statements about the complexity of the folding structure. Chan and Dill pointed out that no conceivable supercomputer could begin to explore the free energies of all the possible protein folding structures; then they went on to say that the protein itself does not have the "time" or opportunity to achieve a minimum-free-energy structure. Moreover, only one or at most a few of the possible local structures of a given amino acid chain can be biologically significant.

Is it possible that as amino acid chains are replicated from a given RNA template, they do indeed form all or a great deal of the false structures? Perhaps only one in a million or even a billion of the chains that are formed are biologically active. Chan and Dill do indeed point out that chain formation would have to occur on a nanosecond time scale for a biologically significant number of active proteins to form. This would seem to require a violation of the diffusion laws that are normally associated with molecules in solution.

I had another thought on the complexity of the RNA and DNA templates. Since the discoveries of Francis Crick and James Watson, for heuristic purposes DNA has always been represented by a geometrically simple helical pattern. However, it must be that DNA and hence RNA have complex folded patterns that are "inherited" as these molecules are replicated. Perhaps a given protein's folding pattern is determined by that of the RNA that generated the protein, and the ensemble of such folding patterns is passed on, perhaps with slight mutations, from individual to individual of a species. Maybe the DNA genetic code itself is not sufficient to describe the molecule, and the DNA's folding and unfolding pattern as well is an essential part of the description. These patterns may determine "forever" the observed folded forms of the globular proteins.

RNA is generally depicted as splitting from the DNA parent in a regular fashion, like a zipper unzipping. Suppose that the DNA is folded and that the unzipping begins at many points on the molecular surface, much as happens with a damaged mechanical zipper. Suppose further that protein formation does not await the complete separation of the RNA half. This then might be a mechanism for replicating a folded structure from a folded template.

Doubtless by this time the reader can guess that I was not trained as a physicist. My first love was biology, and my training was in chemistry. Chan and Dill's quest for free energy minima seems a bit mechanistic to me, although I freely grant the usefulness and even the necessity of statistical mechanics as one approach to the subject. On the other hand, I am enough of a scientist to be a bit uncomfortable with the mystical elements that could be read into some of my thinking. The combination of the genetic code and the folding structure could be interpreted as a "life force," a concept that Friedrich Wöhler refuted by his synthesis of urea. Let us spare ourselves metaphysical speculations concerning the "first" biologically active DNA molecule and get on with the fine work described in Chan and Dill's article.

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CHAN AND DILL REPLY: A number of experiments show that the RNA or DNA templates cannot be imparting structure to proteins. Proteins are routinely "refolded," that is, put into denaturing conditions and then renatured *in vitro* in the absence of any other biological agents. Remarkably, the proteins return to their original active native structures, often in quite high yields. Hence the encoding of the protein structure must fully reside within the amino acid sequence.

The nanosecond time scale we mentioned applies to the current *computational* limit of molecular dynamics methods. The time scale for protein folding is nearer to milliseconds to seconds, which does not exceed diffusion limits. It follows that current molecular dynamics techniques cannot simulate the entire folding process and that many real proteins—at least those that are small and have globular native states—are able to fold to their global free-energy-minimum structures within milliseconds to seconds.

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A Woman Who Ran Los Alamos's Weapons Work

The August 1993 Washington Reports (page 41) states that Martha Krebs, as the Lawrence Berkeley Laboratory associate director for planning and development, was the "first woman associate director in the whole DOE national laboratory system." Back before people kept track of that sort of thing, before DOE swallowed the Energy Research and Development Administration and the Atomic Energy Commission, and before assistant directors became associate directors at Los Alamos and some other national labs, Jane Hall ran the nuclear weapons program at Los Alamos Scientific (now National) Laboratory as the assistant director for weapons from 1958 to 1970.

Hall commanded respect and was seen as discharging her responsibilities with strength and careful judgment. Looking back, I wonder if she would have been as professionally respected had she been seen as a "first woman" rather than being recognized for her abilities. Similarly, I wonder if Krebs might find it easier to be regarded on the basis of her abilities by PHYSICS TODAY and the public she will deal with, rather than as a "first woman." Does PHYSICS TODAY do Krebs a disservice by falling into the politically correct rhetoric of today?

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What Today's Physicists *Really* Need to Learn

Physicists must abandon their "welfare mentality" and stop complaining. The world does not owe us a living. Unemployment is an essential mechanism of the free-market economy that cleanses the labor force of those who are unfit or unwilling to adapt themselves to market forces. Physicists need only learn to supply what the free market demands. We must strive to acquire the new skills that we need to compete in the global economy. Physics curriculums and indeed the whole of physics education need to be completely restructured. What skills does the modern physicist need?

The professional physicist spends a considerable amount of time writing research proposals and making presentations. It is not enough merely to communicate knowledge; you must impress the audience—especially those who allocate funds. As much as possible the message should be conveyed pictorially, since few executives have time to read anything. For this purpose good color graphics are absolutely indispensable: One picture is worth a million dollars. The modern physics curriculum should include courses in the graphic arts, including data visualization—preferably oriented toward advertising.

If you actually do find a job, more time than you realize will be devoted to advertising your skills and marketing your achievements, so you might as well take a couple of courses on advertising and marketing. The importance of good demonstrations

cannot be overstated. Perhaps the most celebrated case is that of the World War II German rocket developers, who incorporated the drama of the countdown into a rocketry demonstration. The nontechnical "boss" was so impressed that he funded the project. But for a single demonstration, we might never have landed on the Moon! Actually you don't even need a working demonstration. *Star Wars*—the film that launched a thousand (test) missiles—generated untold billions in research funding. Multimedia technology and virtual reality simulations are now within reach of even the leanest budget. No physicist can afford to ignore these rapidly emerging capabilities.

Proposals must state your case in simple but moving language that is intelligible by nontechnical people. Research sponsors are flooded with hundreds of brilliant proposals. Find out what the sponsor wants ("Know thy sponsor") and how you can deliver it ("Ask not what your research sponsor can do for you, but what you can do for your research sponsor"). Good communication and writing skills are essential. Your future could well be decided by the phrasing of a single "bullet." Even if you hated language arts, you should take a couple of writing courses. You should visit all potential sponsors before submitting proposals. A smooth personality and good "people skills" are not only a plus but an absolute necessity. A few drama and psychology courses might help. Introverted geniuses had better hire a good agent.

In this global economy physicists must be prepared to seek funding opportunities wherever they occur. Thus physics students should study foreign languages of emerging research sponsors, such as Arabic, Farsi and Korean, and should do their utmost to find out about other likely sponsors.

Money doesn't grow on bushes (and even where it does, you still have to know how to process the leaves). Too many physicists lack even basic technical abilities. Experimentalists should acquire such skills as plumbing and welding so that they are not dependent on costly outside technical support (and so they will be employable even outside of physics). Practical computer skills (such as the ability to turn out a color transparency on short notice) will make you an asset to any employer. Speaking of money, if you do get funded, you will have to manage and account for it. Every physicist should take a course in accounting. Actually, it would not hurt to take a few business courses. You might even want to do an MBA, which could put you on a management track: When cutbacks occur, somebody has to manage them; also, you would have the skills to start your own business. In addition it would be useful to take a course in patent law in case you make any useful discoveries.

The graduate admissions process must be completely overhauled. Prospective graduate students should be required to submit proposals detailing their study and research plans, including "milestones" and budget estimates with full accounting of such factors as administrative overheads and salaries. Those who survive this first cut would then be invited to give an oral presentation. To ensure that only those who can function in the real world are admitted, the admissions committee would consist of the football team. Of course those with their own funding could bypass this process.

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9/93

Why 'Rule of Thumb' Is a Sore Point

From the number of times I've encountered physicists using the term "rule of thumb" lately, the most recent being Lawrence E. Tannas Jr (December 1992, page 55), it is obvious that many physicists do not know how offensive this term is. The historical origins of the rule of thumb lie in the old English common-law doctrine that "a husband had the right to whip his wife, provided that he used a switch no larger [thicker] than his thumb."[1] There is no specific year or decade to which one can point in which the husband lost his authority to beat his wife,[2] but the rule of thumb was affirmed in Mississippi in 1824 and denied in North Carolina in 1874. The English law was derived from the One Hundred and Seventeenth New Constitution of Roman Emperor Justinian I, published in 529 CE. Roman law gave a husband freedom to beat his wife for committing treason or adultery, plotting against his life, attending banquets or bathing with strangers against his wishes, or attending circuses, theaters or other public exhibitions without his knowledge or against his wishes.[3] This law also prohibited a woman from divorcing her abuser if he beat her for other reasons, although unlike early English law, Roman law made the husband pay her restitution in that case.

Why should anyone care about using such language now? Half of all women in the United States will be battered by an intimate partner at some time in their lives.[4] The violence in 1 in 12 such assaults is so severe[5] that battering is the single most important context for serious injury to women in the US.[6] At least one-third of all visits by women to emergency medical services are caused by battering.[7] According to the FBI, over the last seven years 29.4% of all women murdered were killed by their husband or partner.[8]

Why should physicists in particular care? One reason for the low percentage of women in physics is overt sexual harassment by men, but another is the chilly climate fostered by men's ignorant use of insensitive remarks. We each have a responsibility to educate ourselves and replace terms that restimulate terror, like "rule of thumb," with emotionally neutral or positive terms, like "commonsense rule" or "benchmark rule."

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3/93

One Scientist Who Made His Stamp

Re: Recent letter suggesting stamps honoring scientists (November 1992, page 120). See stamp. [*Editor's note*: This letter arrived on a postcard bearing a 29¢ US stamp depicting "Theodore von Kármán: Aerospace Scientist."]

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1/93