

Roald Hoffmann and Shira Leibowitz

Pure/Impure

New England Review
1994, 16(1): 41-64.

I have made you an assayer of my people
—A refiner—
You are to note and assay their ways.
They are bronze and iron
They are all stubbornly defiant;
They deal basely
All of them act corruptly.
The bellows puff;
The lead is consumed by fire.
Yet the smelter smelts to no purpose—
The dross is not separated out.
They are called “rejected silver,”
For the Lord has rejected them.¹

The Book of Jeremiah 6:28–29

LEIBOWITZ: In this jeremiad, the prophet berates his people for having gone astray. His language is strong, high, and poetic. And it is interspersed with several passages which indicate substantial familiarity with metallurgy.

An interpretation has been provided by the much-maligned former American President, Herbert C. Hoover, who was a talented, unusually well-educated mining engineer, and by his wife, Lou H. Hoover.^{2, 3a,b} The Hoovers discern in the Jeremiah passages the ancient process of cupellation: an impure mixture of silver or gold with undesired admixtures is melted in a cupel, a shallow dish shaped from bone ash. Lead is added. A blast of air oxidizes the non-precious metals. The base metal oxides dissolve in the lead oxide, which is skimmed off, leaving behind the pure silver or gold. Jeremiah invokes the process metaphorically; the wickedness of his people is so great, they will not be purified. The Hoovers remark:

From the number of his metaphors in metallurgical terms we may well conclude that Jeremiah was of considerable metallurgical experience, which may account for his critical tenor of mind.⁴

Jeremiah's stern criticism caught our eye in its conjoining of a scientific or technological argument and an appeal to purity, a condemnation of mixture. Purity is a traditional feature, indeed a desired goal, of religious systems.

HOFFMANN: That passage from Jeremiah is not as clear as you think. If toward the end the prophet uses a powerful metallurgical metaphor for purity, he undermines

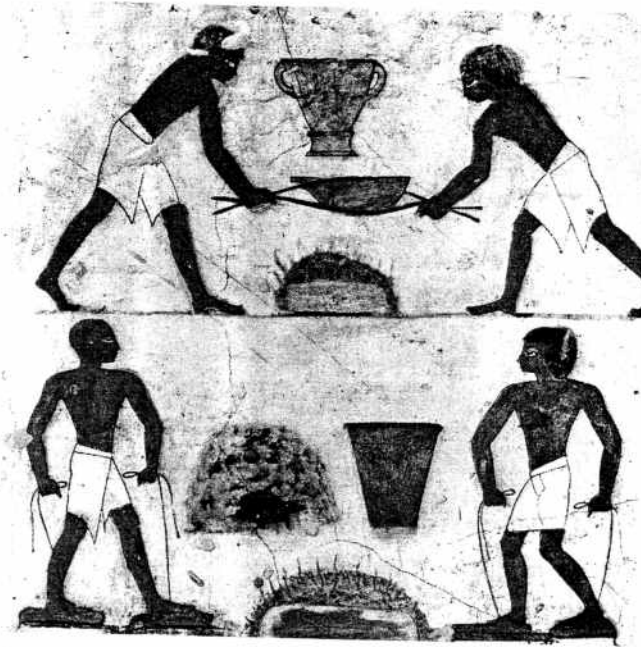


Illustration 1. Wall mural from the grave of Rekhmire at Thebes, 15th Century BCE, showing refining (of gold?) and the foot-driven bellows for smelting. Jeremiah was familiar with these processes.

his aim by invoking iron and bronze near the beginning. Jeremiah's assessment of these metals as "stubbornly defiant" (emphatically repetitive in Hebrew, *sorerey soreyim*) admits their strength, as materials.⁵

And why are they strong? *Because* they are impure, mixtures, alloys. I suspect that Jeremiah, good metallurgist that he was, knew that bronze, in the swords and ploughshares of the Israelites, was a mixture of copper and another metal, tin. And carbon in iron strengthens it; properly processed it becomes steel.

Science teaches us that nothing is pure; moreover that complete admixture is the natural course of events. And chemistry gives us abundant examples of superior impure materials.

So religion squares off against science once again, purity vs. impurity. Or so it seems . . .

I. RELIGION AND THE ASPIRATION TO PURITY

COLETTE: As that word "pure" fell from her lips, I heard the trembling of the plaintive "u," the icy limpidity of the "r," and the sound aroused nothing in me but the need to hear again its unique resonance, its echo of a drop that trickles out, breaks off, and falls somewhere with

a splash. The word “pure” has never revealed an intelligible meaning to me. I can only use the word to quench an optical thirst for purity in the transparencies that evoke it—in bubbles, in a volume of water, and in the imaginary latitudes entrenched, beyond reach, at the very center of a dense crystal.

*The Pure and the Impure*⁶

HOFFMANN: Words such as “pure” and “impure” carry a multitude of meanings. The sense least encumbered with moral connotation is that describing the distinction between objects composed of one substance versus those consisting of a mixture of several. So Vicks Throat Lozenges are a mixture of benzocaine, cetylpyridinium chloride, menthol, camphor, eucalyptus oil, D&C Red No. 27, D&C Red No. 30, flavor, polyethylene glycol, sodium citrate, sucrose, and talc. D&C Red No. 27 is tetrabromotetrachlorofluorescein; D&C Red No. 30 is 6-chloro-2-(6-chloro-4-methyl-3-oxo-benzo[b]thien-2(3H)-ylidene)-4-methyl-benzo[b]thiophen-3(2H)-one, alias “helindone pink CN.”⁷ “Flavor” certainly contains several molecular components. Other examples of mixtures are your breakfast cereal (read the ingredients!) and pure mountain spring water (*certain* to contain, at the parts per million level, calcium, magnesium, chloride, sodium, sulfate, bicarbonate, and organic matter, and at the parts per billion level all kinds of things you don’t want to know about, such as ammonia, borate, fluoride, iron, nitrate, potassium, strontium, aluminum, arsenic, barium, bromide, copper, lead, lithium, manganese, phosphate, and zinc).⁸

From that reasonably neutral starting point of mixture, the meaning of “pure” and “impure” develops. First, there is a metaphorical movement to the realm of the emotions, carrying with it a certain confusion with the ideas of concentration and intensity. A saint, Buddhist or Christian, who meditates intently, is pure in soul. He is not distracted; she is intense.⁹

Second, the movement to the figurative sphere inevitably triggers the association of a positive ethical or moral value to the pure, and a negative one to the impure. To be spotless, unblemished, to be pure in mind, is to approach godliness. “How blest are those whose hearts are pure: for they shall see God,” it says in the Sermon on the Mount,¹⁰ echoing the 24th Psalm:

Who may ascend the mountain of the Lord? Who may stand in his holy place? —He who has clean hands and a pure heart, who has not taken a false oath by My life or sworn deceitfully.

To be pure is to testify to the holiness of God and his people. Purity becomes symbolic, good and *of* God.

LEIBOWITZ: Is there any doubt that purity is a positive good of religion? It is an important factor behind the complex rituals and regulations governing marriage, inheritance, sacrifice, and cooking. Entire tractates of the Talmud, that rich body of initially oral law governing the behavior of observant Jews over 2000 years, are devoted to the rules and regulations of ritual and physical purity. To an outsider the discussion might seem esoteric, a debate between rival rabbinical schools as to how many drops of milk accidentally spilled into a veal stew will cause the dish to become thereby a forbidden milk/meat mixture. But for the Jewish people, every act must be a sancti-

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*ONE OF THE B VITAMINS.

U D

Illustration 2. A 1910 advertisement for Quaker Wheat Berries touting their purity. (Warshaw Collection of Business Americana. Archives Center. National Museum of American History. Smithsonian Institution.)

fication of His holiness. The exhortation to purity is there in the Torah, the Five Books of Moses:

You shall be holy, for I, the Lord thy God, am holy . . . You shall observe My laws. You shall not let your cattle mate with a different kind; you shall not sow your fields with two kinds of seed; you shall not put on cloth from a mixture of two kinds of materials [*shaatnez*].

Leviticus 19:2 and 19

Rationalist attempts to find hygienic or scientific arguments for these rules, or to seek their economic origin abroad. So in *shaatnez*, the prohibition of mixing wool and linen, some people see the ancient struggle between shepherds and farmers. But while these explanations are ingenious, tracing the inevitable interrelatedness of the spiritual and physical world, the reasons for the ubiquity of proscriptive ritual must be deeper.



Illustration 3. The search for *shaatnez*, the forbidden mixture of wool and linen, often uses the tools of modern science. Here is a view of a Brooklyn *shaatnez* laboratory. (Photo courtesy of Cary Sol Wolinsky.)

MARY DOUGLAS: Defilement is never an isolated event. It cannot occur except in view of a systematic ordering of ideas . . . The only way pollution ideas make sense is in reference to a total structure of thought whose key-stone, boundaries, margins and internal lines are held in relation by ritual of separation . . . To be holy is to be whole, to be one; unity, integrity, perfection of the individual and of the kind. The dietary rules [in Leviticus] merely develop the metaphor of holiness on the same lines . . . the underlying principle of cleanness in animals is that they shall conform fully to their class. Those species are unclean which are imperfect members of their class, or whose class itself confounds the general scheme of the world.

Purity and Danger, Ch. 3, "The Abominations of Leviticus"^{11a}

HOFFMANN: In her perceptive 1963 book *Purity and Danger*, Mary Douglas views rites avoiding pollution or impurity as ritual demarcations of the normal from the unnatural. Douglas notes that what disturbs the Lele people of the Congo region about the scaly anteater is that it is *as an animal* abnormal—it is egg-laying, but suckles its young; it is scaly like a fish, but climbs trees; its young are born singly, as those of humans. She constructs a plausible parallel argument for a cultural basis of the prohibited animal species of the Jews, the so-called abominations of Leviticus.

Douglas goes on to argue persuasively that "where the social system requires people to hold dangerously ambiguous roles, these persons are credited with uncontrolled, unconscious, dangerous, disapproved powers—such as witchcraft and evil eye."^{11b} The disordered, or that simply outside the ordered, is not just static and expelled. It spells danger to a stable society. Danger is power.

For a stable society, or a stable form of matter, danger may be as simple as change. In a phase transformation, the precipitous change of one form of matter to another

(for instance water to steam or ice), the beginning (nucleation, as it is called) is always at a locus of disorder, or an impurity.

LEIBOWITZ: Douglas correctly describes the immense importance of separation in the Biblical scheme, and its relationship to purity and holiness. This idea is articulated in the blessing said at the end of the Jewish Sabbath, setting it off from the weekdays:¹²

You have graced us with intelligence . . . You have distinguished between the sacred and the secular, between light and darkness, between Israel and the peoples, between the seventh day and the six days of labor . . . Our Father, Our King, begin for us the days approaching us . . . free from all sin, cleansed from all iniquity.

But an anthropologist analyzing the terminology of purity in a foreign culture through the veil of English will be handicapped.

First of all, highly developed religious systems do make a definite distinction between physical and ritual impurity.¹³ Thus in Hebrew we have *tahor*—pure, clean physically (and spiritually, by metaphoric extension). This can be negated, as *lo tahor*—impure, not clean physically and spiritually. But spiritual defilement, pollution, is described by another adjective, *tamey*. The Biblical candelabra were made of pure (*tahor*) gold, but these might or might not be *tamey*, depending on their contact with a source of defilement (a corpse, a reptile, etc.).¹⁴

Even if an anthropologist studies a culture in terms of its own language, she may be comparing—really confusing—concepts which seem similar but aren't. There are Biblical laws which superficially seem to be about the same concerns: mixtures and impurities. These laws are gastronomic (meat/milk, leaven/non-leaven); about fabric (linen/wool); animal breeding (horse/donkey); marriage (Israelites/neighborly pagan peoples); temporal (*eruv tavshilin*, mixing of holidays and Sabbaths); geographic (*eruv tehumim*, mixing of public and private domains); and metaphysical (impurity due to proximity to sources of ritual defilement). But each concept is embedded in its own legal infrastructure from which it cannot be extricated and compared with others out of their contexts.¹⁵

This problem is endemic to anthropological approaches. In a deconstruction of Indian marriage laws, Wendy Doniger recently observed that "the attempt to rationalize other people's apparent irrationalities is a game that many scholars of religion have enjoyed playing, particularly . . . in this era of moral relativism."¹⁶

Ultimately, the strong claims of religions do not depend on what men and women call reason. This has been the conclusion of Jewish thought—witness the Book of Job, or Rav, a 3rd-century sage, who commenting on a passage from Psalms (18:31), "the Lord's utterance is pure," asserts, "What difference does it make to the Holy One whether one eats unclean or clean substances? It follows that the commandments were given only to purify people."¹⁷



HOFFMANN: The connection between purity and religious aspiration is awesome. Listen to George Frideric Handel in an oratorio where he set several lines of the prophet Malachi's call to the music of thirty singers and an equal number of instruments:

And who shall stand when he appeareth?
 For he is like a refiner's fire,
 And like fuller's soap;
 And he shall sit as a refiner and purifier of silver;
 And he shall purify the sons of Levi,
 And purge them as gold and silver.

Malachi 3:2-3

Jeremiah was not the only prophet who knew metallurgy.

II. SCIENCE AND THE DRIVE TOWARD IMPURITY

NICOLÁS GUILLÉN:

I am not going to tell you that I am a pure man.
 Among other things
 we have yet to know if what is pure exists.
 Or if it is, say, necessary.
 Or possible.
 Or if it tastes good.
 Have you ever had chemically pure water,
 laboratory water,

without a grain of dirt or excrement,
without a bird's small excrement,
water composed only of oxygen and hydrogen?
Puah! What filth!

I do not say, then, that I am a pure man,
I will not tell you that: everything to the contrary.
That I love (women, naturally,
for my love can speak its name),
and like to eat pork with potatoes,
and chickpeas and sausages, and
eggs, chicken, lamb, turkey,
fish and clams;
and I drink rum and beer and brandy and wine,
and fornicate (even on a full stomach).
I am impure, what can I say?
Absolutely impure . . .

From "I Declare Myself an Impure Man"¹⁹

HOFFMANN: When a chemist runs any reaction in the laboratory or when he or she sees some immunosuppressant activity in an extract from a fungus, the product at hand is almost certainly a mixture. Guillén's "water composed of only oxygen and hydrogen" indeed not only tastes flat to us but is unnatural.

Why all that impurity? In the realm of the living, that's an easy question to answer. A living organism is complex. Even within one specialized cell there are thousands of chemical reactions going on. The multitude of tasks accomplished is staggering—can I begin to describe what transpires as the energy of light and water and carbon dioxide combine in a chain of reactions in which we have identified dozens of steps (and a role for iron, copper, manganese, and magnesium) on the way to a sugar molecule in a lily-of-the-valley?^{20a} More than the 100 or so elements, it's the millions of molecules that we sculpt from them that shape the chemistry of the universe. The complexity of plants, our own complexity, demands variety. Two hundred seventy-five constituents have been identified in rose oil, a certain rose essence extract.^{20b}

So mixtures and impurity are natural. More than that—there is a natural drive to *maximize* mixing, called entropy.²¹ It's not a matter of seeking actively for the most messy state of the universe. It's simply the democratic principle of all possible states being equally likely. Even with small numbers the tendency to disorder is evident. If you toss a coin three times you will get one of the equally likely results HHH, HHT, HTH, THH, TTH, THT, HTT, TTT. (H = heads, T = tails). The two "pure" results (HHH, TTT) are unlikely, *not* because on a given toss there is a preference for a single head or a single tail (they're equally likely for the fair coin assumed). The net outcome of three heads or that of three tails is rare (\equiv unlikely, improbable) because each represents only one of eight possible equally likely outcomes. Imagine for 10^{23} coins (that's how many molecules there are in a slurp of water) how improbable it is that all 10^{23} should give heads on a toss! As improbable as that a toss of a properly mixed Caesar salad should lead to three kinds of lettuce neatly segregated, the anchovies on top, the cheese underneath, the egg reconstituted, croutons all together.²²

It's not far from an identification of the pure with the good to the impoverishing notion that behind every observable of this world is a single cause. In biology, as Thomas Eisner has mentioned to us,²³ such ideas have positively inhibited understanding. Take the one gene-one enzyme theory, or the assumption that each pheromone must be a single molecule.

Insects have a chemically rich communication system. Sometimes a male of a species can detect a handful of molecules of one kind wafted by a female among billions of extraneous molecules. Such pheromones have been sought and isolated, a triumph of modern chemistry.

The story of the sex pheromone of the cabbage looper moth, *Trichoplusia ni*, is instructive. The pheromone was first (1966) thought to be a single molecule ((Z)-7-dodecenyl acetate). Then in 1980 a second crucial component was identified, and in

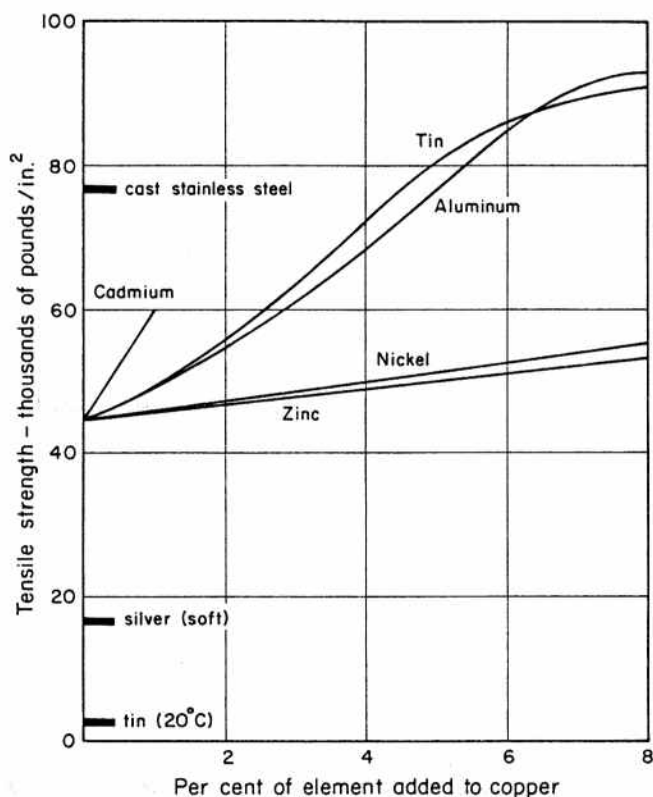


Illustration 4. The influence of metal impurities (alloying) on the tensile strength of cold-rolled copper. (After *Copper Data* 1936, British Copper Development Assoc., London.) The bars at left indicate the tensile strength of tin, silver, and one kind of steel. Note that bronze (copper alloyed with tin) is stronger than either pure copper or pure tin, and may be as strong as steel.

1984 a clue in the way the main component was synthesized by the insect caused Bjostad, Linn, Du, and Roelofs to seek other components, finally demonstrating that a total of no less than six molecules was involved.²⁴ The western pine bark beetle, an economic pest, has an aggregation pheromone, a mixture that signals all comers, male or female, of that species, to assemble. It is a blend of three molecules: one from the male, one from the female, and one, remarkably enough, from the tree.²⁵ These are not isolated examples; most pheromones are blends.

The entropy of the universe increases. We may be able to reverse that trend locally, grow a nearly perfect crystal, to write a poem, bring a child to term. But this can be done only with an input of energy, at a cost. A price that makes some other part of the universe messier.

ROBERT LOUIS STEVENSON (from Henry Jekyll's full statement): My provision of the salt, which had never been renewed since the date of the first experiment, began to run low. I sent out for a fresh supply, and mixed the draught; the ebullition followed, and the first change of colour, not the second; I drank it, and it was without efficiency. You will learn from Poole how I have had London ransacked; it was in vain; and I am now persuaded that my first supply was impure, and that it was that unknown impurity which lent efficacy to the draught.

*The Strange Case of Dr. Jekyll and Mr. Hyde*²⁶

HOFFMANN: Not only is there a natural tendency to mix, but chemists and physicists are constantly made aware of the occasionally superior properties of imperfect, disordered matter (glass is such), or of composites. This was certainly appreciated by the metallurgist side of Jeremiah, familiar with bronze and brass, knowing solders and precious metal alloys. Bronze, an alloy of copper and tin (or other elements; the first bronzes were alloys with arsenic), has mechanical properties superior to either pure metal. It was common in the weapons, tools and decorative objects of the Biblical period. Pure metals, and even more so alloys, are strong and ductile precisely because of the existence of imperfections (called "dislocations") in their structure.²⁷

A SUMERIAN DISPUTATION: Silver, only in the palace do you find a station, that's the place to which you are assigned. If there were no palace, you would have no station, gone would be your dwelling place . . . In the [ordinary] home, you are buried away in its darkest spots, its graves, its "places of escape" [from this world]. When irrigation time comes, you don't supply man with the stubble-loosening copper mattock, that's why nobody pays any attention to you! When planting time comes, you don't supply man with the plough-fashioning copper adz; that's why nobody pays any attention to you! When winter comes, you don't supply man with the firewood-cutting copper ax; that's why nobody pays any attention to you! . . . Silver, if there were no palace, you would have neither station nor dwelling place; only the grave, the "place of escape," would be your station.

Copper's speech to Silver²⁸

LEIBOWITZ: The above text dates to about 2000 B.C.E. It is a "debate" between silver and copper. It may be that copper here really stands for a copper alloy, arsenical copper or bronze, more likely to have been used in tools than native copper by this time.²⁹

This debate is not unique in Sumerian literature. The Sumerians were a combative, verbally aggressive people. We have evidence of this in their texts, their litigiousness

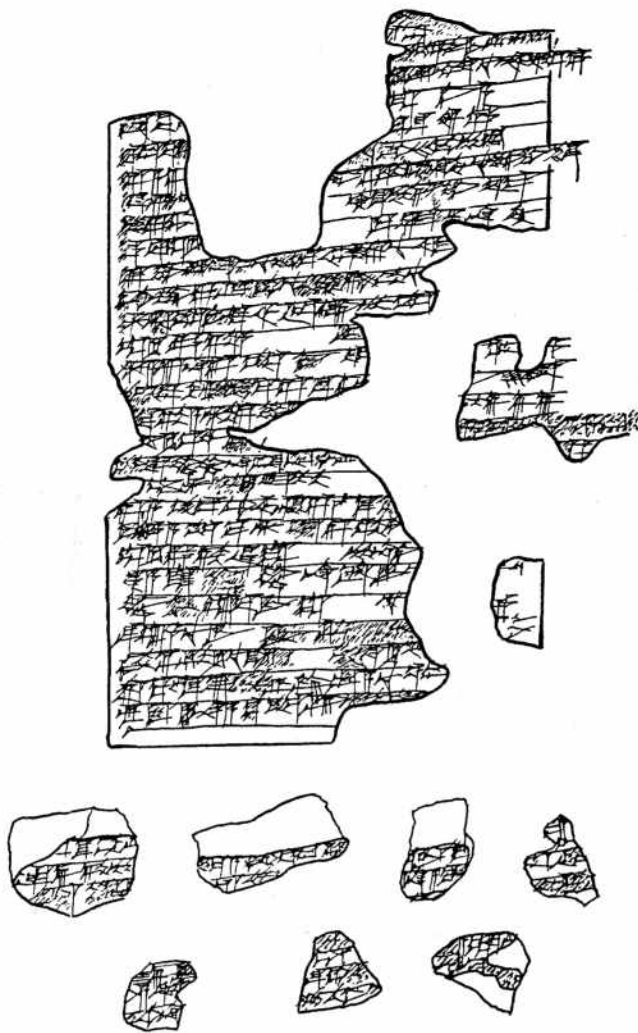


Illustration 5. A transcription of one of the cuneiform tablets of the disputation between copper and silver. The original tablet is in the University Museum, University of Pennsylvania. (Reproduced from the *University Museum Bulletin*, 17, No. 2, Dec. 1952.)

and legal codes. The level of verbal invective and confrontation in their surviving writings is remarkably high.

CYRIL STANLEY SMITH: No metallic material has had more influence upon man's history than iron and its simple alloy with carbon, steel . . . Steel differs in composition from pure iron essentially only by the presence of a small amount of carbon . . . The relation between properties and compositions was fairly clear in the case of the bronzes . . . The fact that steel was also an alloy was not so clear; indeed it was not definitely accepted until the very end of the eighteenth

century [of our era!], 3000 years after the practical discovery. This knowledge arose out of and contributed to the Chemical Revolution in an intimate way.

*The Discovery of Carbon in Steel*³⁰

HOFFMANN: An instructive story of the resistance of science to the evidence of the senses (and their extension, instruments) is to be found in the history of the establishment of the correct composition of steel. The material is not new—think of medieval Japanese swords, or Damascus steel. Steel is an alloy, but—and this was a large part of the difficulty metallurgists faced in thinking about its structure—not an alloy of a metal, iron, with another metal. Steel is an alloy, an intimate mixture on the atomic level, with a non-metal, carbon. And the carbon sneaked in, so to speak, through the carbonaceous fuel used in the inevitably intimate contact of heating. Moreover, the optimum admixture of carbon into iron is small, no greater than 1.5%, so it was difficult to detect.

Cyril Stanley Smith, a metallurgist very much interested in the interface of science and art, tells beautifully the story of the establishment of steel as an iron-carbon alloy. In the early part of Smith's story the scientists and philosophers don't come off too well:

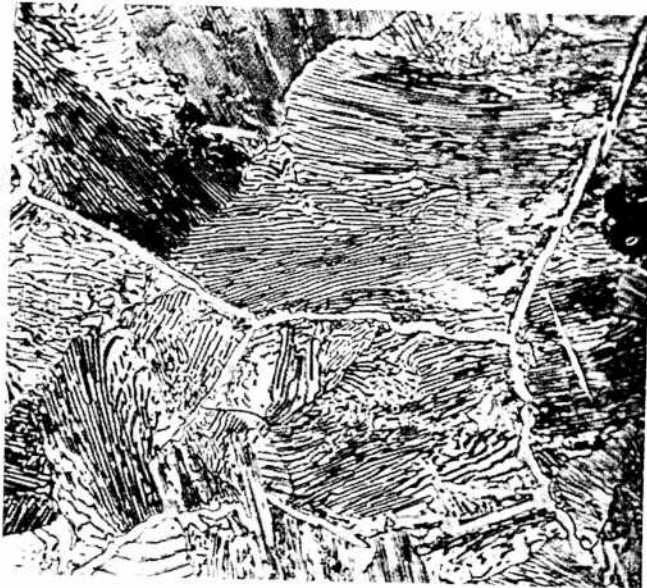


Illustration 6. Photomicrograph of a typical, strong, carbon steel. In this structure there may be seen lamellae (layers) of iron (with some carbon dissolved in it, called ferrite) and iron carbide (a compound Fe_3C , cementite). (Reproduced, with permission from Donald S. Clark and Wilbur R. Varney, *Physical Metallurgy for Engineers*, 2nd ed. [Princeton: D. Van Nostrand, 1962], 123.)

At the end of the seventeenth century, then, we have the practical man (guided as he always will be by the knowledge in his fingers and his eyes) unconsciously putting carbon into iron by his steelmaking processes, while the philosopher thought that some deleterious principle was being removed.³¹

The story unfolds contemporaneously with the ascendance and passing of an erroneous but plausible theory of chemical reactivity, phlogiston. Experimentation and that theory (despite its being wrong) convinced people correctly that something was being added to iron to make steel. Next, practical observation and careful analysis led Swedish chemists to conclude that what was present besides iron was a carbonaceous residue called "plumbago." Interestingly, the earliest written record of carbon in steel is in John Pettus's *Volatiles from the History of Adam and Eve*, which mentions "charcoal" unconsumed by fire rising out of molten cast iron and uses this as a metaphor to bolster man's hope for resurrection.³² In France, in the years just before the Revolution, within the framework of a revolutionary theory of chemistry, the admixture in steel was identified as carbon.

MIRCEA ELIADE: It has been established that among miners, rites calling for a state of cleanliness, fasting, meditation, prayers, and acts of worship were strictly observed. All these things were ordained by the very nature of the operation to be conducted because the area to be entered is sacred and inviolable; subterranean life and the spirits reigning there are about to be disturbed; contact is to be made with something sacred which has no part in the usual religious sphere—a sacredness more profound and more dangerous. There is the feeling of venturing into a domain which by rights does not belong to man—the subterranean world with its mysteries of mineral gestation which has been slowly taking its course in the bowels of the Earth-Mother.

*The Forge and the Crucible*³³

HOFFMANN: Eliade proceeds to cite numerous examples of miners, smelters, and smiths purifying themselves as they prepared to make metals. There is an anthropological and religious dimension to the art of winning metals from their ores and alloying them, as evidenced by the elaborate rituals surrounding primitive mining and metallurgy.

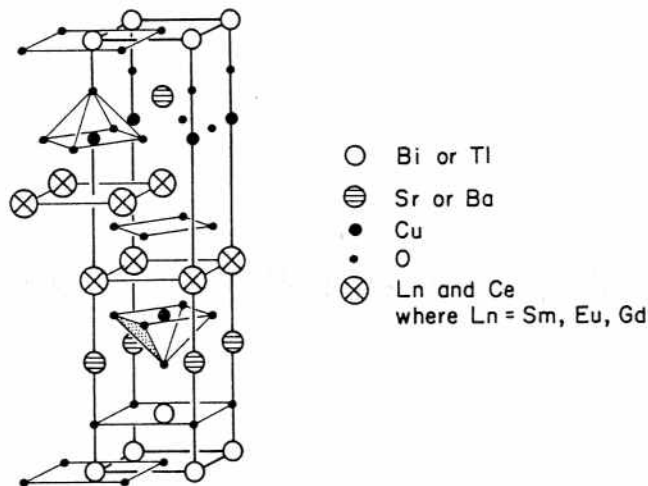
Extending to inanimate ores and metals the life-giving sexuality of the biological world made eminent sense. The idea was especially strong in China, given that civilization's philosophical acceptance of the *yang* and *yin* cosmological principles and its metallurgical skills. The "marriage of metals" that is alloying is an ancient notion, reflected, as Eliade points out, in the *coniunctio* or *Chymical Wedding* of alchemy. And perhaps in another guise in Hegelian dialectic.

Scientists continue to make happy marriages of the elements. In the 1980's a new class of materials was synthesized. It was ceramic in nature and conducted electricity without resistance at temperatures much, much higher than other previously known superconductors. The first superconductors, discovered early in this century, were pure metals. The world record holders until recent times had been alloys of two elements. The new superconductors are compounds of four, five, or even six elements.³⁴



Illustration 7. A view of the Chymical Wedding, Conjunction, from the *Viridarium Chymicum . . .* of Daniel Stolcius de Stolcenberg, 1624. (Reproduced from "Chymisches Lustgärtlein," published by Wissenschaftliche Gesellschaft, 1987.)

Here is a structure of one of these superconductors. Not only are there several elements in it, but for the ceramic to exhibit its properties a certain departure of the oxygen concentration from an integral atom ratio, a certain measure of nonstoichiometry, as it is called, is needed. So the superconductor is not only a mixture, but also "imperfect," departing from the simple composition our naive minds want it to have.



Superconductors, superalloys. Conferring power, if not danger. Or maybe danger, too, steel in the unpredictable hands of man. It seems that nature is following Mary Douglas's vision of the impure imparting power.

LEIBOWITZ: Given all this, you might imagine that scientists should come out clearly on the side of mixing, disorder, and impurity; whereas the stance of religion, to which we already alluded, would be the opposite, advocating a pure soul and body. But things are not so simple.

III. THERE IS ALSO ASPIRATION TO PURITY IN SCIENCE

HOFFMANN: The extraordinary properties of some substances emerge only when they are pure. Examples are polymers, such as polyethylene (used in food wrap and a myriad other products), which are stronger when they are crystalline and pure. Silicon, in computer chips and transistors, has to be made exceedingly pure before it exhibits its immensely useful semiconducting properties. But then, to confound things, the pure silicon is "doped" by "impurity atoms" (roughly one impurity to every 10^7 atoms of silicon). This enhances the electronic efficiency of the purified silicon by many orders of magnitude.

Our favorite metal, copper, whose strength was increased by an admixture of tin (or aluminum, or nickel, see Illustration 4), has its prized electrical conductivity decreased by the very same alloying. The purer the copper, the better it serves us, electrically.

THOMAS MORTON: Underlying everything we do is the notion of a pure compound—without that concept we'd be powerless (which is one of the obstacles in studying olfaction, since subjectively "pure" odors are often complex mixtures, while chemically pure compounds often possess subjectively "complex" odors). The definition of purity allows us to function with purpose.³⁵

HOFFMANN: What Morton, a thoughtful organic chemist, says has both historical and philosophical import. Chemistry developed by refining methods of separation, isolation, and purification. If we need to worry about harmful dioxins at the parts per billion level, we must have methods of detecting and identifying them in a complex mixture.

Philosophically, it is impossible to define impurity in the sense of mixture, without the notion of purity or the unmixed. Only the establishment of one substance as a pure compound allows one to call another a mixture.

Recall the *blend* of chemicals that characterizes a typical natural insect communication system, the cabbage looper moth sex pheromone, mentioned above.²⁴ Roelofs and coworkers identified six molecules, in definite proportions, as being necessary. How did they do so? By synthesizing all six separately, then concocting blends that would elicit male flights against an opposing air stream in a wind tunnel.³⁶

In science, especially in chemistry, we are continuously engaged in the dialectic of purity and are made aware of the complementary claims of the simple and the mixed.

IV. MIXTURES AND IMPURITY IN RELIGION

Preliminary morning service: The incense was composed of the following eleven kinds of spices: balm, onycha, galbanum, and frankincense, seventy *minas*' weight of each; myrrh, cassia, spikenard, and saffron, sixteen *minas*' weight of each; twelve *minas* of costus; three *minas* of an aromatic bark; and nine *minas* of cinnamon. [Added to the spices were] nine *kabs* of Karsina lye, three *seabs* and three *kabs* of Cyprus wine—if Cyprus wine could not be obtained, strong white wine might be substituted for it—a fourth of a *kab* of Sodom salt, and a minute quantity of *ma'aleh ashan* [a smoke-producing ingredient]. Rabbi Nathan says: A minute quantity of Jordan amber was also required. If one added honey to the mixture, he rendered the incense unfit for sacred use, and if he left out any of its ingredients, he was subject to the penalty of death.³⁷

LEIBOWITZ: While this admonition to good practice upon penalty of capital punishment should be posted in all chemistry laboratories, the recipe given clearly describes the blending of a ritual prescription, of a mixture. The quoted passage from the morning service, originally in the Talmud, is striking counterevidence to the seemingly inevitable emphasis on purity in religious ritual.^{38, 39}

Nothing can be omitted, not even the foul-smelling galbanum. Its admixture serves the Talmud as a morality metaphor:

A prayer quorum in which none of the sinners of Israel participates is no prayer quorum; for behold the odor of galbanum is unpleasant, yet it was included among the species for incense.³⁷

Another example of required mixtures: In normal clothing, the observant Jew should avoid the forbidden mixture of wool and linen, *shaatnez* as we mentioned earlier. But in Exodus 28, in the detailed prescriptions for building the Tabernacle and the attendant rites, the robes of Aaron and his sons, the priests, are to be woven with gold; violet, blue, and scarlet wool yarn; and fine linen, all five materials twisted in each thread.

The fact that linen/wool *shaatnez* mixtures are, according to the circumstances, sometimes forbidden and sometimes required, suggests that there isn't anything intrinsically bad—or good—about such combinations. Maimonides puts this philosophically when he places these precepts under the rubric of the command to control one's desires:

A man should conquer his passions, and is warned not to say, "By nature, I do not lust after prohibited things . . . I am repulsed by meat mixed with milk, I am repulsed by *shaatnez*, I am repulsed by forbidden sexual unions." Say instead, "They are attractive but what can I do? My Father in Heaven has forbidden them!"⁴⁰

In its penchant for specificity, the Talmud deals repeatedly with the problem of defining loss of purity by mixture with the impure. Depending on the sanctity of the commandment, either a majority rule applied, or the prohibited object had to be nullified by a large excess, 60 to 1, of the allowed or pure. In some cases, as for leavening in Passover, no nullification was possible.⁴¹ There is an interesting analogy here to the Delaney Clause, a controversial amendment of the US Federal Food, Drug and Cosmetic Act, which in principle banned the addition to food of all substances that were shown to be carcinogenic, at *any* level, in humans or test animals.⁴²



Illustration 8. The certification (in English and Yiddish) that Coca-Cola® is kosher for Passover. (From "Lev Tuviah," edited by Joel Ziff, published by the Rabbi Tobias Geffen Memorial Fund in 1988.)

HOFFMANN: In evaluating the permissibility of admixture, rabbinical law made a substantive distinction between intended and fortuitous acts. There's a wonderful account of this logic in the resolution by Rabbi Tobias Geffen of a problem facing the observant Jew wishing to imbibe Coca-Cola®.⁴³ R. Geffen inquires in 1935 of the secretive and successful Coca-Cola® company about their ingredients, a guarded formula known only to a few officials. He discovers that one ingredient (named only "M" to respect the penchant for confidentiality of the soft drink company) is made from meat and fat tallow of non-kosher animals, another ("A") is made from grain kernels, kosher but constituting leaven, therefore impermissible at Passover.

Ingredient M is there only in one part per thousand (as Geffen, properly cautious, has the chief chemist of the state of Georgia establish). No matter that that is below the halakhic admixture rate of 1:60—M nevertheless makes the beverage unacceptable, because its inclusion is intended, an act of volition.

Rabbi Geffen does not give up:

Because Coca-Cola® has already been accepted by the general public in this country and in Canada, and because it has become an insurmountable problem to induce the great majority of Jews to refrain from partaking this drink, I have tried earnestly to find a method of permitting its usage. With the help of God, I have been able to uncover a pragmatic solution . . .⁴³

He learns from some chemists that M can be replaced by a plant oil such as cottonseed oil, and A by an extract of sugar cane. Astonishingly, he convinces the Coca-Cola® company to make this substitution!

LEIBOWITZ: Most interesting in the Talmudic argument is the development of a calculus of probabilities and statistical inference. A classic case is the problem of a

liquid mixture of a forbidden substance with a permitted one (e.g. milk in a meat broth; forbidden animal oil into permissible oil). If a sample is taken, can it be inferred that when actual mixing occurs, "there is homogeneity" (Hebrew: *yesh bilah*) throughout and therefore the proportions of the sample reflect exactly the proportions of the original? How large does the sample have to be with reference to homogeneity and are the rules different for liquids and solids? To learn the rabbis' solution to the problematic solution you would have to consult the Talmud.⁴⁴

MARY DOUGLAS: The final paradox of the search for purity is that it is an attempt to force experience into logical categories of non-contradiction. But experience is not amenable and those who make the attempt find themselves led into contradiction.

*Purity and Danger*⁴⁵

HOFFMANN: Douglas reaches for an existentialist conclusion to the question why, if dirt and pollution are nearly universally repulsive, do so many rites use unclean, impure, even abominable substances. The Lele, mentioned before, consider the anteatr unclean. But they also have a cult of this animal, whose initiates touch and eat the creature.

Douglas thinks that the incorporation into human rite of absolutely everything, even the "unnatural," is inevitable. It is nature's way and so the way of societies.

It is thus evident that neither the realm of religion nor that of science is unequivocal in its stance on purity. The sacred texts of this world, despite their aspirations to purity, acknowledge the claims of inevitable, even desired admixture. And science, which first recognized the inherent tendency of the universe to mix, nevertheless strives mightily for the purity that is indispensable for a definition of impurity.⁴⁶

V. METAPHORS THAT COMPEL

TACITUS: For myself, I accept the view that the peoples of Germany have never contaminated themselves by intermarriage with foreigners but remain of pure blood, distinct and unlike any nation . . . Silver and gold have been denied them—whether as a sign of divine favour or of divine wrath, I cannot say . . . Even iron is not plentiful; this has been inferred from the sort of weapons they have.

*Germania*⁴⁷

HOFFMANN: Advocacy of purity seems harmless. More than that, as an inducement for the betterment of a human being in body and soul, for throwing off an idol or a drug, it serves us well. The quest for purity is normative, it describes how we *should* be. However, what gives me pause about the positive validation of purity is its abiding use by most known nationalist totalitarian movements, from fascism to apartheid.

The appeal sounded by such regimes and their propagandists is beguiling. It goes as follows: once upon a time the people were pure in body and mind, beautiful and strong. Then they were corrupted by outside forces, by foreign gods. If only the people returned to this natural pure state, if they expelled the foreign elements, if they cast out the admixture in spirit and flesh of the outsider, then, once again, the people, ah the people, would be fair and strong.

Never mind the diverse ethnic origins of Italians—such shining phrases were at the heart of Mussolini's fascist appeal. Never mind that Turks, Jews, Ukrainians, and Russians have lived among Moldavians for centuries—that's the battle cry of today's Moldavian nationalists, passing laws to keep all those others out of "their" university in Kishinev. And who marches in the vanguard of these racist, divisive forces—the intelligentsia, the religious, and the young people!

LEIBOWITZ: One must separate the legitimate from the nefarious in ethnic pride. The desire of a nation, which may be small in number, to feel it must aggressively guard its language, customs, culinary habits, and religious traditions if it is to maintain its ethnic identity (in an age when Coca-Cola is the least common denominator for all cultures) is understandable.

In Jewish law, anyone, absolutely anyone, who is willing to adopt the regimen of true observance can join the tribe. The archetypical example is Ruth, the Moabitess, mother of Davidic royalty. But a small people cannot extend the same toleration to those of its own people who want to go the other way and leave the tradition. A chemical analogy to the sweet and strong bounds of tradition might be a semiporous osmotic membrane. A barrier that permits one-way flow in, but not out.

MICHEL TOURNIER: Purity is the malign inversion of innocence. Innocence is love of being, smiling acceptance of both celestial and earthly sustenance, ignorance of the infernal antithesis between purity and impurity. Satan has turned this spontaneous and as it were native saintliness into a caricature that resembles him and is the converse of the original. Purity is horror of life, hatred of man, morbid passion for the void. A chemically pure body has undergone barbaric treatment in order to arrive at that state, which is absolutely against nature. A man hagridden by the demon of purity sows ruin and death around him. Religious purification, political purges, preservation of racial purity—there are numerous variations on this atrocious theme, but all issue with monotonous regularity in countless crimes whose favorite instrument is fire, symbol of purity and symbol of hell.

*The Ogre*⁴⁸

HOFFMANN: It may be that the scary similarity of religious and totalitarian appeals to purity derives from their parallel rhetorical structure. The aim is to convince, with words. The situation before Mussolini or Jeremiah is the following, human one: "We are in (physical, emotional) state I (for impure), which I do not like. I want to exhort you to move to state P (for pure)." The exhortation naturally takes the form of postulating a prior state P' and the presence of a disturbing factor X.

But rhetoric is not ethics, which is what got rhetoric into trouble. There is a world of difference, an ethical and spiritual essence of a difference, between fascist (or ethnic Moldavian) claims and Jeremiah. Which the parallel rhetoric, or parallel guiding metaphors, disguises.

PRIMO LEVI: The course notes contained a detail which at first reading had escaped me, namely, that the so tender and delicate zinc, so yielding to acid which gulps it down in a single mouthful, behaves, however, in a very different fashion when it is very pure: then it obstinately resists the attack. One could draw from this two conflicting philosophical conclusions: the praise of *purity*, which protects from evil like a coat of mail; the praise of *impurity*, which gives rise to changes, in other words, to life. I discarded the first, disgustingly moralistic, and I lingered to consider the second, which I found more congenial. In order for the wheel to turn,

for life to be lived, impurities are needed . . . Dissension, diversity, the grain of salt and mustard are needed: Fascism does not want them, forbids them, and that's why you're not a Fascist; it wants everybody to be the same, and you are not.

*The Periodic Table*⁴⁹

HOFFMANN AND LEIBOWITZ: The pure/impure dichotomy is another aspect of the central theme of man and the universe. Its other incarnations are the one and the many, the same and not the same, natural and unnatural. If there be more than one of any thing, and a way of naming or classifying each, if there is a choice, material or spiritual, the problem of purity will arise. A motion in one direction, say to segregate, inevitably raises the opposite possibility.

Two extreme arguments could be made. First, there is the line we might today call "entropic," that the natural is the most mixed. So the true path need be that of miscegenation. Support for this way could be adduced from hybrid vigor in biology. Another, contrary philosophy departs from the basic fact that the human body, in its intense local order, is inherently "contraentropic." And so we are fated to support in our thought systems and societies an opposition to mixing. To yield to disorder would be tantamount to surrendering our place in the scheme of things.

We find validity in both views and no inconsistency in a philosophy that encompasses the two. Only change is eternal. The segregated, isolated, pure, and the completely mixed impure are each in their own ways motionless and impotent. Everything else is tense, poised between pure and impure, ambiguous, therefore interesting. Alive.

NOTES

1. For most of the Bible passages we have used the new translation of *The Holy Scriptures*, Philadelphia: Jewish Publication Society, 1978. One exception is our translation of the Hebrew word *nekhoshet*, which can mean copper ore, bronze, or brass. We have followed the *Biblical Encyclopedia* in translating it as bronze everywhere except when it is clear that the context refers to copper ore in the earth.
2. Herbert C. Hoover and Lou H. Hoover in footnotes and historical notes in their translation of Georgius Agricola, *De Re Metallica* (New York: Dover Publication, 1950). See especially pp. 362, 390-93, 465-66.
3. For some leading references to ancient metallurgy see: (a) Robert Maddin ed., *The Beginning of the Use of Metals and Alloys*, Papers from the Second International Conference on the Beginning of the Use of Metals and Alloys, Zhengzhou, China, Oct. 1986 (Cambridge, Mass.: MIT Press, 1988). (b) Leslie Aitchison, *A History of Metals*, vol. 1 (New York: Interscience Publishers, 1960). (c) George Rapp, "On the Origins of Copper and Bronze Alloying," pp. 20-27 of Maddin, *op. cit.* (d) James D. Muhly, "The Beginnings of Metallurgy in the Old World," pp. 2-20 of Maddin, *op. cit.*
4. Hoover and Hoover, *op. cit.*, p. 391.

- being difficult even for the greatest sages. The only way to master them is to expend days and lose nights, and to progress as one accumulates penny by penny a great fortune."
15. A variety of views on the rationale for the forbidden foods are contrasted by Nehama Leibowitz, "The Dietary Laws," in *Studies in Vayikra (Leviticus)*, translated by A. Newman (Jerusalem: World Zionist Organization, 1983), pp. 76–86.
 16. Wendy Doniger, "Why Should a Priest Tell You Whom to Marry? A Deconstruction of the Laws of Manu," *Bulletin of the AAAS* 44, no. 6 (March 1991): 18–31.
 17. *Midrash Tanhuma, Parashat Shemini*.
 18. George Frideric Handel, *The Messiah*, Section 7, Chorus, "And He Shall Purify." Other metal metaphors are used in the oratorio, in Section No. 43, Air for Tenor, based on Psalm 2:9, "Thou shalt break them with a rod of iron," and in Section No. 5 "for he is like a refiner's fire." The illustration shown is in the hand of John Christopher Smith, his principal copyist. We are grateful to Peter A. Ward Jones of the Bodleian Library for his instructive comments.
 19. Nicolás Guillén, "I Declare Myself an Impure Man" (Digo que yo no soy un hombre puro), in *¡Patria y Muerte! The Great Zoo and Other Poems*, edited and translated by R. Márquez (Havana: Editorial de Arte y Literatura, 1972), 210–213.
 20. (a) For an introduction to the marvels of photosynthesis, see Lubert Stryer, *Biochemistry*, 3rd ed. (New York: W. H. Freeman), chap. 22. (b) Günther Ohloff, *Perfumes and Flavors* 3 (1978): 11.
 21. That there is a relentless natural tendency to disorder has been disputed, most eloquently by Ilya Prigogine. In fact, the English title of his book with Isabelle Stengers is "Order Out of Chaos." Prigogine agrees with the classical view that in closed systems (no transfer in or out of matter or energy) approaching equilibrium, entropy maximization reigns. But he and Stengers argue that in open systems, far from equilibrium, "new types of structures may originate spontaneously. In far-from-equilibrium conditions we may have transformations from disorder, from thermal chaos, into order." (Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue with Nature* [New York: Bantam, 1988], p. 12. That is so, but only locally, over a finite period of time, and not without a disordering cost elsewhere in the universe. Prigogine's ideas are stimulating and thought-provoking. But we think they are easily overstretched, to give us what our minds desire, that order out of chaos is natural. See also the review of the Prigogine and Stengers book by Heinz R. Pagels, "Is the Irreversibility We See a Fundamental Property of Nature?" *Physics Today* (Jan. 1985): 97–99; and Rolf Landauer, "Nonlinearity, Multistability and Fluctuations. Reviewing the Reviewers," *American Journal of Physiology* 241 (1981): R107–13.
 22. A most readable account of thermodynamics is to be found in Peter W. Atkins, *The Second Law* (New York: Scientific American Books), 1984.
 23. Thomas Eisner, Letter [to Roald Hoffmann], 18 March 1991.
 24. Of course it takes six for sex: L. B. Bjostad, C. E. Linn, J.-W. Du, W. L. Roelofs, "Identification of New Sex Pheromone Components in *Trichoplusia ni*, Predicted from Biosynthetic Precursors." *Journal of Chemical Ecology* 10, no. 9 (1984): 1309–23. Wendell Roelofs, and Thomas Glover, "Genetics of a Moth Pheromone System," chap. 9 in *Chemical Senses*, vol. 3, edited by C. J. Wysocki and M. R. Kare (New York: Marcel Dekker, 1991). Charles E. Linn, and Wendell Roelofs, "Pheromone Communication in the Moths and Its Role in the Speciation Process," to be published.
 25. Robert M. Silverstein, "Pheromones: Background and Potential for Use in Insect Pest Control," *Science* 213: 1326–32, and references therein.
 26. Robert L. Stevenson, *Dr. Jekyll & Mr. Hyde, the Merry Men and Other Tales* (London: J. M. Dent, 1925), p. 61. This quotation was brought to our attention by a beautiful column by David Jones, which makes some of the same points our paper does: David Jones, "Impure Thoughts," *Chemistry in Britain* 28 (1992): 928.

5. Biblical commentators disagree on the explanation for Jeremiah's disparagement of bronze and iron in this metaphor. For instance, Sh. D. Luzzato (19th century, Trieste) views the base metals bronze and iron as less valuable than gold and silver. On the other hand, Rashi (11th century, France) interprets the metaphor thusly: The people are slanderers strong as bronze and iron, inflicting injury upon their fellow man.

For a recent exploration of the metaphor, see Paula McNutt, *The Forging of Israel: Iron Technology, Symbolism, and Tradition in Ancient Society* (Sheffield: Almond Press, 1990).

6. Colette, *The Pure and the Impure*, translated by H. Briffault from *Ces Plaisirs* (Paris, 1932). Retitled in French in 1942 as *Le pur et l'impur* (New York: Farrar, Straus, and Giroux, 1966), p. 174.
7. In case you'd like to find out what D&C Red No. XY is, we recommend Daniel M. Marmon, *Handbook of U.S. Colorants for Foods, Drugs and Cosmetics*, 2nd ed. (New York: John Wiley, 1984).
8. Frank N. Kemmer, ed., *The NALCO Water Handbook*, 2nd ed. (New York: McGraw-Hill, 1988).
9. The meanings of pure are not exhausted by this discussion. There is a rich discourse on "pure" painting and on "pure" poetry. For poetry this may be seen in the wonderful essay by Robert Penn Warren, "Pure and Impure Poetry," in *Criticism: Foundations of Modern Literary Judgment*, edited by M. Schorer, J. Miles, G. McKenzie (New York: Harcourt, Brace and World, 1958). For art in Clement Greenberg, "Towards a New Laocoon," *Partisan Review*, July–August 1940, reprinted in John O'Brian, ed., *Clement Greenberg. The Collected Essays and Criticism. Volume I. Perceptions and Judgments 1939–1944* (Chicago: University of Chicago Press, 1986), pp. 32, 34. (The Greenberg citation comes from an interesting discussion of Anselm Kiefer's painting by Jack Flam, "The Alchemist," *New York Review of Books*, Feb. 13, 1992: 31–36.)
 Not to speak of the senses of the word as used by (a) Mary Daly, *Pure Lust*. (Boston: Beacon Press); (b) Irwin Silverman, *Pure Types are Rare* (Westpoint, Conn.: Praeger Scientific); (c) Arthur Silverstein, *Pure Politics and Impure Science: The Swine Flu Affair* (Baltimore: Johns Hopkins University Press, 1981).
10. Matthew 5:8. The translation is from *The New English Bible* (Oxford: Oxford University Press, Cambridge University Press, 1980).
11. (a) Mary Douglas, *Purity and Danger: An Analysis of Concepts of Pollution and Taboo* (London: Ark, 1984, 54–72). See also the discussion of the Douglas thesis in Robert Alter, "A New Theory of Kashruth," *Commentary* (August 1979): 46–52; and Michael P. Carroll, "One More Time: Leviticus Revisited," in Bernhard Lang, ed., *Anthropological Approaches to the Old Testament* (Philadelphia: Fortress Press, 1985), pp. 117–26. (b) Douglas, *op. cit.*, p. 99.
12. What is particularly intriguing is that the notion about separations voiced in the blessing is intimately related to, and in fact begins with, a statement about intelligence. In explaining this, the Jerusalem Talmud asks rhetorically, "If there is not wisdom, how can there be differentiation?" This passage is inserted into the prayer for intelligence, *binah*, in the Saturday night service. Scherman, Nossou, ed. and trans, *The Complete ArtScroll Siddur* (Brooklyn: Mesorah Publ., 1984).
13. For an interesting discussion of another passage from the Prophets concerned with ritual purity, see Victor Hurowitz, "Isaiah's Impure Lips and their Purification in Light of Akkadian Sources," *Hebrew Union College Annual* 60 (1989): 39–89.
14. It cannot be emphasized enough that the concept of *taharah* (purity) is one of the most complex and baffling aspects of Jewish law. The Mishnaic order of "Purities" is the longest of the six orders, and in his commentary on it, Maimonides warns that: "I wrote this introduction to disabuse you of the notion that these laws are like those of the Feast of Tabernacles, or Judges' Oaths, so that you will not read the laws of Purities and think you have grasped them on first sight . . . These are among the most abstruse of the Talmud,

27. For a leading reference see Ian Baker, "Metals Pass the Endurance Test," *New Scientist*, May 30, 1992: 34–38; also J. E. Gordon, *The Science of Structures and Materials* (New York: Scientific American Library, 1988), chap. 5.
28. Samuel Noah Kramer, *The Sumerians: Their History, Culture, and Character* (University of Chicago Press, Chicago: 1963), 264–65.
29. We are grateful to Prof. Yaakov Klein of Bar-Ilan University for introducing the authors to the world of Sumer and for his thorough investigation of whether the copper in the dispute is pure copper or an alloy.
 Professor Klein personally is of the opinion that the copper, in the above disputation, represents the basic, pure copper, from which all objects, whether of pure copper or of its alloys, were manufactured. Similarly, its opponent, the silver, seems to represent all objects made from pure silver or its alloys.
 Note, however, that the term used for copper throughout this dialogue is *urudu-kal-ga*, copper the strong one, which may be a synonym for *zabar*, bronze. See Henri Limet, *Le Travail du Métal au Pays de Sumer*, Bibliothèque de la Faculté de Philosophie et Lettres de l'Université de Liège, vol. 155 (Paris: Les Belles Lettres, 1960).
30. Cyril Stanley Smith, "The Discovery of Carbon in Steel," chap. 2 in *A Search for Structure: Selected Essays on Science, Art, and History* (Cambridge, Mass.: MIT Press, 1981). First published in *Technology and Culture* 5: (1964): 149–75.
31. Smith, *op. cit.*, p. 35.
32. John Pettus, *Volatiles from the History of Adam and Eve* (London: T. Bassett, 1674). We are grateful to Cyril Smith for bringing this remarkable text to our attention.
33. Mircea Eliade, *The Forge and the Crucible*, translated by S. Corrin (Chicago: University of Chicago Press, 1962), p. 56.
34. Robert Hazen, "Perovskites," *Scientific American* (June 1988): 52–61. Robert J. Cava, "Superconductors beyond 1–2–3," *Scientific American* 263 (no. 2, August 1990): 42–49. R. Simon, A. Smith, *Superconductors Conquering Technology's New Frontier* (New York: Plenum, 1988).
35. Thomas Hellman Morton, Letter [to Roald Hoffmann], 12 December 1990.
36. Some excellent examples of the necessity of precisely defined mixtures are to be found in perfumery: Édouard Demole, "Parfums et Chimie: Une Symbiose Exemple," *L'Actualité Chimique* (May–June 1992): 227–37.
37. This paragraph from the Jewish daily morning service originates in the Talmud, *Kritot* 6a, where the metaphor involving galbanum also appears.
38. Purity is not a simple concept. While from a physico-chemical viewpoint the incense is patently a mixture, from the ritual perspective it is "pure and holy" (Exodus 30:35).
39. According to A. Varvoglis, University of Thessaloniki, a Holy Myrrh of 57 ingredients is prepared ceremonially every decade by the Patriarchate of Constantinople, and then distributed worldwide. A 38-component version is specified in the *Mega Euchologian*, the Greek Orthodox expanded prayer book.
40. Maimonides, Introduction, chap. 6, *Commentary on the Mishnah* (in Hebrew) (Jerusalem: Mosad Harav Kook, 1978).
41. For an introduction to this subject see A. Steinsaltz, *The Essential Talmud* (New York: Basic Books, 1987), chap. 22.
42. The Delaney clause has occasioned impassioned debate since its 1958 passage. For a good introduction to its history and currency see the testimony in: United States Congress, House Committee on Government Operations, Human Resources and Intergovernmental Relations Subcommittee, *FDA's Regulation of Carcinogenic Additives* (Washington, D.C.: U.S. Government Printing Office, 1977).
43. Tobias Geffen, "A *Teshuvah* Concerning Coca-Cola," translated by Louis Geffen and M. David Geffen, in *Lev Tuviah: The Life and Works of Rabbi Tobias Geffen*, edited by Joel Ziff (Newton, Mass.: Geffen Memorial Fund, 1988), 117–21.

44. Nachum L. Rabinovitch, "Variability in Samples," in *Probability and Statistical Inference in Ancient and Medieval Jewish Literature* (Toronto: University of Toronto Press, 1973), p. 82.
45. Douglas, *op. cit.*, p. 162.
46. As might have been expected, our legal systems also struggle with the notion of purity. Does the purification of a known, patented mixture result in a product that is newly patentable? One line of legal reasoning holds that it does, another focuses on whether there is a difference "in kind" rather than "in degree" in the utility of the newer compound. See Donald S. Chisum, *Patents*, vol 1 (New York: Matthew Bender, 1978), pp. 53-57, §1.02 [9]. Also *Amgen Inc. v. Chugai Pharmaceutical Co. Ltd.*, 13 U.S.P.Q. 2d 1737, 1759 (D. Mass. 1989). We are grateful to C. Frederick Leydig for bringing these cases to our attention.
47. Tacitus. "Germania," 4-6, translated by H. Mattingly (Hammondsworth: Penguin, 1970), 104-105.
48. Michel Tournier, *The Ogre*, translated by Barbara Bray (Garden City: Doubleday, 1972), p. 75. The French original is entitled *Le Roi des Aulnes* (Paris: Gallimard, 1970), p. 85.
49. Primo Levi, *The Periodic Table*, translated by R. Rosenthal (New York: Schocken, 1984), 33-34.

Acknowledgment: Many friends and colleagues made useful comments on drafts of this contribution, or pointed us toward important references. We thank Herbert Deinert, Thomas Eisner, Hillel Furstenberg, Yaakov Klein, C. Frederick Leydig, Thomas Morton, David Owen, Wendell Roelofs, Elizabeth Sherman, Cyril Stanley Smith for their help.