who, having climbed to the top of one of this chain of encircling mountains, has thrust his head and shoulders through the dome of heaven, and with a gesture of amazement is gazing at undreamed of marvels out beyond. The artist was evidently straining his imagination to the very utmost to conceive of wheels and spokes and strange cloud-like formations to place beyond the dome of heaven to excite the wonder of the adventurous shepherd. But how commonplace, tepid, insipid, and apparently uninspired are his imaginings compared with the actual marvels of the deep regions of space beyond the range of the human vision! By the aid of telescope and photographic plate the remote depths of space have yielded up some of their secrets, and the physicist in his laboratory collaborating with the astronomer has shown us a world of extent and grandeur undreamed of in earlier years.

"Distance unexpressible by numbers that have name" - so wrote John Milton, and we recall that he visited the aged Galileo in Italy, when the latter perhaps ~~and no doubt the latter~~ expounded to him the new views of the universe which his own observations with his astronomical telescope had done so much to establish. ~~No doubt~~ Perhaps, too, Milton was privileged to see the telescope that Galileo had himself invented, and to [redacted] look upon some of the new wonders of the external world which no eye had seen until Galileo turned his glass upon them - the four satellites of Jupiter, the ever moving, ever changing, dark areas on the surface of the sun, the star clouds of the Milky Way. ~~Perhaps, too~~ Conceivably, Milton was shown the great Nebula of Orion, that vast abyss of wildly chaotic gases, some radiating light, some dark and lowering. Is it too great a flight of the imagination to guess that such a sight, perhaps that very sight inspired the lines in [11] Paradise Lost [11]:-

> "Behold the throne
> Of chaos and his dark pavilion spread
> Wide on the wastful deep".

With the mathematical researches of Sir Isaac Newton a new era dawned - dynamical astronomy came into being; and with the invention by Newton, in 1675, of the reflecting telescope a new tool was placed in the hands of the astronomer by means of which to carve out the picture of still greater depths of space. Sir William Herschel, and later Lord Rosse, made telescopes after the Newtonian model, which revealed the first details of the Spiral Nebulae. Here was something to excite the wonder of mankind. The Andromeda Nebula, to the unaided eye, is merely a hazy, fuzzy little patch of light like a small puff of smoke; but in the telescope it is a vast aggregation of stars arranged in spiral arms extending out from a denser, more nebulous centre. Other spiral galaxies of stars even more striking in appearance were seen for the first time, The Whirlpool Nebula, for example. Today, at several [redacted] observatories [redacted] intensive study of the spirals is being carried on; more than 20,000 have been noted on [redacted] photographic plates, while the spectra of the brighter ones are being obtained [redacted] and calculations of masses and distances [redacted] attempted. The nearest of these [redacted] spirals is so far away that the light from its stars only comes to us after journeying nearly a million years, while some of the more remote are known to be a hundred times more distant.

The study of the spirals has carried us very far away from the geocentric model of the universe. Men thought the earth was the centre of the whole revolving universe; but it was not so. Later they placed the sun at the centre of the system of planets and imagined that the stars lay more or less symmetrically in all directions; but it was not so. Herschel began the task of making systematic star-counts which has been carried on with greater and greater exactitude to fainter and fainter stars until, in recent years, it has appeared that the stars of our great galaxy are arranged in a vast lens-shaped volume of space extending much further out all around one plane than anywhere at right angles to this plane, that our sun is a quite ordinary star situated well away from the centre of the galaxy, so that looking out around us from this little planet near the sun, we see a very lob-sided picture of the galaxy. The Milky Way gives us our bearings relative to this galactic plane, but the number of stars that can be photographed in the direction of the constellations Sagittarius, Scorpio and Ophiuchus far exceeds the number in any other region. This leads to the conclusion that in that direction lies the centre of our galaxy comprising some ten thousand million suns. Perhaps many astronomers thought this was the main part of the material universe, but it was not so. Every one of the thousands upon thousands of spiral nebulae is a galaxy of millions of stars, comparable to our own galaxy.

We turn from the contemplation of the vastest things of which man has knowledge to the smallest things, the atoms and their constituents, the protons and the electrons. There is no greater achievement of the human mind than that which has revealed to us some understanding of atomic structure and atomic radiations. Heat and light from a candle, light from the electric spark that jumps from your finger to your kitten's head as you stroke her in the dark, are these phenomena worth a life long study? Assuredly the answer is in the affirmative for to elucidate these "commonplace" things, is to pave the way towards an understanding of the significance of the sunshine and the secrets of the starlight.

V.

This lure of mystery becomes, in the life of the man of science, a great driving force. It never leads to a life of ease, it rarely leads to wealth, but it brings its own reward nevertheless. When Professor Einstein was awarded the Gold Medal of the Royal Astronomical Society in London in 1926 for starting "a revolution in scientific thought to which, as yet, we can see no end, to which indeed we can hardly imagine an end", to quote from the President's address, his reply revealed the true source of happiness which results from this pursuit of the unknown. This is the translation of a paragraph from his letter of acceptance and thanks:- "He who discovers a line of thought which permits us to penetrate even a little deeper into the eternal mystery of Nature, is greatly privileged. He, who, in addition, is encouraged by recognition, sympathy and help from the best minds of his time, experiences more happiness than anyone can realize......"

There is a freedom of thought, an unconstrained spirit of adventure in the very atmosphere in which the scientific worker lives his life. Possibly nowhere is this more alive and intensely real than in the realm of cosmological investigation at the present time. In earlier times the average man looked upon the heavens with awe, but it was an awe born largely of ignorance and superstition, a dread that the forces of nature were hostile. Today man likewise looks outward towards the heavens and contemplates the universe with all its, as yet, unsolved mysteries, and he too is conscious of a feeling of awe and wonder, but it is an awe born of certain knowledge that the heavens declare their kinship with the earth - things celestial and things terrestrial are not two, but one in the evidence they bear to the fundamental unity of all nature, the underlying harmony of the universe.

But there is something rigid and creed-like about the average man's beliefs. It is a rude shock to him to find that the absolute truth of an idea of long standing is questionable - whether it be a doctrine of salvation, a doctrine of capital and labour, a law of supply and demand, or a law of universal gravitation set forth for all time (so men assumed) in simple stately terms by Sir Isaac Newton. To such an one it is inconceivable that the men of science can not only view with equanimity but actually welcome the accessions to knowledge which seem to undermine their fundamental theories, to upset their elaborate hypotheses. He sees them as poor unfortunate sailors dangling from broken rigging amid the flotsum and jetsum of a wreck, shaken in spirit and mind, bewildered, disappointed and dismayed. It is wasted sympathy. The sailors dangling in the torn rigging are not broken in spirit, they are not even fundamentally perturbed. This is for them a real adventure and already in imagination they see a yet more stately, more seaworthy ship arising from the wreckage, and all their mental energies, all their skill of experimental technique, are turned towards that task. "A theory," says Sir J.J. Thomson, "is a tool, not a creed"[*]; and often the most valuable achievement to the credit of a tool is that it aided in the making of a still better tool than itself.

[*] Sir J.J. Thomson, O.M., Physicist, Master of Trinity, Cambridge.

No one familiar with scientific thinking can wade through the interminable <u>Education</u> of Henry Adams (interminable is here used quite literally, for one pictures him as still attempting unsuccessfully to complete his education in the spirit world) without being struck with just ~~this~~ his static attitude towards the scientific theories of his day. He exemplifies most strikingly the attitude of the average man towards changing scientific thought. He went to Paris about 1900 and there came into contact for the first time with speculative geometry. He found men pondering over the geometry of the world and he was amazed, staggered, shaken to the very foundations of his intellectual being, by the simple utterance of the great Poincaré regarding Euclidean geometry - "I do not know whether it be true, but I know it will always be convenient". We can see how perplexing, how incomprehensible to the average person is the game of the modern geometers, who, like children trying to fit together the mosaic of a picture puzzle, have been attempting to fit the observed facts of nature first into a cylindrical universe, then into a spherical model, and lastly into a bold new model, the expanding universe of today.

<u>Quo Fata Vocant</u> - this is the motto of a famous British regiment, the Fighting Fifth, the Northumberland Fusiliers, and it might well be the motto of the typical man of science. Whither the Fates - the Unknown - the Mysteries of Nature call - thither will the feet of the man of science lead him in the great struggle for knowledge. Without dogmatic prejudice, without rigid preconceptions, with untrammelled mind, he carefully and hopefully feels his way forward into the misty regions of thought, while to his ears ever and anon there comes "the deep music of the rolling world".

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THE MUSIC OF THE SPHERES

"Heard melodies are sweet, but those unheard
Are sweeter; therefore, ye soft pipes, play on:
Not to the sensual ear, but, more endear'd,
Pipe to the spirit ditties of no tone.

Out of the depths of a very ancient past there has come down to us the idea that there is a music, a rhythm, a harmony in Nature not to be apprehended by the crude physical ear but by the spirit of man. It is to the Greeks, in particular that we owe the conception of the music of the spheres—the mystic music produced by the sun, moon, planets, and stars in their supposed motions about the earth.

For many centuries before the rise of Greece, the heavens had been studied with much diligence by the Chaldeans and the other wise men of Babylonia. Three or four thousand years before the time of Christ, they had mapped the heavens and plotted the apparent motions of the sun, the moon, and the five planets visible to the naked eye, Mercury, Venus, Mars, Jupiter, and Saturn, against the background of the seemingly fixed stars. With amazingly vivid imaginations these ancient star gazers had identified various groups of stars, or constellations, with animals, birds, dragons, fish, giants and other mythical figures. One group of these constellations was of special interest and importance because it covered the broad belt around the sky in which the seven exceptional heavenly bodies (sun, moon and five planets) were always to be found. This great belt is called the Zodiac. So exact were the Babylonian observations of the apparent motions of the sun and moon and planets against the background of the star groups of the Zodiac, that they could predict such events as eclipses of sun or moon, times of high or low tide, with extreme accuracy; and due to the computations of such men of high scientific attainment as Naburiannu and Kidinu it was known that the cycle of lunar phenomena repeated itself every fifty-four years and one month.

All this knowledge as well as a great mass of unexplained observations of planetary positions came into the hands of Aristotle about 300 B.C. and the keen Greek minds at once began to construct a geometrical model of the universe to account for these motions. Even a casual observation of the heavens shows that the sun and moon move eastward relative to the almost unchanging background of the stars, but the planets move with less apparent regularity—sometimes eastward and sometimes westward. To portray these motions the Greek astronomers imagined the sun, the moon, and each of the planets to be imbedded in crystal spheres, one sphere for each. The outermost sphere was supposed to be the one in which all the stars were fixed. Beyond this was the Region of the Blessed! As each of these eight spheres had to rotate about the earth at a different speed, and not always at a constant speed, there was inevitably a friction between the nine surfaces, and this friction was the cause of the music, so delicate, so exquisite that the ear of ordinary mortal man could not detect it.

Milton had this in mind when he wrote his poem "On the morning of Christ's Nativity", a poem which has been thus described, "For dignity, grace, and music, it is one of the gems of our English language"; -

'Ring out, ye crystal spheres,
And bless our human ears,
(If ye have power to touch our
senses so),
And let your silver chime
Move in melodious time
And let the bases of heavn's deep
organ blow,
And with your ninefold harmony
Make up full consort to the
angelic symphony'.

Shakespeare has referred to this ethereal music of the spheres in a well known passage where Lorenzo says to Jessica:

"There's not the smallest orb which thou behold'st
But, in his motion like an angel sings,

Still quiring to the young-eyed cherubims.
Such harmony is in immortal souls;
But whilst this muddy vesture of decay
Dost grossly close us in, we cannot hear it."

The sound of the ethereal music has permeated our literature. With one poet, ( ), we catch

"The deep pulsations of the world,
AEonian music, measuring out

The steps of time-----"

With Keats we pause and listen—and lo!

---------the glorious pealing
Of the wide spheres—an everlasting tone."

Perhaps with Alfred Austin we meditate in the night watches and the solemnity of this vast universe over-awes us,

"Within the hollow silence of the night
I lay awake and listened. I could hear
Planet with punctual planet chiming clear,
And unto star, star cadencing aright.
Nor these alone: cloistered from deafening sight
All things that are made music to mine ear:
Hushed woods, dumb caves, and many a soundless mere,
With Arctic mains in rigid sleep locked tight.
But ever with this chant from shore and sea,
From singing constellation, humming thought,
And Life through Time's stops blowing variously
A melancholy undertone was wrought;
And from its boundless prison-house I caught
The awful wail of lone Eternity.

Perchance, with Shelley, we contemplate—

"The eternal orbs that beautify the night
------------------the majestic laws
That rule yon rolling orbs.
The depth of the unbounded universe
Above and all around
Nature's unchanging harmony."

And many there be who are constrained to sing with Addison:

"The spacious firmament on high
And all the blue ethereal sky,
The spangled heavens, a shining frame,
Their great Original proclaim

Forever singing as they shine,
The hand that made us is divine.

Alfred Noyse has given us in poetic form a translation of some writings of that remarkable man—a famous astronomer with a mystic poetic sense that led him to try to put into notes the music of the spheres as it vibrated in his own spirit—John Kepler (1571-1630).

He (Kepler) spoke of poetry as the "flowering time
Of knowledge," called it "thought in passionate tune
With those great rhythms that steer the moon and sun;
Thought in such concord with the soul of things
That it can only move like tides and stars,
And man's own beating heart, and the wings of birds,
In Law, whose service only sets them free."

In a beautiful sonnet entitled Twilight, a Canadian poet, Chas. Heavysege, has introduced the idea that the music of the spheres is the "golden chime" which sounds the passing of the years, millenium upon millenium for the "horologue of time."

"The day was lingering in the pale north-west,
And night was hanging o'er my head,—
Night when a myriad stars were spread;
While down in the east where the light was least,
Seemed the home of the quiet dead.
And as I gazed on the field sublime,
To watch the bright pulsating stars,
Adown the deep, where the angels sleep,
Came drawn the golden chime
Of those great spheres that sound the years
For the horlogue of time;—
Milleniums numberless they told
Milleniums a millionfold
From the ancient hour of prime!

But let us return to Shelley for perhaps the finest description of the music of the spheres, this universal music

"----------- music
Itself the echo of the heart."

In his Prometheus Unbound after the chorus of Hours and Spirits, Panthea and Ione are speaking:

(Ione) Even whilst we speak
New notes arise. What is that awful sound?

(Panthea) 'Tis the deep music of the rolling world
Kindling within the strings of the waved air
AEolian modulations.

(Ione) Listen, too,
How every pause is filled with under-notes
Clear, silver, icy, keen, awakening tones,
Which pierce the sense, and live within the soul,
As the sharp stars pierce winter's crystal air.

II.

This belief in the rythmic, harmonious movements of the heavenly bodies, giving rise as it did to the idea of the music of the spheres, was no idle fancy. After Copernicus had propounded the theory that the sun was the centre of the planetary system, the earth being simply one of the minor planets; and after Galileo, about the year 1610, had made observations strongly supporting this helio-centric theory, John Kepler established for all time the rythmic harmony of the solar system. As a result of his almost superhuman efforts in examining the observations of the times and positions of the planets, made and collected during the long life of that picturesque astronomer, Tycho Brahe, it was given to Kepler to discover three remarkable laws, the mathematical simplicity of which both astonish and delight the mind of man even as does some unexpected sequence of similar chords which may be found to form the basis of an elaborate and complex symphony.

Kepler's first law states that the orbit of every planet is an ellipse, the Sun being at one of the foci. Now the conic sections— circle, ellipse, parabola, hyperbola—had been thoroughly studied in Greek times and so geometers feel very much at home when considering planetary orbits. Kepler's second law showed that while the planets do not move with uniform speed in their orbits, there is nothing uncertain or haphahazard about their motion; the radius vector, or line joining sun to planet sweeps over equal areas in equal times. This means that every planet speeds up as it passes nearest to the sun, and gradually slows down as it recedes from perihebion towards the more remote part of its orbit. So, too, the comets moving slowly on the outskirts of the solar system are obedient to the same fundamental law, their velocities increasing as they approach the sun, round which they pass at their maximum speed, again to withdraw at lesser and lesser velocities.

The third law discovered by Kepler is often referred to in terms strongly suggestive of music—the harmonic law. It reads like a verse of poetry in the ear of the astronomer—the squares of the periodic times of the planets vary as the cubes of their average distances from the sun. And then, as the crowning glory of celestial mechanics, the Newtonian law of gravity supplied the missing factor of proportionality, namely the sum of the masses of sun and planet. Here, truly, is an heavenly lyric of surpassing beauty, delicately majestic in its entirety, graceful and stately in its rhythmic harmony, universal in its applicability, for whether it be earth and moon, or earth and sun, or Mars or Jupiter, or Neptune, or the multiple stars like Algol and Mizar far off in the sky, or even twin galaxies in the remotest depths of space—all revolving systems are radiant embodiments of this celestial lyric.

Without the harmonic law, astronomical knowledge would be very limited. Even within our own solar system we would be unable to measure the masses of the planets, while the masses of the stars would be an insoluble mystery. With the aid of this law, astronomers have weighed the stars, placed our sun as a very average dwarf star, found very, very few stars as much as one hundred times as massive and not one star as little as one-tenth the mass of the sun. Here was a problem which aroused the curiosity of the astronomers. Supposing there were a time when all the matter of the entire galaxy was more or less evenly spread out as a vast gaseous nebula, then with the random movements of the individual molecules or atoms there would inevitably be formed places of greater concentration and these would act as gravitating centres of attraction. Thus, stars would be gradually formed from the chaos of nebulosity, but it appears that there are upper and lower limits to the mass of the stars ~~thus~~ so formed. How is this accomplished? By what system of weights and measures does Nature apportion out her clouds of gases to form each star—the old problem of Shylock, a pound of flesh, no more, no less—or, to be more correct, not very many times more nor very much less.

The answer to this question was supplied a few years ago by Sir A.S. Eddington and it is but another example of the harmonious balance of natural forces, like the various parts of a great orchestra kept in control by a master musician. In the growing star three forces are making a bid for supremacy. Gravitation tends to augment the mass of the star and increase its density indefinitely, by attracting more and more matter to the star and drawing it nearer and nearer to the centre. But the more gravitation succeeds, the hotter grows the interior of the star, like the air compressed into a bicycle tire; and the higher the temperature the greater the kinetic energy of the atoms, hence the faster they move and the greater becomes the gas pressure tending to expand the star against gravitation. The third force likewise comes into play more and more vigorously as temperature increases, the pressure of the radiation generated within the star. This radiation is of the nature of heat when the temperature in the star is low, but as temperature rises the star will begin to glow, radiation of the wave-lengths of visible light being generated within it. At still higher temperatures more and more penetrating radiations, like X-rays, are generated within, and all these radiations rushing outwards towards the surface of the star, ultimately to escape into outer space, exert an outward pressure buoying up the gases composing the star.

The pressure of light! Not many years ago the most learned man of science would have said that the pressure of light was as unreal, illusory and fantastic as was the music of the spheres— an intangible figment of the imagination. But today the pressure of light is recognized as one of the major forces of nature. It preserves the equilibrium of the stars by balancing gravitational force; it prevents the stars from growing to abnormal size by blowing off as with a mighty rushing wind the excess gases that the rival force of gravitation would embrace and enfold with an insatiable hunger; it tosses up clouds of atoms of hydrogen and helium and calcium like spray from the surface of our sun, and radiating their distinctive lights of red and violet, these lofty clouds excite the wonder and the curiosity of the astronomer. Pressure of radiation is responsible, in part, at least, for one of the phenomena which through all the ages has awakened the emotions and imaginations of men, the beautiful spectacle of the long, luminous tail of a comet. Pressure of radiation, acting with explosive violence, is probably the cause of the rejuvenation of a faint star, a phenomenon which occurs in the heavens from time to time and is usually referred to as the appearance of a "new star" or nova. What the astronomer observes is the rapid brightening of a star never previously recorded as being other than steadily faint. In the course of a few hours or days its brightness may increase many thousandfold, after which it slowly and fluctuatingly loses its brilliance again. This is in reality a cataclysm of nature of a magnitude unparalleled in the whole range of scientific knowledge. We know not how or why, but in such a star there has evidently occurred a sudden liberation of vast stores of hitherto locked-up energy, and this energy being suddenly released as radiation exerts a pressure so tremendous that it lifts layer upon layer of the star's substance and hurls it outward in all directions with terrific velocity; and the light of the star, breaking from its surface and rushing headlong through the turbulent luminous clouds of ejected gases, wings its way outward into the vast regions of interstellar space,—ever outward, never slowing down, on and on, year after year, century after century—until in the fulness of time perchance a minute fraction of that out-streaming light falls upon the lens or the mirror of a telescope set up by man on the surface of a very small planet which circles interminably about one somewhat insignificant star. From lens or mirror this little glimmer of light finds itself hurtling through the prisms of a spectograph which cause its component rays to spread out in order of wave-length like the notes of a musical scale. Thence in ordered array it falls upon the emulsion of the photographic plate. Here its long journeyings come to an end for the radiant energy becomes transformed into chemical energy--the molecular readjustments in the emulsion which develop out as the photographic image of the starlight. But the transformation of energy takes place in such a way that every detail of the incoming light is retained and preserved in the photographic record, Thus it is possible for the astrophysist to unravel the majestic story of such a star from the image of its light, just as a musician contemplating a printed score can reconstruct the full grandeur and solemnity of an immortal oratorio.

III.

Let us give full rein to our imaginations and frolic with some of these ideas of the ancient mystic astronomers. Let us see how the various instruments are placed upon the stage of the Universe--these celestial instruments, whence comes this heavenly music.

The musical instruments, then, are the stars, the sun, the planets, and their satellites, and they give rise to music by reason of their motion. The planets move in their respective orbits about the sun, and the sun as one star of a great galaxy of ten thousand million stars, partakes of the vast rotational motion of the galaxy. Recent investigations by astronomers of half a dozen nationalities have led to the belief that a star situated about where our sun is in the vast galaxy, completes one journey about the centre in something of the order of 200 million years. Here, indeed, is a stately symphony whose prelude was played many millions of millions of years before ever man awakened into being upon this earth, and whose finale, if there be a finale, at all, is in so remote a future that human calculation fails entirely to find numerical expression for that time.

In this great galactic orchestra, every here and there we find a pair of stars singing a duet as they revolve about one another; elsewhere a quartette, two pairs of stars playing a complicated roundalay as each revolves about its own partner, while simultaneously one pair moves around the other pair; and the yet more intricate harmonies of the sextette systems like the Mizar-Alcor system where Mizar is really four great stars and Alcor is two, where each of the three pairs is in rotation, and the Alcor pair revolve about the Mizar system whose two pairs revolve about one another, and each around its own partner.

Nor are the stars of our galaxy the only music makers in the Universe—there are the millions of other orchestras, the other island galaxies far out in space in all directions, each adding its peaen of melody to swell the vast harmonies of the universal symphony of all the stars.

Upon the plastic yet resiliant spirit of man this music falls. It comes now loud, now soft, now joyous and triumphant, now solemn, occasionally very sad, more often serenely sympathetic, deep, rich and companionable—according to the mood, not of an unseen musician, but of the listening spirit. We see this reflected in the following excerpts from Keats' poems. In one mood he writes, "The stars look very cold about the sky"; in a more sympathetic frame of mind he refers to them as "those silver lamps that burn on high." With a sense of inspiration drawn from the stars, a sense of kinship with the great universe, he pens his sonnet, To Chatterton,

"----- -------thou art among the stars
Of highest heaven; to thy rolling spheres
Thou sweetest singest; nought thy hymning mars
Above the ingrate world and human fears."

In his sonnet, To Kosciusko, the Polish patriot and statesman, he thrills at the memory of "thy great name", and turning to the stars for the only adequate simile, he writes,

"It comes upon us like the glorious pealing
Of the wide spheres—an everlasting tone."

And in the last sonnet that he wrote, there is the pathos of the eternal longing of the human soul to escape from the frailty, indecision, and instability of its own nautre—

"Bright star! Would I were steadfast as thou art."

In one of his Philosophical Essays, written in 1877, W.K. Clifford, a highly esteemed Professor of Mathematics at the University of London, discusses what he terms the "cosmic emotion" produced in mankind contemplating the Universe about him. He notes how it sometimes takes the form of awe, of an oppressive submission of spirit, but on the other hand he finds its most general effect to be "an overpowering stimulus to action, like the effect of the surrounding orchestra upon a musician who is thereby caught up and driven to play his proper part with force and exactness of time and tune."

This should be the effect of the music of the spheres upon the individual man, himself a unit in the vast cosmical orchestra. He scans "the multitudinous circling of the stars" and like Ptolemy of Alexandria he feels himself no longer standing upon the earth but endowed with the immortality and omnipotence of Zeus.

Shelley has summed it all up in three imperishable lines—

"And music lifted up the listening spirit
Until it walked, exempt from mortal care,
Godlike, o'er the clear billows of sweet sound."

A. VIBERT DOUGLAS.
Lecturer in Astrophysics.
McGill University.
MONTREAL.

Return to

A. Douglas.

Keats knew the beauty of inaudible harmonies when he wrote —

THE MUSIC OF THE SPHERES

"Heard melodies are sweet, but those unheard
are sweeter; therefore, ye soft pipes, play on:
Not to the sensual ear, but, more endear'd,
Pipe to the spirit ditties of no tone.

Out of the depths of a very ancient past there has come down to us this idea that there is a music, a rhythm, a harmony in Nature not to be apprehended by the crude physical ear but by the spirit of man. It is to the Greeks, in particular that we owe the conception of the music of the spheres—the mystic music produced by the sun, moon, planets and stars in their supposed motions about the earth.

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Dawn
R.H. Bridges

But let us return to Shelley for perhaps the finest description of the music of the spheres, this universal music

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Itself the echo of the heart."

In his Prometheus Unbound after the chorus of Hours and spirits, Panthea and Ione are speaking:

(Ione) Even whilst we speak
New notes arise. What is that awful sound?

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II.

pp. 6-12 not given in lecture

This belief in the rythmic, harmonious movements of the heavenly bodies, giving rise as it did to the idea of the music of the spheres, was no idle fancy. After Copernicus had propounded the theory that the Sun was the centre of the planetary system, the earth being simply one of the minor planets; and after Galileo, about the year 1610, had made observations strongly supporting this helio-centric theory, John Kepler established for all time the rythmic harmony of the solar system. As a result of his almost superhuman efforts in examining the observations of the times and positions of the planets made and collected during the long life of that picturesque astronomer, Tycho Brahe, it was given to Kepler to discover three remarkable laws, the mathematical simplicity of which both astonish and delight the mind of man even as does some unexpected sequence of similar chords which may be found to form the basis of an elaborate and complex symphony.

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The third law discovered by Kepler is often referred to in terms strongly suggestive of music--the harmonic law. It reads like a verse of poetry in the ear of the astronomer--the squares of the periodic times of the planets vary as the cubes of their average distances from the sun. And then, as the crowning glory of celestial mechanics, the Newtonian law of gravity supplied the missing factor of proportionality, namely the sum of the masses of sun and planet. Here, truly, is an heavenly lyric of surpassing beauty, delicately majestic in its entirety, graceful and stately in its rhythmic harmony, universal in its applicability, for whether it be earth and moon, or earth and sun, or Mars or Jupiter, or Neptune, or the multiple stars like Algol and Mizar far off in the sky, or even twin galaxies in the remotest depths of space--all revolving systems are radiant embodiments of this celestial lyric.

Without the harmonic law, astronomical knowledge would be very limited. Even within our own solar system we would be unable to measure the masses of the planets, while the masses of the stars would be an insoluble mystery. With the aid of this law, astronomers have weighed the stars, placed our sun as a very average dwarf star, found very very few stars as much as one hundred times as massive and not one star as little as one-tenth the mass of the sun. Here was a problem which aroused the curiosity of the astronomers. Supposing there were a time when all the matter of the entire galaxy was more or less evenly spread out as a vast gaseous nebula, then with the random movements of the individual molecules or atoms there would inevitably be formed places of greater concentration and these would act as gravitating centres of attraction. Thus, stars would be gradually formed from the chaos of nebulosity, but it appears that there are upper and lower limits to the mass of the stars ~~thus~~ so formed. How is this accomplished? By what system of weights and measures does Nature apportion out her clouds of gases to form each star—the old problem of Shylock, a pound of flesh, no more, no less—or, to be more correct, not very many times more nor very much less.

The answer to this question was supplied a few years ago by Sir A.S. Eddington and it is but another example of the harmonious balance of natural forces, like the various parts of a great orchestra kept in control by a master musician. In the growing star three forces are making a bid for supremacy. Gravitation tends to augment the mass of the star and increase its density indefinitely, by attracting more and more matter to the star and drawing it nearer and nearer to the centre. But the more gravitation succeeds, the hotter grows the interior of the star, like the air compressed into a bicycle tire; and the higher the temperature the greater the kinetic energy of the atoms, hence the faster they move and the greater becomes the gas pressure tending to expand the star against gravitation. The third force likewise comes into play more and more vigorously as temperature increases, the pressure of the radiation generated within the star. This radiation is of the nature of heat when the temperature in the star is low, but as temperature rises the star will begin to glow, radiation of the wavelengths of visible light being generated within it. At still higher temperatures more and more penetrating radiations, like X-rays, are generated within, and all these radiations rushing outwards towards the surface of the star, ultimately to escape into outer space, exert an outward pressure buoying up the gases composing the star.

The pressure of light! Not many years ago the most learned man of science would have said that the pressure of light was as unreal, illusory and fantastic as was the music of the spheres--an intangible figment of the imagination. But today the pressure of light is recognized as one of the major forces of nature. It preserves the equilibrium of the stars by balancing gravitational force; it prevents the stars from growing to abnormal size by blowing off as with a mighty rushing wind the excess gases that the rival force of gravitation would embrace and enfold with an insatiable hunger; it tosses up clouds of atoms of hydrogen and helium and calcium like spray from the surface of our sun, and radiating their distinctive lights of red and violet, these lofty clouds excite the wonder and the curiosity of the astronomer. Pressure of radiation is responsible, in part, at least, for one of the phenomena which through all the ages has awakened the emotions and imaginations of men, the beautiful spectacle of the long, luminous tail of a comet. Pressure of radiation, acting with explosive violence, is probably the cause of the rejuvenation of a faint star, a phenomenon which occurs in the heavens from time to time and is usually referred to as the appearance of a "new star" or nova. What the astronomer observes is the rapid brightening of a star never previously recorded as being other than steadily faint. In the course of a few hours or days its brightness may increase many thousandfold, after which it slowly and fluctuatingly loses its brilliance again. This is in reality a cataclysm of nature of a magnitude unparalleled in the whole range of scientific knowledge. We know not how or why, but in such a star there has evidently occurred a sudden liberation of vast stores of hitherto locked-up energy, and this energy being suddenly released as radiation exerts a pressure so tremendous that it lifts layer upon layer of the star's substance and hurls it outward in all directions with terrific velocity; and the light of the star, breaking from its surface and rushing headlong through the turbulent luminous clouds of ejected gases, wings its way outward into the vast regions of interstellar space,—ever outward, never slowing down, on and on, year after year, century after century— until in the fulness of time perchance a minute fraction of that out-streaming light falls upon the lens or the mirror of a telescope set up by man on the surface of a very small planet which circles interminably about one, somewhat insignificant star. From lens or mirror this little glimmer of light finds itself hurtling through the prisms of a spectograph which cause its component rays to spread out in order of wave-length like the notes of a musical scale. Thence in ordered array it falls upon the emulsion of the photographic plate. Here its long journeyings come to an end for the radiant energy becomes transformed into chemical energy--the molecular readjustments in the emulsion which develop out as the photographic image of the starlight. But the transformation of energy takes place in such a way that every detail of the incoming light is retained and preserved in the photographic record, Thus it is possible for the astrophysist to unravel the majestic story of such a star from the image of its light, just as a musician contemplating a printed score can reconstruct the full grandeur and solemnity of an immortal oratorio.

III.

Let us give full rein to our imaginations and frolic with some of these ideas of the ancient mystic astronomers. Let us see how the various instruments are placed upon the stage of the Universe--these celestial instruments, whence comes this heavenly music.

The musical instruments, then, are the stars, the sun, the planets, and their satellites, and they give rise to music by reason of their motion. The planets move in their respective orbits about the sun, and the sun as one star of a great galaxy of ten thousand million stars, partakes of the vast rotational motion of the galaxy. Recent investigations by astronomers of half a dozen nationalities have led to the belief that a star situated about where our sun is in the vast galaxy, completes one journey about the centre in something of the order of 200 million years. Here, indeed, is a stately symphony whose prelude was played many millions of millions of years before ever man awakened into being upon this earth, and whose finale, if there be a finale, at all, is in so remote a future that human calculation fails entirely to find numerical expression for that time.

In this great galactic orchestra, every here and there we find a pair of stars singing a duet as they revolve about one another; elsewhere a quartette, two pairs of stars playing a complicated roundalay as each revolves about its own partner, while simultaneously one pair moves around the other pair; and the yet more intricate harmonies of the sextette systems like the Mizar-Alcor system where Mizar is really four great stars and Alcor is two, where each of the three pairs is in rotation, and the Alcor pair revolve about the Mizar system whose two pairs revolve about one another, and each around its own partner.

Nor are the stars of our galaxy the only music makers in the Universe—there are the millions of other orchestras, the other island galaxies far out in space in all directions, each adding its peaen of melody to swell the vast harmonies of the universal symphony of all the stars.

Upon the plastic yet resiliant spirit of man this music falls. It comes now loud, now soft, now joyous and triumphant, now solemn, occasionally very sad, more often serenely sympathetic, deep, rich and companionable--according to the mood, not of an unseen musician, but of the listening spirit. We see this reflected in the following excerpts from Keats' poems. In one mood he writes, "The stars look very cold about the sky"; in a more sympathetic frame of mind he refers to them as "those silver lamps that burn on high." With a sense of inspiration drawn from the stars, a sense of kinship with the great universe, he pens his sonnet, To Chatterton,

> "----- -------thou art among the stars
> Of highest heaven; to thy rolling spheres
> Thou sweetest singest: nought thy hymning mars
> Above the ingrate world and human fears."

In his sonnet, To Kosciusko, the Polish patriot and statesman, he thrills at the memory of "thy great name", and turning to the stars for the only adequate simile, he writes,

> "It comes upon us like the glorious pealing
> Of the wide spheres—an everlasting tone."

And in the last sonnet that he wrote, there is the pathos of the eternal longing of the human soul to escape from the frailty, indecision, and instability of its own nautre--

> "Bright star! Would I were steadfast as thou art."

In one of his Philosophical Essays, written in 1877, W.K. Clifford, a highly esteemed Professor of Mathematics at the University of London, discusses what he terms the "cosmic emotion" produced in mankind contemplating the Universe about him. He notes how it sometimes takes the form of awe, of an oppressive submission of spirit, but on the other hand he finds its most general effect to be "an overpowering stimulus to action, like the effect of the surrounding orchestra upon a musician who is thereby caught up and driven to play his proper part with force and exactness of time and tune."

This should be the effect of the music of the spheres upon the individual man, himself a unit in the vast cosmical orchestra. He scans "the multitudinous circling of the stars" and like Ptolemy of Alexandria he feels himself no longer standing upon the earth but endowed with the immortality and omnipotence of Zeus.

Shelley has summed it all up in three imperishable lines--

"And music lifted up the listening spirit
Until it walked, exempt from mortal care,
Godlike, o'er the clear billows of sweet sound."

July 30 - Nov 11

THE POETRY OF HEAVEN

"Ye stars which are the poetry of heaven ..... a beauty and a mystery". So wrote Byron ~~These words were written by Byron~~ while ~~he was~~ thinking of the stars in the dark sky above the Alps, and of their deep reflections in Lake Leman. They ~~The words~~ suggest three ~~types of~~ human reactions ~~on the part of mankind~~ towards the stars. The first is, ~~that most general reaction experienced by countless thousands,~~ ~~There is, the~~ simple acceptance of their beauty, and enjoyment of the nightly pageant of the skies. ~~Most of us have experienced this reaction many times.~~ ~~There are, one hopes,~~ Very few people, one hopes, are so dull of spirit, so lacking in imaginative response, that they take the heavens for granted with unthinking disregard. Shelley and Browning, ~~and Shelley~~ however, must have come across such individuals, for ~~Paracelsus meets a man~~ converses with a friend "whose eyes saw in the stars mere garnishry ~~of heaven" and~~ Shelley writes of one "..to whose passive ken

(small type)

> "Those mighty orbs that gem infinity
> Were only specks of tinsel, fixed in Heaven,
> To light the midnights of his native town."

~~And Browning's Paracelsus speaks of "Kindsmen's souls"~~ (other side)

Eyes have they — these unfortunates ~~individuals~~ — yet they see not "the wonder of the beauty that is manifest in the world". They have ears, but they hear not the music of the spheres. And of the many ~~the vast numbers who have both the eyes and the ears, on whom Nature can and does cast her~~ who can acknowledge Nature's magic spell, how few there are who ~~be that~~ are not utterly tongue-tied in the presence of great beauty or solemn grandeur! They have a glorious, a compelling experience, and can only speak a platitude — immediately to regret it; for is not silence more expressive than any platitude?

To very few is given that great gift of the gods, the ability to capture the intangible things of the spirit, to feel the poetry of earth and heaven and to crystallize that experience in musical words. ~~It is a glorious gift and the~~ Poets in every age ~~through the centuries~~ have enriched the treasure-house of literature with passages of exquisite beauty, ~~with luminous metaphor and scintillating simile~~, whose subject, object and inspiration were a star, a galaxy of stars, a ~~or~~ sun, or moon, planet, comet, meteor, sunrise or sunset. <u>Quicquid</u> <u>nitet</u> <u>notandum</u> is the motto of the Royal Astronomical

And Browning's Paracelsus tells Festus of

. . . . herdsmen's souls
Of ancient time, whose eyes, calm as their flocks,
Saw in the stars mere garnishry of heaven.

Society of London — Whatever shines is to be noted. It is a good motto for astronomers, but ~~might it not have been the motto of~~ was it not good also for Dante, ~~of~~ Shakespeare, ~~of Byron~~ Keats and ~~of~~ Shelley? Dante erects his Paradise upon the revolving spheres of the Ptolemaic universe, and the light of planets, meteors and stars irradiate his cantos. Shakespeare harnesses his imagination to everything that shines, from 'little candle' and 'smallest orb' to 'glorious sun' and 'inlaid floor of heaven', and to our quickened ear he brings, like Milton, the quiring of the stars, the silver chime, the nine-fold harmony. To Keats there is no state of mind and spirit but finds its best expression, its most perfect image in the light of a star. Shelley ~~basks, rolls and frolics in the starlight;~~ piles orb on orb and world on world 'till soaring fancy staggers' in its daring task to build a fitting temple to the Spirit of Nature.

Take from literature every reference to the stars and their celestial train, and what devastation, what irreparable havoc you would have wrought! Truly the poets' debt, and, through them, our debt to the stars is very great.

~~If we would enquire~~ To the question, What is poetry? perhaps the answer of the old astronomer John Kepler, is as satisfying as any other, at least to those ~~of us~~ who have not entirely outgrown the accident of having been born Victorians! It has been rendered into English verse by Alfred Noyes, but the underlying idea is said to be Kepler's:

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"... Thought in passionate tune
With those great rhythms that steer the moon and sun;
Thought in such concord with the soul of things
That it can only move, like tides and stars
And man's own beating heart, and the wings of birds,
In law, whose service only set them free."

'Poetry, beauty, mystery,' wrote Byron. It is the third of these, the mystery, that gives rise to another reaction of mankind to the stars — the awakening of scientific curiosity. What <u>are</u> the stars? The Greek philosophers ~~speculated widely and often wildly~~ thought deeply on this question. Anaxagoras taught that the sun was a red-hot stone, and Parmenides, that the stars were compressed fire. Aristotle imagined a perfect immutable, non-terrestrial element capable only of perfect circular motion — this was the essence of which the stars were formed, the stars being spherical, eternal, intelligent, and divine.

~~It was~~ Not until Galileo had liberated the minds of men from the enslavement imposed upon them by this dogma of the changelessness of the stellar substance ~~that~~ did a physics of the stars became a possibility. The practical application of the prism in the analysis of light, begun by Sir Isaac Newton, brought to birth the science of astrophysics, which has resolved so many of the mysteries and revealed a far vaster universe than the unaided eye can see.

What is a star? The answer of modern science is not speculation, but knowledge gradually built upon observation, hypothesis, deduction, crucial tests which confirm or modify theory, ~~or lead to its modification or revision, fuher and further observations~~, with physics, mathematics and chemistry all contributing to the picture.

Today we know by spectrum analysis the very atoms that are in the atmospheres of the sun and stars and the temperatures which must exist there in order that these atoms may radiate or absorb light as they do; and we know, at least in part, how temperature, density, pressure, and atomic state must change at greater and greater depths towards the centre of these vast globes of hot gases. We can weigh the stars, we can classify them according to their distributions and their motions; according to their stability or the types of variability; or we can classify them as giants, super-giants, white dwarfs, or as ~~quite~~ normal blue, white, yellow, orange, or red members of the great family of heaven. ~~It is~~ A picture of ~~vast~~ ~~great~~ immense scope and diversity ~~that~~ is set before us, but a diversity of phenomena within the embrace of fundamental physical laws whose operations can be expressed ~~are expressible~~ in the symbolism of mathematical physics.

The mystery of motion has challenged natural philosophers in all the centuries. It led the Greeks to almost superhuman efforts to make a geocentric universe meet the facts of observation, it caused ~~led~~ Copernicus to postulate a Solar System, it drove Kepler to elliptic orbits, it made ~~brought to~~ Halley the realize ~~realization~~ that the stars themselves are in no sense fixed in space, and it led Herschel to determine the motion of the sun towards the constellation of Hercules. In recent years it has led successively to the investigation of star streaming, rotation of the galaxy, recession of distant spiral galaxies and even to the hypothesis of expanding space. (amplify)

~~Imagination goes forth, said Blake, in its uncurbed glory. It is to just such adventure of mind and spirit that astronomers throughout the centuries have led the way.~~

Looking upon some of the photographs of distant spiral galaxies, the result of long exposures with sensitive photographic equipment and the light-gathering power of the great modern telescopes, ~~of today~~, one almost invariably begins to philosophize. The unanswerable questions concerning the eternal mysteries flash anew before the mind. The vastness of space shakes us out of parochial ~~our local~~ complacency. Imagination is quickened by that inevitable result of the finiteness of the velocity of light,— ~~namely~~ that as we look deeper and deeper into space, we are seeing farther and farther backwards in time. In the perspective of this vision, the span of a human life assumes its true proportion. In the spirit of Voltaire we summon a Micromegas from a distant orb that against the background of a cosmic setting he may set before us in its stark reality the folly and madness of mankind who by greed and selfishness, by war and injustice, make~~s~~ of this little earth a hell for untold thousands, ~~instead of its being~~ when it would be an oasis of rich spiritual value in the midst of a vast universe of material and radiant energy.

"Imagination," said Blake, "goes forth in its uncurbed glory." It is to just such high adventure of mind and spirit that the stars issue their challenge -- a challenge to all kinds and conditions of men, but especially to the natural philosopher, the lover of beauty, and the poet.

A. VIBERT DOUGLAS
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MONTREAL.

1939 March 30.

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To at Mtly
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Pd. May 8th