The 27th William Blum Lecture
Presented at the 73rd AESF Annual Convention (SUR/FIN 1986)
in Philadelphia, Pennsylvania
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Introduction

I am humbled and honored to have been selected as a recipient of the AESF Scientific Achievement Award. There is a saying that the greater the gratitude the shorter the comment of thanks. If that were the rule on this occasion, I must confess I would have by now completed my remarks because words cannot convey the fullness of my appreciation. I am particularly indebted to those who nominated me and to those who voted for me and offer them my special gratitude.

Dr. William Blum, in whose honor this lecture is presented, once wrote, "Every award to an individual scientist is a tribute to the institution for which he has worked." I agree with this statement and would like to briefly single out those institutions that have made my 36-year career in our industry possible. Ted and Arnold Pavlish of Cleveland Supply Co. (now PAVCO) introduced me to this exciting field and nurtured me through school; Battelle Columbus Laboratories exposed me to some of the truly scientific pros in the industry; Sandia National Laboratories gave me many years to further refine my skills and share the results in publications and presentations; and Lawrence Livermore National Laboratory continues to do the same while also providing me the opportunity to help mold the careers of others. To these institutions and the friends that helped me along the way, I also add a grateful thank you.

More often than not, the person presenting this lecture givesa review paper summarizing the progress to which he has contributed or describes the state of the art. A few have broken from this tradition and I will do the same. Any contributions I have made are already in the literature since l have not been bashful about publishing.

Thesis: Similarity

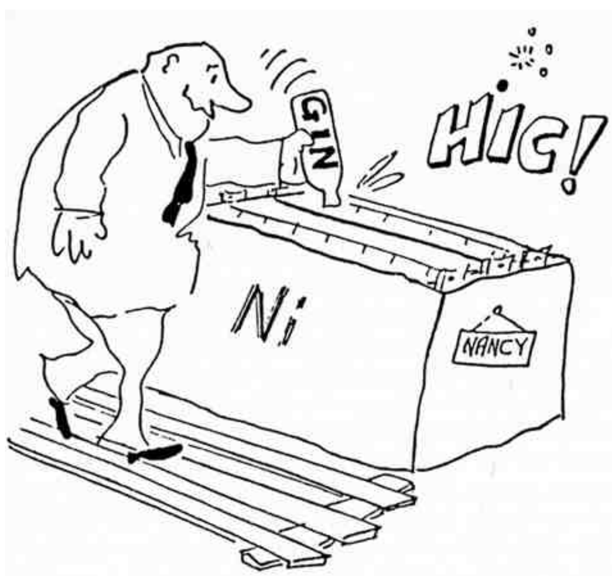
A thesis I would like to propose is that a plating solution is much like the human body (Table 1). The body is nothing more than a gigantic complex of molecules and chemicals working together in harmony; so is a plating solution. The body needs water, and so does a plating solution. We have to feed our bodies and we also have to feed plating solutions. We often have to remove impurities from a plating solution and this is done by pumping, filtering and carbon treating. The body has an excellent pump and many filters plus built-in carbon treaters to remove impurities. A plating solution is operative only when we pass electrical current through it. The muscles in our bodies also behave as a response to electrical action with waves of electrochemical activity traveling down our nerves and propelling our muscles into action. Lastly, chelating or sequestering agents are used for many purposes in both plating solutions and the body.

People these days are characterized as having Type A or Type B behavior. Type A has been described by Friedman and Rosenman as an action-emotion complex that can be observed in any person who is aggressively involved in a chronic incessant struggle to achieve more and more in less and less time.[1] On the other hand, the Type B individual seldom feels any sense of time urgency or impatience. We now have Type A and Type B acid copper plating solutions.[2] The Type B solution is "laid back," just like the Type B person, whereas the Type A solution is much more strongly responsive to agitation, just like the Type A person.

Table 1 - Some similarities of plating solutions and bodies.

Common need	Plating solution	Body
Water	Cu, Ni, Cr and other baths contain about 70% water.	Made up of 70% water.
Food	Some grain refiners, brighteners, anti-oxidants, etc. are foods for the body, too.	Postum, glucose and sulfur compounds are among food common to body and bath.
Filtration	Impurities removed with pump and filter media.	Heart is a pump; filtration devices include liver and kidneys.
Electricity	DC or other current essential for plating.	Brain, nerve and muscle actions depend on electrical impulses.
Chelation	Holds metal in soluble form or retains impurities.	Enzymes contain metal in chelated form.

We even have a book on plating with the title *Nancy Prefers Gin*.[3] It consists of a selection of editorial comments and other pieces published in *Electroplating and Metal Finishing* between 1953 and 1970. The title of the book has to do with a plating tank named Nancy that did indeed need gin to plate properly.



Plating solutions have even been known to imbibe libations. (Courtesy 'Nancy Prefers Gin," Robert Draper Ltd.)

Need for water

Seventy percent of the human body is water. Of interest is the fact that a number of plating solutions, including copper, nickel and chromium, contain approximately 70% water (Table 2).[4] Raw water contains impurities of various types in varying proportions depending on the geographical location. These impurities can range from 30 to 2000 ppm and may include soluble cations, anions, acid constituents, dissolved gases and other items such as sediment, algae, and microorganisms.

The detrimental effects of impurities on plating solutions are fairly well known although we do not have all the answers. In terms of the body in this age of environmental concern, we are learning more and more about how sensitive we are to impurities in the ppm and even the ppb range. Documentation of the effects of impurities on the body and on plating solutions could easily cover a number of papers.

Table 2 - Plating solutions containing about 70% water.

Plating solution	Composition	% Water
Copper (RTNS)	Copper sulfate, 150 g/L Sulfuric acid, 225 g/L Specific gravity, 1.22	69
Chromium	Chromic acid, 413 g/L Specific gravity, 1.29	68
Sulfamate nickel	Nickel sulfamate, 340 g/L Boric acid, 40 g/L Specific gravity, 1.21	69
Watts nickel	Nickel sulfate, 240 g/L Nickel chloride, 45 g/L Boric acid, 30 g/L Specific gravity, 1.13	72
Wood's strike	Nickel chloride, 240 g?L HCl, 55 g/L Specific gravity, 1.12	74

Food comparison

We have to feed our bodies and we also have to feed plating solutions. Of particular interest is the fact that many substances that we feed our bodies also serve well as additives for plating solutions (Table 3). This started with the early patents for brighteners issued in the 1920s.[5-9] Items patented included licorice, glucose, protein substances such as egg albumen and gluten, dextrose, cereal extract, carmelized sugar and molasses. Continuing with the list of items fed to the body as well as plating solutions, saccharin is used as an artificial sweetener in many food and drink items and it has long been used as a stress reducer in nickel electrolytes. Postum is used as a cadmium brightener and ascorbic acid (Vitamin C) as an anti-oxidant in depositing iron alloys. Glucose, which is a form of sugar very important for our bodies, is used as a grain refiner in acid copper solutions.

Table 3 - Some foods common to body and plating solutions.

Chemical	Body	Plating use
Glucose	Sugar	Acid Cu grain refiner
Dyes	Control of infection	Acid Cu brighteners
Coumarin	Oral anticoagulant	Ni brightener
Saccharin	Artificial sweetener	Ni brightener and stress reducer
Postum	Non-caffeinated cereal beverage	Cd brightener
Vitamin C	Scurvy and cancer preventative; anti-oxidant for foods	Anti-oxidant for iron alloys.
Sulfones and sulfonamides	Treatment for leprosy and urinary tract disorders.	Carriers in Ni brighteners

Dyes are used in some plating solutions to help produce deposits with specific properties and in other instances to camouflage the color of plating additives. In a similar vein, dye compounds and chemicals with pigmentary properties are used in the medical field.

Morton, who was one of the pioneers in the introduction of ether for anesthesia, added red dye to help disguise it because others were very skeptical about the use of ether.[10] Another interesting fact about this material is that it really did not work until Morton and co-workers found a highly purified grade. I am certain many plating solutions have suffered banishment to the sewer or landfill simply because they were not purified enough. An example I can point to is some work we did with the use of hydrazine as a substitute for hypophosphite as a reducing agent for electroless nickel deposition. In 1967, we published a paper showing that sound, thick deposits could be obtained when hydrazine was used.[11] About five years after publication, we were called on to produce some more deposits in the hydrazine solution and could not reproduce our earlier work. Eventually, we discovered that the nickel salt we were using had a few more ppm of copper than the salt we had used originally. Everything worked fine as long as the nickel salt was quite pure and had only a few ppm of copper. But an increase in copper by a few more ppm drastically affected the process.

Sulfur plays a key role in the body. It protects against radiation and pollution and can help slow down the aging process, act as an anti-oxidant, deactivate free radicals, neutralize toxins, aid in protein synthesis, and prevent cellular change. Sulfur compounds are common brighteners in nickel plating solutions.[12] Another nickel brightener, coumarin, is used as an oral anticoagulant for the body.

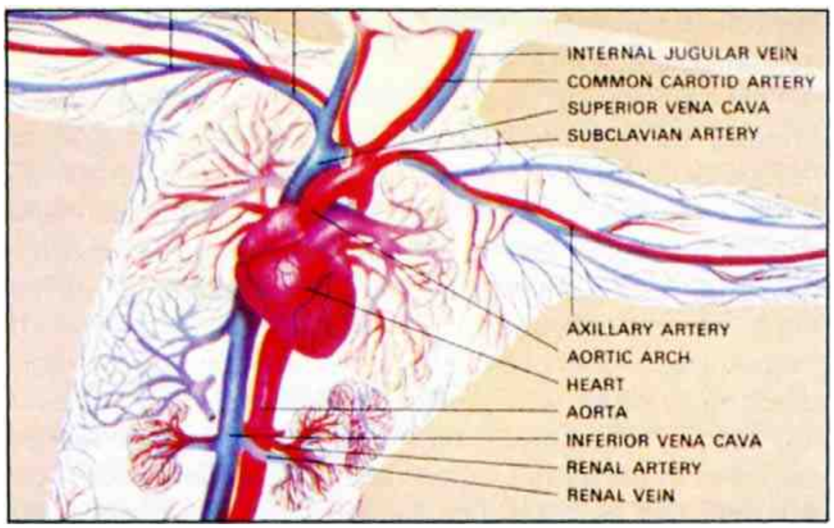
Sulfones and sulfonamide compounds are effective as carriers in nickel brighteners. These same types of chemicals are among those used in the treatment of leprosy and other diseases.[13,14] The sulfonamides have also been used since their first appearance in the 1930s to control infection in urinary tract disorders.

Filtration/carbon treatment

Deposit roughness is created by airborne dirt, particles from anodes, or particulates dragged in with parts to be plated. Filtration, which is the separation of particulate solids from the plating solution, is used to prevent rough deposits. It is accomplished by passing the contaminant-laden solution through a filter medium such as cloth (textile or wire), paper, non-woven fabric or porous tubes.

Organic contaminants can be introduced to the solution in the form of oil, grease or polishing compounds as a result of insufficient cleaning or as airborne dust, particularly if the polishing shop is situated near the plating tanks. However, the most potent source of organic contamination is the formation of degradation products of the brighteners by electrolytic reduction at the cathode. The usual method of removing organic contaminants is treatment with activated carbon. Purification can be carried out either as a batch operation or in large installations as a continuous process, in which case some of the solution is passed through a filter that has a layer of carbon on the filter medium. The typical filtration rate used in plating is 1-3 solution volume turnovers per hour.

The blood in our bodies is also filtered but its circulation rate is considerably faster than that of plating solutions. Namely, our total blood circulates once every 13 seconds with 60 quarts of blood passing to the brain and kidneys per hour. The speed at which blood is pumped from the heart is 40 mph and the turnover rate is greater than 80 per hour. The volume of blood that is moved is tremendous and it is this action that gives us the ability to run - to keep enough oxygen and sugar moving to our legs and arms so that our muscles can move even after hours of exertion.



Human heart is an incomparable pump, driving blood through some 60,000 miles of vessels, beating 100,000 times a day, yet weighing just 11 oz.

The most fascinating pump ever developed is the human heart. It has been described by Dr. Denton Cooley, one of the famous Texas heart surgeons, as a fist-sized pump that can fill the Astrodome. It is no bigger than a clenched fist and weighs no more than 11 oz. in an average-sized adult, but it drives the blood through some 60,000 miles of blood vessels. Working ceaselessly, the heart beats 100,000 times a day, 2.5 billion times in a full lifetime.

All this activity - about 5 quarts of blood squeezed by a fist-sized pump through 60,000 miles of piping in less than a minute - must not stop; if it does, the body dies within minutes. The longest round trip - from the heart to the big toe and back - takes less than a minute. Squeezing out about 2.5 oz. at every beat, the heart daily pumps at least 2500 gallons of blood with a total weight of 20 tons. Not meaning to be disrespectful to those who manufacture and sell pumps for our industry, but I have yet to see the plating solution pump that could come close to meeting these performance characteristics.

The detrimental effects of impurities on plating solutions are fairly well known although we do not have all the answers. In terms of the body in this age of environmental concern, we are learning more and more about how sensitive we are to impurities in the ppm and even the ppb range. Documentation of the effects of impurities on the body and on plating solutions could easily cover a number of papers.

Next in line as filters in the body are tonsils and adenoids, provided to see us through our early years of life when we seemed to always have a cold or sore throat. The tonsils filter out bacteria that enter through the mouth, nose or throat and fight them with lymphocytes. At the back of the tongue there are 35 to 100 nodes of additional tonsillar tissue called lingual tonsils, which act in much the same way as the other tonsils. What we commonly call adenoids are really pharyngeal tonsils located at the back of the nasal passage.

Farther on, the lungs protect us with the action of goblet cells and ciliated cells that line the trachea. The bulged-out shape of the goblet cells that line the airways like a blanket produce mucous, which traps harmful pollutants that might be inhaled as well as some dangerous bacteria and other infectious agents. The ciliated cells that line the air passages are microscopic, hairlike projections that sweep the mucous with a back-and-forth motion about 12 times a second - moving mucous toward the throat, where it is cleared out of the airways into the mouth and unconsciously swallowed.[15]

The liver is the largest gland in the body and one of the largest organs. At 3 to 4 lb., it is 17 times larger than it needs to be to perform its estimated 500 functions, providing the body with a margin of safety for this vital organ. One of its key chemical activities is the filtration and detoxification of poisonous materials from the blood stream. To date, experiments with different kinds of artificial livers have not resulted in duplication of this highly complex organ. One technique uses activated charcoal and an ion-exchange resin to purify the blood of its poisons.[15] This, of course, sounds very similar to the earlier discussion in this section on purification of contaminated plating solutions.

The kidneys also play an important role in filtration. The body is supplied with two kidneys, one on either side of the back wall of the upper abdomen, roughly behind the liver and stomach. The kidneys act as filters that clean the blood by removing waste products through the production of urine. The chemical balance of blood is maintained by its circulation through the kidneys, which eliminate through the processes of filtration and absorption the organic wastes of digestion, excess salts, water, and small protein molecules present in excessive amounts. The basic filtering units of the kidneys are some 2 million nephrons, a tiny network of tubules that clear the blood of unwanted waste products.

Another function of the kidneys is to play a major role in maintaining the balance of water in the body. Each day the body excretes 1½ to 2 quarts of urine containing the products of protein digestion, uric acid, urea and creatinine. To do this, the kidneys filter about 48 gallons of blood every 24 hours - close to four times the body's liquid weight. This amounts to almost 1.3 million gallons filtered in a lifetime of 73 years. At any one moment, as much as one-fourth of a person's blood passes through his kidneys for laundering.[15]

Electrical current

In the introduction, the importance of electrical current in both electrodeposition and our bodily functions was briefly noted. Without electrical current, we are not electroplaters and without the current in our bodies, we don't have much of a body (or life).

Electroplating is generally associated with direct-current electrolysis, although, in most applications, pure DC is rarely used because some form of ripple is present. In some instances, however, deliberate use is made of other forms such as alternating current, superimposed AC on DC, periodic-reverse, and pulsed current.

The manner in which electrical impulses serve our bodies is a fascinating subject. The human body, like the bodies of all living things, creates its own electromagnetic field. Every cell contributes to this field, especially the active gland cells and the muscle cells, which produce relatively strong electrical current upon each contraction. The nervous system is a network of unceasing electrical activity; the brain an incredibly complex switchboard on which every light is twinkling, night and day. The electrical activity in the brain is organized into pulsing waves, which can be measured on the surface of the scalp and which also can propagate out into space at the speed of light. The difference in electrical potential between the outside and inside of a nerve cell membrane is usually between 1/20th and 1/10th of a volt, and it is this difference (constantly maintained by the inside-outside sodium and potassium ionic balance) that propagates the nerve impulse along the axon. This microelectricity is equal to about 1/40th the amount it takes to light up a standard two-battery flashlight.[15]

The heart and its extended system of blood vessels produce electrical current and magnetic force with an accompanying electromagnetic field. The current generated by the heart itself can be measured on the surface of the chest as a charge of as much as a hundredth of a volt. The electromagnetic field associated with the cardiovascular system has been detected by sensitive instruments several feet away from the body.

Most medical treatments are based on altering the body's chemistry with drugs. In the decades ahead, doctors will treat a wide range of problems by altering the body's internal currents with external electrical fields (Table 4). Use of electricity in medicine is a natural adjunct to drug therapy since our body is as much an electrical power plant as a chemical factory. The idea that current can cure body ills is hardly original. Electroshock therapy has survived from the 18th century. Prior to this, Dr. Scribonius Largus, who practiced medicine in Rome more than 1900 years ago, had a sure-fire treatment for pain. He had his patients grip electric eels or torpedo fish underwater and the sudden surge of voltage through their bodies swiftly banished their pain - for a while at least.

Table 4 - Use of electricity in medicine.

- Heart pacemakers and defibrillators
- Brain pacemaker
- Electrical muscle stimulators
- Pulsed EM therapy
- Transcutaneous electric nerve stimulators
- Mate electronic genital stimulators
- Cancer treatment

Pacemakers and defibrillators, lifesaving devices developed to aid an ailing heart, operate on electrical action. Pacemakers deliver rhythmical electrical stimulation to the heart when it is needed through electrodes attached to the inside of the right ventricle. Defibrillators deliver an electrical shock of greater than 200 watts to stop ventricular fibrillation and return the heart to its normal rhythm.

There is also a brain pacemaker. It consists of three metal electrodes, each one-millionth of an inch in diameter, implanted on the brain's surface. The electrodes discharge tiny, painless electrical currents to relieve or modify a host of neurological afflictions such as back pain or schizophrenic behavior. It has been shown that the levels of beta-endorphin-like substances (pain killers) in brain fluid increased two to four times with the use of electrical stimulation.[15]

Joan Benoit's near-miraculous recovery from arthroscopic knee surgery 17 days before she won the 1984 Olympic marathon trial focused attention on the use of electrical stimulation in the field of sports medicine. Physical therapists have found that, depending on the type and strength of current used, electrical muscle stimulators can "exercise," or repeatedly contract, muscle fibers immobilized by an injury - a broken leg, for example - to prevent atrophy of the muscle. They can also decrease pain and even increase the size and strength of the muscle tissues.

Bones are not the only parts of the body that respond favorably to electrical fields. It has been demonstrated that pulsed electromagnetic fields can reduce the swelling of tissues bruised in accidents or lacerated by surgery. Pulsed EM therapy accelerates the growth of new skin over burned areas of patients' bodies.

It is important to note that we are talking about a pulsed instead of a continuous electromagnetic field. If the energy in the waves is delivered continuously to a portion of the body, a buildup of heat would burn the surrounding tissues. When the energy is transmitted to the injured area in rapid bursts of 80 to 600 pulses a second, the heating effect is avoided and treatment time can be greatly increased.[16] A lot of this sounds similar to pulse plating, which has found increased usage in electroplating in recent years. Pulse plating is simply the interruption of DC at high frequencies and in many instances has had a marked effect on improving the mechanical properties of deposits and in reducing internal stress.[17] In another example, the relaxation time between pulses has been shown to allow chromium deposits to outgas hydrogen and thus be deposited crack free.

The science of neurostimulation is moving swiftly, offering patients an alternative to repeated surgery or narcotics. The devices that send current across the skin are known as TENS, for transcutaneous electrical nerve stimulators. TENS devices operate in two modes, controlling different types of pain through different mechanisms. One mode sends high-intensity electrical pulses at very low frequencies - only two or three cycles per second - and is used most often when pain is moderate, superficial or localized. The second mode uses low-intensity electrical pulses at much higher frequencies - 50 cycles or more per second. The high-frequency machines are dramatically effective in cases of painful nerve injuries.

Chicago bioengineers, relying on the knowledge that walking involves a complicated interaction of gait and swing in the torso and upper limbs, have connected upper back electrodes to a microprocessor, which in turn was connected to electrical stimulators on a patient's legs. The electrodes capture signals measuring 1 mV each when the patient moves his upper body and the microprocessor amplifies the signal to 80 to 100 V. Pulsing occurs 10 to 30 times a second and goes unnoticed in the patient but the current is enough to activate the previously paralyzed muscles to walk and make that big first step toward freedom from wheelchair confinement.[15] An example is paraplegic Jennifer Smith, whose spinal cord was damaged by a sniper's bullet in Houston six years ago. In December, she covered about one-fourth of the Honolulu marathon aided by a walker and a computerized, electronic, muscle stimulation device that she wore like a girdle.

It is estimated that more than 10 million men are chronically impotent. Recent research suggests that this problem can be treated with electricity. It has been discovered that electrical stimulation of bundles of nerves near the prostate of monkeys triggers erections. By surgically implanting electrodes that can be activated by radio signals, these erections in the animals can be induced and maintained for up to several hours. A Philadelphia-based firm, Biosonics, now has such a device under development for humans.[21] Continuing with this trend of thought, it has been shown that pleasure centers of the brain can be electronically stimulated with electrodes carrying electrical current. The postulation is that in a few decades, this approach may allow people to buy bunches of orgasms by simply pressing a button on a control box.[15]

Swedish radiologist B. Nordenstrom postulates that electricity as well as blood flows through the blood stream and that by using a DC treatment processor, the body's ability to fight tumors is enhanced.[22] In his view, the electrical system is as critical to the well-being of the human body as the flow of blood. Disturbances in this electrical network are thought to be involved in the development of cancer and other diseases. Nordenstrom has put his ideas to work, using electricity to treat lung and breast tumors. Considering the immaturity of the science, he has had remarkable success on isolated tumors, the largest being 4 cm across.[22]

Importance of chelation

Chelating or sequestering agents are used for many purposes in plating and are also very important to the body. The word chelate comes from the Greek chele, meaning "claw" as a crab or lobster's. It refers to the way certain chemicals and body proteins can bind molecules. A chelated compound is one in which the metal is contained as an integral part of a ring structure and is not readily ionized.[23] A chelated metal has entirely different properties than the metal alone or the chelating material alone. The binding of the metal is very sensitive to changes in temperature, acidity, concentrations of metal and chelating substance, presence of other metals, and other chemicals in the system - whether it is a plating solution or the body. This means that, although the metal is tightly held, a change in the above conditions can result in release of the metal and an exchange for another one or binding of more or less of the same metal. In this way, chelators naturally present in the body or a plating solution can pick up metals from one location, transport them to another, and readily release them when certain factors change.

Examples of the use of chelating or sequestering agents in metal finishing include: (1) holding a relatively large reserve of metal in soluble form in the plating solution, and (2) keeping impurities in solution that would otherwise create problems or increase in concentration to the point of plating out with the desired metal. Table 5 compares the use of chelating agents in plating solutions and the body.

Table 5 - Uses of chelating agents.

Plating	Body
Electroless Ni and Cu solutions	Chelation therapy for clogged arteries
Zincating solutions for aluminum	Iron and zinc control
Non-phosphated cleaners	Treatment of Wilson's disease

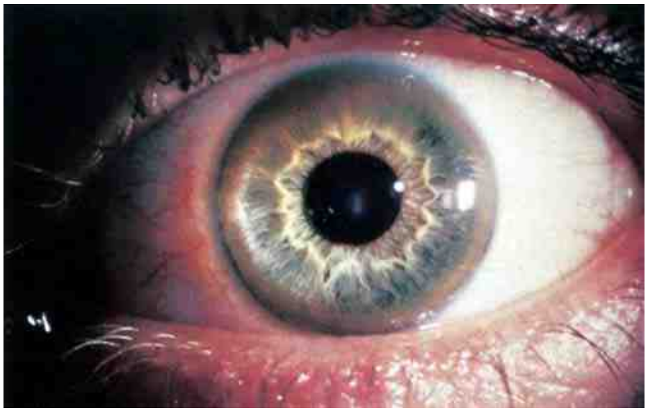
One of the best known and widely used types of medical intervention in cardiovascular disease is the coronary bypass operation. Briefly, a section of vein (usually from the patient's leg) is grafted to the aorta and to a diseased coronary artery at a point "downstream" of a blockage in the artery that is cutting off the blood supply to the heart; blood is thus detoured around the blockage and reaches the heart muscle.

Chelation therapy is an alternate treatment to the bypass operation for clogged arteries. It is performed by injecting EDTA into the blood stream, where it chelates calcium ions and carries them to the kidneys for excretion in the urine. The missing blood calcium is replaced from the nearest available source - the calcium which serves as a "glue" binding the artery-clogging fat plaques together. This allows the plaques to break up and leave the body harmlessly.[24]

Practically every enzyme in the body has some small amount of metal involved in its chemical structure that is bound in chelated form. Without the trace metal, the enzyme is inactive. Chelation therefore is a process vital to our proper function and survival. Iron and zinc are two important metals present in the body and their transportation and migration in and out of the cells are handled by the chelation process. The iron in hemoglobin, which is the pigment present in the red blood cells and is the oxygen carrier, is an example of a chelated metal. Excess amounts of other metals, perhaps more active chemically than the correct ones, may replace the normal one in the protein structure and block the proper action of the enzyme. This is how excess lead, mercury, arsenic and other environmental poisons may cause damage to vital structures by blocking normal enzyme action.

Copper is one of several elements essential in minute quantities to the normal functioning of the human body. It makes possible the assimilation of iron, but like some other members of this company (most notably iron) its impact in large quantities has long been known to be toxic. Wilson's disease is essentially chronic copper poisoning. In it, the natural balance between copper ingestion and copper excretion is disturbed and the copper thus retained is stored in certain organs. The liver is its first and chief repository. In time, as the storage capacity of the liver is exhausted, the continuing accumulation passes from the liver into the blood stream and is carried to the other organs for which copper has a grim affinity. These are most conspicuously the brain and the cornea of the eye. The relentless retention of copper begins at birth, but so efficient is the liver in its protective role that 10 to 20 years may elapse before the first intimations of morbidity are felt. The gravitation of copper to the eye has a curious impact. It produces a phenomenon known to medicine (in celebration of two German investigators who were its pioneer observers) as the Kayser-Fleischer ring. It consists of a more or less complete ring of rusty brown pigmentation - a literal implantation of copper - around the rim of the cornea, or, put another way, a deposit of copper. It is not known just how the copper is deposited in this location.

Symptoms of the disease include a sweeping range of neurological disturbances - slurred speech, failing voice, excessive salivation, drooling, difficulty in swallowing, tremors, uncoordination, spasticity and muscular rigidity, progressing to bedridden helplessness. In many cases, the patients are wrongly treated for psychiatric disorders. One of the experts on Wilson's disease suggests that all individuals admitted to psychiatric wards between the ages of six and 32 be screened for that disease with a ceruloplasmin test, which requires only a blood sample.



Rusty brown pigmentation around rim of cornea is actually a copper deposit and known as Kayser-Fleischer ring.

The treatment of Wilson's disease is basically very simple and straightforward.[21] The idea is to remove the toxic concentration of copper in the body and prevent its reaccumulation. A material that is used is penicillamine, a derivative of penicillin. Penicillamine is a chelator and mobilizes copper from the tissue and excretes it in the urine. Penicillamine is truly a life-saving drug and the results can be dramatic. Little by little, the liver returns to normal, the Kayser-Fleischer rings fade away, and the neurological manifestations disappear. The standard regimen combines penicillamine and potassium sulfide. Potassium sulfide acts to prevent the absorption of copper by forming an unabsorbable copper sulfide in the gut. Since penicillamine is a treatment rather than a cure, it is continued for the lifetime of the patient. Potassium sulfide is usually discontinued within six months to a year.

Copper is removed as a sulfide in nickel plating solutions. It has been shown that pure nickel can passivate readily when it is made anodic in either solutions of dilute acids or in typical electroplating baths. However, the incorporation of sulfur in the nickel effectively prevents passivation and allows dissolution to proceed at more active potentials. The sulfur in the active anode material remains behind in the anode bags as a sulfide residue, giving rise to one practical advantage of the active material. Copper sulfide is less soluble than nickel sulfide; thus, copper can displace nickel from the sulfide anode residue. This is important in nickel plating because copper, an undesirable contaminant, is thereby removed from the solution.[25]

Summary

It is now evident that many of the diseases that serve as killers of mankind are contracted because we abuse our bodies and treat them poorly. Heart attacks are not something that happen overnight to healthy individuals. More often than not, they are the result of years of improper feeding of the body. Another example is lung cancer, which is often the result of smoking and which can eventually destroy the microhairs (cilia) that protect the lungs and clean them, thus making them susceptible to disease.

Likewise, plating solutions do not just stop providing acceptable deposits overnight. Improper filtration, buildup of contaminants, lack of proper maintenance and control, and sometimes a limited understanding about decomposition products of additives are some of the reasons solutions eventually produce poor deposits. The conclusion is that the body and plating solutions, besides being complex mechanisms with very much in common, require proper care and attention to function at full capacity.

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About the author:

This piece was written at the time Mr. Dini was announced as the recipient of the 1985 Scientific Achievement Award.

Jack Dini of Lawrence Livermore National Laboratory was named 1985 recipient of the AESF Scientific Achievement Award on July 18 during SUR/FIN® '85 in Detroit. The announcement was made by H.R. Johnson, chairman of the award committee.

The Scientific Achievement Award is the most prestigious of those conferred by the society. It is presented annually to recognize an individual who has made outstanding scientific contributions advancing the theory and practice of electroplating and allied sciences, raised the quality of products or processes, or enhanced the dignity of the profession. Mr. Dini qualifies in all of these areas.

He earned a Bachelor of Metallurgical Engineering degree from Cleveland State University and began his career in the 1950s with Cleveland Supply Co. (now Pavco). He spent a few years at Republic Steel's research center and Battelle Columbus Laboratories. In 1962, he joined Sandia Laboratories, Livermore, CA, where he was involved with electrodeposition projects for 18 years before moving to Lawrence Livermore (LLNL) in 1980. Today, he is section leader, fabrication processes. Responsibilities include direction of activities in four groups: electroplating and metal finishing, vacuum processes, metal fabrication, and plastics.

Mr. Dini is a prolific scientist. He is the author or coauthor of some 125 technical papers and, while many researchers are content to specialize in one or two fields, this award winner has made significant contributions to more than half a dozen disciplines in surface finishing. The scientific community is fortunate that he has carefully documented his work, sharing it with others around the world.

This synopsis illustrates his broad interests and many contributions:

- *Plating uncommon metals*: Mr. Dini is an authority on difficult-to-plate metals. Refractory elements such as titanium, molybdenum, columbium and tungsten are troublesome to plate because they passivate readily and it is a tough proposition to obtain an adherent overplate. He developed several ring-shear tests for quantifying bond strength and conducted extensive experiments to evaluate published pretreatments and procedures for these metals. He also introduced techniques for plating on radioactive materials like uranium.

- *Alloy plating*: The award winner has published a number of papers on alloy plating, many centering on nickel. He was one of the first scientists to recognize the beneficial influence of codepositing nickel to improve the corrosion performance of zinc coatings.

- *Printed circuits*: Mr. Dini's name appears on about 20 papers that deal with improvements in surface finishing for PC boards and other electronic devices. His research on electrodeposits for hybrid microcircuits resulted in an award-winning report. Several of his papers cover technical achievements with electroless deposits.

- *Chemical milling*: He devoted several years to compiling one of the most comprehensive literature surveys on this subject. This extensive work was published in 1975 as Review 194 of the *International Metallurgical Reviews* and recently updated for *American Machinist* (Special Report 768, July 1984).

- *Electroforming/property data*: The award winner has elevated electroforming to a high level of sophistication. He developed unique methods to fabricate complicated parts for the aerospace and nuclear industries. Furthermore, he enhanced the usefulness of both electroformed structures and engineered, adherent coatings by determining property data, which were especially significant in identifying optimum procedures to obtain gold and nickel alloy deposits with desired characteristics.

  During examinations of the impact of impurities on deposit properties, he observed for the first time the effect of increasing the carbon content to improve the strength of nickel. He also established the role of sulfur in reducing the impact strength and ductility of nickel and its alloys, and documented the beneficial effect of codepositing about 0.1% manganese to counteract these harmful effects.

  In a new area of technology, Mr. Dini contributed to the production of precise, optical, reflective metal surfaces by diamond turning. He and coworkers at LLNL showed that electroless and electroplated finishes free of voids and microscopic defects are necessary for these applications, and helped to identify methods for achieving these defect-free coatings.

- *Electrojoining*: Mr. Dini demonstrated repeatedly that structures can be fabricated by joining two or more prefabricated parts by means of electrodeposition. Large, high-quality components have been produced by the methods he helped devise, and some 15 papers describe case histories.

One of his most recent contributions, published in the July 1985 edition of *Plating & Surface Finishing*, documents cases in which electroplating and vacuum deposition have been used to complement one another. Aluminum, beryllium, glass, molybdenum and titanium were among the substrates coated with techniques described in that report.

Mr. Dini's byline also appears in several books. He has contributed to *Modern Electroplating*; *Hydrogen in Metals*; *Properties of Electrodeposits: Their Measurement and Significance; Adhesion Measurement of Thin Films, Thick Films and Bulk Coatings* (ASTM STP-640); and *Industrial Applications of Titanium and Zirconium* (ASTM STP-830).

Finally, Jack Dini has been a workhorse for the AESF. He is the immediate national past president of the society, has served a term on its Board of Directors, and has been involved with organizing two annual conferences. As the Scientific Achievement Award recipient, he will present the 27th William Blum Lecture at SUR/FIN® '86 in Philadelphia, June 23.