

Biological Determinism: What Genes Mean

Laurence Levine

RACISM STANDS deeply rooted in our beliefs about the inevitabilities foretold by the genes we inherit. Racists believe that what we perceive of as "undesirable" characteristics in "inferior" people breed as truly as kittens from cats. They preach that loose morals, shiftless behavior, and low intelligence accompany dark eyes and black skin. There are other combinations that go with other minorities -- everyone must have heard, by now, what they say about Jews, Slavs, and Italians.

All their ranting and furtive whispers have more insidious intentions. They warn that the sinister characteristics of minorities will spread through intermarriage, and that spells doom for nation. They then work to institute policies to control undesirable minorities. Historically, various nations have instituted programs of sterilization, murder, Jim Crow restrictions, warehousing in mental institutions or homes for the retarded, and immigration quotas.

The irony is that the genes do determine destiny and more than just going through life as a blond with blue eyes. The Tay-Sachs infant and sickle cell anemic, the cystic fibrosis sufferer and the hemophiliac can not lead normal lives. But in

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quite another perspective, our genes also determine who we are -- humans, we take for granted, but think about what that means. Beyond the unique pattern of our teeth we have a certain curvature of the jaw, the upright torso, the special skull, and within that, our brains. That the genes can do these organs means that they also orchestrate the seat of the emotions, the mind, conscience, creativity, and language. And it is here that we arrive at an astonishing paradox.

Our genes program us to be born all hooked up with our brains -- "hard-wired," for example, as the optic nerve connects to the eyes -- and "soft-wired" as well. Here, part of the genetic program determines that the brain can change as the environment leaves its imprint. The genes build in a degree of plasticity that lets the brain change to new configurations with new experiences.

This feature ought to silence those who rant about the control of "lesser" persons through restricted access. The operation of plasticity invalidates their argument. If a change is desirable, begin with equal opportunity.

The Roots of Racism

The little man that stands beside the furnaces at Dachau stands in silent eloquence for all those who were consumed there. If statues could talk he would speak volumes. But no matter. His posture and attitude says it all -- hands in the pockets of his long coat, out on a stroll in sturdy shoes, he symbolizes innocence. Yet his shorn head, the hollow eyes, and sunken cheeks tell the unspeakable tales of the misery that befell him and all the others: the Chaims, Rebeccas, Marias, and Ladislavs. And for those who come there to place bouquets at his feet, he is a very real memorial to the lost friend, relative, lover, to everyone who went. And for all the inscription on the pedestal, "To honor the Dead, and to warn the living,"² the lesson is plain. Be careful. Beware of the leaders who seek to enforce their view of biological determinism to achieve national goals.

² "DEN TOTEN
ZUR EHR
DEN LEBENDEN
ZUR MAHNUNG"

Determinism and the Nazis³

The Nazis believe that irrefutable biological laws rule human destiny, that everyone is shaped by preordained "truths" sealed in the unyielding jaws of Darwinian evolution. They declared that natural selection operates on all persons and that everyone takes part in an eternal struggle (the German word for struggle is *kampf*) for existence, from which only the super-race will emerge victorious. To ensure that outcome meant the creation of a master race, a breeding population of superior Germans, to conquer and rule over the planet, by enforcing natural selection as national policy. So the orders went out: cull the weak, the infirm, the undesirables. Secure only the best of the German genes with the iron hand of the totalitarian state.

And who were these so-called supermen? The Nazis used "science" to "prove" that the master race bore the Aryan imprint -- that symmetry of head and face, the perfection of limb and torso -- and they, themselves, fit the bill. Anyone who fell short of the State's Aryan yardstick belonged to the lower races, subspecies comprised of persons psychologically nearer to the lower mammals than to the civilized European. They attached little or no value to the lives of such persons.

To the Nazis, liberalism, democracy, and enlightenment were so much drivel. Such ideas were "scientifically" false because they required an assumption of the operation of free will. To them, no one had a choice. It was blut (blood lines or heredity) and boden (the homeland, fir trees⁴ included) all the way.

Hitler's "Logic" ⁵

Hitler used pop-science to buttress his plan to ensure Germany's survival and dominion in the world of the future. He correctly hypothesized that the future would not be bright, that the planet would be much depleted through over-population, and that there simply would not be enough resources left

³ George Stein J., "Biological Sciences and the Roots of Nazism." *American Scientist* 76 (1988): 50-58.

⁴ Images of these trees are as much a part of the volksh (folksy) tradition as *lederhosen*...or leather trousers, knee length and replete with colorful suspenders.

⁵ "My ::>truggle." I suppose he meant *his* struggle for existence. *Mein Kampf*, Chapter 4 Voll

to meet the demands of all nations. His plan for survival in such a world followed from a series of proposals which he summarily rejected to reach his most devastatingly infamous conclusion.

Proposal: Use birth control to restrict population to a size compatible with the available resources. Hitler rejected this. He argued that Germany can not restrict its population while potential enemies allow theirs to grow. Besides, he had no use for birth control because it interferes with *natural selection*. Nature does not restrict procreation but adjusts population through the constant struggle against the harsh realities of existence. The struggle is a test of strength for the most fit. Denial of this struggle is unnatural. Without it the nation will weaken because large numbers of the less fit will get through. And sooner or later those nations that have developed according to the laws of nature will grow strong through rigorous selection, and they will drive out the weak .

Proposal: Increase yields through modern technology. But, he argued. you can only get out so much and no more and this will be the condition of the whole planet. Nature will then reward the strongest. "Mankind has grown great in eternal struggle (Le. *the struggle for existence*) and only in eternal peace does it perish." (italics. mine. page 135). Here is the same argument again: the idyllic life holds no challenges. no tests in which the strong can win with their muscle and breed more of their own kind

Proposal: purchase the needed resources through the cooperative and combined efforts of all nations. This proposal must also be rejected. Survival can not be left to the mercy of foreign (and potentially hostile) states.

Conclusion: we are left with only one alternative. Wage war. It is our natural right to take what is needed for self-survival.

U.S. Immigration Act of 1924

Sadly enough this country may have had a hand in placing the Chaims, the Rebeccas, Marias and Ladislavs on the pedestal outside the furnaces, first by outright rejection on the docks at the Port of Entry, then by the enactment of restrictive legislation.

The precedents to exclude persons of "inferior" genetic racial stock went back to the last century and were based on the tenets of the eugenics movement.⁶

In the early 1900s powerful and influential eugenicists became deeply concerned when the geographical tide of immigration changed from northwestern Europe to the eastern and southeastern regions of the continent, bringing in people of a different look. They were no longer the Nordic/Aryan stocks, not the blonde, blue-eyed, and willowy types, but darker more swarthy persons, much shorter in stature and certainly poorer. They were the Jews, the Italians and Hungarians, Poles and Russians. Because of the way they looked, the eugenicists regarded them as threats to the purity of racial stock in America. So they believed that these immigrants had to be regulated, and the eugenicists chose to do their dirty work under a smoke screen they could call, "science." Intelligence became the principal arbiter of the right to enter this country, and they set about recruiting the right person for the project.

They hired Henry Herbert Goddard, then Director of a School for Feeble-minded Boys and Girls, as top administrator. He was a visible proponent of intelligence testing and a logical choice to lead the eugenicists' crusade, since he already had much experience with the mentally incompetent.

Goddard started his work in 1912 down on the docks of Ellis Island (the largest entry facility in the country). He brought his cadre of young women who would test the newly arrived immigrants by asking them questions about certain common objects in their native languages. They would also look the immigrants over and match them against the intelligence profile they established, much as modern airport attendants look for the terrorist profile at airport arrival/departure gates.

Their efforts yielded astonishing results: 87 percent of the Russians and about 80 percent of all the others placed in the feeble minded category.⁷ They had the proof that these

⁶ Galton originated the term, eugenics, for his movement to maintain the superior racial stock of the civilized nations by preventing contamination by lesser mortals. He also coined nature/nurture to focus the weight debate about which is most important in shaping intelligence, environment or heredity. He believed that heredity was the sole arbitrator of intelligence.

⁷ Rather, they were dubbed "morons," to bypass use of the French *deblles*, or weak ones. This latter term was used on the original Binet test for the group of individuals whose intelligence was at the lower limits of the population, but far above the bottom.

groups were predominantly "inferior," carriers of the bad blood that would soon weaken the nation, and this gave sufficient cause for deportation on the spot.

These same kinds of arguments convinced legislators to pass the Immigration Act, later on, in 1924. Only in this case techniques became even more "scientific." The intelligence testing community had established a base line from the results of tests administered to American World War I army recruits. But it did not much matter. The results were practically the same. The data reinforced and confirmed preconceived notions. They gave "scientific" evidence to show that Jews, Slavs, and Italians were mentally incompetent. It followed, therefore, that they were also morally deficient. The exhortations came in loud and clear: no doubt about it, these people constitute a menace. The Jews and the others would soon overload our prisons and strain the social welfare system. But there were even more dreadful prognostications. The exhorters also invoked the hand of biological predestination.

Everyone knew bad blood from good, that intelligence ran in families, that "intelligence genes" could be passed on to future generations. These swarthy unsavory aliens would surely mate with the more desirable Nordic/Aryan stocks. Their bad genes would worm their way into and despoil America's purest stock. It would not be long before Americans began to look and think like them. That kind of talk deeply influenced legislators to build a wall of exclusion around the country to regulate the "undesirables." with unfavorable quotas

As a result, many were trapped in the towns, the villages and the ghettos of Europe. They could not leave at the time and paid very dearly in the years to come when the concentration camps consumed them for many of the same reasons that blocked their earlier escape.

The Inevitabilities

Ann Frank was among those that died in the Bergen-Belsen concentration camp, but she did not go in the gas chambers. She succumbed to the second most deadly exterminator in the camps. Ann Frank died of typhus, a disease

The American version for this category came from a Greek word which means dull. If names reveal bias, this one does. It was an unfortunate choice.

that is as terrible as war itself, certainly in terms of casualties, for it has taken more persons than all of the weapons shot off in all of the wars. Failing the introduction of specific countermeasures, this disease invariably breaks out anytime sanitation collapses in the midst of the social and geopolitical upheavals.⁸

The germ that causes this disease is a *Rickettsia*.⁹ Rats carry it, and the lice that feed on them transmit the infection from rat to rat. But as they die off, the lice feed on humans and transmit the disease directly to them.

Inborn Diseases

The disease perils do not end with infections. They may be caused by what we inherit through our own genes, stuck in the lineage. Bleeder's disease or hemophilia, for example, places persons in the mortal danger of bleeding to death from the slightest scratch. The genes can be carried by females without danger to them because it is mainly expressed in males.¹⁰ The results can be serious enough for the recipients, but when queens become carriers, the effects can topple empires.

Queen Victoria and her children passed the gene into the male heirs of some of the most important royal families of the day, among them, the rulers of Russia and Spain. The appearance of the bleeder-princes in these nations during times of great social upheaval must have added the fury of disenchantment (the seats of divine power were "flawed") to the sparks that kindled the revolution in Russia and the civil war in Spain.

Other examples of inborn diseases include: Down's syndrome, cystic fibrosis, Tay-Sachs disease, Huntington's Chorea (Woody Guthrie died from this disease),¹¹ Duchene's

⁸ For an account of plagues in general, and how they have moved history along, see: William McNeill H., *Plagues and People*, (Garden City: Anchor Press/Doubleday, 1976) 369.

⁹ A kind of bacterium that belongs to the same general group that causes Lyme disease.

¹⁰ The gene for hemophilia is sex linked. It is carried on the sex chromosome and is manifested in males much more frequently than in females.

¹¹ A disease characterized by uncontrolled movements (hence chorea, taken from the Greek), progressive deterioration of the brain and its commensurate effects on mental processes.

muscular dystrophy, at least one form of Alzheimers disease, and possibly schizophrenia.

Oncogenes: Genes that cause cancer

Viruses, environmental pollutants, even slight mistakes in the normal processing of chromosomes, can cause genes to become dislocated. Lifting genes from their normal surroundings can unbridle the controls on them and lead to their inappropriate expression. When this happens certain benign genes can become oncogenes and thus they add to the store of potential killers that we carry within us - but not transmitted, unless these genes happen to have been transformed in the ova and/or sperm.

II. The Cancer Vine

Old man by the window
Lit by the sinking sun
That sets the panes awash
With golden flames
That can not ignite
The ashes within.

Old light for the window,
New light for the vine,
Good light for the sweepers
In the stores below
As they make ready
For the shoppers
Who come and go
With the rumble of the
train

In the tunnel below.
And conversing over
trays
Of apples and pears,
They do not know
The vine that hides
In the man upstairs
Who recedes now
Behind the panes
Above the sweepers
Hurrying now With the
last of the light
Before the deep rumble
Of the next passing
train.

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The Nature of Biological Determinism

The presence of these genes (and all the others) adds to the store of biological inevitabilities to this extent: the recipients are extremely likely to show the effects of what they may receive. But the process of shuffling out genes to the sperm and eggs makes it impossible to foretell exactly which of the offspring will receive it, and to foretell the severity of symptoms that will appear. For example, one half of the children born to a carrier of Huntingtons Chorea ¹³ will be at risk for developing symptoms. However, we can not tell, who, nor predict exactly, either when the disease will appear, or its level of severity. Symptoms should develop somewhere between the ages of 30 and 50 years. The final outcome is a tragic certainty, but the range between onset and end is wide and may last 10 to 15 years.

Because genes deliver a range of possibilities, the notion that biological determinism is a rigid and unyielding force of destiny is simply not true.

No Gene Acts Alone

Old family pictures should verify that our predecessors were shorter in stature. The Dachau statue should serve as another example. Our Chaim is short and slight. Visitors to historical birthplaces have to duck to make it through the door jambs. Suits of armor meant for the staunch knights of the realm, could hardly hold today's prepubescent, one more piece of evidence that modern day humans grow taller.

What has happened over the generations? The genes that contribute to growth have not changed, but our knowledge of the nutritional requirements for growth has. We can provide the essential nutrition for the stature-determining genes to come closer to their potential, so, *all else being equal*, people have grown taller today through changes in the environment in which the genes operate. Of course, the genes do play a role in this as in all the other traits. They establish the range of possibilities but the actual outcome depends upon the envi-

¹³ Let us say that there are four children involved here. two sons and two daughters. Assume that their mother had the disease and so did their grandfather, but their grandmother and father were free of it. This being the case, anyone of the children carries a 50 percent risk of having received the gene.

ronmental conditions in which they operate. No gene can act entirely on its own.

The attainment of body stature serves as a general model for how genes and environment interdigitated at all the levels of their operation: the genes orchestrate the building of muscle and sinew, the lengthening nerves, the release of hormones to synchronize all the complex events, and much more. But they require an appropriate nutritional environment to back them up.

Deprivation Dwarfism

There are conditions, however, where normal growth is thwarted even though all the required factors, both genetic and nutritional, are present. Children can suffer *deprivation dwarfism*¹⁴ in nutritionally adequate, but emotionally deprived, environments. Children reared in such circumstances fail to do as well as those reared in more enriched settings. It seems that the impoverished environments (as in certain institutions) affects hormone secretions of a gland attached to the brain (the pituitary). Experiences, therefore, can control stature through their influence on brain function.

Genes and the Brain

The brain, like all of our other vital parts lay encoded in the genes at the time of conception. Development sets body building processes in motion. Signals activate the right kind of cells in the right places: skin cells stay on the outside, gut cells on the inside, and nerve cells where they belong. These latter send out extensions that probe outwards towards their destinations, eventually, hooking up every part of the body, the eyes with the vision controlling centers in the brain, the ears in the auditory circuit, every muscle, gland and millimeter of skin on line.

The neuronal extensions find their way to their destinations by following streams of discrete substances exuded by the targets themselves, like locating Hansel and Gretel by fol-

¹⁴ Lytt I. Gardener, "Deprivation Dwarfism." In *The Nature and Nurture of Behavior. Readings from Scientific American*, ed. William T. Greenough. 102-107. 1973. For a delightful reading, see: Diane Ackerman. *A Natural History of the Senses*. (New York: Random House, 1990) 71-80.

lowing the bread crumbs. All the interconnections wire the body. In the brain, the billions of neurons and all their legions of interconnections generate the mind and form the seat of emotions. But there is more than just the trails of "bread crumbs" involved.

The functioning of the brain depends upon neurons generating signals and shunting them from cell to cell so that the messages weave their way through the maze of complexity along their correct paths much as the switching networks in the freight yards get the trains out in the right tracks for their destinations. Impulses from the eyes go primarily to the visual centers for processing and interpretation as visual experience. They do not go to the auditory centers, otherwise we would "hear" them.

The generation of signals, switching and shunting them, depend upon the release of neurotransmitters and other reactive substances, neuropeptides, synthesized under the control of the genes in the nerve cells which release them. Normal external experience causes the release of neurotransmitters and/or neuropeptides and this is what leads to sensation. How the sensation is experienced depends upon where in the brain the release event occurs.

But these same substances can also be released with no apparent *external* cause. Something stirs them from deep inside the cells, and even though one originated from external experiences and the other from intracellular events, the results are practically the same. The brain "feels," the mind interprets the feelings. The brain experiences hallucinations about mice in the corner of the room without any mice around. In dreams the brain rouses itself from within. The dream experiences seem "real" enough to touch and feel, yet their "reality" is not more than the seething chemistry of localized brain eruptions interacting with the mind.

The brain transforms reality to chemistry, and chemistry dilates to experience. Your loved ones can be storms of tiny pulses. The memory of those no longer with us remain imbedded in neuronal networks waiting to glow again like some distant phosphorescence.

Programmed Plasticity¹⁵

The brain works from within itself because the genes have contributed the wiring diagram, along with the master blueprint for the manufacture of the neurotransmitters required for the generation of signals to interact with the mind.

But the genes have also programmed the brain cells to respond to the repeated release of neurotransmitters by changing the circuitry and the structure of its component neurons. Memory, for example, correlates with changes in certain of the neuronal extensions (the development of dendritic spikes); visual experiences during early development alter the paths followed by neurons and their projections upon the areas of the brain responsible for vision. The brain changes according to what the eye sees, what the hand moves, and what the nose smells. External events leave their imprint.

It is this programmed plasticity that demolishes the arguments we heard earlier about intelligence being determined strictly by the genes, by forces erupting from the inside. As previously stated, the eugenicists were responsible for this doctrine and held no quarter for external influences. They would not accept that experience can alter anyone's mental equipment.

Back to the Docks

Consider Chaim again just off the boat on the docks at Ellis Island earlier in the century. As he descended the gangplank, staggering out of steerage onto land again after months at sea, docked, at last, but among strangers, not the least of whom was that official-looking woman making her way towards him. She was asking him questions, jabbering in a language that he vaguely understood as his own. The sounds had a foreign ring to them. They seemed to spill out from too far forward in the mouth, and slipped over the root of the tongue, altogether said too hurriedly. It spooked him. Her dress, trim and bustled, and her official manner seemed too forward, and he worried that she might be "unclean." To add to the confusion, she was asking him foolish question about matters he

¹⁵ Chlye Aokl and Philip Slekovltz. "Plasticlty In Brain Development." *Scient!flc American*, (1988),56-64.

did not care about, so taken together, all these things gave him reasons to be warily hesitant. He could not help but believe that this woman was the latest incarnation of the devil sent to test his faith among foreigners.

Goddard and his cohorts were convinced that Chaim's confusion, and his hesitation in responding to their questions revealed his diminished intelligence and thus signaled the presence of defective genes to go along with lower mentality. He could not conceive that particular external circumstances, the rightful confusion of the estranged, would factor into the equation.

Nothing better can be said for the later versions of intelligence tests. Although changed, they still retained their strong cultural bias, so that even Einstein would score in the moron class 16. Many people believe that the Caucasian cultural emphasis on present intelligence tests explains why blacks routinely score lower than whites. The situation is analogous to Chaim's behavior on the docks, and to many, a signal of the inferior genes in lesser people, destined for the dregs of society.

Recent extensive identical twin studies strongly confirm that heritable variations correlates strongly with variations in intelligence,¹⁷ We can not tell exactly how genes might reach out into whatever abstractions operate to produce the fuzzy context of intelligence based upon the performance of artificial tasks. Perhaps it is the "wiring" or the quantity and structure of neurotransmitters. More likely than not intelligence involves multiple genes. So the genetics of intelligence could not be like sickle cell anemia or hemophilia, but more like the inheritance of body stature. "Nutrition" of the mind then becomes as important for its "growth" as nutrition is for the achievement of normal body stature.

What is Biological Determinism?

It starts in the genes. Although genes define inevitability, they can only do so with a blurred focus. The effects of inborn

16 Allen Chase. *The Legacy of Malthus: The Social Cost of the New Scientific Racism.* (New York: Knopf, 1977) 244.

17 Thomas Bouchard J. Jr. et al. "Sources of Human Psychological Differences: The Minnesota Study of Twins Reared Apart." *Science* 250.12 October (1990): 223-228.

diseases must be considered within their proscribed ranges. Furthermore, the grip of the genes is weakened by the statistical nature of their transmission and the environmental selection of a narrow range of outcomes from their relatively broad range of potentialities.

So biological determination is not just one restricted destiny. It is multifaceted and one of its most astonishing and paradoxical aspects is its control of the brain's plasticity. Genes set it up to change with experience as much as to control elementary functions. It is with this understanding that we have our greatest challenge and come upon our most dangerous junction.

A Challenge: Make it Possible

Thus there is no doubt that environment plays a large role in determining both average levels and individual differences in intelligence within our society. Its influence tends to be exerted gradually and cumulatively, however, through the pervasive effects of home and culture over years and decades.

For this reason, the attributions of black-white or other differences in IQ to genetic factors is not justified, even though one may believe that heredity plays some role in determining individual intelligence levels. There is no question but that Black Americans have typically been reared in environments less likely than those of whites to foster success on tasks like intelligence tests. Adoption studies have shown that black children, like all children, benefit intellectually from being reared in stimulating and prosperous home environments. There is no question but that systematic improvement of the conditions under which black children are reared will reduce the deficit in their average IQs. Indeed, there is no reason to think that the attainment of genuine environmental equality, sustained over a generation or two, would not reduce that deficit to zero.

From Raymond E. Fancher¹⁸

¹⁸ Raymond Fancher E., *The Intelligence Men: Makers of the 19 Controversy*. (New York: Norton. 1985) 238.

A Warning

In an age of declining resources for the disadvantaged, and when the rascals everywhere attempt to mold their "scientific" view of biological determinism into national policy, remember the statue at Dachau and what it stands for.

Bibliography

- Ackerman, Diane. *A Natural History of the Senses*. New York: Random House, 1990. 331.
- Allen, John, S., and Vincent Sarich M. "Schizophrenia in an Evolutionary Perspective." *Perspectives in Biology and Medicine* 32.#1 (1988): 132-150.
- Aoki, Chiye, and Phillip Siekovitz. "Plasticity in Brain Development." *Scientific American* 259.#6, December (1988): 56-64.
- Bouchard, Thomas, J., Jr. et al. "Sources of Human Psychological Differences: The Minnesota Study of Twins Reared Apart." *Science* 250.12 October (1990): 223-228.
- Chase, Allen. *The Legacy of Malthus: The Social Cost of the New Scientific Racism*. New York: Knopf, 1977. 686.
- Fancher, Raymond, E. *The Intelligence Men: Makers of the IQ Controversy*. New York: Norton, 1985. 269.
- Gardener, Lytt, I., ed. *Deprivation Dwarfism*. San Francisco: Freeman, 1973. 102-107.
- Gazzaniga, Michael, S. *Mind Matters*. Boston: Houghton Mifflin, 1988. 255.
- Gould, Stephen, Jay. "Science and Jewish Immigration." *Hen's Teeth and Horse's Toes*. New York: W. W. Norton, 1983. 291-302.
- Kety, Seymour, S. "Disorders of the Human Brain." *Scientific American* 241.#3 (1979): 202-214.
- Koshland, Daniel, E., Jr. "Nature, Nurture, and Behavior." *Science* 235 (1987): 1445.
- Levine, Laurence. "The Cancer Vine." *Perspectives in Biology and Medicine*. 1989. 42: 525.

- Lewontin, Richard, C., Steven Rose, and Leon Kamin J. *Not in Our Genes: Biology, Ideology and Human Nature*. New York: Pantheon, 1984. 322.
- Maddox, John. "Genetics and Heritable IQ." *Nature* 309.14 June (1984): 579.
- McNeill, William, H. *Plagues and People*. Garden City: Anchor Press/Doubleday, 1976. 369.
- Restak, Richard. *The Brain*. New York: Bantam, 1984. 370.
- Snyder, Solomon, H. *Drugs and the Brain*. *Scientific American Library*. New York: Scientific American Books, 1986. 228.
- Stein, George, J. "Biological Sciences and the Roots of Nazism." *American Scientist* 76 (1988): 50-58.
- Wurtman, Richard, J. "Nutrients that Modify Brain Function." *Scientific American* 246.#4 (1982): 50-59.
- Zinsser, Hans. *Rats, Lice and History*. Boston: Little Brown, 1935. 301.