CONCLUSIONS

In cases of varicose veins the competence or gross incompetence of the perforators is of fundamental clinical importance. If the perforators are competent, high saphenous ligation will overcome the venous stasis. In cases of severe postphlebitic lymphedema it can be assumed that the perforators are grossly incompetent and that the orthostatic venous hypertension cannot be overcome by the pumping action of muscular contraction in the lower part of the leg. All previous methods of treating venous stasis with gross incompetence of the perforators have had serious defects. By the application of a regulated pulsatile air pressure to the lower part of the leg, the venous stasis can be overcome. Swelling due to postphlebitic lymphedema or to varicose venous stasis is adequately controlled by this method. Inflammatory swelling is not necessarily adequately controlled. The induration of the skin and subcutaneous tissues, so characteristic of the later stages of venous stasis in the lower part of the leg, gradually recedes. Uncomplicated postphlebitic and varicose ulcers in the lower part of the leg are regularly healed while the patient is ambulatory. Certain local complicating factors which may prevent rapid healing are outlined, and methods are cited for overcoming these conditions. Certain precautions which should be taken in order to obtain satisfactory results with this method of treatment are listed. Application of the pulsatile air-pressure ("aero-pulse") in the treatment of postphlebitic and varicose venous stasis has been successful in severe cases, when all previous standard methods have failed.

260 Crittenden Blvd.

PROFOUND ACCIDENTAL HYPOTHERMIA

Harold Laufman, Ph.D., M.D., Chicago

My associates and I had the unusual opportunity of studying a patient who had been subjected to severe freezing conditions. We believe this case to be unique insofar as the degree of hypothermia was more profound than is ordinarily followed by recovery in the human or in most animals. The critical level in humans is unknown, but it is commonly considered to be between 68 and 74 F. Although some nonhibernating experimental animals have recovered from more profound hypothermia than did this patient, their periods of hypothermia were considerably shorter.

CASE REPORT

At 8 a.m., Feb. 8, 1951, a Negro woman, 23, was brought into the admitting room of Michael Reese Hospital. She had been found by policemen about 15 minutes previously in a nearby alley in a frozen coma. The policemen assumed that she was dead because they were unable to detect any apparent respirations. The admitting intern and the admitting surgical resident observed a respiratory rate of 3 to 5 per minute. The apical pulse rate ranged from 12 to 20 per minute. The pulse was highly irregular, with periods of asystole up to 8 seconds. A vein was located in the antecubital area of the left arm and an ampul of caffeine and nikethamide (coramine®) was injected intravenously. The administration of human plasma was begun through this venipuncture. Oxygen was given by mask.

Physical Examination.—I saw the patient for the first time at 9:15 a.m., 75 minutes after admission. She was a moderately obese young Negro woman whose weight was judged to be 150 lb. (68 kg) and height 5 ½ ft. (163 cm.). The patient was in deep coma. Respirations were 16 per minute. The apical pulse was highly irregular but strong, averaging 20 beats per minute with periods of asystole up to 6 seconds. Blood pressure by sphygmomanometer in each arm was zero.

Head: The head could not be moved from side to side except by exertion of considerable force. Furthermore, it was impossible to flex or extend the head. This was due to an extreme rigidity of the neck muscles.

Eyes: The lids were partially open, allowing a palpebral fissure of roughly ½ in. (0.65 cm.). Manual pressure on the eyeballs over the lids revealed an extreme degree of hardness, giving one the impression of pressing on glass. An area of opacity corresponding to the exposed bulbar conjunctiva covered most of the cornea, but the color of the iris could be seen. No blinking lid reflex was present. The pupils were fixed at a diameter of 3.5 mm. and did not react to strong light thrown suddenly into the eyes. A finger tip was placed directly on the cornea to test the corneal reflex. It was found to be absent.

Nose and Ears: The nose and ears were cool, but there was no evidence of frostbite. No abnormalities were present.

Mouth: It was impossible to open the jaws either manually or by attempting to insert bits of various kinds between the teeth.

Neck: The neck was very stiff, and the skin felt cool and could not be lifted appreciably by the finger tip. There were no abnormal masses palpable.

Chest: The breasts were rubbery in consistency and no abnormal masses were palpable. Percussion of the heart borders revealed no abnormalities in shape or size. The apical beat was strong and highly irregular with pronounced bradycardia. The periods of asystole came at irregular intervals and varied in length from 2 to 6 seconds at this time. Auscultation revealed no discernible murmurs. The beats were loudest at the apex. Auscultation of the lungs revealed no ruts or rales.

Abdomen: The entire abdomen was firm and rubbery to palpation. Neither the liver nor the spleen could be palpated, because of the difficulty in denting the abdominal wall. Auscultation revealed a complete absence of peristaltic sounds.

Upper Extremities: No pulse could be palpated in the radial, brachial, or axillary arteries on either side. The skin temperature by palpation was progressively lower as one palpated from the shoulders to the hands. Touching the fingers or hands gave one the impression of touching ice. The elbows could be flexed only with great force. The hands and fingers were hard and could

From the Department of Surgery, Michael Reese Hospital.
not be dented. No attempts were made to manipulate the joints of the hands or fingers. Despite the patient's naturally dark skin color, there appeared patchy areas of dark violaceous lividity of most of the fingers and both hands to just above the wrists.

**Lower Extremities:** No pulse could be palpated in the femoral, popliteal, or dorsalis pedis arteries bilaterally. The garter area above the knees was still slightly indented from circular elastic garters, which had been removed. The skin of the thighs was rubbery and cool and could be dented on palpation. However, the skin of the area below the garter indentation was woody and could not be dented by the palpating finger. Touching these parts gave the impression of touching ice, or perhaps very cold metal. The skin from the knees to the tips of the toes was violaceous. The surface of this area appeared granular, the granularity being composed of what appeared to be desquamated epithelial cells. These areas were patchy and were more pronounced on the right side of each leg, that is, the lateral aspect of the right leg and the medial aspect of the left leg. Similar patchy areas of discoloration were found on the outer aspect of the right thigh and right buttock. The toes like the fingers were very hard and were not manipulated.

Back: Both buttocks exhibited areas of frostbite as described above; these areas were particularly pronounced on the right side.

**Further Observations and Treatment.**—At 9:30 a. m., 90 minutes after the patient's admission, a chemical thermometer calibrated according to centigrade scale was inserted into the patient's rectum for a distance of 5 in. (13 cm.). It was removed after three minutes and registered 18 C (64.4 F). The thermometer was reinset so that readings could be taken at regular intervals (Fig. 1).

At this time 200 mg. of cortisone was injected intramuscularly into what appeared to be the warmest portion of the patient's body, the rectus abdominis muscle, just below the umbilicus.

A cut-down was made in the right antecubital fossa and the blood could not be drawn into a syringe readily since it was very thick in consistency. Consequently the blood was allowed to flow from the needle into test tubes for blood chemistry determinations. The flow of blood was encouraged by intermittent pressure on the upper arm. Some of the laboratory determinations, as shown in Table 1, and 2, will be of interest since they were taken when the body temperature was 64.4 F. Of particular interest are the severe acidity of the blood and the extremely high serum glucose.

At 10:15 a. m. 24 hours after admission, the rectal temperature was 20 C (68 F). At this time a basal metabolism test was undertaken. The metabolic rate was —7.8%. The oxygen consumption graph shown in Figure 2 was taken an hour before clinical evidence of respiratory embarrassment necessitated an emergency tracheotomy. An electrocardiogram was taken at this time, when the rectal temperature was 20 C (68 F), and is shown in Figure 3.

The patient was catheterized at 10:20 a. m.; 675 cc. of almost colorless urine was obtained from the bladder. The temperature of the catheterized urine was 21.5 C (70 F). Results of urinalysis were as follows: pH 5; specific gravity 1.011; albumin 4+; sugar 2+; and no acetone. Microscopic examination of the centrifuged specimen showed 2 to 6 coarsely granular casts per high power field, 2 to 4 finely granular casts, occasional red blood cells, 2 to 10 white blood cells, few squamous epithelial cells, occasional degenerated renal cells, and occasional bacteria (Table 3).

By 11:30 a. m. the patient appeared to have difficulty in breathing despite the oxygen mask. Further unsuccessful attempts were made to open the patient's jaws. A lubricated catheter inserted into the nose could not be passed as far as the nasopharynx on either side. Attempts to pass this tube caused slight bleeding from the nose, probably due to erosion of nasal mucosa. The patient appeared to have obvious oxygen hunger, as evidenced now by the gurgling sounds in the throat and the choking sounds that came with labored breathing. Consequently it was decided that an emergency tracheotomy should be done. The tracheotomy was performed at 11:45 a. m., 33 hours after admission. Oxygen was administered through the tracheotomy tube, and the patient appeared to breathe much more easily.

At this time it appeared that the patient might recover. Therefore, it was decided that the upper and lower extremities should be dressed in pressure bandages, because of the possibility that massive edema might result later. At 12 noon, four hours after admission, the legs and hands were gently washed with cotton pellets and diluted soap liniment, since they were covered with gross dirt. Petrolatum gauze was applied, fluff gauze dressings were placed over this layer, and elastic bandages completed the pressure dressings. The temperature of the room was set empirically at 68 F, which was roughly equivalent to the patient's internal temperature at this time. Except for the arms and legs, which were bandaged, the body was exposed to the open air.

---

**Table 1.—Blood Chemistry**

<table>
<thead>
<tr>
<th>Component</th>
<th>Normal</th>
<th>Feb. 18</th>
<th>Feb. 19</th>
<th>Feb. 20</th>
<th>Feb. 21</th>
</tr>
</thead>
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<tr>
<td>pH</td>
<td>7.4</td>
<td>7.17</td>
<td>7.35</td>
<td>7.46</td>
<td>7.4</td>
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<tr>
<td>Hematocrit</td>
<td>45</td>
<td>33</td>
<td>39</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>CO₂ comb, mO/L.</td>
<td>23-35</td>
<td>27.9</td>
<td>22.5</td>
<td>25.8</td>
<td>24.9</td>
</tr>
<tr>
<td>Glucose, mg./100 cc.</td>
<td>70-120</td>
<td>425</td>
<td>731</td>
<td>78</td>
<td>88</td>
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<tr>
<td>Serum urea nitrogen, mg./100 cc.</td>
<td>9-10</td>
<td>10.4</td>
<td>21</td>
<td>65.9</td>
<td>32.9</td>
</tr>
<tr>
<td>Serum creat.</td>
<td>1-2</td>
<td>1.05</td>
<td>2.0</td>
<td>5.95</td>
<td>0.9</td>
</tr>
<tr>
<td>Serum Na, mEq./L.</td>
<td>135-145</td>
<td>159.5</td>
<td>138.8</td>
<td>131.2</td>
<td>137.5</td>
</tr>
<tr>
<td>Serum Cl, mEq./L.</td>
<td>90-106</td>
<td>106</td>
<td>98</td>
<td>94.8</td>
<td>102.2</td>
</tr>
<tr>
<td>Serum P, mg./100 cc.</td>
<td>3.4-5</td>
<td>6.6</td>
<td>7.1</td>
<td>7.3</td>
<td>4.8</td>
</tr>
<tr>
<td>Serum K, mEq./L.</td>
<td>4.5</td>
<td>4.6</td>
<td>4.75</td>
<td>6.2</td>
<td>4.5</td>
</tr>
<tr>
<td>Total protein, gm./100 cc.</td>
<td>6-8</td>
<td>7.8</td>
<td>7.4</td>
<td>6.9</td>
<td>7.1</td>
</tr>
<tr>
<td>True albumin, gm./100 cc.</td>
<td>2.3-4.4</td>
<td>4.1</td>
<td>2.7</td>
<td>3.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Total globulin, gm./100 cc.</td>
<td>2.6-3.8</td>
<td>3.7</td>
<td>4.7</td>
<td>3.7</td>
<td>4.3</td>
</tr>
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<td>Alpha globulin</td>
<td>0.7-1.3</td>
<td>1.1</td>
<td></td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Beta globulin</td>
<td>0.7-1.3</td>
<td>1.15</td>
<td></td>
<td>1.45</td>
<td>1.35</td>
</tr>
<tr>
<td>Gamma globulin</td>
<td>0.7-1.3</td>
<td>1.45</td>
<td></td>
<td>1.65</td>
<td>1.35</td>
</tr>
<tr>
<td>Serum bilirubin, mg./100 cc.</td>
<td>0-1.7</td>
<td>0.6</td>
<td>0.4</td>
<td>0.4</td>
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<tr>
<td>Total serum cholesterol, mg./100 cc.</td>
<td>120-300</td>
<td>129</td>
<td>121</td>
<td></td>
<td></td>
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<tr>
<td>Esterified cholesterol, %</td>
<td>68-74</td>
<td>62</td>
<td>63.5</td>
<td></td>
<td></td>
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<tr>
<td>Thymol turbidity, units</td>
<td>0-2</td>
<td>1.4</td>
<td>0.9</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Thymol flocculation</td>
<td>0-1+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cephalin-cholesterol flocculation</td>
<td>0 to 1+</td>
<td>+++</td>
<td>++++</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

* Rectal temperature 16.4 F.
† Rectal temperature 16.0-16.6 F.
‡ Rectal temperature 16.0-16.2 F. (extreme values).

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**Fig. 1.—Temperature recovery curve from hypothermic levels.**

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The eyes were examined at 12 noon. They were fixed in the primary position of gaze. The lids were essentially normal and the conjunctivae very pale, owing to constriction of blood vessels. Tactile tension was normal. The corneas were clear. The anterior chamber had normal depth. The pupils measured 2 by 2 mm., were vertically oval and did not react to light. The irises were brown, with no nodules or tumors. The lenses were clear. The vitreous was clear. The optic nerve heads were very pale and

By 3:30 p.m. the rectal temperature had risen to 25 C (77 F). The pulse rate was 72, with frequent dropped beats; respirations were 16 per minute. The administration of plasma was discontinued, 1,500 cc. having been given. The heart tones were of good quality, but the blood pressure was still unobtainable in the arms.

At 5:15 p.m. the rectal temperature had reached 27 C (80.6 F). The patient, although unable to speak, opened her eyes and

the capillaries severely constricted. The margin, size, and shape of the nerve heads were normal. The maculas were clear. The veins, which were full, were a deep burgundy. On slight pressure the veins emptied at the disk, but no definite pulsation was evident. The veins again filled at the disk when pressure was released. There was no arterial pulsation evident, and it could not be elicited by pressure; the arterioles were diffusely narrowed. There was a good light reflex; the retinas and choroid were slate gray. There was no evidence of hemorrhage or exudate. It was our impression that ischemia retinae was present.

followed objects and people; she appeared to be able to see. The pupils reacted sluggishly to light. There were no voluntary muscular movements in any part of the body. No peristaltic sounds could be heard on abdominal auscultation. The patient was again catheterized, but no urine was obtained.

At 5:40 p.m. the patient responded to loud questioning by shaking her head affirmatively or negatively. When she was asked about pain she responded in the negative. Muscular move-

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**Table 2.—Hematologic Findings**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hb, gm. (%)</td>
<td>10.9 (94)</td>
<td>10.8 (95)</td>
<td>7.0 (45)</td>
<td>12.0 (77)</td>
<td>8.9 (57)</td>
<td>9.7 (62)</td>
<td>12.0 (77)</td>
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<tr>
<td>Red blood cells</td>
<td>3.5</td>
<td>3.5</td>
<td>2.66</td>
<td>4.3</td>
<td>3.00</td>
<td>3.31</td>
<td>4.01</td>
</tr>
<tr>
<td>White blood cells</td>
<td>16,000</td>
<td>11,800</td>
<td>17,400</td>
<td>32,200</td>
<td>10,300</td>
<td>7,000</td>
<td></td>
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<tr>
<td>Hematocrit</td>
<td>33</td>
<td>39</td>
<td>25</td>
<td>36</td>
<td>28</td>
<td>22</td>
<td>38</td>
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<tr>
<td>Color index</td>
<td>0.90</td>
<td>0.96</td>
<td>0.86</td>
<td>0.93</td>
<td>0.95</td>
<td>0.94</td>
<td>0.96</td>
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<tr>
<td>Mean cell volume</td>
<td>99</td>
<td>97</td>
<td>95</td>
<td>99</td>
<td>98</td>
<td>96</td>
<td>96</td>
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<tr>
<td>Sedimentation rate</td>
<td>55</td>
<td>56</td>
<td>55</td>
<td>55</td>
<td>60</td>
<td>58</td>
<td>55</td>
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<td>Corrected sedimentation rate</td>
<td>54</td>
<td>60</td>
<td>30</td>
<td>41</td>
<td>38</td>
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<td>Polymorphonuclear segment cells</td>
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<td>72</td>
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<td>60</td>
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<td>Polymorphonuclear nonsegment cells</td>
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<td>18</td>
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<td>14</td>
<td>8</td>
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<td>Eosinophils</td>
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<td>3</td>
<td>2</td>
<td>4</td>
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<tr>
<td>Lymphocytes</td>
<td>16</td>
<td>9</td>
<td>14</td>
<td>14</td>
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<td>Monocytes</td>
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<td>7</td>
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<td>Metamyelocytes 7+</td>
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<td>Basophils</td>
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<td>Macroglobules++</td>
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<tr>
<td>Microcytes</td>
<td>+2</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
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<td>Sickle</td>
<td>Negative</td>
<td>Negative</td>
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<tr>
<td>Plasma color</td>
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<tr>
<td>Prothrombin time (Quick) (min.)</td>
<td>14.5</td>
<td>13.8</td>
<td>20.5+</td>
<td>20.5+</td>
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<tr>
<td>Coagulation time (min.)</td>
<td>11.5</td>
<td>291</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
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</table>

* Rectal temperature -18 C (64.4 F).
† Phenylendiamine was used as the anticoagulant from February 16 through February 23.
‡ The patient was receiving heparin at the time of this determination.

**Table 3.—Results of Urinalysis**

<table>
<thead>
<tr>
<th></th>
<th>Feb. 8 *</th>
<th>Feb. 9</th>
<th>Feb. 16</th>
<th>Feb. 23</th>
<th>Feb. 28</th>
<th>June 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Pale, clear</td>
<td>Bronze, cloudy</td>
<td>Pale, cloudy</td>
<td>Straw, cloudy</td>
<td>Straw, clear</td>
<td>5.5</td>
</tr>
<tr>
<td>pH</td>
<td>5.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>5.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.011</td>
<td>1.010</td>
<td>1.012</td>
<td>1.022</td>
<td>1.094</td>
<td></td>
</tr>
<tr>
<td>Albumin</td>
<td>4+</td>
<td>5+</td>
<td>5+</td>
<td>2+</td>
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</tr>
<tr>
<td>Sugar</td>
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<td>0</td>
<td>0</td>
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<td>Acetone</td>
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<td>Urobilinogen</td>
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<td>Urinalysis in 24 h</td>
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<td>Bacteria</td>
<td>Moderate</td>
<td>Trichomons</td>
<td>Many yeast organisms (catheterized)</td>
<td>Rare</td>
<td>Few calcium oxalate</td>
<td>Moderately</td>
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* Rectal temperature -18 C (64.4 F).
† Rectal temperature 96-100.6 F.
‡ Rectal temperature 100-102 F. (extreme values).
§ Bloodline test.

4. Examination by Drs. Theodore A. Shapiro and Irving S. Krause.
ments were now possible on a voluntary basis to a limited extent. The patient could bend her elbows but apparently could not move her legs. Another attempt at catheterization failed.

At 6 p.m., 10 hours after admission, the rectal temperature had reached 28.5°C (83 F) and a light blanket was placed over the patient's body. At this time she responded well to all questions. Ausculcation of the abdomen revealed a return of peristalsis, although the sounds were somewhat hypoactive. The patient complained of being thirsty and asked for cold drinks. She took water eagerly. Within the next few minutes the patient complained of being cold and had a slight chill, which lasted a few minutes. More blankets were added to the covering. Although blood pressure was still unobtainable on the upper extremities, it was deemed advisable to move the patient from the emergency room to a ward bed. This was done with no apparent ill-effects to the patient.

At 8 p.m., 12 hours after admission, the patient's rectal temperature had reached 30°C (86 F), the apical pulse rate 120, and the respirations 16 to 18 per minute. Despite the tracheotomy tube, the patient was able to make sufficient sound to be understood when she spoke. At this time she asked for her father, who was called into the room; the patient immediately recognized him.

At 9 p.m. the rectal temperature was 31°C (87.8 F). The apical pulse rate was 100 and the respiratory rate 16 per minute. Bowel sounds were still hypoactive. Blood pressure was still unobtainable. Heparin administration by intravenous drip, 50 mg. every four hours in 100 cc. of 5% glucose and water, was begun. The patient requested and received sips of cold liquids. At 11:20 p.m., 15 hours and 20 minutes after admission, the first blood pressure was obtained; it was 100/80 on the left arm. Rectal temperature was 32°C (89.6 F). The patient asked to be moved to a more comfortable position, since apparently she could not yet control her muscular movements very well. At 11:40 p.m. the rectal temperature was 93.2 F; an ordinary rectal thermometer was used from this point on. Respirations were 15 per minute; the pulse rate was 100. The patient was catheterized, and 240 cc. of concentrated bronze-colored urine was obtained. Results of analysis of this specimen were as follows: pH 5, albumen 3+, sugar 1+; centrifuged sediment showed 10 to 15 casts per high power field, including mainly granular and occasionally red cell casts; tubular epithelium; occasional red blood cells and white blood cells; and no bacteria. The patient complained of a cold sensation in the hands and legs and shivered slightly.

At midnight the rectal temperature had risen to 95 F. At 1:10 a.m., 17 hours after admission, the rectal temperature was 98 F, pulse rate 120, respirations 18, and blood pressure 118/80.

At 3 a.m., 19 hours after admission, the rectal temperature reached 101 F, pulse rate 120, respirations 18, and blood pressure 118/80. The patient complained of a fleeting chest pain, which disappeared spontaneously.

The rectal temperature remained at about 100 F for the next six hours. The patient began to get restless. At about 5 a.m. she complained of an uncomfortable feeling of warmth. The blankets were removed, and only a sheet remained to cover the patient.

A history obtained from the patient's father and husband indicated that she had been drinking more or less steadily for some nine hours prior to the time she lost consciousness. Apparently she had slipped on the ice at about 9 p.m. and, because of her inebriated condition, had had great difficulty in arising and lost consciousness. Therefore, it appears that her exposure had lasted 11 hours, from about 9 p.m. on February 8 to 8 a.m. on February 9. The patient had been dressed lightly; she wore a three-quarter length coat, sheer stockings, and light shoes; she had not worn gloves.

Conversations with the patient brought to our attention the fact that for the first 36 hours following return to normal temperature she had had amnesia for all events in the 12 hours immediately prior to her exposure until the time she regained consciousness. However, her memory for previous events was lucid and detailed. Thirty-six hours after the patient's temperature reached normal ranges she was able to recall the events that occurred within the 12-hour period prior to exposure. The amnesia for recent events following recovery from hypothermia has been observed previously.3

COMMENT ON HYPOTHERMIC PERIOD

Many questions arise concerning the reasons for this patient's recovery. There are many unanswered questions of physiologic significance. The accumulated data cannot answer all these questions, but it is hoped that these data will stimulate further experimental studies.

The recovery curve (Figure 1) followed a remarkably straight line in a room temperature of 68 F. The rise in deep rectal temperature during the recovery period averaged one degree per hour. No attempts were made to warm the patient. We had the choice of either the rapid or slow warming methods, each of which has its adherents. We chose to warm the patient slowly because of the extreme degree of hypothermia and the length of exposure. Under these circumstances we felt that rapid warming might cause a shift of body fluids from the intravascular to the extravascular space and possibly result in secondary shock. The only pronounced devi-

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ation in the recovery curve from a relatively straight line is the sharp rise immediately following the intramuscular injection of 200 mg. of cortisone. The significance of this deviation cannot be ascertained at this time, since the question arises as to the degree of absorption that would occur under such circumstances.

A projection of the straight line temperature curve to the time of admission would bring the rectal temperature on admission to about 16 C (60.8 F). To our knowledge recovery from such low temperatures has not been recorded in man.

The patient apparently had lain on her right side throughout the period of unconsciousness, since this was the side having the most marked areas of frostbite. The circular garter marks above the knee might have been a contributing factor to the extreme degree of frostbite below this area. It is well known that pressure is a contributory part of tissue destruction in frostbite.

Initial treatment of frostbitten extremities by the application of petrolatum gauze and fluff dressings with mild external elastic pressure is controversial. This type of treatment was used here since it is the therapy usually employed in burns at this hospital. Its rationale can be defended on the basis that the dressings protected the extremities against further trauma and against a secondary state of shock which might have followed extravasation of fluids into the tissues on warming. However, in the light of developments in the post-hypothermic period, the question might well be raised as to whether the sappophytic invasion of the tissues in the extremities, particularly by anaerobes, might not have been encouraged by occlusive dressings.

The question of vasodilating measures was considered from the beginning. The most definitive work on this subject in instances of severe frostbite indicates that vasodilating measures are probably contraindicated, since they enhance local edema and might precipitate gangrene.\(^8\) Other work has shown that this may not be true in milder cases.\(^9\) In the light of this information, we used no local vasodilating measures in this case.

Anticoagulant therapy was begun as soon as peripheral blood pressure was perceptible, about 12 hours after admission. Experimental evidence indicates that anticoagulant therapy may prevent gangrene when the latter is due to thrombosis following frostbite, particularly when used very early.\(^10\) There is also some circumstantial evidence that this may hold true in human cases.\(^11\)

The rapid lowering of this patient's temperature in relatively dry cold surroundings might have contributed to her survival. The relative humidity according to the United States Weather Bureau ranged from 58% to 70% during the period of the patient's exposure, and the official temperatures for this period ranged from -1 F to -7 F. Unofficial temperatures in the neighborhood varied from -11 F to -15 F.

Regarding the effect of alcohol ingestion, we believe the alcohol could have served as an initial soporific comparable to the administration of barbiturates or light anesthesia to experimental animals to offset the intense psychomotor disturbances and panic of the first stages of abrupt chilling.\(^12\) Furthermore, alcohol is known to produce peripheral vascular dilatation at the expense of deep body temperature. Under such conditions a greater volume of blood would be exposed to the cooling effect of the surroundings and hasten a drop in body temperature. It is unlikely that ingested alcohol could work in any other manner. In Rascher's Nazi experiments,\(^24\) the ingestion of alcohol could not be evaluated since the amount given was very small and post-hypothermic observations were inadequate. It remains for controlled animal experimentation to clarify the effect of alcohol in this condition.

**Metabolism.**\(^13\) The metabolic rate of -7.8% which was obtained at a rectal temperature of 20 C (68 F) is not actually a basal reading, nor is it altogether accurate. This figure was calculated from the DuBois tables, as modified by Boothby and Sandiford, for normal body temperatures. Yet the actual metabolic rate extrapolated to the temperature of the patient would modify this figure only slightly. There are, however, several reasons why one would not expect a remarkably low metabolic rate in this patient: 1. The patient had ingested large amounts of alcohol prior to her exposure. Therefore, although all metabolic processes were diminished during the period of unconsciousness, there was nonetheless some absorption and metabolism of alcohol, albeit more slowly than under normal conditions. 2. Clinically imperceptible muscle fascilitation and fibrillation during hypothermia are known to prevent pronounced drops in metabolic rate.

The oxygen consumption curve taken at a rectal temperature of 20 C was compared with a later curve taken after recovery. Respirations at the time of the first test were about 12 per minute. The slow irregular rate and the irregularity in depth of respirations may be noted (Fig. 2), as contrasted with the normal pattern for this patient (Fig. 3).

Cortisone was given on the basis that this patient had undergone a severe degree of stress, with possible adrenal exhaustion. Proof of the value of either cortisone or corticotropin (ACTH) in hypothermia would depend on the results of controlled animal experiments. Evidence that there was a pronounced degree of adrenal stimulation induced by the stress condition of hypothermia is probably reflected in this patient's remarkable hyperglycemia (serum glucose 483 mg per 100 cc) in the frozen state. This situation is perhaps the result of both adrenal medullary and cortical stimulation. Glycogen-

12. Metabolic observations were made in collaboration with Dr. Rachmiel Levine.
lysis due to epinephrine may have been the initial cause of the hyperglycemia. Selye 13 has shown that exposure to cold superimposed on a period of fasting intensifies and accelerates the appearance of a secondary hyperglycemic peak after "fasting hyperglycemia." According to Selye, this rise in blood sugar appears to depend on the secretion of adrenocorticoids. As can be seen in Table 1, the serum glucose level fell to 121 mg. per 100 cc. within 24 hours after admission and to within the normal range by the following day, where it remained for the duration of the patient's hospital stay. Urinalysis showed no evidence of ketonuria either during the frozen state or thereafter. The severe acidosis during hypothermia (blood pH 7.17; carbon dioxide combining power 17.9 mM/L) is probably an expression of the reduced blood flow to the muscles with consequent accumulation of lactic acid.

THE IMMEDIATE POST-HYPOTHERMIC PERIOD

The day following admission the patient was feeling rather comfortable, with no specific complaints. A complete inventory of the chemistry of the blood and urine was obtained (Tables 1 and 3). The only indication that difficult days lay ahead might have been seen from the urinary findings of albuminuria and the presence of coarsely granular casts. The pH of the blood during hypothermia had now approached normalcy and the hyperglycemia was definitely diminished, but there was present a 2+ cephalin-cholesterol flocculation with a slight dereangement of the albumin-globulin ratio.

The therapeutic plan at this time involved three major objectives: (1) preservation, as far as possible, of frostbitten tissue; (2) prevention of infection; and (3) general care to reestablish a state of normalcy in body functions.

Frostbite Care.—The four-hour doses of 50 mg. of heparin were supplemented by an initial dose of 300 mg. ofbishydroxycoumarin (dicumarol*) the day after admission. Heparin was discontinued within two days when therapeutic levels of prothrombin time were reached. After two days ofbishydroxycoumarin we were able to obtain a supply of 2-phenylindanedione; anticoagulant therapy was maintained at therapeutic levels with this drug for 22 days. This drug was chosen because our experience with it in the laboratory 14 indicated that more even prothrombin levels can be maintained with it than withbishydroxycoumarin and that its effect disappears more rapidly after discontinuance.

The day following admission the patient complained, for the first and only time, of pain in the legs. We were unwilling to use opiates of any kind and decided to give the patient 500 cc. of a 0.2% procaine hydrochloride solution by slow intravenous infusion. Within five minutes after the start of the infusion the patient no longer complained of pain.

The morning following admission it was decided that the extremities should be rewrapped, since the dressings had been hurriedly applied in the emergency room the day before, when it was not known whether the patient would survive. The dressings were removed under sterile conditions in the presence of several surgeons. Inasmuch as the digits of both upper and lower extremities were frozen hard on admission, we took advantage of this opportunity to examine the functional state of these parts. We found that the patient was able to move the digits of all four extremities individually and collectively through a normal range of motion. Furthermore, some proprioceptive sense seemed to be present in each digit. Large blisters now covered the palms and dorsal surfaces of both hands, including the fingers, and were also present in a patchy pattern on both legs, the outer aspect of the right thigh, and the buttocks. The ankles and feet, though not actually blistered, appeared puffy and felt very cold to the touch. No pulsations could be felt in either dorsalis pedis artery, although they could be felt in the poplitical space bilaterally. Each extremity was carefully rewrapped, with petrolatum gauze, fluff dressings, and elastic bandage, in the position of function.

Measures to Prevent Infection.—On the day of admission penicillin therapy was instituted; the patient received 600,000 units daily thereafter for a period of three weeks. Subsequent antibiotic therapy is mentioned below. The day following admission prophylactic injections of 5,000 units of tetanus antitoxin as well as an ampul of polyvalent gas gangrene antitoxin (2,000 units of Clostridium welchii antitoxin and 2,000 units of Clostridium septicum antitoxin). Aseptic precautions were strictly observed in all dressings.

General Care.—We decided not to limit the patient's intake of food or fluid, since she appeared to enjoy and perhaps even need whatever she ingested. This plan may have played a role in later problems in fluid and electrolyte balance. The tracheotomy tube was removed 48 hours after admission, and the wound was closed with a Michel clip.

POST-HYPOTHERMIC SEQUELAE

Since the detailed account of the day-to-day course in the weeks following admission would be too lengthy for this report, the post-hypothermic sequelae will be summarized categorically below. In some categories, progress to healing occurred in the absence of complications. In other instances the complications were so severe as to endanger the patient's life. These studies represent the cooperative efforts of a large number of hospital staff members, only a few of whom are mentioned below.

Ocular Findings.16—Eye examination the day after admission revealed that the pupils dilated well with eucatropine (euphthalmine*) hydrochloride 2% and hydroxyamphetamine (paredrine*) hydrobromide 1%. Vision was 12/20 on the right and 12/18 on the left. The patient could accommodate with either eye to 12 type at 14 in. The lids were normal and of good color, with no evidence of injury or infection. The conjunctivas were of good color, with no evidence of pathology. The preauricular nodes were not palpable. Tactile tension was normal. No pus or mucus could be expressed from the lacrimal sacs. The corneas were clear. There was no evidence of damage to the epithelium or endothelium. The anterior chambers were clear (no cells or transudation), with normal depth. The pupils were round and equal (2 by 2 mm.) and reacted

15. Drs. Theodore A. Shapiro and Irving S. Krause.*
to light, direct and consensual. The irises were deep brown, with no tumors or masses; vascular markings were clear, with good pigment ruff at the papillary border and no evidence of hippus. The lenses and vitreous were clear. External ocular muscle action was good; the levator palpebrae superioris was especially strong. There

Fig. 4.—Electrocardiographic tracing taken at rectal temperature of 20 C (68 F). The tracing is distorted by extracardiac artifacts due to muscle tremor. No P waves can be distinguished. The ventricular action is irregular at an average rate of 42 per minute. The longest R-R intervals are equal, corresponding to a rate of 30, and intervals of less duration, separating the longest intervals, show progressive shortening. Auricular fibrillation cannot be excluded. However, the spacing of the ventricular complexes suggests the presence of nodal rhythm with second degree atrioventricular block and Wenckebach periods below its point of origin. Under this assumption depression of the primary pacemaker (complete sinus standstill) or complete sinoauricular block could be the primary disturbance of rhythm. The S-T-T complexes show marked prolongation and bizarre configuration. The Q-T interval of the longer cycles measured 0.78 sec. Instead of the expected 0.48 ± 0.04 sec S-T is elevated in most of the leads and forms a broad concavity between two peaks, thus giving the impression of a double T wave. (Interpretation by Drs. A. Pick and L. N. Katz.)

was good convergence power, within 125 mm. Pcb. Duction and version movements were normal in the cardinal positions of gaze. There was no evidence of tropia. There was mild exophoria, of about 12 prism diopters. The right and left fundi were essentially the same. The disks were round and normal in size but showed mild temporal pallor; the nasal vein was pink, with sharp borders and normal excavation; there was no evidence of edema. The maculas were clear, with good foveal reflex and no disturbance of pigmentary epithelium. The arteriovenous ratio of the retinal vessels was 1:1.5; there was a good arteriolar reflex, with no evidence of sheathing or arteriovenous compression, undue tortuosity, or exudates or hemorrhages. A spontaneous venous pulsation was noted at the disk. There appeared to be little evidence of ocular pathology. The ischemic retinae noted the previous day had completely cleared. The retina and optic nerve revealed no permanent damage at this time. The vision was excellent. Subsequent eye examinations revealed no residual pathology.

Electrocardiographic Data.16—With the return to normal ranges of temperature there appeared a sinus tachycardia, which persisted until 12 days after admission. Electrocardiograms were taken daily from the time of entry. A detailed study of these is being reported separately. An electrocardiogram taken six days after admission (Fig. 5A) showed a configuration commensurate with a pattern seen in acute diffuse pericarditis. By February 21, thirteen days after admission, the pulse rate returned to within normal limits and the

Fig. 5.—A, electrocardiographic tracing taken Feb. 14, 1951, six days after admission. Rate 115; P-R interval 0.18 sec.; sinus tachycardia. S-T is no longer deviated, and Q-T is of normal duration. The configuration of the T waves is similar to a pattern seen in the course of acute diffuse pericarditis. B, electrocardiographic tracing taken Feb. 21, 1951, 13 days after admission. Rate 68; P-R interval 0.18 sec.; restitution to normal.

Hematologic Findings.17—Figure 6 and Table 2 show the parallel course followed in the post-hypothermic period by the hematocrit, the hemoglobin, and the red blood cell levels. This could have been due to a post-

17. Work done in collaboration with Dr. Karl Singer.
hypothermic anemia or to hemodilution. A transfusion of 500 cc of blood was given on February 20 (12 days after admission) without full knowledge of what the drop in the red blood cell count actually signified. The transfusion had no observable effect on the downward course of the red blood cell count. Unfortunately blood volume studies were not made at this time. However, evidence that the drop in hematocrit, hemoglobin, and red blood cell levels was probably not the result of anemia was obtained from blood marrow studies on February 17 (nine days after admission). The marrow examination showed no evidence of increased erythrocytogenesis. The complete marrow report was as follows:

full marrow; megakaryocytes adequate; erythroblast-granulocyte ratio 1:4; red cell series normoblastic; no foreign cells or parasites. The marrow was considered essentially normal.

No eosinophils were found in the blood smears on the day of admission. The significance of the lack of eosinophils in the hypothermic period can probably be ascribed to adrenal stress.\(^{18}\) The next day two eosinophils per 100 leukocytes were found. This count persisted until March 5, when again no eosinophils could be found. On this date the patient exhibited a skin rash. The rash disappeared when all antibiotics were stopped. After March 12 four eosinophils per 100 white cells appeared; this count persisted fairly consistently throughout the entire hospital stay.

The cold agglutinin titer on February 19 was 1:1, not a significant titer. Results of a saline erythrocyte fragility test, on February 20, when the anemia was severe, were within normal range.

\textit{Electroencephalographic Data.}\(^{19}\)—Unfortunately it was impossible to get an electroencephalographic tracing while the patient was in coma. The first tracing was made on February 13, five days after admission. The base line showed low voltage waves of 4.5 cps throughout. A moderately well-sustained 10 to 11 cps rhythm was found occipitally and to a lesser degree centrally when the slower rhythms were in abeyance. Except for slow waves, the diagnostic impression was that there were no gross abnormalities.

The test was repeated on June 21, some 18 weeks after admission, at which time the record was not notably different from that of February 13, and was classified as within normal limits. It can be surmised that the hypothermic period resulted in no permanent change in the electroencephalographic record.

\textit{Changes in Blood Pressure, Water Balance, Electrolyte Balance, and Renal Function.}\(^{20}\)—The blood pressure became perceptible 14 hours after admission, when the rectal temperature was 33 C (91.4 F). The blood pressure then was 100/86. Blood pressures in the range of the patient's norm of 118/80 (available from a previous record) persisted for only 36 hours, when hypertension gradually became evident. As can be seen from Figure 5, the blood pressure reached definite hypertensive levels two days after admission and remained high for a period of 18 days. During this period blood pressure ranged from 170/100 to 200/120 with few exceptions. A detailed description of the data accompanying this hypertension forms the basis for a separate report, but a summary of the available data will be made here.

The fluid intake of this patient was governed largely by her desires, since we were unaware of any possible ill-effects that this might entail. We were concerned mainly with the question of urinary excretion. Beginning the fourth day the patient began to excrete abnormally large amounts of urine. In Figure 6 it can be seen that the excessive fluid output from the third to the 13th day, paralleled the excessive daily fluid intake for this period. Yet the urinary specific gravity at no time within the first seven days fell below 1.009 or went above 1.012. Following this period (after the 13th day) the daily urinary output was relatively low and the intake varied from low to moderately excessive. The specific gravity rose to 1.022 by February 28, at a time when the urinary output was markedly diminished.

The only intravenous supplementation of intake throughout the charted period consisted of 1,500 cc. of plasma and 1,000 cc. of 5% glucose in saline intravenously on the day of admission, 500 cc. of saline containing 0.2% procaine hydrochloride the next day, 500

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\(^{19}\) Drs. Herman M. Serota and M. Torman.

cc. of blood on February 20, 12 days after admission, and 1,000 cc. of 5% glucose in saline on February 21, 13 days after admission.

Figure 6 demonstrates the correlation between excessive fluid intake and hemodilution, as evidenced by the parallel drop in hemocrit readings, hemoglobin, and erythrocyte counts. The assumption that a hypertensive state existed was supported by the bone marrow evidence against anemia, although blood volume studies were not performed.

During this same period there was a marked degree of azotemia, with a peak serum urea nitrogen of 66 mg. per 100 cc. on February 13, five days after admission. Serum creatinine levels increased proportionately, reaching a peak of 6 mg. per 100 cc. one day before the maximum elevation of urea nitrogen. Urinary creatinine measured in grams per 24 hours was extremely low during most of the period in which the serum creatinine was elevated, indicating a defect in creatinine clearance. Also, throughout the two-week period following injury albuminuria (2+ to 4+) was present and lipid casts were found in the centrifuged sediment.

From this data it would appear that, in addition to the apparent hypervolemia associated with hypertension, kidney damage was also present. Lewis and Thompson 21 found "acute nephrosis" in rabbits exposed to local cold injury. The urine of their animals exhibited lipid casts and degenerated renal cells similar to those found in this patient.

The other chemistry determinations during this period indicated that there was a relatively normal serum sodium, but an extremely low output of sodium in the urine (Fig. 7). The serum chloride levels more or less paralleled those of the sodium except for a short period in which there was mild hypochloremia. Salt intake, although unmeasured, was considered normal. Because of the apparent hemodilution, the normal serum sodium levels could actually represent relative hypernatremia. On the other hand, the extremely low urinary sodium and chloride levels expressed in milliequivalents per 24 hours represented an absolute diminution in excreted sodium and chlorides, again suggesting sodium retention. This picture might be consistent with the disturbance in renal function produced by Selye 22 in animals treated with desoxycorticosterone acetate. The sodium retention in our case might have been due to renal damage. However, it is more probable that it was due to adrenal hyperactivity, especially in view of the fact that potassium excretion was abnormally high for a prolonged period at a time when pronounced nitrogen retention occurred.

During the period under discussion there was moderate hyperphosphatemia and a diminution in urinary phosphates. Both of these deviations were corrected as the blood pressure approached normal limits and the azotemia disappeared. Urinary creatine was significantly elevated from the period three days after admission for eight days.

It is impossible to state whether there was any relationship between the effects of tissue destruction and the persistence of hypertension. However, there seems to be an apparent correlation between the two, inasmuch as the final recession to the patient's norm of 118/80 did not occur until five days after amputation of the legs.

The available data suggests that we were dealing with a combination of events. There seemed little doubt that kidney damage was present, involving both tubular and glomerular elements. The voluntary demand for excess fluids by the patient might have been due to the resulting isosthenuria, leading in turn to hypervolemia.

Frostbite Sequelae.—Despite massive dressings and intensive antibiotic therapy as previously outlined, it became necessary to change the dressings on all four extremities every 48 hours after the fourth day because of permeation of large amounts of malodorous drainage. Débridement of epidermal layers was carried out as indicated on a conservative basis. Large blisters were not opened. When such blisters ruptured spontaneously the necrotic overlay was removed.

Although it was evident after five days that there was no sign of viability in the tissues of either foot, the patient was still able to dorsiflex both feet and move the toes, but this latter movement was not through as wide a range of motion as previously. There was no sensation in either foot or leg up to just below the knee level. On the seventh day the hands, as well as the fingers, were covered with huge blisters on both the dorsal and volar surfaces, but the patient had an almost full range of
motion in all joints of all fingers. She was also able to abduct and adduct all fingers and to oppose the thumbs. This indicated viability in the intrinsic muscles of the hands. The larger blebs were aspirated of clear straw-colored fluid, the volume of which was estimated to be 300 cc. from both hands.

On February 16 (eight days after admission) a coat of necrotic epidermis was removed over the palm and the dorsum of both hands and wrists. The underlying tissue proximal to the metacarpophalangeal joints appeared pink and smooth, while distally this layer was dark red and partially demarcated from the pink tissues proximally. At no time was there pain associated with redressing or with active motion of the fingers (Fig. 8).

After two days the blisters on the buttocks were exposed to air under a bed cradle, since it was difficult to keep them dressed. They were treated with boric acid dressings periodically throughout each day.

Dressings of the lower extremities on February 21 (13 days after admission) revealed that with the exception of large areas on the right side of each leg, in which the superficial tissue now appeared black and nonpliable, most of the surface of the legs was covered by what appeared to be pink epithelium. The skin of the toes was still adherent. The lesions of the leg appeared delimited from the milder blisters of the thigh by the garter line in the superpatellar region.

There was evidence now of foot drop, and the patient was no longer able to dorsiflex the ankles. Dressings of the hands the same day revealed the beginning formation of a dark brown firm eschar over the fingers.

A dark eschar developed over the legs and feet over the next few days. Aquaphor® (ointment containing hydroxyl animal fats) dressings and saline soaks were used on the hands in an attempt to soften the eschars. This apparently proved to no avail and was discontinued after four days. The eschars on each finger were bivalved on February 25. The right hand was placed in an aluminum cock-up splint between soakings, since a moderate wrist drop appeared to be developing.

Dressings were done daily from this point on, and débridement was carried on in which small amounts of the eschar were taken away from the proximal edges as far as spontaneous separation would allow. We were encouraged by the fact that as the eschar was cut away from both the hands and the legs, pink granulation tissue was invariably found underneath.

On March 4 examination of the legs revealed that, while some areas in the upper third were epithelialized, about 60% of the exposed surface of the legs between the eschar and the knees had lost a full thickness of skin. The eschar at this time had been débrided to about the level of the lower third of the tibia. Directly over the lower aspect of the tibialis anterior muscle the granulation tissue did not appear as healthy as did the higher areas. Deeper débridement at this time, through the fascia and into the belly of the tibialis anterior muscle, revealed the muscle to be salmon pink, foul smelling and noncontractile on cutting. Nonetheless, bleeding was brisk from spurring small arteries which were cut across when the muscle was incised. There was no pain at any time during this débridement without anesthesia. The bacon rind eschar from this point distally was not removed but was bivalved to a deeper level. A deliberate incision was made over the dorsum of the left foot, revealing black, foul-smelling necrotic tissue to the bone. It became obvious to us at this time, that, despite all measures to preserve tissue, it was necessary to amputate both lower limbs at least as high as the lower third of the tibia.

Surgery was postponed because of a severe generalized skin rash, presumably caused by penicillin. Maximum temperature elevation during this period was in the neighborhood of 100 F. The pulse rate during this period ranged from 120 to 130, and the patient appeared toxic. Terramycin, 2,000 mg. per day, was given in place of penicillin. Within 48 hours the stools became tarry and were strongly positive for blood. Anticoagulant therapy was stopped on March 6, 26 days after admission, as was all medication, including terramycin. Vitamin K was administered.

On March 8, with the use of cyclopropane and ether anesthesia, the amputations were performed. Guillotine amputations were performed at the lowest possible level commensurate with viable tissue. This was approximately 9 in. (23 cm.) below the knee bilaterally. The patient took anesthesia very poorly and had a pulse rate between 120 and 160 throughout surgery. After the first leg was amputated, the patient's blood pressure dropped.

Fig. 8.—Appearance of hands and legs on Feb. 16, 1951, eight days after admission. At this stage there was still motion in fingers and toes.
to zero, despite continuous blood transfusion, and amputation of the second leg was delayed for 45 minutes while resuscitative measures were administered. During surgery 1,500 cc. of blood were given. Detailed pathologic and bacteriologic studies on the specimens are to be reported elsewhere.

The pulse rate ranged between 128 and 140 for 10 days after operation. Electrocardiograms during this time revealed only sinus tachycardia. Despite the persistently rapid pulse the patient's general condition appeared much improved within 48 hours after surgery. She appeared less toxic, and her appetite, which had diminished with the occurrence of drug sensitivity and toxicity, was now back to normal.

On March 13 the patient was taken to the operating room for débridement of the hands with the prospect of amputation of portions of the fingers. Débridement revealed red tissue under some areas of the eschar; amputation was therefore delayed. On March 20 the patient was returned to the operating room, at which time it was apparent that amputation of some of the fingers would have to be performed. Guillotine amputation was done through obviously mummified tissue, and the proximal escars were removed. This procedure was carried out in the hope that spontaneous separation of necrotic from viable tissue would result in greater preservation of the digits.

On April 6 thick split skin grafts from the thighs were applied to portions of both leg stumps. The patient was returned to the operating room on April 12 for skin grafting of the remaining areas of the leg stumps. It was our impression that split thickness grafts did not take as well on frostbite granulation, as had been our previous experience in burn cases. Although the granulation appeared very healthy and compressed, we obtained no better than 60% takes in our grafting.

On May 3 the patient was returned to the operating room, where final débridement of the fingers was done. The only completely normal digit of the hands that remained was the left thumb, which underwent several episodes of peeling as well as loss of the nail. The four fingers of the left hand remained only as stumps of the proximal phalanges. Tissue loss on the right hand consisted of the loss of all digits, including the heads of all metacarpals. The first metacarpal was necrotic in its distal half. All that remained of the right hand was the palm.

Subsequent care consisted of dressings and treatment of a Pseudomonas aeruginosa infection of all wounds with dilute acetic acid at each dressing. Under careful guidance of special nurses the patient learned to hold a fork and spoon in her left hand by means of opposing the thumb to the stump of the forefinger. She soon learned to hold a pencil and crayons in this manner and underwent a systematic process of learning to write. Occupational therapy consisted of teaching her to control implements of various types and to make such objects as leather folders.

On May 20 physical therapy was begun. The result was excellent, in that full range of motion of both knees and both wrists was obtained within a short time.

The patient complained about gaining too much weight and asked to be placed on a reducing diet. Her frame of mind was excellent, and it improved as she learned to do things with the remaining thumb. The appearance of the extremities on June 28, 1951, is shown in Figure 10. The lower limb stumps were revised on July 16 to accommodate prostheses. The patient was discharged to a convalescent home on Aug. 8, 1951, six months after admission, where she awaited fitting of lower limb prostheses.

**COMMENT ON POST-HYPOTHERMIC SEQUELAE**

The sequelae that have been described in this case were apparently much severer than those described in previous reports of human hypothermia. They occurred in the presence of what we believe can be considered good present day treatment.

The severest physiologic sequelae in our case occurred within the two-week period following exposure. They were reflected in most of the body systems, predominantly in electrocardiographic changes and in alterations in water and electrolyte metabolism. During this period there occurred an apparent hypervolemia with

concomitant hypertension, sodium retention, and azotemia. Attempts to analyze the basis for these deviations from the normal led us to the supposition that actual anatomic damage to the kidney was superimposed on the functional derangements in such organs as the adrenal gland, the kidney, and the heart. This damage was evidenced by the presence in the urine of degenerated renal cells containing fatty droplets, which appeared in the early post-hypothermic period. In another sense, the presence of gangrenous peripheral tissues (hands and legs) may have superimposed further functional deviations through absorption. Evidence for this may be seen in the extremely high potassium excretion and the disappearance of hypertension after the amputations.

The destruction of peripheral tissues due to frost injury presents a difficult therapeutic problem insofar as it is necessary to balance the ill-effects from absorption against a conservative surgical standpoint in which one wishes to preserve the maximum amount of tissue by allowing demarcation to take place.

It appears that some of the views concerning the pathogenesis of frostbite injury to tissues in milder cases require reevaluation when applied to severer cases. For example, in milder cases the loss of viability in peripheral tissue following frostbite is apparently the result of vascular spasm and thrombosis. Observations in a severer case, such as ours, indicate that the loss of viability resulting from direct thermal injury is more responsible for irreversible damage to tissue than is vascular occlusion. Evidence for this is based on the presence of patent, spurring arteries in the midst of necrotic muscle tissue at the time of débridement, as well as the pathologic findings in the amputated lower extremities. At least as far as muscle involvement is concerned, we consider thermal injury rather than vascular occlusion the cause for tissue necrosis in this case. This view coincides with that of Stein and with recent experimental work of Lewis.

We found viable superficial granulation tissue and grossly viable fascial structures with underlying necrotic muscle. We feel that this can probably be explained by the fact that muscle is a highly specialized tissue that cannot recover as muscle tissue. It either is destroyed or heals by connective tissue scar. Thus identical exposure of muscle and other loss specialized tissue can result in destruction of muscle tissue and not of other tissue.

Anticoagulant therapy was begun 12 hours after admission and continued for some 22 days at therapeutic levels. Yet this therapy had no observable effect on the preservation of tissue. Recent work has indicated that anticoagulant therapy, if begun early enough, is of value in milder cases of frostbite.

We cannot explain the fact that one digit retained its viability despite the fact that it underwent the same apparent degree of frostbite and exhibited the same early stages of tissue change as did the other digits. There appears to be an urgent need for intensive animal experimentation to answer several of the questions raised by the study of this interesting case. We feel that such experimentation should concentrate on physiologic studies and treatment of the more profound degrees of hypothermia and frost injury to tissues, since it appears from our study that conclusions reached in much of the work on milder degrees of cold exposure do not apply to the severer types.


**Genetics and the Environment.**—One of the earliest and farthest-reaching fallacies in the philosophical approach to human problems was the belief that if a genetic basis were demonstrated for a certain trait, that trait could not be subject to environmental modification; and conversely, if a trait were shown to be influenced by the environment, it could not at the same time be genetically determined. Although many of us have for years called attention to this fallacy, it still crops up in the literature, especially that of medicine, sociology, psychology, and education.

There is usually an element of fear present in the case of the heredity-environment fallacy. For the physician, there may be a certain reluctance to accept the genetic basis for a disease or anomaly on the grounds that it would thereby be useless to attempt therapy. For the sociologist or psychologist, the reluctance involves the fear that new or changed attitudes could not be brought about if there were any genetic basis for the original development of individual differences in behavior.—Laurence H. Snyder, M.D., Old and New Pathways in Human Genetics, *The American Journal of Human Genetics*, March, 1951.