analyzed by gel electrophoresis (Fig. 2). On the basis of its electrophoretic mobility, the crystalline material was judged identical to uncrystallized IFLrA. Bioassays showed that the crystals contained interferon activity. Furthermore, in the presence of PEG-4000 (100 mg/ml) virtually all of the active IFLrA added to the solution could be recovered in the crystals.

At high IFLrA concentrations (4 to 5 mg/ml) and low PEG-4000 concentrations (1.0 to 2.0 mg/ml), masses of large prismatic crystals appeared after about 5 days (Fig. 3).

We conclude that interferon synthesized by bacteria is sufficiently homogeneous to crystallize quantitatively. Crystals large enough for an x-ray crystallographic structure determination can be obtained. Whether these crystals give suitable x-ray diffraction patterns has not yet been demonstrated.

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Thermal Insulating Capabilities of Outdoor Clothing Materials

Abstract. *A single heat transfer measurement technique was used to determine the thermal insulating capabilities of four materials used in outdoor clothing—goose down, wool, polyester, and polyolefin. It was found that all provide very similar degrees of insulation.*

The increased interest in outdoor winter activities has produced a striking increase in the market for insulated outerwear. Although the down of northern geese has long been the filler material of choice, the growing market and the rising price of goose down have stimulated industrial chemists to search for synthetic substitutes for natural fibers. Periodically, new materials are put on the market which are claimed to have thermal insulating capabilities superior to those of goose down.

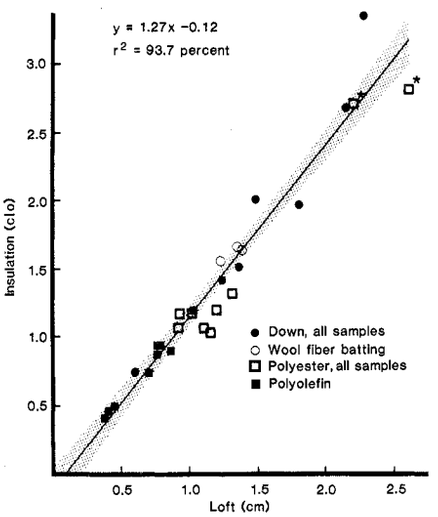

Fig. 1. Thermal insulation of various clothing materials, plotted against swatch loft as measured on the heat transfer apparatus. The shaded area delineates the 95 percent confidence limits and the asterisks indicate swatches that had multiple layers.

Using a modified guarded hot-plate technique, we measured the thermal insulation of goose down, wool, and polyester and polyolefin fibers. Our results show no superiority of any of the synthetic materials over the natural fibers as thermal insulators, although down has a marked advantage in weight per unit loft (thickness).

We prepared the materials as they would be prepared for use in the manufacture of jackets, vests, and other outerwear garments. The filler material was encased in a nylon shell. The shell was quilted with 13-cm squares and its edges were bound to form a swatch with an area of about 1 m^2. Initial loft was determined by making 12 measurements at planned points at a pressure of 0.7 g/cm^2. The weight of the swatch was determined to within 0.1 g on a top-loading balance (Mettler P2010). "Density" was calculated from measured area, loft, and weight.

Each swatch was placed horizontally over a 50 by 50 cm constant heat source. A heat sink in the form of a copper plate equal in area to the heat source was placed on top of the material. The heat sink produced a pressure of 1.2 g/cm^2; each material was examined at the same force of compression. The temperature gradient across the swatch was measured by a thermistor and the rate of heat

Table 1. Physical properties of thermal insulating materials used in clothing.

Material	Loft (cm)		Density (g/m^2 per centimeter)	Insulation	
	Measured on flat surface at 0.7 g/cm^2	Measured during experiment at 1.2 g/cm^2		clo	clo/cm
$Down_1$*	1.2	0.6	179	0.73	1.22
$Down_2$†	2.1	1.5	170	1.64	1.09
$Down_3$‡	2.8	2.0	179	2.68	1.34
Wool§	1.9	1.3	271	1.52	1.17
$Poly_1$‖	1.7	1.2	229	1.20	1.00
$Poly_1$	3.6	2.6	229	2.82	1.03
$Poly_2$¶	1.7	1.2	224	1.11	0.93
$Poly_2$	3.4	2.2	224	2.71	1.23
$Poly_3$**	1.1	0.9	368	1.02	1.13
Polyolefin	0.6	0.4	424	0.45	1.13
Polyolefin	1.0	0.8	415	0.83	1.04
Polyolefin	1.2	1.0	310	1.14	1.14

*Prime 80/20 goose down (80 percent down, 20 percent feathers) at 76.4 g/m^2. †Prime 80/20 goose down at 152.8 g/m^2. ‡Prime 80/20 goose down at 229.2 g/m^2. §Wool fiber batting. ‖One hundred percent polyester staple (Dacron II). ¶One hundred percent polyester continuous filament fiber. **One hundred percent polyester staple (Dacron 66).

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transfer was measured by a heat flow disk (Sensable B-1, Hy-Cal Engineering). Thermal insulation in clo units was calculated from the following equation (*1*):

$$\text{clo} = \left(\frac{T_1 - T_2}{H}\right)\left(\frac{1}{0.18}\right)$$

where T_1 is the temperature of the surface of the heat source (in degrees Celsius), T_2 is the temperature of the heat sink's lower surface, and H is heat flow [the product of heat energy (calories) and area (square meters) divided by time (hours)].

Temperatures and heat flow were observed until readings were constant over a period of 30 minutes. The experiment was repeated two more times, each preceded by dismantling and reassembling of the apparatus. The data were averaged, tabulated (Table 1), and plotted (Fig. 1).

Loft of the natural and synthetic insulating materials ranged from 0.6 to 3.6 cm. During the heat transfer measurements, lofts were reduced by compression to 0.4 to 2.6 cm. Density ranged from 170 to 424 g/m^2 per centimeter. Insulation ranged from 0.93 to 1.34 clo/cm (mean, 1.12 clo/cm), values which correspond closely with published values (0.7 to 1.33 clo/cm; mean, 1.08 clo/cm) (*2*).

Insulating capabilities varied little among materials. Down provided somewhat higher value (mean, 1.22 clo/cm) than polyester (mean, 1.08 clo/cm). The polyolefin fibers and wool filler provided intermediate degrees of insulation (1.13 and 1.17 clo/cm, respectively). These variations are unlikely to be detectable by the consumer. If one considers weight an important factor, down (233 g/m^2 per clo) had a decided advantage over wool (339 g/m^2 per clo), polyester (328 g/m^2 per clo), and polyolefin (464 g/m^2 per clo).

Many physical scientists have maintained that no particular fabric provides superior insulation; air is the insulating material, and how it is immobilized makes little, if any, measurable difference. The importance of this study is in the application of a single heat transfer measurement technique to a variety of natural and synthetic filler materials, especially the newly developed polyolefin fillers.

Questions might be raised regarding a technique that measures heat transfer of compressible materials subjected to a compression force of 1.2 g/cm^2. Filler materials exhibit different qualities of compliance. If compression of a swatch were to increase the density of the heat-conducting fillers, heat transfer might be expected to increase as well. However, in 38 determinations on 12 samples of down, polyester, and polyolefin we have found no significant effect of compression on thermal insulating properties at reductions in loft to 52 percent of the control value.

Burton and Edholm (*3*) observed that the principal function of the filling material is "merely to immobilize the enclosed air, preventing convection currents and making it effectively 'dead air.' " Our findings, gathered by a single method comparing the thermal insulating qualities of fillers in the form they are used by the consumer, confirm this statement. None of the synthetic fillers has a superior ability to provide "warmth" in clothing. It seems that factors other than thermal insulation, such as weight, drapability, durability, and cost should be the major factors in selecting outerwear containing thermal insulation materials. The effects of moisture and bellows action produced by the wearer's activity may outweigh thermal insulative values in the wearer's perception of warmth.

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Haptoglobin: A Natural Bacteriostat

Abstract. *The combination of bacteria and blood in a wound can have lethal consequences, probably because hemoglobin iron supports prolific bacterial growth. Rats inoculated intraperitoneally with pathogenic* Escherichia coli *and small amounts of hemoglobin die. Simultaneous administration of haptoglobin, a naturally occurring hemoglobin-binding protein, fully protects against lethality. Therefore, haptoglobin may not only accelerate the clearance of free hemoglobin, but also limit its utilization by adventitious bacteria. Haptoglobin may have therapeutic potential in the treatment of life-threatening, hemoglobin-driven bacterial infections.*

Physicians have long been aware that the coincidence of blood and bacteria in a wound may engender life-threatening infection (*1*). Blood or free hemoglobin has a synergistic effect on the lethality of intraperitoneal or subcutaneous inocula of bacteria such as *Escherichia coli* (*2*). The effective component of hemoglobin is iron, and various soluble iron compounds exert an equivalent adjuvant effect (*3, 4*). It has been suggested that hemoglobin interferes with phagocytic destruction of the bacteria (*5*). We have, however, been unable to detect such interference. Instead, we found the following (*6*):

1) The phagocytosis and killing of *E. coli* by neutrophils in vitro is unaffected by the presence of hemoglobin.

2) The migration of neutrophils to the peritoneal cavity in response to intraperitoneal inoculation with *E. coli* is equally rapid and effective whether hemoglobin is present or not.

3) The rate of clearance of heat-killed, radioactively labeled bacteria from the peritoneal cavity is unchanged by simultaneous injection of hemoglobin.

4) Even if live *E. coli* are entrapped in 0.2-μm Nuclepore chambers implanted intraperitoneally, injected hemoglobin still exerts an adjuvant effect.

Thus, hemoglobin does not appear to reduce the phagocytosis and killing of *E. coli*. We therefore hypothesized that hemoglobin might serve simply as a source of nutritional iron, promoting the growth of inoculated *E. coli*. Although the total iron concentration in mammalian body fluids is $2 \times 10^{-5}M$, almost all of the iron is tightly associated with specialized, iron-binding proteins, leaving a free iron concentration of $10^{-18}M$ (*7*). Most aerobic bacteria require $\sim 10^{-6}M$ iron for growth (*7–9*). Thus, as Weinberg (*9*) argued, the availability of iron may be the major nutritional limitation to the replication of many pathogenic bacteria in vivo.

In the experiments reported here, we used a single strain of pathogenic *E. coli* first isolated from an infected patient. The techniques for the routine culture and passage of this organism have been described elsewhere (*5*). When we cultured the organisms in synthetic, iron-

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