

# A NATURAL-BORN FIBER

Roald Hoffmann

There is no question, at least for me, that there is something deeply spiritual in people that compels us to prefer the natural—that leads us to choose a real window over a lighted space covered by a photographic transparency, a live plant over an artful imitation. Even as my soul desires the intense *artifacts* that are art, I believe that a predilection for the natural is a positive feature of human nature. But that preference for the natural over the artifactual, the synthetic, the man- and woman-made, the unnatural—whatever you want to call it—is also tinged with a romanticism that at times I succumb to, with feeling. And at times I fight it.

Recently I heard a lecture about the construction (through advertising) of a positive value for nylon and rayon over cotton, linen and wool. It was all so neatly laid out—the Bad Guys versus the Good Guys. I rise to oversimplification. So I suspended, just temporarily, my sympathy for the natural and began to think about how the real world confounds every attempt to categorize a product of use to people as natural or synthetic.

Let's in fact take cotton, rayon and nylon. At first sight things are always simple: Cotton is a natural fiber; nylon and rayon are synthetic. The first is grown in fields, the product of a live plant. The other two are products of a chemical factory.

But it is hardly simple. The domesticated cotton plant, *Gossypium*, has been bred for high yield, for better fiber and for other advantageous properties over hundreds of years. Modern cotton cultivars are, I suspect, genetically distant from the natural precursors first domesticated. A typical field of Egyptian cotton receives several treatments with insecticides, herbicides and chemical fertilizers. The fiber is separated from the seed (ginned), carded and spun into a yarn. For modern shirting, cotton is also treated in a variety of chemical baths, bleached and dyed. It may be "mercerized," strengthened by treatment with lye (sodium hydroxide). Optical brighteners or flame retardants might be added. Eventually the cotton is woven into cloth, cut and sewn into a garment. It may be blended with another fiber for strength, comfort or some other desirable property.

That's an awful lot of manipulation by human beings and their tools, and to sharpen the point,

manipulation by *chemicals*, synthetic and natural, going into your natural cotton shirt!

Nylon was invented in 1935 by Wallace Carothers at DuPont. Its most common variant, nylon 6,6, is a polymer of hexamethylenediamine and adipic acid. These are a mouthful, but actually they are just the component "monomer" molecules that are linked alternately to form the long-chain "polymer" called nylon.

### So, What is Natural?

Where does nylon come from? To say "out of a chemical factory" has about the same level of facing up to meanings as saying that "babies come out of hospitals." The two component "monomers" that are linked up in giant reaction vessels to tons of polymer derive from "feedstocks"—a generic name for the bulk starting materials of industrial chemical synthesis. The chemical origins of both monomers are in petroleum, natural gas and the nitrogen of the atmosphere. And where does petroleum come from? Yes, yes, we know it's from an oil well. But what are the origins of oil? Natural, to be sure. This important raw material formed from the transformation over long, long times of ancient, abundant plant growth.

Rayon has a still more complicated (intellectually, not chemically) path to that lovely blouse. Rayon begins as a contemporary and most natural product—wood. Actually, that wood is a product of silviculture, as much of human origin as cotton. Cellulose is extracted from wood pulp and then chemically modified and regenerated. The simplest kind of rayon is just regenerated cellulose, the same

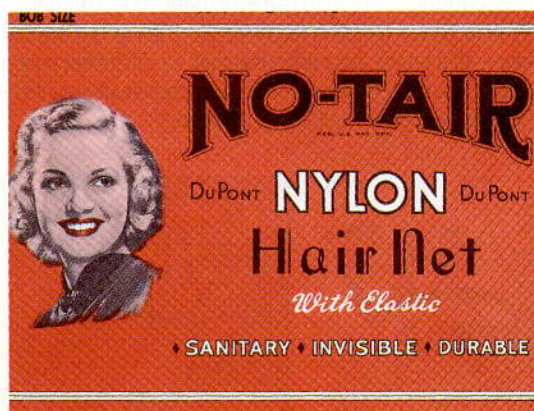


Figure 1. Advertisement for nylon hair net, circa 1947.

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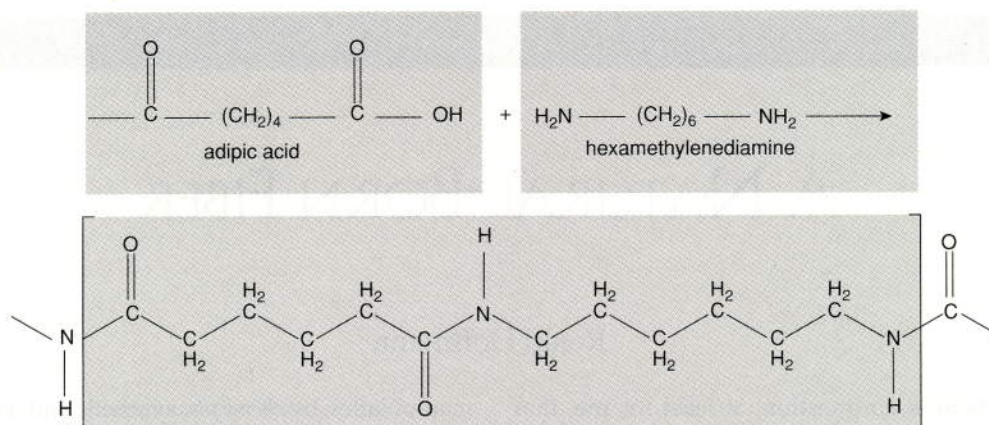


Figure 2. Adipic acid and hexamethylenediamine are alternately linked to form nylon 6,6, the most common variant.

long-chain molecule that makes up 99 percent of clean cotton. I would call rayon a "semisynthetic" polymer. In fact, some rayon is made using cellulose from cotton, not wood!

So now that we know how these fibers are made, we ask the question: How much more natural is cotton than nylon, than rayon? They all began life with a seed—cotton in an Egyptian field, nylon in a prehistoric jungle and rayon in a Georgia (U.S.) forest. Interestingly, only the seed that many million years later led to nylon—only that prehistoric seed—can lay full claim to being natural! The other seeds were planted by human beings. And of all three plants, it is again only the nylon "plant" that can lay full claim to growing naturally, freely, untended by people. Then, in a sequence of human transformations, all three plants (or their remnant, the oil) eventually become the fibers of our textiles. The details differ, of course, and so does the scale. But please don't tell me that modern agriculture is all that different from a chemical factory. On some spiritual level we would all like it to be different, but it isn't. The logic of transformations (a human logic, done with human tools) is quite similar.

Let me put it another way. Every atom of the cotton cellulose, the copolymer of nylon, the regenerated cellulose of rayon—every atom of oxygen, hydrogen, nitrogen and carbon in these fibers—began life in a "natural" molecule. And every molecule of the cotton fiber, really no less than those of nylon or rayon, is the consequence of *human* transformations of matter.

Into these transformations go ingenuity and labor—the same ingredients that in different ways entered into a Benin bronze and the drafting of the "Declaration of the Rights of Man."

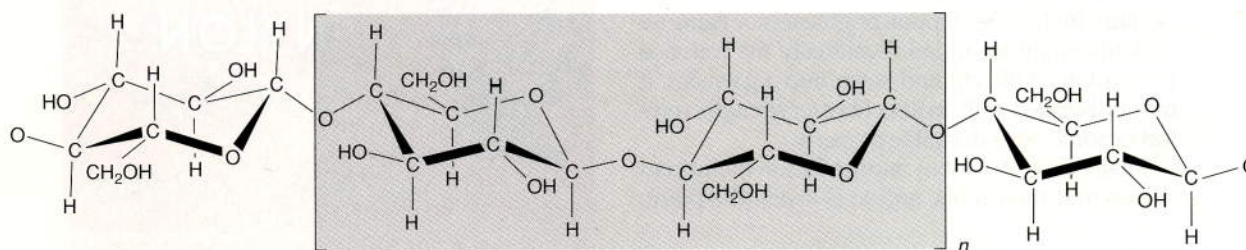


Figure 3. Cellulose is the main constituent of both cotton fiber and rayon.

### Indexing Naturalness

Could one set up a measure of "naturalness"? Here is how it might go: Make a flow chart of all the physical or chemical transformations from the point where the constituent atoms were taken by a human being (or machine) from earth, air or water, all the way to the final manufactured product. If chemicals were used in these transformations, or energy (fires, not to speak of electricity, are made by people), tally those up as well. Next, and this is most difficult, you'll need some measure of the transforming quality. Could one count up the number and type of chemical bonds that had to be broken per molecule of product formed—or, better, the entropy added to the universe as a result of the transformation (because getting all of those molecules we want is not free, but done at some cost to the universe)? Perhaps you can assign a "transforming intensity"—I've just made that up—to each step, sum the intensities over the steps. Then you'll have an index of artificiality, or how man- or woman-made an object is. The index will be small for very, very few things near to us.

Such an index (perhaps a similar one has already been devised) just might be of value to the tax authorities of all countries, for if it were plausibly conceived, it could serve as the basis of a tax predicated on the true value added to nature. Meanwhile, I (no better than most people) really think that a cotton shirt feels better. I believe it, without even trying it on.

### Note

The complex and remarkable life of Wallace Carothers is described in a recent highly readable biography by Matthew E. Hermes. 1996. *Enough for One Lifetime*. Washington D.C.: American Chemical Society.