

THE GAIA HYPOTHESIS

'GEOPHYSIOLOGY'

NEW PERSPECTIVES FOR

SCIENTIFIC RESEARCH

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Gaia: The life of a theory

The Gaia hypothesis symbolically arose out of the lifeless dust of the red planet. In the late 1960s, NASA was beginning to plan the mission that would later send the Viking spacecraft to Mars, and British scientist James E. Lovelock was helping the agency develop ways to test for the possible presence of martian life.

Lovelock proposed that no probe need actually visit Mars to determine that life does not grace that planet. He reasoned that if Mars supported life, then earthbound scientists could detect signs of organic activity through observations about the martian atmosphere.

In examining our own planet, Lovelock noted that the earth's atmosphere is an unstable, potentially explosive mixture of gases. Life, he proposed, uses the gaseous layer encircling earth both as a source of raw materials and as a repository for waste. This kind of interaction has kept the atmosphere from reaching equilibrium.

In contrast, scientists knew that the atmosphere of Mars — like that of Venus — is made almost entirely of carbon dioxide and is in a state of equilibrium. To Lovelock, this stability indicated that Mars was devoid of life.

In the early 1970s, he expanded on these ideas and coauthored the Gaia hypothesis with biologist Lynn Margulis of Boston University. In essence, the theory states that the lower atmosphere of earth is part of life itself. The plant and animal populations interact with that atmosphere and regulate certain aspects of it, including its temperature and chemical composition.

Some scientists attacked the theory for being teleological or implying that life must be working toward an optimal end. They said the theory required that organisms be altruistic, behaving in a way that helps the aggregate of life. In general, however, the theory received little scientific attention. "Up till now," says Lovelock, "people tended to ignore it."

Rather than attracting the interest of scientists, the Gaia theory originally found support in an ironic mix of extreme ecology groups and industrial polluters, says climatologist Stephen H. Schneider. The ecologists interpreted Gaia as implying a unification of life. And the industrialists translated it as a license to pollute, on the premise that life would counteract any deleterious effects from pollution.

The Gaia theory does not actually

support the latter idea. By extension, it does imply that life may help the earth recoil from the effects of human pollution, but the process would take millions of years. And when earth finally recovers, humans might not be around to appreciate the revitalized planet.

In recent years, however, the Gaia hypothesis has started to achieve an air of scientific legitimacy. Lovelock, Margulis and others have reacted to the early objections and have refined the definitions of the theory. Moreover, they have helped illustrate specifically how Gaia might work by proposing regulatory mechanisms such as the plankton-climate relationship. Says Lovelock, "There's a lot of excitement and interest. And I think a lot of what I will call Gaia-fence-sitters are beginning to feel uncomfortable with their position on the fence."

Scientists are by no means suddenly embracing the theory in record numbers. Many do not accept the idea of long-term regulation and argue that the environment has changed throughout earth's history, sometimes causing extinctions on a massive scale. Others, like James C.G. Walker of the University of Michigan at Ann Arbor, believe that if any process is regulating the environment, it must be the inorganic geophysical systems of the earth.

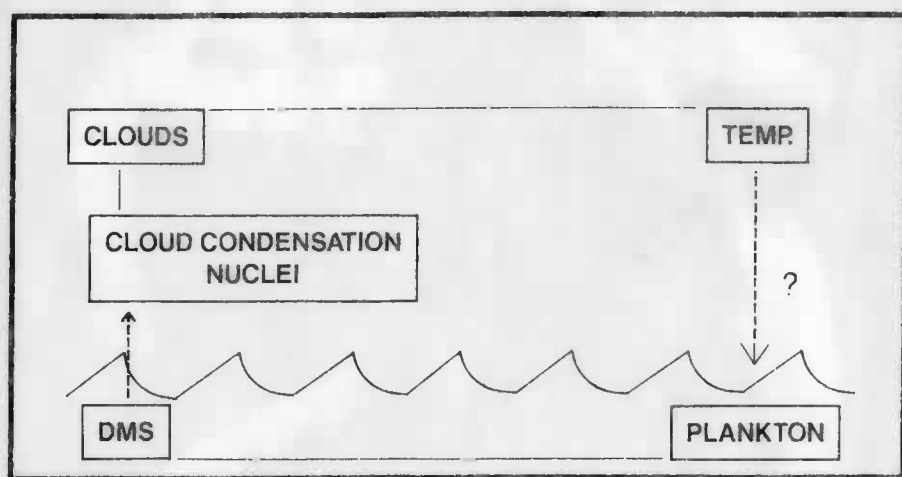
Regarding Gaia, says Walker: "I think that's something that you really just believe or you don't believe, because it's quite hard to prove the case. My personal belief is that's simply not how life works."

But in contrast to earlier times, the general scientific community is now beginning to debate seriously the evidence for and against Gaia. Next March, an international conference sponsored by the American Geophysical Union will convene eminent scientists from disparate fields to explore the hypothesis.

Whether scientists accept or reject the theory is not a major concern of Lovelock's. He says he's primarily delighted that it is stimulating research. "All that matters at this stage of the game," he says, "is that they don't just ignore it, and that they go out and experiment and try to prove it wrong."

As a case in point he mentions that it was the Gaia theory that prompted scientists to discover the relationship between plankton and climate. "What's exciting about all this is that by following our noses along a certain trail, we're finding a lot of interesting science."

— R. Monastersky



In the ocean, plankton produces DMS, which accumulates in the seawater. DMS then diffuses into the atmosphere and undergoes reactions that allow these particles to serve as the condensation nuclei for developing cloud particles. The number of cloud particles influences the reflectivity of clouds, which in turn affects the surface temperature of the earth. In this sequence of steps, an increase in plankton productivity will help cool the earth. But it is still unclear how temperature affects the productivity of plankton. If an increase in temperature causes plankton to produce more DMS, then the relationship is helping to stabilize the temperature of the earth. This type of relationship, called negative feedback, would support the Gaia hypothesis

BACKGROUND

IN THE LATE 1960S JAMES LOVELOCK, A BRITISH SCIENTIST HIRED BY NASA TO DETERMINE HOW TO DETECT LIFE ON MARS, PROPOSED THAT THE EARTH WAS ALIVE. BY THIS, HE MEANT THAT THE EARTH ITSELF BEHAVED AS A SELF-REGULATING SYSTEM. INSTEAD OF THE CONVENTIONAL VIEW THAT LIFE EXISTS ONLY BECAUSE THE MATERIAL CONDITIONS ON EARTH HAPPEN TO BE JUST RIGHT, HE ARGUED THAT LIFE DEFINES THE MATERIAL CONDITIONS NEEDED FOR ITS SURVIVAL AND MAKES SURE THEY STAY THERE!

IN THE ENSUING TWO DECADES, HIS IDEAS AND THE RESEARCH IN PARTICULAR OF LYNN MARGULIS HAVE GENERATED NOT ONLY CONTROVERSY BUT AN AMAZING AMOUNT OF NEW TYPES OF RESEARCH. OVER 100 OF THESE WORKERS MET LAST WINTER AT THE AGU CHAPMAN CONFERENCE ON THE GAIA HYPOTHESIS. AT THIS MEETING IT BECAME CLEAR THAT NO ONE REALLY KNEW HOW TO EVEN STATE THE HYPOTHESIS IN TESTABLE TERMS MUCH LESS DEFINE 'LIFE'. NONETHELESS, STUDENTS AT MANY MAJOR UNIVERSITIES AND RESEARCH CENTERS PRESENTED WORK DONE IN GAIAN TERMS AND SHOWED THAT SO-CALLED MAINSTREAM SCIENTISTS WERE USING TECHNOLOGIES AND POSING QUESTIONS THAT FIT GAIAN PERSPECTIVES. THERE WAS A SENSE THAT SCIENCE WAS BEGINNING TO MATURE ADEQUATELY TO HANDLE SUCH COMPLEX ISSUES. THE GAIAN FOCUS IS ON SYSTEMS ANALYSIS AND INTERDISCIPLINARY APPROACHES, TWO NECESSARY PREREQUISITES TO APPROACHING GLOBAL ISSUES SUCH AS GREENHOUSE, OZONE, ACID RAIN AND TROPICAL FOREST DEVASTATION.

I PROPOSE THAT GAIA IS NOT REALLY AN HYPOTHESIS BUT IS A PERSPECTIVE WHICH IS ESSENTIAL FOR SOLVING COMPLEX SCIENTIFIC ISSUES OF SOCIAL IMPORTANCE. IT IS A PERSPECTIVE WHICH BRIDGES THE SO-CALLED HUMANITIES-SCIENCE TWO-CULTURE GAP; IT BRINGS SCIENCE INTO A REALM THAT MAKES BETTER SENSE TO THE AVERAGE TAXPAYER (OR CONGRESSMAN); IT IS AN EFFECTIVE WAY TO INCORPORATE MORE WOMEN INTO SCIENCE AND PERHAPS OTHER MINORITIES.

THE 'HYPOTHESIS'

A SCIENTIFICALLY TESTABLE DEFINITION OF LIFE HAS PROVED ELUSIVE TO BOTH FRIENDS AND FOES OF GAIA. LOVELOCK SETTLES FOR LIFE AS THAT WHICH IS LOVABLE, EDIBLE, OR LETHAL. I SUSPECT THAT THE QUESTION WILL BE BEST PURSUED IN THE REALM OF ARTIFICIAL INTELLIGENCE WHERE IT SEEMS THE BOUNDARIES BETWEEN HUMAN AND MACHINE ARE GETTING EVER LESS WELL-DEFINED. ONE COULD SUGGEST THAT THE ARROGANCE OF A PERSON WHO CANNOT ACKNOWLEDGE THE POSSIBILITY OF A 'MIND' ON A LARGER SCALE THAN HUMAN IS RATHER UNSCIENTIFIC.

LOVELOCK ACTUALLY NOTED THAT THE FATHER OF GEOLOGY, JAMES HUTTON, PROPOSED IN 1785 THAT THE EARTH IS A SUPERORGANISM AND SHOULD BE STUDIED PHYSIOLOGICALLY. IN VIEWING THE EARTH AS A LIVING PLANET, LOVELOCK SUGGESTS THAT WE NEED TO DEVELOP THE SCIENCE OF GEOPHYSIOLOGY AND INVESTIGATE FEEDBACK LOOPS WHICH WOULD DEMONSTRATE THE SYSTEM'S INTERDEPENDENCY. IF LIFE EXISTS AT THE PLANETARY SCALE, THESE LOOPS MUST BE GLOBAL IN EXTENT. THE KEY QUESTION SEEMS TO BE NOT WHETHER LIFE INTERACTS WITH THE PLANET BUT WHETHER IT REGULATES THE PLANET (A SELF-REGULATING, SELF-ORGANIZING ENTITY).

LYNN MARGULIS REFERRED TO GAIA AS APPROXIMATELY THE SURFACE OF THE EARTH AND ARGUED THAT THE EARTH'S TEMPERATURE, ACIDITY, ALKALINITY, REDOX RELATIONS, COMPOSITION OF REACTIVE GASES ARE ALL MAINTAINED (NOT NECESSARILY CONSTANT) THROUGH TIME BY THE BEHAVIOR, GROWTH AND INTERACTIONS OF LIVING ORGANISMS. GAIA IS A COMPLEX ENTITY INVOLVING EARTH'S BIOSPHERE, ATMOSPHERE, OCEANS, AND SOIL; THE TOTALITY CONSTITUTES A FEEDBACK (CYBERNETIC) SYSTEM WHICH SEEKS TO OPTIMIZE THE PHYSICAL AND CHEMICAL ENVIRONMENT FOR LIFE. SHE ALSO WAS AWARE OF THE RELIGIOUS AND POLITICAL LEGACIES WHICH CONTROL THE PRACTICE OF SCIENCE IN THE U.S.

ANDREW WATSON, LOVELOCK'S ASSOCIATE, IS CURRENTLY INVESTIGATING GAIAN CYCLES. HE VIEWS GAIA AS A COMPLEX OF INTERCONNECTED VARIABLES IN MULTIPLE,

NON-LINEAR, FEEDBACK SYSTEMS. IN PARTICULAR, HE IS WRITING EQUATIONS TO BALANCE BIO-GEOCHEMICAL CYCLES FOR PO_4 , C, SI, WEATHERING RATES AND SEA LEVEL. HE ALSO IS CO-AUTHOR OF THE INCREASINGLY COMPLEX 'DAISYWORLD' MODEL OF CLIMATIC FEEDBACK.

JIM KIRCHNER ARGUED AT THE CONFERENCE, THAT THE GAIA HYPOTHESES AS ORIGINALLY STATED CAME IN AT LEAST FIVE FORMS RANGING FROM WEAK TO STRONG. NONE OF THESE IS BOTH USEFUL AND TESTABLE. HE SUGGESTED THAT A TESTABLE HYPOTHESIS FOR GAIA MIGHT BE: A SYSTEM CONTAINING A BIOCHEMICALLY AND BIOPHYSICALLY DIVERSE COLLECTION OF SPECIES WILL BE MORE RESISTANT TO CHEMICAL/PHYSICAL PERTURBATIONS FROM THE STABLE STATE THAN A SIMILAR SYSTEM WHICH DOES NOT CONTAIN LIFE. THIS IDEA SEEMS TO FIT WELL WITH MARGOLIS' SUGGESTION FOR EXPERIMENTS THAT WOULD INVOLVE STERILIZED BOXES TO WHICH MUCK (I.E., BACTERIA) ARE ADDED UNDER CONTROLLED CONDITIONS.

I WOULD SUGGEST THAT AT THE VERY LEAST, THE GAIAN PERSPECTIVE INVOLVES A KUHNIAN-LIKE PARADIGM SHIFT FROM WHICH TO PURSUE SCIENCE. GAIA IS A GUIDING PRINCIPLE FOR RESEARCH WHICH CONTRASTS NEATLY WITH 'MACHINA': THE EARTH IS A MACHINE. HAS EITHER PARADIGM BEEN PROVEN? WHICH VIEW FITS BETTER WITH OUR NATURAL EXPERIENCE? - IS THE EARTH A MACHINE WHICH WE OPERATE OR IS IT A LIVING SYSTEM OF WHICH WE ARE A PART? WHAT EFFECT WOULD PURSUIT OF RESEARCH ON THE EARTH'S HEALTH DO FOR OUR UNDERSTANDING OF EARTH SYSTEMS? COULD RAPPORT WITH THE EARTH DEEPEN OUR SCIENTIFIC INSIGHTS (E.G., BARBARA MC CLINTOCK)? SHOULD WE SEEK TO UNDERSTAND NATURAL PHENOMENA WITH A BLUEPRINT OR WITH MORE INTIMATE COMMUNICATION?

KEY PERSPECTIVES ON GAIA

1. THE EARTH IS VIEWED AS A LIVING SYSTEM RATHER THAN AS A MACHINE. HISTORIANS OF SCIENCE HAVE REMINDED US THAT THE EXPERIMENTAL METHOD WAS ORIGINALLY DEVELOPED WITH THIS VIEW, BUT THAT A FLEDGLING SCIENCE MAY HAVE BEEN FORCED TO ADOPT A MECHANICAL VIEW WITH ITS IMPLICATION OF A CREATOR TO APPEASE THE RELIGIO-POLITICAL POWERS OF THE TIMES.
2. HUMANS ARE VIEWED AS BELONGING TO AND EMBEDDED WITHIN THE NATURAL WORLD RATHER THAN AS SEPARATE 'OBJECTIVE' OBSERVERS. THIS ALSO FLIES IN THE FACE OF JUDEO-CHRISTIAN MYTHOLOGIES WHICH PLACE MAN ABOVE NATURE.
3. NATURE IS NOT SOMETHING TO BE CONTROLLED OR DOMINATED BUT TO BE CARED ABOUT AND WORKED WITH. THE ROLE OF VIOLENCE IN MODERN SCIENCE IS OBVIOUS WHEN THIS PRINCIPLE IS INVOLVED.
4. EMPHASIS IS ON COMPLEX, INTERACTING SYSTEMS (PERHAPS REQUIRING COMPUTER CAPABILITIES WE ARE JUST BEGINNING TO IMAGINE) RATHER THAN ON LINEAR, REDUCTIONIST, SIMPLISTIC-DICHOTOMY REASONING. THE LATTER APPROACH BROUGHT US A GREAT DEAL OF UNDERSTANDING, BUT BASIC CAUSE-EFFECT REASONING IS, ACCORDING TO LOVELOCK, INADEQUATE TO DEAL WITH GLOBAL SYSTEMS.

SOME THOUGHTS ON THE GAIA PERSPECTIVE

THE GAIA PERSPECTIVE RUNS COUNTER TO A LOT OF SCIENTIFIC TRADITIONS, MOST OF WHICH ARE ASSUMPTIONS WHICH SHOULD HAVE BEEN QUESTIONED YEARS AGO. FIRST, GAIA IS CLEARLY NON-ANTHROPOCENTRIC AND PLACES MEN BACK WITHIN NATURE (WOMEN WERE ALREADY THERE!). IT RAISES QUESTIONS ABOUT RESPONSIBLE RESEARCH WHICH DID NOT TROUBLE SCIENTISTS TINKERING WITH MACHINES. IT HAS BEEN SUGGESTED THAT THE 21ST CENTURY WILL PROBABLY REGARD RACHEL CARSON AS THE PRE-EMINENT SCIENTIST OF OUR CENTURY. GAIA VALIDATES THE OBVIOUS 'FACT' THAT SCIENTISTS OPERATE FROM WITHIN GAIA AND SHOULD CEASE PRETENDING THAT SEPARATION AND NON-INVOLVEMENT ARE NECESSARY FOR SCIENTIFIC OBJECTIVITY (I.E., SEE FOX KELLER'S GENDER AND SCIENCE FOR DEFINITIONS OF DYNAMIC OBJECTIVITY). BARBARA MC CLINTOCK'S ABILITY TO VIEW NATURE AS ALIVE, GROWING, INTERNALLY ORDERED AND RESOURCEFUL, INSTEAD OF AS PASSIVE, MECHANICAL AND RULED BY EXTERNALLY-IMPOSED LAWS LED TO A NOBEL PRIZE! SHOULD WE BE ENCOURAGING MORE STUDENTS IN THIS VIEW? CERTAINLY, THE RESPONSE OF MY CLASSES TO TREATING NATURE NATURALLY RATHER THAN MECHANICALLY SUGGESTS THAT WE HAVE AN UNTAPPED POTENTIAL FOR PRODUCING GUNG-HO AND CAPABLE SCIENTISTS!

A FEW ADVANTAGES TO THE GAIAN PERSPECTIVE ON RESEARCH

1. INTERDISCIPLINARY GLOBAL APPROACH

TO DO GAIAN RESEARCH REQUIRES A SCIENTIST TO BE CAPABLE OF COMMUNICATING WITH COLLEAGUES IN ALL FIELDS AND OF SYNTHESIZING GLOBAL INFORMATION. INVOLVING STUDENTS IN RESEARCH PROJECTS WHICH CAN BE PLACED IN SUCH A PERSPECTIVE; SHOWING STUDENTS HOW INTERDISCIPLINARY RESEARCH PROCEEDS THROUGH TEAM-TEACHING AND COOPERATIVE EFFORTS ARE EFFECTIVE MEANS OF INCREASING INTEREST IN SCIENCE.

2. RECRUITMENT OF NEW SCIENTISTS

BASED ON THE (ADMITTEDLY LIMITED) SAMPLE OF MY STUDENTS, A GREAT MANY STUDENTS, PARTICULARLY WOMEN, ARE VERY INTERESTED IN THE GAIA HYPOTHESIS AND ARE WILLING TO CONSIDER MAJORS THEY HAD BEEN SURE HAD NOTHING TO OFFER THEM. IF WE ARE SERIOUS ABOUT WANTING MORE WOMEN IN SCIENCE, SHOULD WE CONTINUE TO PRETEND THAT OFFERING MONEY IS A REALISTIC WAY OF ATTRACTING WOMEN TO SCIENCE, OR SHOULD WE SUPPORT RESEARCH IN AREAS WHICH INTRIGUE THE AUDIENCE WE WISH TO ATTRACT.

3. SOCIAL IMPACT

GAIAN RESEARCH NECESSARILY DEALS WITH ISSUES OF GLOBAL SCALE THAT DIRECTLY IMPACT THE POSITION OF HUMANS WITHIN THE EARTH'S SYSTEM. AS A WAY OF FOCUSING PUBLIC INTEREST, ESPECIALLY TAXPAYERS, CONGRESSMEN, AND FUNDING AGENCIES ON SIGNIFICANT ISSUES OF IMMEDIACY TO HUMANS GAIA IS EXTREMELY EFFECTIVE (RESPONSES TO LOVELOCK'S HYPOTHESIS RAN ABOUT 2:1, NON-SCIENTISTS TO SCIENTISTS). ISSUES SUCH AS ACID RAIN, OZONE DEPLETION, GREENHOUSE EFFECTS, TROPICAL FOREST DEVASTATION, CONTINENTAL MARGIN DEVELOPMENT, EL NINO EFFECTS, ETC., ARE PROBLEMS WHICH CAN BEST BE DEALT WITH FROM A GAIAN PERSPECTIVE AND CAN STIR PUBLIC INTEREST. IF WE WISH TO SEE SCIENCE LOOKED AT FAVORABLY BY THE GENERAL PUBLIC, THE GAIAN APPROACH CLEARLY MAKES SENSE TO A LOT OF NON-SCIENTISTS IN A WAY THAT 'MACHINA' NEVER DID.

A CLASSROOM EXERCISE FOR CREATING THE GAIA HYPOTHESIS

LAST YEAR, I LED MY CLASSES TO THE REALIZATION OF GAIA THROUGH A PHILOSOPHICAL DISCUSSION OF SCIENCE THAT CENTERED ON FEMINIST CRITIQUES OF SCIENCE. WE BEGAN BY REVIEWING THE PHILOSOPHY OF SCIENTIFIC APPROACHES FROM ARISTOTLE TO THE AMERICAN PRAGMATIST PEIRCE. IN THE TWENTIETH CENTURY WE REVIEWED THE EFFORTS OF THE POSITIVISTS AND THEIR RESCUERS LIKE HEMPEL, AS WELL AS KUHN, HANSON, SCHEFFLER AND OTHERS WHO HAD STUDIED FRAMEWORKS AND PERSPECTIVES. I THEN ASKED FOR A LIST OF THE CHARACTERISTICS WHICH, AS THE STUDENTS UNDERSTOOD SCIENCE, UNDERLAY OUR PRACTICE. THIS LIST INCLUDED THE USUAL CALCULATING, DISTANT OBSERVER MANIPULATING NATURE FOR CONTROL AND TO SUIT HIS OWN PURPOSES.

I THEN REQUESTED A LIST OF THE CHARACTERISTICS WHICH OUR SOCIETY USES TO DISTINGUISH MALE AND FEMALE, NOTING THAT OF COURSE SUCH STEREOTYPES WERE INAPPLICABLE TO MEMBERS OF THIS CLASS. SEVERAL WOMEN, FRESH OUT OF WOMEN'S STUDIES CLASSES, JUMPED RIGHT IN WITH MEN AS DOMINEERING, NEEDING TO BE IN CONTROL, ISOLATED, ETC. ONE MAN RESPONDED WITH WOMEN ARE BITCHY AND WE WERE OFF AND RUNNING! WHEN WE RAN OUT OF IDEAS, A SIMPLE COMPARISON OF THE MASCULINE LIST WITH SCIENTIFIC PRACTICES REVEALED A ONE-TO-ONE CORRESPONDENCE. IT WAS NOTHING THEN TO ASK THEM HOW WE MIGHT CONSTRUCT AN ALTERNATIVE SCIENCE. THE DISCUSSION OF GAIA FOLLOWED NATURALLY, THOUGH I FLAVORED IT WITH A HEARTY DOSE OF ECOFEMINIST PHILOSOPHY.

AT THE END OF THE COURSE, STUDENTS WERE ASKED TO PREPARE RESEARCH PAPERS ON SIGNIFICANT GLOBAL PROBLEMS. ALL OF THEM, MALE AND FEMALE ALIKE, ADOPTED THE GAIAN STANCE IN CRITIQUING MODERN EFFORTS. THE VIEW IS SO NATURAL THAT I NO LONGER WONDER WHY SCIENCE DEVELOPED AS IT DID, ISOLATED AND DISTRUSTED WHILE BEING USED BY SO MANY. SHOULD WE REALLY CONTINUE TO DISTANCE OURSELVES FROM THE PEOPLE WE NEED TO SUPPORT OUR RESEARCH? CAN WE AFFORD IN THE CLIMATE

OF MODERN EDUCATION TO CONTINUE REPELLING STUDENTS WHO WOULD MAKE GOOD SCIENTISTS?

PERHAPS, AS THOMAS KUHN SUGGESTED, PARADIGM SHIFTS ARE RESOLVED NOT THROUGH ARGUMENT BUT WHEN THE OLD GUARD (FUDDY-DUDDIES) DIE OFF!