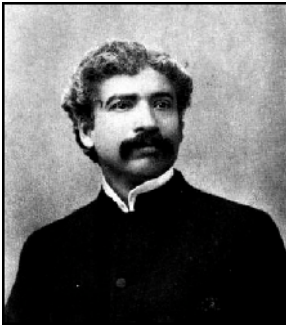
A portrait of Jagadish Bose, a man with a thick mustache and curly hair, wearing a dark, high-collared jacket. He is seated at a desk with various scientific instruments, including a large ornate apparatus on the right and a smaller one on the left. The background is a stylized, colorful pattern of leaves in shades of orange, red, and yellow. The title 'Response in the Living and Non-living' is written in a serif font in the upper right corner.

**Response
in the
Living and
Non-living**

JAGADISH BOSE

WITH AN INTRODUCTION BY PARAMAHANSA YOGANANDA



JAGADISH CHANDRA BOSE was born on November 30, 1858, Mymensingh, Bengal, India (now in Bangladesh), and died on November 23, 1937, Giridih, Bihar.

His work as both a physiologist and physicist led to the invention of highly sensitive instruments for the detection of minute responses by living organisms to external stimuli. This enabled him to measure the similarities in response between animal and plant tissues noted by many later researchers.

Bose's experiments on the quasi-optical properties of very short radio waves led him to make improvements on the *coherer*, an early form of radio detector, which contributed to the development of solid-state physics.

After earning a degree from the University of Cambridge (1884), Bose served as professor of physical science (1885–1915) at Presidency College, Calcutta. In 1917, he founded the Bose Institute in Calcutta, which still exists today (www.jcbose.ac.in).

To facilitate his research, he constructed automatic recorders capable of registering extremely slight movements; these instruments produced some striking results, such as his demonstration of the sense of feeling in plants.

Bose also found that non-living matter exhibits the same types of response to stimuli as do both animal and plant matter. This demonstration that everything exists in the field of consciousness was one of his most important discoveries.

RESPONSE IN THE LIVING AND NON-LIVING

Jagdish Chandra Bose

With an introduction by
Paramahansa Yogananda

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PREFACE

I have in this present work put in a connected and a more complete form results, some of which have been published in the following papers:

De la Généralité des Phénomènes Moléculaires produits par l'Electricité sur la matière Inorganique et sur la matière Vivante. (Travaux du Congrès International de Physique. Paris, 1900.)

On the Similarity of Effect of Electrical Stimulus on Inorganic and Living Substances. (Report, Bradford Meeting British Association, 1900. – Electrician.)

Response of Inorganic Matter to Stimulus. (Friday evening discourse, Royal Institution, May 1901.)

On Electric Response of Inorganic Substances. Preliminary Notice. (Royal Society, June 1901.)

On Electric Response of Ordinary Plants under Mechanical Stimulus. (Journal Linnean Society, 1902.)

Sur la Réponse Electrique dans les Métaux, les Tissus Animaux et Végétaux. (Société de Physique, Paris, 1902.)

On the Electro-Motive Wave accompanying Mechanical Disturbance in Metals in contact with Electrolyte. (Proceedings Royal Society, vol. 70.)

On the Strain Theory of Vision and of Photographic Action. (Journal Royal Photographic Society, vol. xxvi.)

These investigations were commenced in India, and I take this opportunity to express my grateful acknowledgments to the managers of the Royal Institution, for the facilities offered me to complete them at the Davy-Faraday Laboratory.

J. C. Bose.

Davy-Faraday Laboratory, Royal Institution,
London, May 1902.

CONTENTS

Introduction / 15

1 The mechanical response of living substances / 27

Mechanical response – Different kinds of stimuli
– Myograph – Characteristics of response curve: period, amplitude, form – Modification of response curves

2 Electric response / 31

Conditions for obtaining electric response – Method of injury – Current of injury – Injured end, cuproid: uninjured, zincoid – Current of response in nerve from more excited to less excited – Difficulties of present nomenclature – Electric recorder – Two types of response, positive and negative – Universal applicability of electric mode of response – Electric response a measure of physiological activity – Electric response in plants

3 Electric response in plants – method of negative variation / 44

Negative variation – Response recorder – Photographic recorder – Compensator – Means of graduating intensity of stimulus – Spring tapper and torsional vibrator – Intensity of stimulus dependent on amplitude of vibration – Effectiveness of stimulus dependent on rapidity also

4 Electric response in plants – block method / 55

Method of block – Advantages of block method – Plant response a physiological phenomenon – Abolition of response by anaesthetics and poisons – Abolition of response when plant is killed by hot water

5 Plant response – on the effects of single stimulus and of superposed stimuli / 63

Effect of single stimulus – Superposition of stimuli – Additive effect – Staircase effect – Fatigue – No fatigue when sufficient interval between stimuli – Apparent fatigue when stimulation frequency is increased – Fatigue under continuous stimulation

- 6** Plant response – on diphasic variation / 73
Diphasic variation – Positive after-effect and positive response – Radial E.M. variation
- 7** Plant response – on the relation between stimulus and response / 79
Increased response with increasing stimulus – Apparent diminution of response with excessively strong stimulus
- 8** Plant response – on the influence of temperature / 89
Effect of very low temperature – Influence of high temperature – Determination of death-point – Increased response as after-effect of temperature variation – Death of plant and abolition of response by the action of steam
- 9** Plant response – effect of anæsthetics and poisons / 100
Effect of anæsthetics, a test of vital character of response – Effect of chloroform – Effect of chloral – Effect of formalin – Method in which response is unaffected by variation of resistance – Advantage of block method – Effect of dose
- 10** Response in metals / 108
Is response found in inorganic substances? – Experiment on tin, block method – Anomalies of existing terminology – Response by method of depression – Response by method of exaltation
- 11** Inorganic response – modified apparatus to exhibit response in metals / 119
Conditions of obtaining quantitative measurements – Modification of the block method – Vibration cell – Application of stimulus – Graduation of the intensity of stimulus – Considerations showing that electric response is due to molecular disturbance – Test experiment – Molecular voltaic cell

- 12** Inorganic response – method of ensuring consistent results / 127
Preparation of wire – Effect of single stimulus
- 13** Inorganic response – molecular mobility: its influence on response / 131
Effects of molecular inertia – Prolongation of period of recovery by overstrain – Molecular model – Reduction of molecular sluggishness attended by quickened recovery and heightened response – Effect of temperature – Modification of latent period and period of recovery by the action of chemical reagents – Diphasic variation
- 14** Inorganic response – fatigue, staircase, and modified response / 144
Fatigue in metals – Fatigue under continuous stimulation – Staircase effect – Reversed responses due to molecular modification in nerve and in metal, and their transformation into normal after continuous stimulation – Increased response after continuous stimulation
- 15** Inorganic response – relation between stimulus and response – superposition of stimuli / 157
Relation between stimulus and response – Magnetic analogue – Increase of response with increasing stimulus – Threshold of response – Superposition of stimuli – Hysteresis
- 16** Inorganic response – effect of chemical reagents / 165
Action of chemical reagents – Action of stimulants on metals – Action of depressants on metals – Effect of poisons on metals – Opposite effect of large and small doses

- 17** On the stimulus of light and retinal currents / 174
Visual impulse: (1) chemical theory; (2) electrical theory
– Retinal currents – Normal response positive – Inorganic
response under stimulus of light – Typical experiment on
the electrical effect induced by light
- 18** Inorganic response – influence of various
conditions on the response to stimulus of light / 184
Effect of temperature – Effect of increasing length of
exposure – Relation between intensity of light and
magnitude of response – After-oscillation – Abnormal
effects: (1) preliminary negative twitch; (2) reversal of
response; (3) transient positive twitch on cessation of light;
(4) decline and reversal – Résumé
- 19** Visual analogues / 195
Effect of light of short duration – After-oscillation – Positive
and negative after-images – Binocular alternation of vision
– Period of alternation modified by physical condition
– After-images and their revival – Unconscious visual
impression.
- 20** General Survey and Conclusion / 205

ILLUSTRATIONS

Figure

1. Mechanical lever recorder - 29
2. Electric method of detecting nerve response - 32
3. Diagram showing injured end of nerve corresponds to copper in a voltaic element - 34
4. Electric recorder - 37
5. Simultaneous record of mechanical and electrical responses - 39
6. Negative variation in plants - 45
7. Photographic record of negative variation in plants - 46
8. Response recorder - 48
9. The compensator - 49
10. The spring tapper - 50
11. The torsional vibrator - 51
12. Response in plant to mechanical tap or vibration - 52
13. Influence of suddenness on the efficiency of stimulus - 53
14. The method of block - 56
15. Response in plant completely immersed under water - 57
16. Uniform responses in plant - 63
17. Fusion of effect under rapidly succeeding stimuli in muscle and in plant - 64
18. Additive effect of singly ineffective stimuli on plant - 65
19. 'Staircase effect' in plant - 66
20. Appearance of fatigue in plant under shortened period of rest - 68
21. Fatigue in celery - 69
22. Fatigue in cauliflower stalk - 69
23. Fatigue from previous overstrain - 70
24. Fatigue under continuous stimulation in muscle and celery - 71
25. Effect of rest in removal of fatigue in plant - 72
26. Diphasic variation in plant - 75
27. Abnormal positive responses in stale turnip leaf stalk transformed into normal negative under strong stimulation - 76

28. Abnormal positive passing into normal negative in a stale specimen of cauliflower - 77
29. Radial E.M. Variation - 78
30. Curves showing the relation between intensity of stimulus and response in muscle and nerve - 80
31. Increasing responses to increasing stimuli (taps) in plants - 80
32. Increasing responses to increasing vibrational stimuli in plants - 81
33. Responses to increasing stimuli in fresh and stale specimens of plants - 82
34. Apparent diminution of response caused by fatigue under strong stimulation - 85
35. Diminution of response in eucharis lily at low temperature - 89
36. Records showing the difference in the effects of low temperature on Ivy, Holly, and Eucharis Lily - 90
37. Plant chamber for studying the effect of temperature and anaesthetics - 92
38. Effect of high temperature on plant response - 93
39. After-effect on the response due to temperature variation - 94
40. Records of responses in eucharis lily during rise and fall of temperature - 96
41. Curve showing variation of sensitiveness during a cycle of temperature variation - 96
42. Record of effect of steam in abolition of response at death of plant - 98
43. Effect of chloroform on nerve response - 101
44. Effect of chloroform on the responses of carrot - 103
45. Action of chloral hydrate on plant responses - 103
46. Action of formalin on radish - 104
47. Action of sodium hydrate in abolishing the response in plant - 106
48. Stimulating action of poison in small doses in plants - 107
49. The poisonous effect of stronger dose of KOH - 107
50. Block method for obtaining response in tin - 109
51. Response to mechanical stimulation in a Zn-Cu couple - 112
52. Electric response in metal by the method of relative depression (negative variation) - 115
53. Method of relative exaltation - 116
54. Various cases of positive and negative variation - 117

55. Modifications of the block method for exhibiting electric response in metals - 121
56. Equal and opposite responses given by two ends of the wire - 123
57. Top view of the vibration cell - 124
58. Influence of annealing in the enhancement of response in metals - 128
59. Uniform electric responses in metals - 129
60. Persistence of after-effect - 132
61. Prolongation of period of recovery after overstrain - 133
62. Model showing the effect of friction - 134
- 63, 64. Effects of removal of molecular sluggishness in quickened recovery and heightened response in metals - 136, 137
65. Effect of temperature on response in metals - 138
66. Diphasic variation in metals - 140
67. Negative, diphasic, and positive resultant response in metals - 141
68. Continuous transformation from negative to positive through intermediate diphasic response - 142
69. Fatigue in muscle - 144
70. Fatigue in platinum - 145
71. Fatigue in tin - 145
72. Appearance of fatigue due to shortening the period of recovery - 146
73. Fatigue in metal under continuous stimulation - 147
74. 'Staircase' response in muscle and in metal - 148
75. Abnormal response in nerve converted into normal under continued stimulation - 150
- 76, 77. Abnormal response in tin and platinum converted into normal under continued stimulation - 151
78. Gradual transition from abnormal to normal response in platinum - 151
79. Increase of response in nerve after continuous stimulation - 152
- 80, 81. Response in tin and platinum enhanced after continuous stimulation - 153
82. Magnetic analogue - 158
83. Records of responses to increasing stimuli in tin - 160
84. A second set of records with a different specimen of tin - 161
85. Ineffective stimulus becoming effective by superposition - 161
86. Incomplete and complete fusion of effects - 163

87. Cyclic curve for maximum effects showing hysteresis - 164
88. Action of poison in abolishing response in nerve - 165
89. Action of stimulant on tin - 167
90. Action of stimulant on platinum - 168
91. Depressing effect of KBr on tin - 168
92. Abolition of response in metals by 'poison' - 169
93. 'Molecular arrest' by the action of 'poison' - 171
94. Opposite effects of small and large doses on the response in metals - 172
95. Retinal response to light - 176
96. Response of sensitive cell to light - 178
97. Typical experiment on the E.M. variation produced by light - 180
98. Modification of the photo-sensitive cell - 181
99. Responses in frog's retina - 183
100. Responses in sensitive photo-cell - 180
101. Effect of temperature on the response to light stimulus - 185
102. Effect of duration of exposure on the response - 185
103. Responses of sensitive cell to increasing intensities of light - 187
104. Relation between the intensity of light and magnitude of response - 188
105. After-oscillation - 189
106. Transient positive increase of response in the frog's retina on the cessation of light - 190
107. Transient positive increase of response in the sensitive cell - 190
108. Decline under the continuous action of light - 192
109. Certain after-effects of light - 194
110. After-effect of light of short duration - 196
111. Stereoscopic design for the exhibition of binocular alternation of vision - 200
112. Uniform responses in nerve, plant, and metal - 207
113. Fatigue in muscle, plant, and metal - 208
114. 'Staircase' effect in muscle, plant, and metal - 209
115. Increase of response after continuous stimulation in nerve and metal - 210
116. Modified abnormal response in nerve and metal transformed into normal response after continuous stimulation - 211
117. Action of the same 'poison' in the abolition of response in nerve, plant, and metal - 213



Paramahansa Yogananda

INTRODUCTION

The following is from Paramahansa Yogananda's *Autobiography of a Yogi*. It describes conversations between the swami and Jagadish Bose.

India's Great Scientist, J. C. Bose

“Jagadish Chandra Bose's wireless inventions antedated those of Marconi.”

Overhearing this provocative remark, I walked closer to a sidewalk group of professors engaged in scientific discussion. If my motive in joining them was racial pride, I regret it. I cannot deny my keen interest in evidence that India can play a leading part in physics, and not metaphysics alone.

“What do you mean, sir?”

The professor obligingly explained. “Bose was the first one to invent a wireless coherer and an instrument for indicating the refraction of electric waves. But the Indian scientist did not exploit his inventions commercially. He soon turned his attention from the inorganic to the organic world. His revolutionary discoveries as a plant physiologist are outpacing even his radical achievements as a physicist.”

I politely thanked my mentor. He added, “The great scientist is one of my brother professors at Presidency College.”

*

I paid a visit the next day to the sage at his home, which was close to mine on Gurpar Road. I had long admired him from a respectful distance. The grave and retiring botanist greeted me graciously. He was a handsome, robust man in his fifties, with thick hair, broad forehead, and the abstracted eyes of a dreamer. The precision in his tones revealed the lifelong scientific habit.

“I have recently returned from an expedition to scientific societies of the West. Their members exhibited intense interest in delicate instruments of my invention which demonstrate the indivisible unity of all life.¹ The Bose crescograph has the enormity of ten million magnifications. The microscope enlarges only a few thousand times; yet it brought vital impetus to biological science. The crescograph opens incalculable vistas.”

“You have done much, sir, to hasten the embrace of East and West in the impersonal arms of science.”

“I was educated at Cambridge. How admirable is the Western method of submitting all theory to scrupulous experimental verification! That empirical procedure has gone hand in hand with the gift for introspection which is my Eastern heritage. Together they have enabled me to sunder the silences of natural realms long uncommunicative. The telltale charts of my crescograph² are evidence for the most skeptical that plants have a sensitive nervous system and a varied emotional life. Love, hate, joy, fear, pleasure, pain, excitability, stupor, and countless appropriate responses to stimuli are as universal in plants as in animals.”

“The unique throb of life in all creation could seem only poetic imagery before your advent, Professor! A saint I once knew would never pluck flowers. ‘Shall I rob the rosebush of its pride in beauty? Shall I cruelly affront its dignity by my rude divestment?’ His sympathetic words are verified literally through your discoveries!”

“The poet is intimate with truth, while the scientist approaches awkwardly. Come someday to my laboratory and see the unequivocal testimony of the crescograph.”

Gratefully I accepted the invitation, and took my departure. I heard later that the botanist had left Presidency College, and was planning a research center in Calcutta.

When the Bose Institute was opened, I attended the dedicatory services. Enthusiastic hundreds strolled over the

premises. I was charmed with the artistry and spiritual symbolism of the new home of science. Its front gate, I noted, was a centuried relic from a distant shrine. Behind the lotus³ fountain, a sculptured female figure with a torch conveyed the Indian respect for woman as the immortal light-bearer. The garden held a small temple consecrated to the Noumenon beyond phenomena. Thought of the divine incorporeity was suggested by absence of any altar-image.

Bose's speech on this great occasion might have issued from the lips of one of the inspired ancient rishis.

"I dedicate today this Institute as not merely a laboratory but a temple." His reverent solemnity stole like an unseen cloak over the crowded auditorium. "In the pursuit of my investigations I was unconsciously led into the border region of physics and physiology. To my amazement, I found boundary lines vanishing, and points of contact emerging, between the realms of the living and the non-living. Inorganic matter was perceived as anything but inert; it was athrill under the action of multitudinous forces.

"A universal reaction seemed to bring metal, plant and animal under a common law. They all exhibited essentially the same phenomena of fatigue and depression, with possibilities of recovery and of exaltation, as well as the permanent irresponsiveness associated with death. Filled with awe at this stupendous generalization, it was with great hope that I announced my results before the Royal Society—results demonstrated by experiments. But the physiologists present advised me to confine myself to physical investigations, in which my success had been assured, rather than encroach on their preserves. I had unwittingly strayed into the domain of an unfamiliar caste system and so offended its etiquette.

"An unconscious theological bias was also present, which confounds ignorance with faith. It is often forgotten that He who surrounded us with this ever-evolving mystery of creation

has also implanted in us the desire to question and understand. Through many years of miscomprehension, I came to know that the life of a devotee of science is inevitably filled with unending struggle. It is for him to cast his life as an ardent offering—regarding gain and loss, success and failure, as one.

“In time the leading scientific societies of the world accepted my theories and results, and recognized the importance of the Indian contribution to science.⁴ Can anything small or circumscribed ever satisfy the mind of India? By a continuous living tradition, and a vital power of rejuvenescence, this land has readjusted itself through unnumbered transformations. Indians have always arisen who, discarding the immediate and absorbing prize of the hour, have sought for the realization of the highest ideals in life—not through passive renunciation, but through active struggle. The weakling who has refused the conflict, acquiring nothing, has had nothing to renounce. He alone who has striven and won can enrich the world by bestowing the fruits of his victorious experience.

“The work already carried out in the Bose laboratory on the response of matter, and the unexpected revelations in plant life, have opened out very extended regions of inquiry in physics, in physiology, in medicine, in agriculture, and even in psychology. Problems hitherto regarded as insoluble have now been brought within the sphere of experimental investigation.

“But high success is not to be obtained without rigid exactitude. Hence the long battery of super-sensitive instruments and apparatus of my design, which stand before you today in their cases in the entrance hall. They tell you of the protracted efforts to get behind the deceptive seeming into the reality that remains unseen, of the continuous toil and persistence and resourcefulness called forth to overcome human limitations. All creative scientists know that the true laboratory is the mind, where behind illusions they uncover the laws of truth.

“The lectures given here will not be mere repetitions of second-hand knowledge. They will announce new discoveries, demonstrated for the first time in these halls. Through regular publication of the work of the Institute, these Indian contributions will reach the whole world. They will become public property. No patents will ever be taken. The spirit of our national culture demands that we should forever be free from the desecration of utilizing knowledge only for personal gain.

“It is my further wish that the facilities of this Institute be available, so far as possible, to workers from all countries. In this I am attempting to carry on the traditions of my country. So far back as twenty-five centuries, India welcomed to its ancient universities, at Nalanda and Taxila, scholars from all parts of the world.

“Although science is neither of the East nor of the West but rather international in its universality, yet India is specially fitted to make great contributions.⁵ The burning Indian imagination, which can extort new order out of a mass of apparently contradictory facts, is held in check by the habit of concentration. This restraint confers the power to hold the mind to the pursuit of truth with an infinite patience.”

Tears stood in my eyes at the scientist’s concluding words. Is “patience” not indeed a synonym of India, confounding Time and the historians alike?

*

I visited the research center again, soon after the day of opening. The great botanist, mindful of his promise, took me to his quiet laboratory.

“I will attach the crescograph to this fern; the magnification is tremendous. If a snail’s crawl were enlarged in the same proportion, the creature would appear to be traveling like an express train!”

My gaze was fixed eagerly on the screen which reflected the magnified fern-shadow. Minute life-movements were now

clearly perceptible; the plant was growing very slowly before my fascinated eyes. The scientist touched the tip of the fern with a small metal bar. The developing pantomime came to an abrupt halt, resuming the eloquent rhythms as soon as the rod was withdrawn.

“You saw how any slight outside interference is detrimental to the sensitive tissues,” Bose remarked. “Watch; I will now administer chloroform, and then give an antidote.”

The effect of the chloroform discontinued all growth; the antidote was revivifying. The evolutionary gestures on the screen held me more raptly than a “movie” plot. My companion (here in the role of villain) thrust a sharp instrument through a part of the fern; pain was indicated by spasmodic flutters. When he passed a razor partially through the stem, the shadow was violently agitated, then stilled itself with the final punctuation of death.

“By first chloroforming a huge tree, I achieved a successful transplantation. Usually, such monarchs of the forest die very quickly after being moved.” Jagadis smiled happily as he recounted the life-saving maneuver. “Graphs of my delicate apparatus have proved that trees possess a circulatory system; their sap movements correspond to the blood pressure of animal bodies. The ascent of sap is not explicable on the mechanical grounds ordinarily advanced, such as capillary attraction. The phenomenon has been solved through the crescograph as the activity of living cells. Peristaltic waves issue from a cylindrical tube which extends down a tree and serves as an actual heart! The more deeply we perceive, the more striking becomes the evidence that a uniform plan links every form in manifold nature.”

The great scientist pointed to another Bose instrument.

“I will show you experiments on a piece of tin. The life-force in metals responds adversely or beneficially to stimuli. Ink markings will register the various reactions.”

Deeply engrossed, I watched the graph which recorded the characteristic waves of atomic structure. When the professor applied chloroform to the tin, the vibratory writings stopped. They recommenced as the metal slowly regained its normal state. My companion dispensed a poisonous chemical. Simultaneous with the quivering end of the tin, the needle dramatically wrote on the chart a death-notice.

“Bose instruments have demonstrated that metals, such as the steel used in scissors and machinery, are subject to fatigue, and regain efficiency by periodic rest. The life-pulse in metals is seriously harmed or even extinguished through the application of electric currents or heavy pressure.”

I looked around the room at the numerous inventions, eloquent testimony of a tireless ingenuity.

“Sir, it is lamentable that mass agricultural development is not speeded by fuller use of your marvelous mechanisms. Would it not be easily possible to employ some of them in quick laboratory experiments to indicate the influence of various types of fertilizers on plant growth?”

“You are right. Countless uses of Bose instruments will be made by future generations. The scientist seldom knows contemporaneous reward; it is enough to possess the joy of creative service.”

With expressions of unreserved gratitude to the indefatigable sage, I took my leave. “Can the astonishing fertility of his genius ever be exhausted?” I thought.

No diminution came with the years. Inventing an intricate instrument, the “Resonant Cardiograph,” Bose then pursued extensive researches on innumerable Indian plants. An enormous unsuspected pharmacopoeia of useful drugs was revealed. The cardiograph is constructed with an unerring accuracy by which a one-hundredth part of a second is indicated on a graph. Resonant records measure infinitesimal pulsations in plant, animal and human structure. The great botanist

predicted that use of his cardiograph will lead to vivisection on plants instead of animals.

“Side by side recordings of the effects of a medicine given simultaneously to a plant and an animal have shown astounding unanimity in result,” he pointed out. “Everything in man has been foreshadowed in the plant. Experimentation on vegetation will contribute to lessening of human suffering.”

*

Years later Bose’s pioneer plant findings were substantiated by other scientists. Work done in 1938 at Columbia University was reported by The New York Times as follows:

It has been determined within the past few years that when the nerves transmit messages between the brain and other parts of the body, tiny electrical impulses are being generated. These impulses have been measured by delicate galvanometers and magnified millions of times by modern amplifying apparatus. Until now no satisfactory method had been found to study the passages of the impulses along the nerve fibers in living animals or man because of the great speed with which these impulses travel.

Drs. K. S. Cole and H. J. Curtis reported having discovered that the long single cells of the fresh-water plant nitella, used frequently in goldfish bowls, are virtually identical with those of single nerve fibers. Furthermore, they found that nitella fibers, on being excited, propagate electrical waves that are similar in every way, except velocity, to those of the nerve fibers in animals and man. The electrical nerve impulses in the plant were found to be much slower than those in animals. This discovery was therefore seized upon by the Columbia workers as a means for taking slow motion pictures of the passage of the electrical impulses in nerves.

The nitella plant thus may become a sort of Rosetta stone for deciphering the closely guarded secrets close to the very borderland of mind and matter.

The poet Rabindranath Tagore was a stalwart friend of India's idealistic scientist. To him, the sweet Bengali singer addressed the following lines:⁶

O Hermit, call thou in the authentic words
Of that old hymn called Sama; "Rise! Awake!"
Call to the man who boasts his shastric lore
From vain pedantic wranglings profitless,
Call to that foolish braggart to come forth
Out on the face of nature, this broad earth,
Send forth this call unto thy scholar band;
Together round thy sacrifice of fire
Let them all gather. So may our India,
Our ancient land unto herself return
O once again return to steadfast work,
To duty and devotion, to her trance
Of earnest meditation; let her sit
Once more unruffled, greedless, strifeless, pure,
O once again upon her lofty seat
And platform, teacher of all lands.

* * *

Notes

1. "All science is transcendental or else passes away. Botany is now acquiring the right theory—the avatars of Brahma will presently be the textbooks of natural history."—Emerson.
2. From the Latin root, *crescere*, to increase. For his crescograph and other inventions, Bose was knighted in 1917.
3. The lotus flower is an ancient divine symbol in India; its unfolding petals suggest the expansion of the soul; the growth of its pure beauty from the mud of its origin holds a benign spiritual promise.

4. “At present, only the sheerest accident brings India into the purview of the American college student. Eight universities (Harvard, Yale, Columbia, Princeton, Johns Hopkins, Pennsylvania, Chicago, and California) have chairs of Indology or Sanskrit, but India is virtually unrepresented in departments of history, philosophy, fine arts, political science, sociology, or any of the other departments of intellectual experience in which, as we have seen, India has made great contributions. . . . We believe, consequently, that no department of study, particularly in the humanities, in any major university can be fully equipped without a properly trained specialist in the Indic phases of its discipline. We believe, too, that every college which aims to prepare its graduates for intelligent work in the world which is to be theirs to live in, must have on its staff a scholar competent in the civilization of India.”

—Extracts from an article by Professor W. Norman Brown of the University of Pennsylvania which appeared in the May, 1939, issue of the *Bulletin of the American Council of Learned Societies*, 907 15th St., Washington, D. C. This issue (#28) contains over 100 pages of a bibliography for Indic Studies.

5. The atomic structure of matter was well-known to the ancient Hindus. One of the six systems of Indian philosophy is Vaisesika, from the Sanskrit root *visesas*, “atomic individuality.” One of the foremost Vaisesika expounders was Aulukya, also called Kanada, “the atom-eater,” born about 2800 years ago. In an article in *East-West*, April, 1934, a summary of Vaisesika scientific knowledge was given as follows:

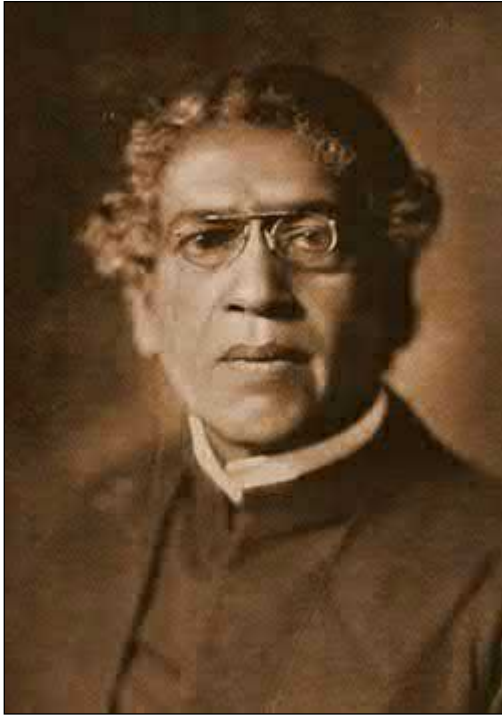
“Though the modern ‘atomic theory’ is generally considered a new advance of science, it was brilliantly expounded long ago by Kanada, ‘the atom-eater.’ The Sanskrit *anu* can be properly translated as ‘atom’ in the

latter's literal Greek sense of 'uncut' or indivisible. Other scientific expositions of Vaisesika treatises include:

- (1) the movement of needles toward magnets,
- (2) the circulation of water in plants,
- (3) akash or ether, inert and structureless, as a basis for transmitting subtle forces,
- (4) the solar fire as the cause of all other forms of heat,
- (5) heat as the cause of molecular change,
- (6) the law of gravitation as caused by the quality that inheres in earth-atoms to give them their attractive power or downward pull,
- (7) the kinetic nature of all energy; causation as always rooted in an expenditure of energy or a redistribution of motion,
- (8) universal dissolution through the disintegration of atoms,
- (9) the radiation of heat and light rays, infinitely small particles, darting forth in all directions with inconceivable speed (the modern 'cosmic rays' theory),
- (10) the relativity of time and space.

Vaisesika assigned the origin of the world to atoms, eternal in their nature, i.e., their ultimate peculiarities. These atoms were regarded as possessing an incessant vibratory motion. The recent discovery that an atom is a miniature solar system would be no news to the old Vaisesika philosophers, who also reduced time to its furthest mathematical concept by describing the smallest unit of time (kala) as the period taken by an atom to traverse its own unit of space.”

6. Translated from the Bengali of Rabindranath Tagore, by Manmohan Ghosh, in Viswa-Bharati.



Jagadish Bose

Chapter I

THE MECHANICAL RESPONSE OF LIVING SUBSTANCES

Mechanical response – Different kinds of stimuli – Myograph – Characteristics of the response curve: period, amplitude, form – Modification of response curves.

One of the most striking effects of external disturbance on certain types of living substance is a visible change of form. Thus, a piece of muscle when pinched contracts. The external disturbance which produced this change is called the stimulus. The body which is thus capable of responding is said to be irritable or excitable. A stimulus thus produces a state of excitability which may sometimes be expressed by change of form.

Mechanical response to different kinds of stimuli

This reaction under stimulus is seen even in the lowest organisms; in some of the amoeboid rhizopods, for instance. These lumpy protoplasmic bodies, usually elongated while creeping, if mechanically jarred, contract into a spherical form.

If, instead of mechanical disturbance, we apply salt solution, they again contract, in the same way as before. Similar effects are produced by sudden illumination, or by rise of temperature, or by electric shock.

A living substance may thus be put into an excitatory state by either mechanical, chemical, thermal, electrical, or light stimulus. Not only does the point stimulated show the effect of

stimulus, but that effect may sometimes be conducted even to a considerable distance.

This power of conducting stimulus, though common to all living substances, is present in very different degrees. While in some forms of animal tissue irritation spreads, at a very slow rate, only to points in close neighbourhood, in other forms, as for example in nerves, conduction is very rapid and reaches far.

The visible mode of response by change of form may perhaps be best studied in a piece of muscle. When this is pinched, or an electrical shock is sent through it, it becomes shorter and broader. A responsive twitch is thus produced. The excitatory state then disappears, and the muscle is seen to relax into its normal form.

Mechanical lever recorder

In the case of contraction of muscle, the effect is very quick, the twitch takes place in too short a time for detailed observation by ordinary means.

A myographic apparatus is therefore used, by means of which the changes in the muscle are self-recorded. Thus we obtain a history of its change and recovery from the change.

The muscle is connected to one end of a writing lever. When the muscle contracts, the tracing point is pulled up in one direction, say to the right. The extent of this pull depends on the amount of contraction. A band of paper or a revolving drum-surface moves at a uniform speed at right angles to the direction of motion of the writing lever. When the muscle recovers from the stimulus, it relaxes into its original form, and the writing point traces the recovery as it moves now to the left, regaining its first position. A curve is thus described, the rising portion of which is due to contraction, and the falling portion to relaxation or recovery. The ordinate of the curve represents the intensity of response, and the abscissa the time (*Figure 1*).

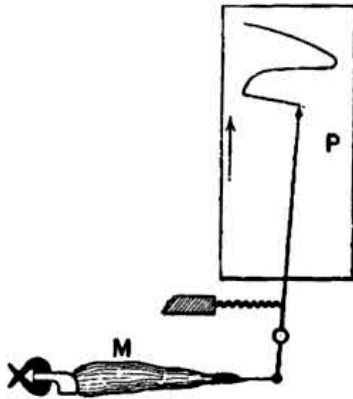


Fig. 1 – Mechanical lever recorder

The muscle **M** with the attached bone is securely held at one end, the other end being connected with the writing lever. Under the action of stimulus the contracting muscle pulls the lever and moves the tracing point to the right over the travelling recording surface **P**. When the muscle recovers from contraction, the tracing point returns to its original position. See on **P** the record of muscle curve.

**Characteristics of the response curve:
(1) period, (2) amplitude, (3) form**

Just as a wave of sound is characterised by its (1) period, (2) amplitude, and (3) form, so may these response curves be distinguished from each other. As regards the period, there is an enormous variation, corresponding to the functional activity of the muscle. For instance, in tortoise it may be as high as a second, whereas in the wing muscles of many insects it is as small as 1/300 part of a second.

“It is probable that a continuous graduated scale might, as suggested by Hermann, be drawn up in the animal kingdom, from the excessively rapid contraction of insects to those of tortoises and hibernating dormice.”⁽¹⁾

Differences in form and amplitude of curve are well illustrated by various muscles of the tortoise. The curve for the muscle of the neck, used for rapid withdrawal of the head on approach of danger, is quite different from that of the pectoral muscle of the same animal, used for its sluggish movements.

Again, progressive changes in the same muscle are well seen in the modifications of form which consecutive muscle-curves gradually undergo. In a dying muscle, for example, the amplitude of succeeding curves is continuously diminished, and the curves themselves are elongated. Numerous illustrations will be seen later, of the effect, in changing the form of the curve, of the increased excitation or depression produced by various agencies.

Thus these response records give us a means of studying the effect of stimulus, and the modification of response, under varying external conditions, advantage being taken of the mechanical contraction produced in the tissue by the stimulus. But there are other kinds of tissue where the excitation produced by stimulus is not exhibited in a visible form. In order to study these we have to use an altogether independent method; the method of *electric response*.

Footnotes

1. Biedermann, *Electro-physiology*, p. 59.

Chapter 2

ELECTRIC RESPONSE

Conditions for obtaining electric response – Method of injury – Current of injury – Injured end, cuproid: uninjured, zincoïd – Current of response in nerve from more excited to less excited – Difficulties of present nomenclature – Electric recorder – Two types of response, positive and negative – Universal applicability of electric mode of response – Electric response a measure of physiological activity – Electric response in plants.

Unlike muscle, a length of nerve, when mechanically or electrically excited, does not undergo any visible change. That it is thrown into an excitatory state, and that it conducts the excitatory disturbance, is shown however by the contraction produced in an attached piece of muscle, which serves as an indicator.

But the excitatory effect produced in the nerve by stimulus can also be detected by an electrical method. If an isolated piece of nerve be taken and two contacts be made on its surface by means of non-polarisable electrodes at A and B, connection being made with a galvanometer, no current will be observed, as both A and B are in the same physico-chemical condition. The two points, that is to say, are iso-electric.

If now the nerve be excited by stimulus, similar disturbances will be evoked at both A and B. If, further, these disturbances, reaching A and B almost simultaneously, cause any electrical change, then, similar changes taking place at both points, and there being thus no relative difference between the two, the galvanometer will still indicate no current. This null-effect is due to the balancing action of B as against A. (See *Figure 2a*)

Conditions for obtaining electric response

If then we wish to detect the response by means of the galvanometer, one means of doing so will lie in the abolition of this balance, which may be accomplished by making one of the two points, say B, more or less permanently irresponsive. In that case, stimulus will cause greater electrical disturbance at the more responsive point, say A, and this will be shown by the galvanometer as a current of response. To make B less responsive we may injure it by means of a cross-sectional cut, a burn, or the action of strong chemical reagents.

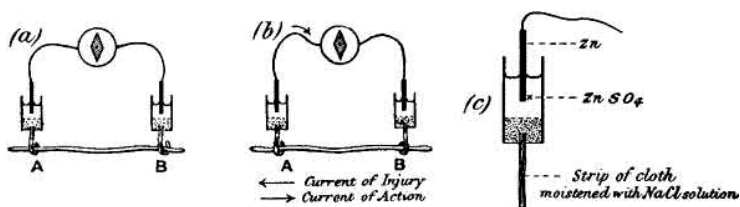


Fig. 2 **Electric method of detecting nerve response**

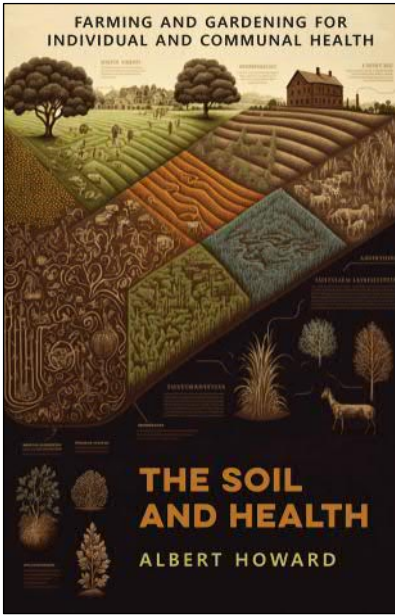
(a) Iso-electric contacts; no current in the galvanometer.

(b) The end B injured; current of injury from B to A; stimulation gives rise to an action current from A to B.

(c) Non-polarisable electrode.

Current of injury

We shall revert to the subject of electric response; meanwhile it is necessary to say a few words regarding the electric disturbance caused by the injury itself. Since the physico-chemical conditions of the uninjured A and the injured B are now no longer the same, it follows that their electric conditions have also become different. They are no longer iso-electric. There is thus a more or less permanent or resting difference



The Soil and Health

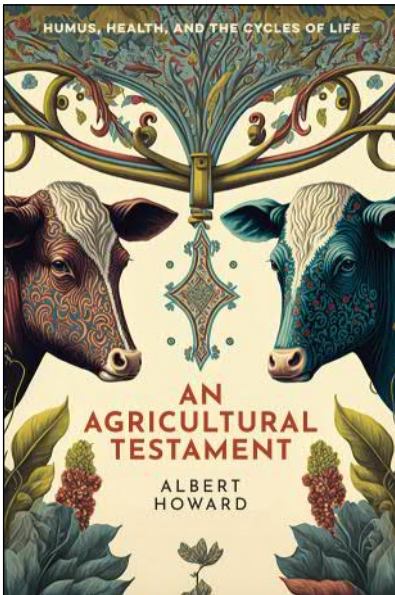
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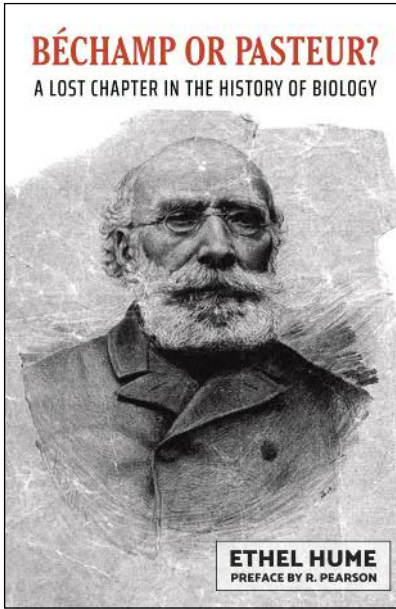
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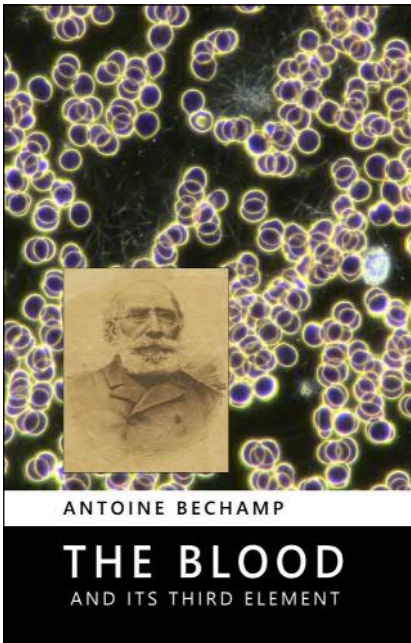
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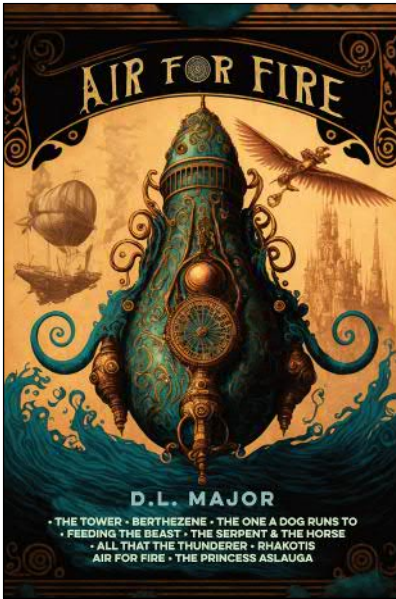
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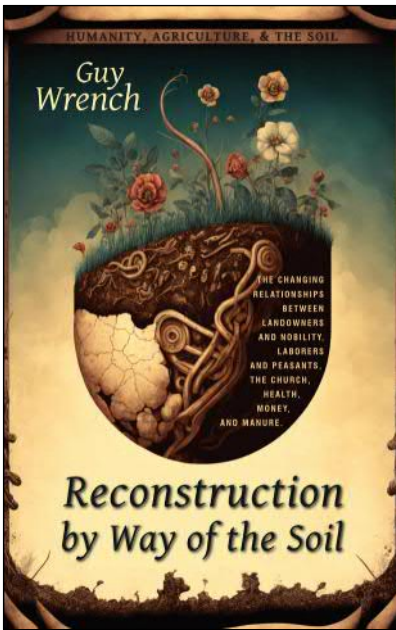
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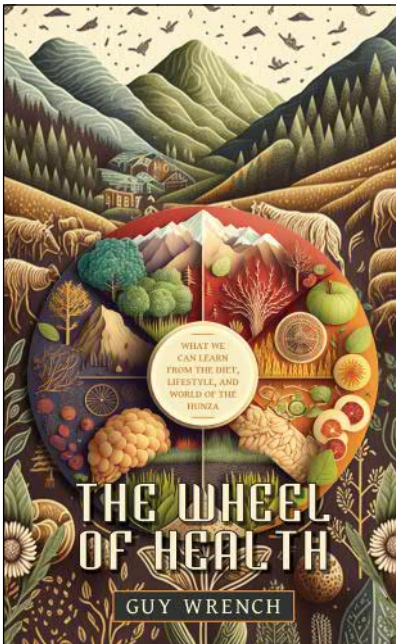
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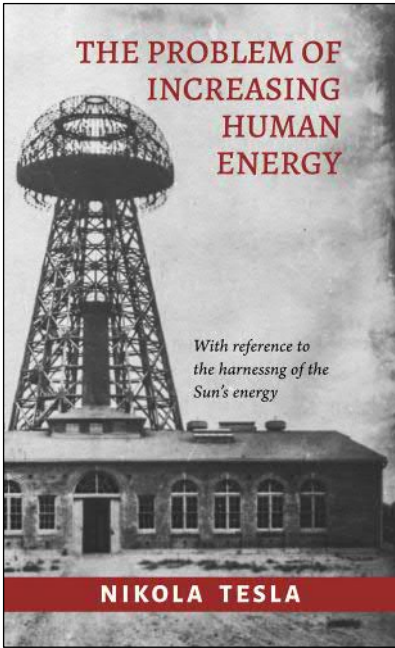
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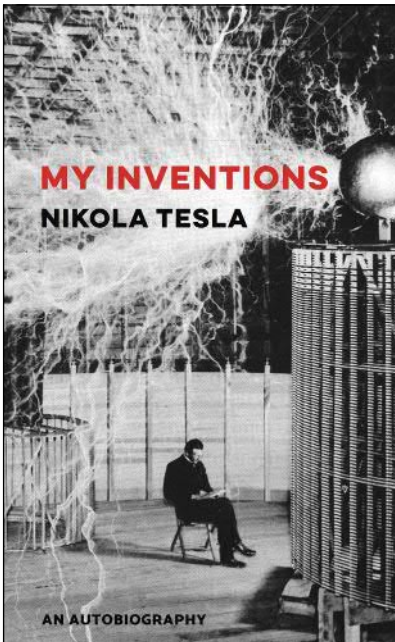
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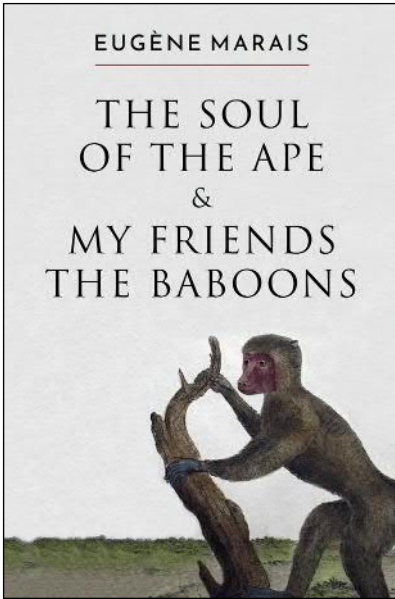
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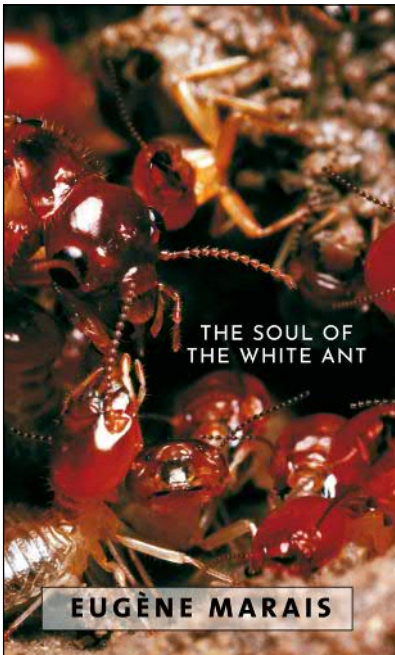
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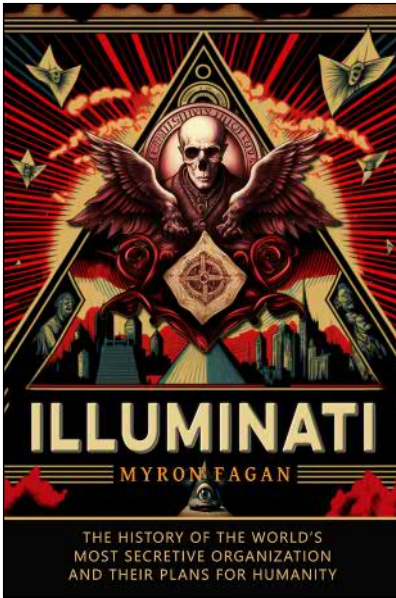
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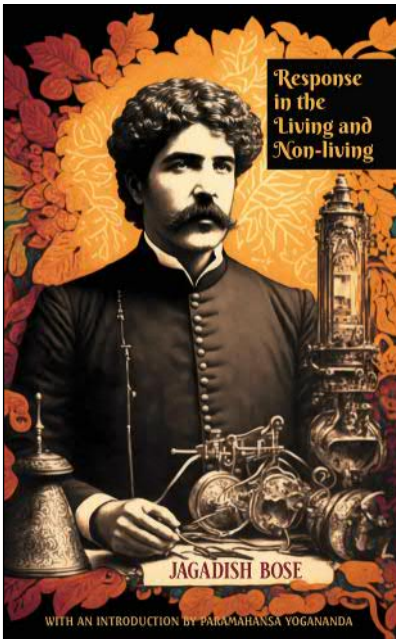
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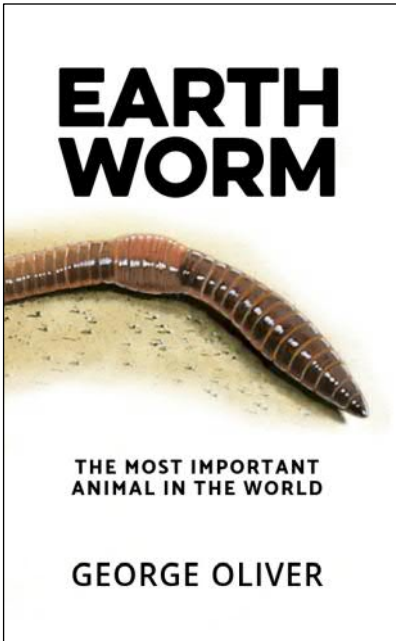
Edmund Morris

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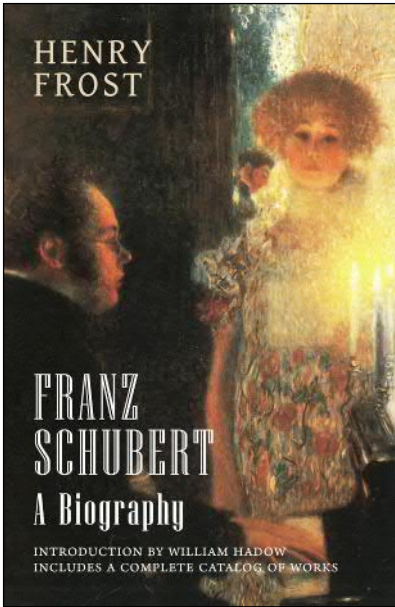
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The author returns the reader to a time and methodology where people took responsibility for what they did and what they produced. In this world of spiraling food prices, huge landfills, diminishing food supplies, loss of topsoil, and water pollution, the reader is reminded that the world's most important animal could well be the humble earthworm.

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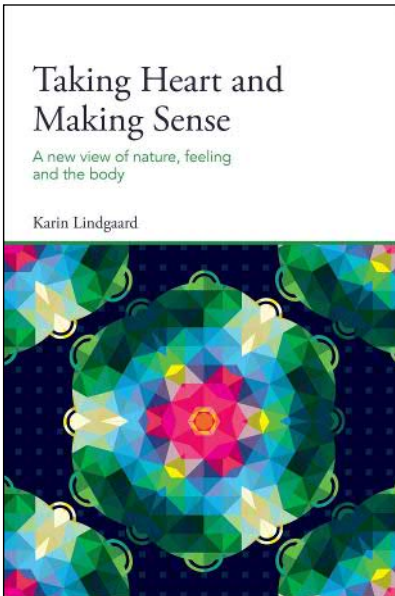
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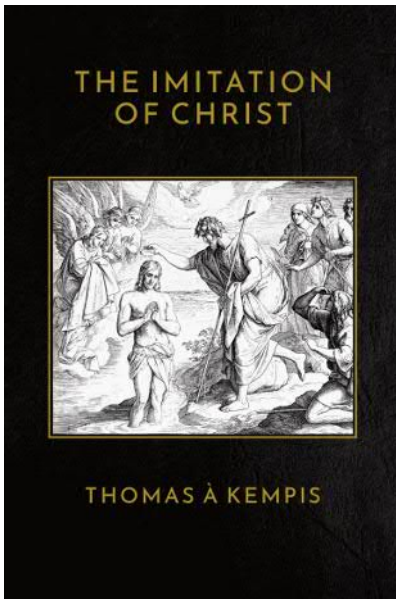
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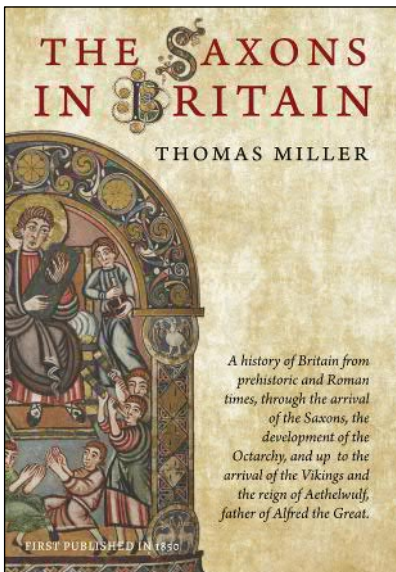
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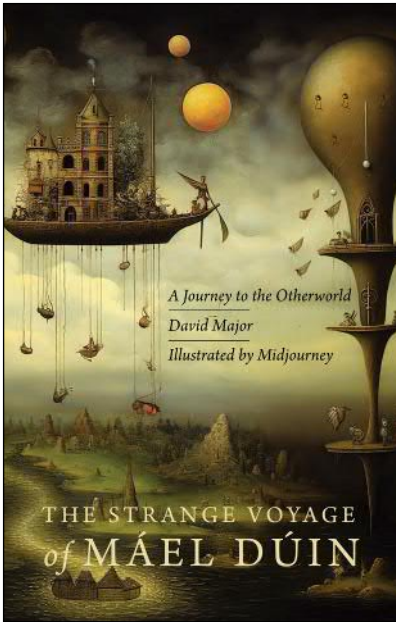
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