REACTIONS OF THE NASAL CAVITY AND POSTNASAL SPACE TO CHILLING OF THE BODY SURFACE.

I. Vasomotor Reactions.

By STUART MUDD, M.D., ALFRED GOLDMAN, M.D., and SAMUEL B. GRANT, M.D.

(From the Department of Pathology of Washington University Medical School, St. Louis, and the Laboratories of Biophysics of the Cancer Commission of Harvard University, Boston.)

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Chilling of the body surface has been shown in earlier communications[1,2] to cause reflex vasoconstriction and ischemia in the mucous membranes of the palate, palatine tonsils, and pharynx. The present study demonstrates a like reflex diminution in the blood supply of the nasal cavity and postnasal space (nasopharynx).

In the postnasal space the reaction is closely similar to that previously described for the oropharynx; with chilling of the body surface the temperature of the nasopharyngeal mucosa has fallen typically between 1° and 2°C.; on rewrapping the subject, mucosa temperature rises, indicating return toward normal of the blood supply, but, typically, under the conditions of our experiments, recovery is not quite complete even after an interval at least as long as ½ hour after wrapping.

In the nasal cavity the reactions are qualitatively similar but quantitatively much more striking; with cutaneous chilling the temperature depression of the nasal mucosa surface has been found in some instances to be more than 6°C. With rewarming, recovery has always been sharp, usually stopping somewhat below control level, but sometimes rising above it in this region notorious for its erratic variations in vasomotor state.

[1] Mudd, S., and Grant, S. B., *J. Med. Research*, 1919, xl, 53.

[2] Grant, S. B., Mudd, S., and Goldman, A., *J. Exp. Med.*, 1920, xxxii, 87.

The threshold of the vasoconstrictor reflex to the nasal and nasopharyngeal mucosa has been found to be lower than that to the skin of the forehead. Merely unwrapping the subject, in the cool room, temperature 14–18°C., in a number of instances caused depression of mucosa temperature without affecting that of the skin.

Profuse discharge of clear mucus, both from the side of the nose directly irritated and from the opposite side, although more abundantly from the former, occurred during most of those experiments in which the thermopile wires used for measuring surface temperature were introduced into the nasal cavity. This rhinorrhea was little if at all affected by the diminution of blood supply and shrinkage of the nasal mucous membrane which occurred in reflex response to chilling of the body surface.

Discharge from the nose has been at most a rare occurrence in experiments in which the nasal mucosa was not directly irritated.

Methods.

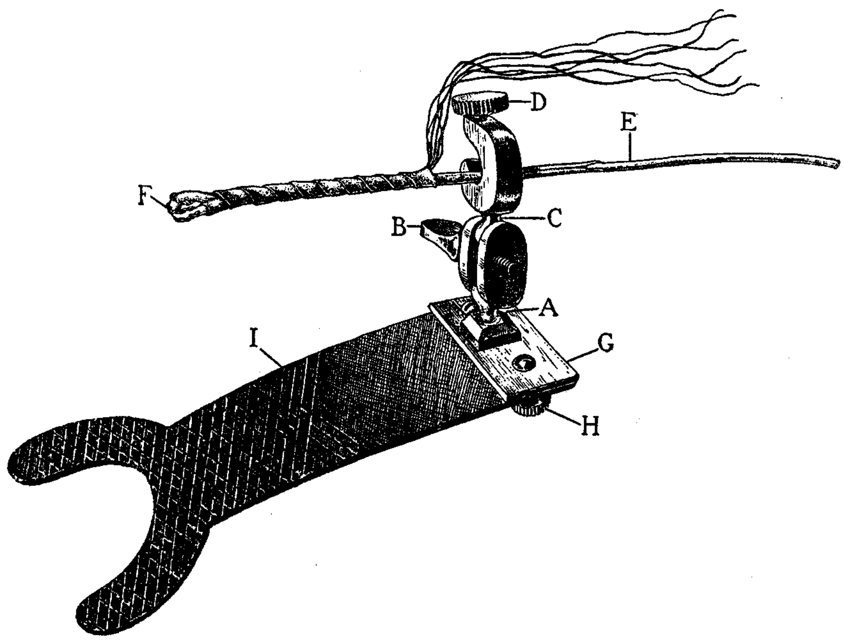
The methods used differed only in detail from those of the earlier papers. The vasomotor reactions were determined as before by following with thermopiles the temperature changes, synchronously, at the surface of the skin of the forehead, and of the particular mucous membrane site under consideration. A fall in surface temperature under the conditions of the experiments indicates vasoconstriction and diminished blood supply, a rise vasodilation.

Respiration as before was controlled by thoracic and abdominal pneumographs and a metronome. Breathing in the present series was through the nose with lips closed, 14 respirations per minute.

Chilling in many of the present experiments was performed in two stages; first the subject's wraps were removed in the cool room; later an electric fan was turned on and directed against the lumbar region of his back. When the fan was turned off, the wraps were replaced at the same time; rewarming was considerably more satisfactory than heretofore as two extra blankets were used for rewrapping.

The thermopile tips were applied by means of No. 12 or 15 galvanized iron wire carriers whose applying ends were so shaped as to conform to the contour of the particular skin or mucous membrane surface in apposition with which the thermopile tips were to be held.

In the nasal cavity, the wire carrier, or applicator, was maintained in position by a special applicator holder. A metal spheroid (Text-fig. 1, *A*), attached to a metal plate, *G*, is connected by metal plates bearing sockets and closed by a set screw, *B*, with a second spheroid, *C*, thus making a double ball and socket joint. The spheroid, *C*, is



TEXT-FIG. 1. Nasal applicator holder with applicator and unknown temperature end of thermopile in position. *A*, metal spheroid mounted on metal plate, *G*. *B*, set screw for tightening lateral plates, bearing sockets, upon *A* and second spheroid, *C*. *D*, thumb screw for holding applicator, *E*, in place in groove in metal crescent continuous with *C*. *F*, applicator tip bearing the three insulated thermal junctions. *H*, one of two thumb screws attaching metal plate *G* to *I*, a fiber-board plate held between the subject's teeth.

continuous with a metal crescent into whose grooved bottom the wire applicator, *E*, fits and is held in the position desired by the thumb screw, *D*. The thermopile, with insulated tips at *F*, is bound to the applicator with adhesive tape.

The whole device is attached by screws fastened by two thumb screws, one of which is shown at *H*, to a plate, *I*, so shaped as to fit firmly between the subject's teeth. This supporting plate is of fiber board, 1.68 mm. thick; although maintaining its shape quite well, it allows of a certain amount of molding by firm pressure. The plate, *I*, is crossed-hatched with a saw to facilitate gripping by the tips of the teeth. Making plates *I* and *G* detachable permits of having a separate fiber board plate for each subject.

The sites studied in the nose, because of the difficulty of making certain application farther back, were all in the anterior half of the cavity. The nasal septum, inferior and middle meatus, and inferior and middle turbinates were studied, the last at about the midportion of its inferior border at a point 5 cm. from the opening of the nostril. Since skin, anterior half of the nasal cavity, postnasal space, oropharynx, tonsils, and palate have now all been shown to exhibit reflex vasoconstriction with diminished blood supply on chilling of the body surface, and vasodilation on rewarming, it seems safe to assume that the posterior half of the nasal cavity does likewise.

For the postnasal space, no applicator holder was needed. The carriers were simply improved models of the original nasopharyngeal applicator shown in an earlier paper.[3]

The applying ends of the applicators of the present series held the thermopile tips against the posterior nasopharyngeal mucosa approximately 2.8, 3.3, and 3.7 cm., respectively, above the posterior margin of the soft palate when in the position of the experiments; *i.e.*, with mouth closed and nose breathing. The applicator with the 3.3 cm. vertical arm was the one chiefly used. As far as we could estimate from specimens in the anatomical museum, this must have carried the tips in most of the subjects as high as the upper half of the posterior nares, in some close to the roof of the nasopharyngeal vault.

For the skin, an applicator somewhat smaller and flatter than the one originally described[4] was used. Skin application was made upon the forehead in all instances.

The subjects of the present series were 3rd and 4th year medical students or recent graduates in medicine. We were fortunate in being able to include men of Aryan, Semitic, and one of Mongolian extraction. No racial differences in the vasomotor reactions were found.

[3] Mudd and Grant,[1] Fig. 1, *E*, p. 57.

[4] Mudd and Grant,[1] Fig. 1, *A* and *A'*, p. 57.

Direct Cooling of the Skin by Air Currents.

Although the sites of application of the thermopiles have been protected from the direct draft of the fan, minor currents and eddies have necessarily been set up by the fan in the small, closed experimental room, and the direct cooling effect of these upon the exposed skin could not be eliminated. This direct cooling, as closely as we have been able to estimate it, probably amounted usually to between one-third and one-half of the observed skin temperature fall. The curves both of this and of the previous series should be studied with this correction in mind.

On the other hand, it is obvious that in experiments in which the mouth was closed and the applicator upon the pharyngeal wall, as in the present series, currents in the room could not have entered at all into the depression of mucous membrane temperature. Similarly, with the applicator in the nasal cavity and nose breathing, again as in the present series, or on the palate or pharyngeal wall, even with the mouth open, direct cooling by air currents in the room could have entered but slightly or not at all into the observed mucous membrane temperature fall. The effect of the air currents, then, has been merely to make appear less striking in comparison with those of the skin the vasoconstrictor reflexes of the mucous membrane blood vessels with chilling of the body surface.

An experiment illustrating the direct cooling of the skin by secondary currents and eddies from the fan is given below.

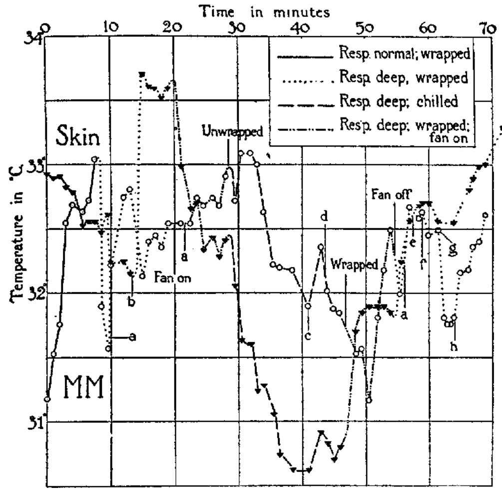
Experiment 1. Control.—Subject 1, F. J. C. July 19, 1920, 3.28 to 4.40 p.m. Application on hard palate, near posterior margin, just to right of midline. Breathing through open mouth. Room temperature about 19°C.

Turning the fan on the back of the subject at 0:20,[5] without removing the heavy wraps, depressed the temperature of the thermopile on the forehead by 1.3°C., without apparent effect upon the mucous membrane (Text-fig. 2). Unwrapping was followed by a further fall of 1.7°C. in skin temperature, one of 1.05° in that of the hard palate. After rewrapping, skin and mucosa temperatures returned to a little below their respective levels of before unwrapping. Turning the fan off, while without obvious effect upon mucosa temperature, was followed by return of that of the skin almost to control level.

In this experiment, therefore, there is no evidence of direct cooling of the mucosa of the hard palate by secondary currents from the electric fan; on the other hand, with the skin of the forehead, of

[5] 0:20, 0:21, etc., indicate the time after the beginning of the experiment; *i.e.*, 0:20 indicates 20 minutes after the beginning of the experiment, 0:21, 21 minutes, etc.

the total temperature depression of 3°C. about 1.3° (43 per cent) was apparently due to direct cooling and 1.7° to loss of blood supply through reflex vasoconstriction.



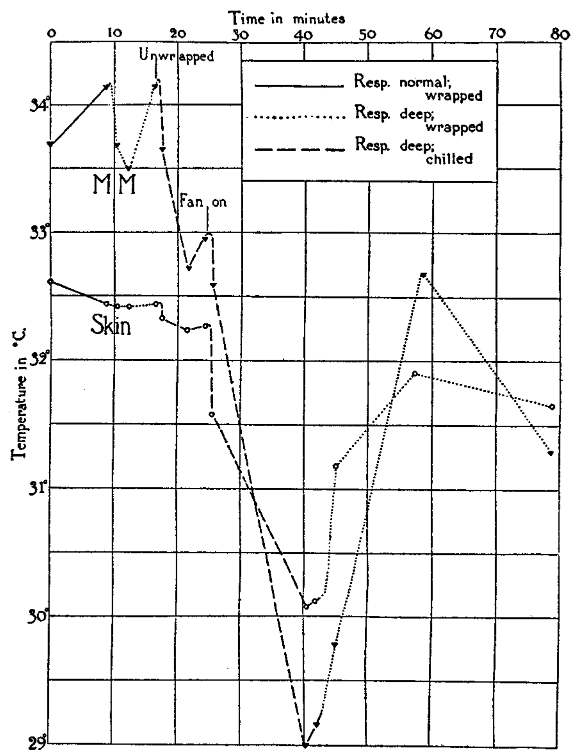
TEXT-FIG. 2. Reflex reactions to chilling and rewarming; direct cooling effect of air currents on skin. Temperatures of skin of forehead and mucous membrane (*MM*) of hard palate, Experiment 1. *a*, respiration shallower than when first deepened; *b*, skin thermopile readjusted; *c*, subject laughed; *d*, no shivering as yet; *e*, respiration deepened; *f*, subject thinks respiration as deep as during chilling; *g*, subject forces respiration as hard as he can; *h*, end of maximal respiration.

Vasomotor Reactions in the Nasal Cavity.

Composite Graph.—The characteristic responses of the mucous membrane of the nasal cavity to chilling of the body surface are shown in Text-fig. 3,[6] a composite graph of seven experiments. Application was made upon the right and left sides of the nasal septum, the right inferior turbinate body, the left inferior turbinate (twice), and in the left middle meatus (twice). The values averaged and plotted were the first and last readings of the experiments, the readings immediately before and after each change of conditions, and the points of maximum

[6] Text-figs. 3 and 4 were used to illustrate a brief summary of the intranasal part of the present study which has recently been published.[22]

response to changed conditions. The point of maximum depression with chilling on the mucous membrane curve is plotted separately, as is the minimal point in the skin curve, instead of, as heretofore, the minimal mucous membrane value only, with synchronous skin value. Similarly, after rewarming, the average maximum skin value and the average maximum mucous membrane value are given separately, and the synchronous point on the other curve in each case is omitted.



TEXT-FIG. 3. Nasal reactions to chilling and rewarming. Temperatures of skin and mucous membranes of nasal cavity; composite graphs of Experiments 2, 3, 4, 6, 7, 8, and 9.

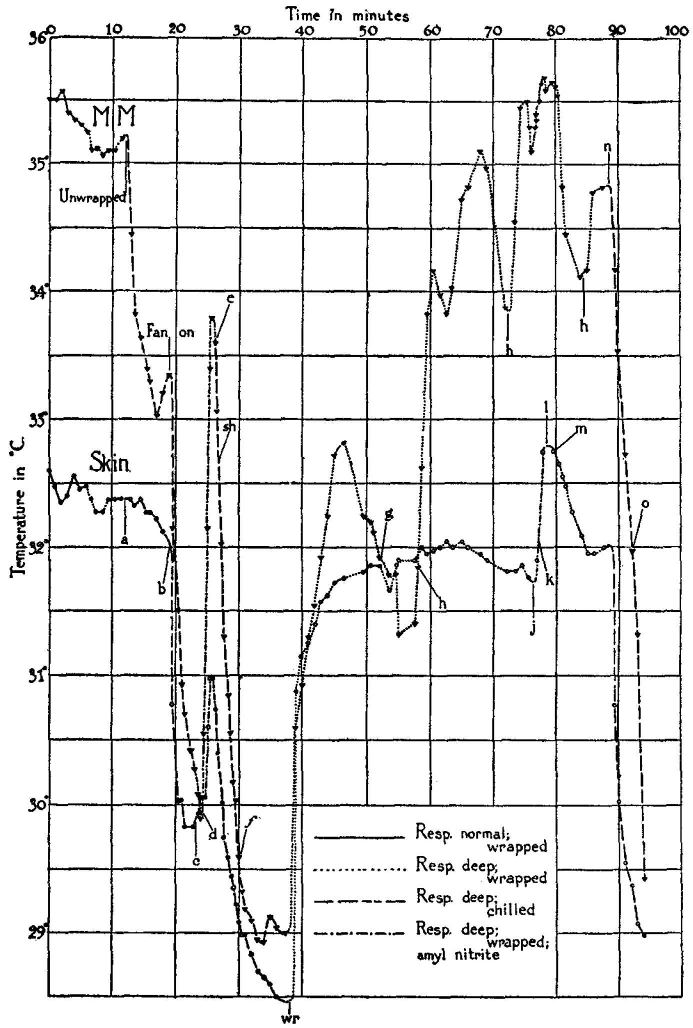
Depression of mucous membrane temperature with deepened respiration was only 0.65°C., and this was transient. Unwrapping the subject depressed mucous membrane temperature 1.4°, but skin temperature only 0.2°.[7] When the fan was turned on the subjects' backs, nasal mucosa and skin temperatures fell together, the former 3.95°, the latter 2.2°. The total mucous membrane temperature fall with chilling was 5.15°C., a very striking result; that of the skin was 2.4.° The average maximum mucous membrane recovery with rewarming was 3.7° (72 per cent), that of the skin, 1.8° (75 per cent).[8]

Experiment 2.—Subject 2, A. G. June 23, 1920, 1.14 to 2.48 p.m. Application on anterior end of left lower turbinate body. Room temperature 16–17°C.

Text-fig. 4[6] illustrates in an individual experiment the reactions brought out in the composite. With unwrapping at 0:12 the skin temperature is not depressed for 2.5 minutes; the mucous membrane temperature in the same interval falls 1.6°C. The pronounced drop in both mucous membrane and skin curves with fan on is interrupted by a sharp rise following amyl nitrite administration at 0:23.25, amounting, in the case of the mucosa, to 3.9°C., in that of the skin to 1.1°C. After rewrapping, the mucous membrane temperature in this experiment slightly more than regained its level of before chilling (in ten of the twelve intranasal experiments it remained somewhat depressed). Inhalation of amyl nitrite in this flushed condition of the mucous membrane resulted in a momentary depression of 0.2°, followed by a rise of 0.6°. Skin temperature rose 1°C., approximately the same as before. The experiment ends with a profound vasoconstriction of mucous membrane and skin vessels incident to a second chilling with the fan.

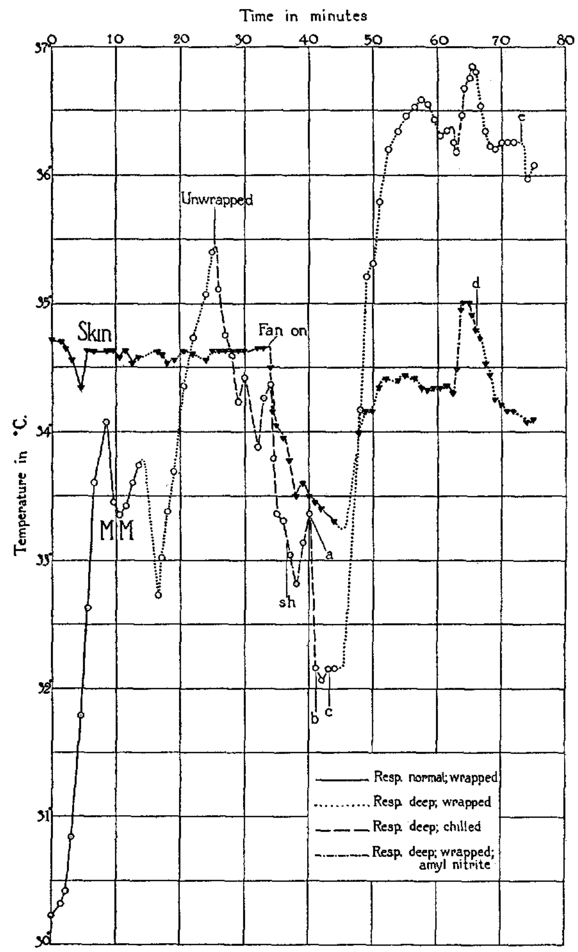
[7] Temperature values are calculated to one-hundredth degree as before, but in this paper are set down only to the nearest tenth (or twentieth when the value falls half-way between), since the accuracy of the method really does not warrant greater precision of statement than tenths of a degree.

[8] The fall in the mucous membrane temperature curve over the last 20 minutes is somewhat deceptive, and follows necessarily from the method of selecting the points for the composite graph. The points of maximum recovery are selected because they are maximal; the final points are merely those with which the experiment happens to end. In this graph a tendency of the mucous membrane applicator to slip forward, slightly out of position, probably contributed also to the apparent terminal temperature fall.



TEXT-FIG. 4. Reactions to chilling, rewarming, and amyl nitrite. Temperatures of skin and mucous membrane of anterior end of left lower turbinate body, Experiment 2. *a*, subject unwrapped; *b*, fan on; *c*, begins to inhale amyl nitrite; *d*, face has begun to flush; *e*, flush fading; stops inhaling amyl nitrite; *sh*, shivers; *f*, shivering; *wr*, fan off, wrapped (two extra blankets added); *g*, mucous membrane applicator feels all right to subject; *h*, subject readjusts applicator so that he can feel it pressing against turbinate; *j*, starts inhaling amyl nitrite; respiration much increased; *k*, skin flushed; *l*, stops amyl nitrite; *m*, flush fading; *n*, unwrapped; fan on; *o*, shivering hard.

Experiment 3.—Subject 3, M. F. W. June 25, 1920, 12 m. to 1.37 p.m. Application in left middle meatus, 3.6 cm. from opening of nostril. Room temperature 16.5–18°C.



TEXT-FIG. 5. Reactions to chilling, rewarming, and amyl nitrite. Temperatures of skin and mucous membrane of left middle meatus, Experiment 3. *sh*, begins shivering; *a*, not shivering; *b*, shivering; *c*, shivering hard; *d*, skin flush fading; *e*, left nose partially occluded; snuffs back mucus.

In Text-fig. 5 the marked upward trend of mucous membrane temperature except where interrupted momentarily by the deepening of respiration at 0:14 and again through the duration of the chilling, suggests one of the spontaneous variations in vasomotor state recognized as of frequent occurrence in the nasal mucous membrane, but little understood. Unwrapping the subject was without effect on the skin temperature but changed the rise in mucosa temperature into a fall of 1.5°C. The total fall in mucous membrane temperature, 3.3°, was with one exception, the smallest obtained in twelve intranasal experiments.

Experiment 4.—Subject 4, S. B. G. June 24, 1920, 9.19 to 10.36 a.m. Application near anterior end of left lower turbinate. Room temperature about 14°C.

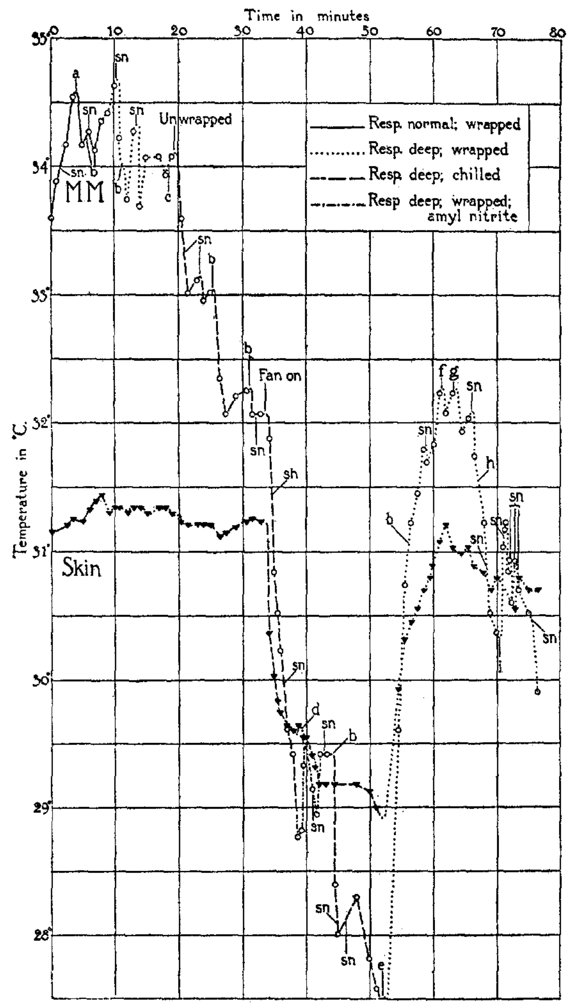
In Experiment 4, even at the low room temperature of 14°C., unwrapping was followed by only a very slight skin temperature fall, 0.2°, while mucous membrane temperature was depressed 2°C. The total mucous membrane fall in this experiment was the largest observed, 6.5°; the maximum recovery after wrapping was 4.65°, an incomplete return which seems to be more characteristic than the hyperemia after wrapping in the two previous experiments. Of the twelve nasal experiments, recovery was incomplete in ten, more than complete in two.

Amyl nitrite interposed a small rise in the mucous membrane temperature fall from chilling.

Some difficulty was occasioned in this experiment because the airway of that side of the nasal cavity in which the thermopile was applied became occluded with mucus. Under such conditions mucosa temperature tended to rise without local vasodilation, but snuffing back usually cleared the airway and showed the true course of the temperature curve (Text-fig. 6).

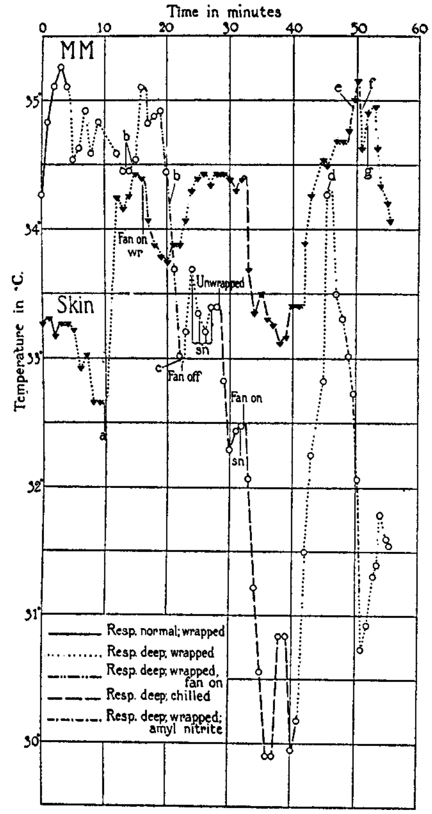
Experiment 5.—Subject 1, F. J. C. June 25, 1920, 3 to 4.21 p.m. Application on left nasal septum, 2.8 cm. from opening of nostril. Room temperature 18–18.5°C.

Text-fig. 7 shows well the effects of graduated chillings. The fan was turned on at 0:16.2 without removing the subject's wraps, which, however, were not quite adequate protection, for the subject felt cold before the fan was turned off. Mucous membrane temperature fell 2.1°C., an effect in which stray air currents can hardly have been



TEXT-FIG. 6. Reactions to chilling, rewarming, and amyl nitrite. Temperatures of skin and mucous membrane of left lower turbinate, near anterior end, Experiment 4. *sn*, snuffs back mucus; *a*, snuffs back several times; *b*, snuffs back twice; *c*, snuffs back three times; can then get air through nose; *sh*, begins shivering; *d*, face flushed; *e*, fan off, wrapped (two extra blankets); snuffs several times; *f*, feels warm; snuffs back; *g*, snuffs hard; *h*, feels warm; *i*, readjusts mucous membrane thermopile; can feel it touching turbinate, apparently in original site; sneezes.

concerned since the nasal cavity was already being ventilated by every respiration. The skin fall of 0.65° was doubtless chiefly due to direct cooling. With the turning off of the fan, skin temperature returned



TEXT-FIG. 7. Reactions to chilling, rewarming, and amyl nitrite. Temperatures of skin and mucous membrane of left nasal septum, Experiment 5. *a*, skin thermopile readjusted; *b*, snuffs mucus back twice; *c*, feels cold; snuffs back three times; *sn*, snuffs back; *d*, snuffs back three times; respiration had been too shallow; deepened; *e*, face flushed; *f*, flush gone; stops amyl nitrite; *g*, face very pale; mucous membrane applicator in correct position.

to control level, but mucosa temperature showed only a small recovery. Unwrapping depressed mucosa temperature 1.1° without particularly affecting that of the skin. Turning the fan on produced the usual marked fall in skin and mucosa curves, from which there was good recovery in both instances after rewrapping. The skin rise with amyl nitrite was characteristic; the negative mucous membrane amyl nitrite reaction, due doubtless to hyperpnea and to a fall in general blood pressure, was the only one obtained in the nasal experiments.

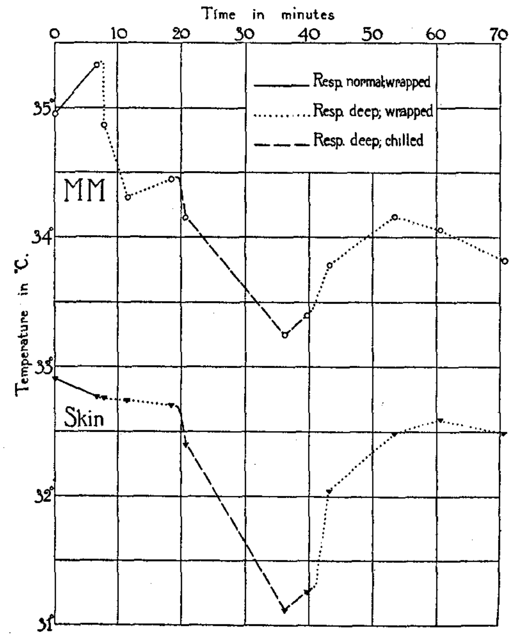
Twelve intranasal experiments were completed in the series, with seven different subjects. Without exception there were a clean-cut temperature fall with chilling, and recovery, partial or complete, with rewarming The sites studied, although all in the anterior half of the nasal chamber, included both the ordinary and the cavernous mucous membrane, and the reactions found—reflex vasoconstriction and ischemia with chilling of the body surface, and vasodilation with rewarming—we believe may be safely regarded as characteristic of at least the respiratory portion of the nasal mucous membrane in general.

The painful irritation of the nasal mucosa incident upon applying the thermopile tips within the nasal cavity caused often also sneezing, lacrimation, and discharge from the nose of clear mucus. The rhinorrhea was more marked usually on the side directly irritated but was present on both sides. It was little if at all affected by the diminished blood supply and shrinkage of the mucous membrane with chilling; of eight experiments in which an attempt was made to estimate whether discharge was more or less during chilling, the result was extremely dubious in four instances; the subject thought that there was more mucus during chilling in three instances and less in one.

Vasomotor Reactions in the Postnasal Space.

Composite Graph.—The characteristic responses of the nasopharyngeal mucous membrane to chilling and rewarming the body surface are shown in Text-fig. 8, a composite graph of seven experiments. The sites of application were all in the postnasal space, in five instances 3.3 cm., in one 2.8 cm., and in one 3.7 cm. above the posterior margin of the soft palate in the position taken during nose breathing with mouth closed. Four different subjects were used. The points selected for averaging and graphing are the same as those for Text-fig. 3, except that in that part of the nasopharyngeal composite which shows recovery after rewrapping the skin point synchronous with the point of maximum mucous membrane recovery, and the mucous membrane point synchronous with the point of maximum skin recovery, are also included.

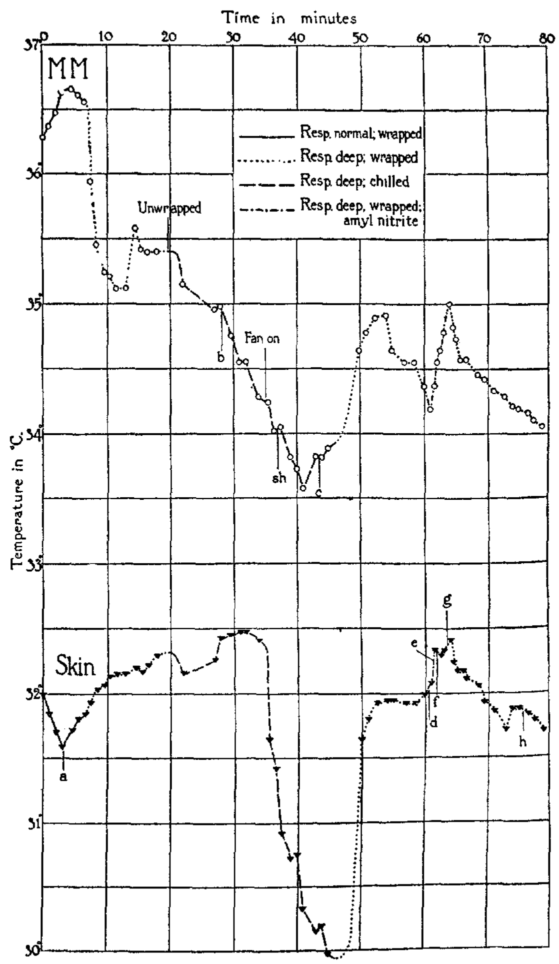
The mucous membrane temperature depression with chilling was 1.2°C., that of the skin 1.6°C. Recovery, measured from minimal points with chilling to maximal points after rewrapping, was 0.9°C. (75 per cent) for mucous membrane, 1.5°C. (94 per cent) for skin. The mucous membrane of the nasopharynx, then, like that of the



TEXT-FIG. 8. Nasopharyngeal reactions to chilling and rewarming. Temperatures of skin and mucous membrane of postnasal space; composite graphs of Experiments 10, 11, 12, 13, 14, 15, and 16.

oropharynx, and palate, has shown somewhat less tendency than the skin of the forehead to recover its normal blood supply upon rewarming after chilling.

It is to be borne in mind that these observed temperature depressions with chilling are somewhat larger than local vasoconstriction alone would make them; direct cooling contributed to the skin fall as explained above, and a lowering of the temperature of the respired air by diminished blood supply and shrinkage of the nasal mucous membrane with chilling must have contributed to the temperature fall of

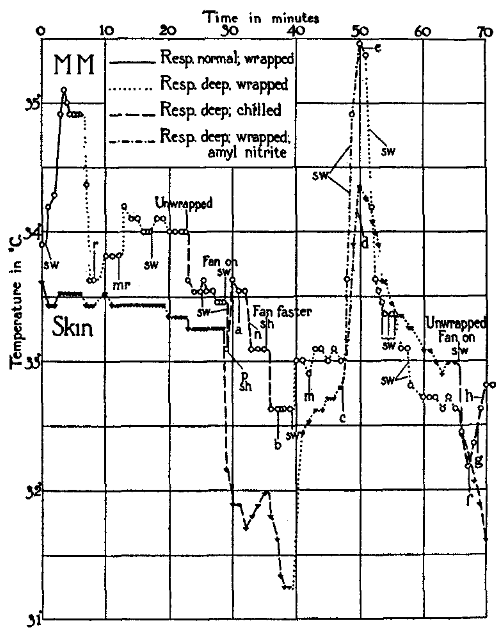


TEXT-FIG. 9. Reactions to chilling, rewarming, and amyl nitrite. Temperatures of skin and mucous membrane of postnasal space, Experiment 10. *a*, skin applicator readjusted; *b*, respiration had for several minutes been less deep than control; deepened; *sh*, shivering begins; *c*, has been shivering since started; *d*, starts inhaling amyl nitrite; *e*, face flushing; *f*, stops inhaling momentarily; *g*, throws away amyl nitrite ampule; flushed; *h*, subject feels neither warm nor cool.

the nasopharyngeal mucosa. The latter factor will be further discussed below.

Experiment 10.—Subject 5, J. C. McK. July 6, 1920, 2.48 to 4.07 p.m. Application on posterior nasopharyngeal wall, 3.3 cm. above posterior margin of soft palate. Room temperature 19.2–20.3°C.

A low threshold for the chilling vasoconstrictor reflex to the nasopharyngeal mucous membrane, just as with that of the nasal cavity, is shown in Experiment 10 (Text-fig. 9). Unwrapping the subject in the room at a temperature of more than 19°C. was followed by a fall



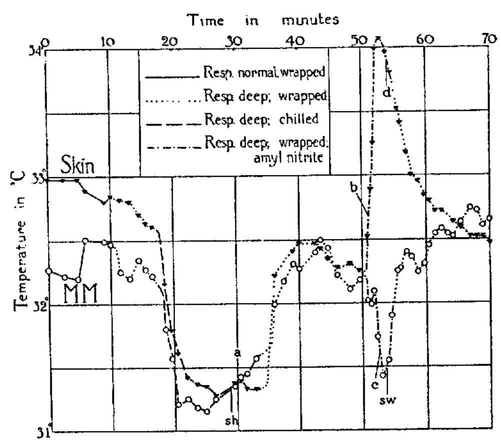
TEXT-FIG. 10. Reactions to graduated chilling, to rewarming, and to amyl nitrite. Temperatures of skin and mucous membrane of postnasal space, Experiment 11. *sw*, swallows; *r*, respiration uncontrolled for about 2 minutes; probably diminished; *mr*, slight movement of pharynx; respiration diminished for about a minute; *p sh*, pain at site of application; begins shivering; *a*, still shivering; fan slows down; *n*, no shivering; *b*, fan still faster; shivering; *m*, muscular contraction of pharynx; *c*, begins amyl nitrite inhalation; swallows five times; *d*, face flushing; *e*, stops inhaling; swallows twice; *f*, swallows three times; pain at site of application; *g*, swallows twice; *h*, swallows; shivering.

of 1.1°C. in the mucous membrane curve, by only a very small (0.15°) and transitory depression of that of the forehead. Recovery and amyl nitrite reactions are characteristic.

Experiment 11.—Subject 6, S. M. July 12, 1920, 10.30 to 11.41 a.m. Application on posterior nasopharyngeal wall, 3.7 cm. above posterior margin of soft palate. Room temperature 16–17°C.

Skin and mucous membrane temperatures in Text-fig. 10 show steplike depressions corresponding to the gradations in chilling. Interruptions in the mucous membrane fall at 0:29 (*p sh*) and at 0:67.2 (*f*) are synchronous with sensation of pain at the site of application and are doubtless due to movement of the applicator tip against the nasopharyngeal wall, which may cause a slight rise in temperature of the thermopile tips, mechanically, merely by pressing them more firmly against the mucous membrane, and by the irritation causing local vasodilation. The latter is probably much the more important factor. The amyl nitrite rise is very pronounced in each curve, 2.45°C. for mucous membrane and 1.55°C. for skin.

Experiment 12.—Subject 7, W. A. H. July 16, 1920, 10.20 to 11.30 a.m. Application on posterior nasopharyngeal wall, 3.3 cm. above posterior margin of soft palate. Room temperature 18.2–19°C.



TEXT-FIG. 11. Reactions to chilling, rewarming, and amyl nitrite. Temperatures of skin and mucous membrane of postnasal space, Experiment 12. *sh*, begins shivering; *a*, subject's back moistened; *b*, face flushing; *c*, swallows twice; can feel applicator against posterior pharyngeal wall; *sw*, swallows; *d*, flush fading.

The temperature depressions with chilling in Text-fig. 11 are characteristic. The recovery curves are of interest as ascending in each case slightly above control level. One other instance among the eight completed[9] nasopharyngeal experiments showed return of the mucous membrane temperature to control level with rewarming; in the other six experiments recovery was incomplete. The negative amyl nitrite reaction in Experiment 12 is the only one in the nasopharyngeal series.

Demonstration that Local Decrease of Blood Supply Underlies Observed Depression of Nasopharyngeal Surface Temperature.—The possibility arose in our minds that the observed depression of temperature of the mucosa surface in the postnasal space consequent upon chilling the body surface might be merely a secondary result of the widening of the airway of the nasal cavity and consequent loss of efficiency in warming the air passing through the nasal cavity into the postnasal space. It is obviously highly improbable *a priori* that the reflex reaction of vasoconstriction and ischemia, the presence of which has been demonstrated in the mucous membranes contiguous above and below the nasopharynx, *i.e.* that of the nose, oropharynx, and palate, should be lacking in the postnasal space. Nevertheless, it was considered worth while to exclude this possibility by definite experimental analysis, and this has been done by the three following sets of observations.

(1) More than doubling the depth of respiration caused less depression of nasopharyngeal mucous membrane temperature than did chilling the body surface. On the other hand, a smaller increase in depth of respiration was followed by a fall in the temperature of the air of the postnasal space more than three times as great as that which followed chilling the body surface. (2) In two parallel sets of experiments, one with application upon the nasopharyngeal and one upon the oropharyngeal mucous membrane, mucosa temperature depression with chilling was somewhat greater in the nasopharynx. The skin

[9] There are in the nasopharyngeal series also one experiment in which temperature depression occurred with chilling but the experiment terminated before rewrapping, and three experiments in which the usual reaction to chilling was masked, presumably due to the local vasodilation occasioned by trauma from an ill fitting applicator.

temperature fall, on the other hand, was somewhat greater in the oropharyngeal set, indicating more severe chilling in that set. But it has been demonstrated in former experiments in which the passage of air currents from the nose into the throat was blocked by plugs in the nostrils, and in which the subject breathed through the open mouth,[10] that the oropharyngeal mucous membrane temperature is depressed with chilling because of local diminution of its blood supply. The inference is that the nasopharyngeal temperature fall must also, at least in considerable part, be consequent upon local vasoconstriction and ischemia. (3) The depression of the temperature of the nasopharyngeal mucosa with chilling of the body surface has been greater than the fall in temperature observed under similar conditions in the air of the postnasal space. If the mucosa depression were merely the effect of a cooler air current passing over it from the nasal cavity, the fall of air temperature would have to be considerably greater than that of the mucosa surface cooled by it.

The evidence summarized above may now be given somewhat more in detail.

(1) For each of the seven experiments of the nasopharyngeal composite, measurement was made of the amplitude of excursion of the pneumograph levers on the respiration record. Twenty thoracic and twenty abdominal respirations were measured before, and a like number after the change from normal to deep respiration. The result showed an average increase in respiratory amplitude of 143 per cent; the rate of respiration was kept constant. The mucous membrane temperature depression which followed this increase to more than double respiratory depth amounted to only 1°C., whereas the mucosa temperature fall with chilling was 1.2°C.

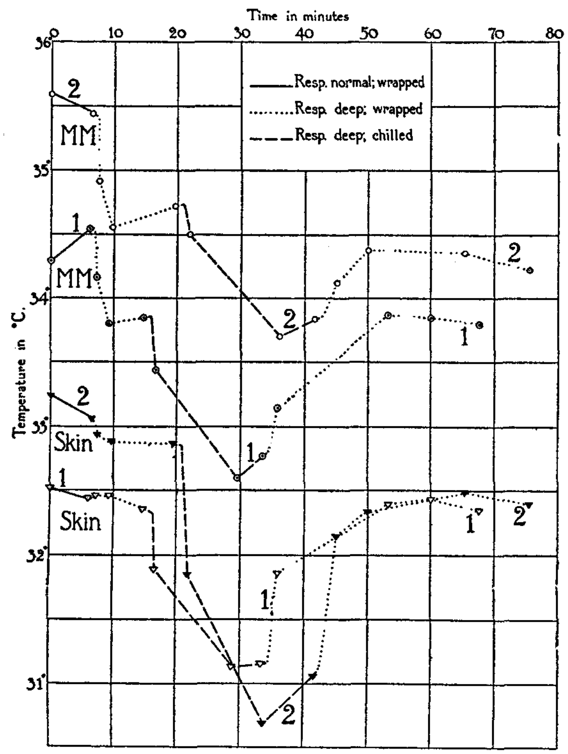
On the contrary, consideration of the two experiments in which the temperature of the air in the postnasal space was followed, shows in one a respiratory increase of 78 per cent, causing a fall in air temperature of 1.4°C. (see Text-fig. 15) and followed by a fall, with chilling, of 1.3°C.; in the other there was an increase in respiration of 191 per cent with corresponding air temperature depression of 2.95°C., followed by no temperature depression at all with chilling. The average shows an increase of respiratory amplitude of 119 per cent producing a depression in the temperature of the air of the postnasal space of 2.2°C., and chilling of the body surface producing a depression of only 0.6°C. (see Text-fig. 14).

The method used for estimating change in respiratory volume we are aware is not a precise one, but we believe the results sufficiently accurate to justify the

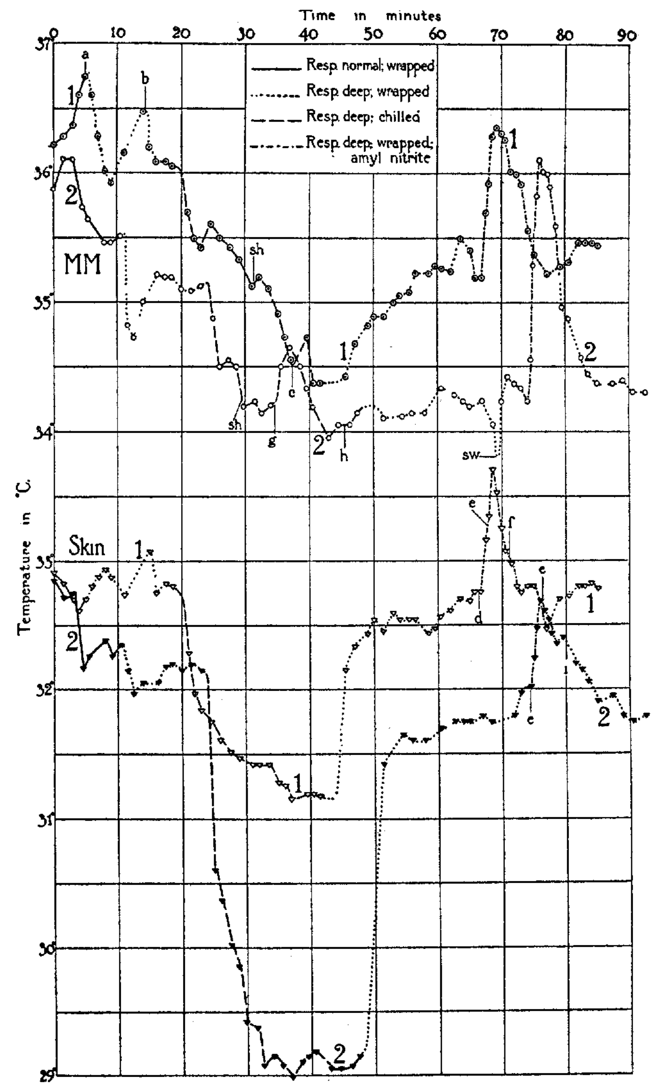
[10] Mudd and Grant,[1] p. 78; Grant, Mudd, and Goldman,[2] p. 92.

conclusion which we draw from them; namely, that the cooling of the air current from the nose into the postnasal space incident upon chilling the body surface is by no means sufficient to explain the observed fall in the surface temperature of the nasopharyngeal mucosa, and that some local change, *i.e.* local diminution of blood supply, is necessarily implied.

(2) The responses of the mucous membranes of the nasopharynx and of the oropharynx, under similar experimental conditions, to chilling and rewarming are shown in Text-fig. 12. Application was made in the nasopharyngeal group 3.3 cm. above the posterior margin of the soft palate of each of three subjects. For the oropharyngeal group application was made upon the posterior pharyngeal wall just below the posterior margin of the soft palate in each of the same three subjects. Experimental conditions were made as much alike as possible in the two sets, except that chilling was a little more severe in the oropharyngeal experiments. The values averaged and plotted in the composite curves are the same as for Text-fig. 8.



TEXT-FIG. 12. Comparison of reactions of nasopharynx and of oropharynx to chilling and rewarming. (1) Temperatures of skin and mucous membrane of postnasal space; composite graphs of Experiments 12, 13, and 14. (2) Temperatures of skin and mucous membrane of oropharynx; composite graphs of Experiments 17, 18, and 19.



TEXT-FIG. 13. Comparison of reactions of nasopharynx and of oropharynx to chilling and rewarming. (1) Temperatures of skin and mucous membrane of postnasal space, Experiment 13. *a*, respiration has been gradually growing shallower; changes to deep respiration; *b*, respiration slightly too shallow; deepened; *sh*, starts shivering; *c*, subject pushes mucous membrane applicator back so that he can feel it touching posterior nasopharyngeal wall; *d*, face flushing; *e*, face flushed; *f*, flush fading. (2) Temperatures of skin and mucous membrane of oropharynx, Experiment 17. *sh*, starts shivering; *g*, cleared throat for first time; still feels applicator touching on original site; *h*, still shivering; has been doing so ever since started; *sw*, swallowed for first time; with swallow, mucous membrane temperature rose 0.5°C.; *e*, face flushed; *i*, flush gone.

Skin depression with chilling was 1.2°C. in the nasopharyngeal set, as compared with 2.2°C. in the oropharyngeal experiments, a consequence, presumably, of the more severe chilling in the latter. Yet the corresponding depression of temperature of the nasopharyngeal mucosa was 1.25°C., that of the oropharynx, only 1°C. But the oropharynx, as mentioned above, had already been shown to possess the power of reacting with vasoconstriction and ischemia to chilling. If then the oropharynx under the influence both of a cooler air current and of local diminution of blood supply falls in temperature only 1°, it can hardly be supposed that the nasopharynx would fall 1.25° under the influence of a cooler air current alone, and the implication is again that the nasopharynx also must suffer a decrease in blood supply.

Two of the individual experiments of which the composite is made up are shown in Text-fig. 13.

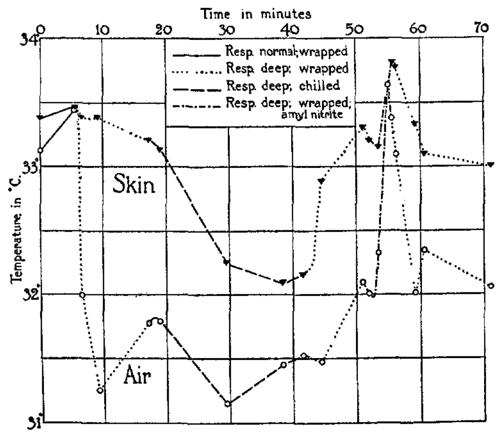
Experiment 13.—Subject 8, G. D. S. July 6, 1920, 11.17 a.m. to 12.42 p.m. Application on posterior nasopharyngeal wall, 3.3 cm. above posterior margin of soft palate. Room temperature 18.5–19°C.

Experiment 17.—Subject 8, G. D. S. July 10, 1920, 9.05 to 10.38 a.m. Application on posterior oropharyngeal wall, just below postérior margin of soft palate. Room temperature 18.2–19°C.

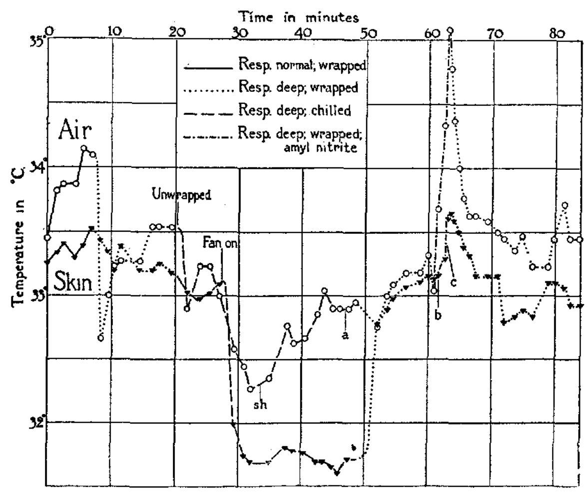
Experiments 13 and 17 are characteristic in their temperature depressions with chilling, partial recoveries with rewarming, and sharp rises with amyl nitrite. The skin depression in the nasopharyngeal experiment is 1.65°C. and that in the oropharyngeal experiment 3.2°C., as contrasted with corresponding mucous membrane temperature falls of 1.7° in the nasopharynx and 1.2° in the oropharynx.

(3) Variations in the average temperature of the air of the postnasal space are shown in Text-fig. 14. The curves are a composite of two experiments under conditions as closely similar as we could make them to those of the series graphed in Text-fig. 12, and with two of the same subjects. The values averaged and plotted are as usual the first and last readings of the experiment, the points immediately before and after each change of conditions, and the points of maximum response to changed conditions. In this graph, however, the skin points synchronous with mucous membrane minimum and maxima and the mucous membrane points synchronous with skin minimum and maxima are included. The response to amyl nitrite is also shown.

The thermopile tips were held in the air of the postnasal space by binding them upon the anterior side of the vertical arm of the nasopharyngeal applicator with the vertical arm 3.3 cm. in length, bending this arm slightly forward, and preventing its touching the posterior nasopharyngeal wall by a small pad of adhesive plaster on its posterior surface. With each respiration the galvanometer reading usually swung through from 4 to 8 mm., falling with inspiration and rising with expiration, and the observer tried to take the mean value as his reading in each case. The difference thus indicated (0.36–0.72°C.) between the temperatures of inspired and expired air is, because of the lag of the apparatus, probably considerably less than the actual difference.



TEXT-FIG. 14. Effects of deepened respiration, chilling, rewarming, and amyl nitrite. Temperatures of skin and air of postnasal space; composite graphs of Experiments 20 and 21.



TEXT-FIG. 15. Effects of deepened respiration, chilling, rewarming, and amyl nitrite. Temperatures of skin and air of postnasal space, Experiment 20. *sh*, starts shivering; *a*, still shivering; *b*, face flushing; *c*, face flushed.

The skin temperature depression with chilling shown in Text-fig. 14 is 1.1°C., almost equal to the fall of 1.2°C. in the comparable series of Text-fig. 12. The maximum depression of the temperature of the air of the postnasal space, however, is only 0.6°C. as contrasted with a fall of 1.25° in the temperature of the mucosa surface in the postnasal space. Mucosa cooling once more, then, cannot be explained merely by air cooling, which to be a sufficient cause would have to be several times as great.

Experiment 20.—Subject 8, G. D. S. July 20, 1920, 1.18 to 2.42 p.m. Thermopile tips in air of postnasal space, 3.3 cm. above posterior margin of soft palate. Room temperature about 20°C.

Text-fig. 15 shows one of the two individual experiments from which the composite graph of Text-fig. 14 is made. The fall in air temperature shown here is 1.3°C., twice that of the composite. The composite value is almost undoubtedly too small because of the averaging in of Experiment 21 in which no air temperature depression with chilling was observed. The failure of the air current to cool at all in Experiment 21 we do not know how to explain unless there was a very slight decrease in respiratory amplitude synchronous with chilling, an hypothesis which study of the respiration record leaves uncertain, since the excursion of the thoracic lever became slightly less and that of the abdominal lever slightly greater when chilling began. Upon rewarming in Experiment 21 air temperature rose 0.8°C. in 4 minutes, thus agreeing with the theoretical expectation.

Text-fig. 15 probably represents more nearly than the composite of Text-fig. 14 the true picture of changes in the temperature of the air of the postnasal space due to deepened respiration, chilling, rewarming, and amyl nitrite.[11]

Local Differences in the Vasoconstrictor Reflex with Slight Cutaneous Chilling.

The chilling caused by completely disrobing the very warmly wrapped subject in a room the temperature of which was slightly below ordinary room temperature seems to have been close to the minimal

[11] An interesting instance, presumably due to decreased blood supply and shrinkage of the nasopharyngeal mucous membrane in response to cutaneous chilling, occurred in July, 1920. The father of one of us, Dr. H. G. M., had been troubled with chronic inflammation of the nasopharyngeal mucous membrane, and in June, 1920, had the mucous membrane cauterized. The swollen membrane at the site of cauterization for some time thereafter on occasion occluded the opening of the left Eustachian tube. Coming in from the golf links one very hot day, he had the congested feeling in his left ear indicative of Eustachian occlusion. Upon getting into a cold shower bath, the feeling of congestion promptly disappeared.

TABLE I.

Comparison of Vasoconstrictor Reflexes to Various Peripheral Areas with Slight Cutaneous Chilling.

Experiment No.	Year.	Subject.	Room temperature.	Skin site.	Maximum skin temperature fall.	Mucous membrane site.	Maximum mucous membrane temperature fall.	Remarks.
			°C.		°C.		°C.	
2	1918	S. M.	20.3–20.75	Left infraclavicular fossa.	2.2	Hard palate.	1.5	Respiration not controlled.
3	1918	S. B. G.	18.25–18.9	Left supraclavicular fossa.	2.5	Soft "	1.4	Respiration not controlled.
6	1918	G. A.	19.05–19.7	Left supraclavicular fossa.	1.4	" "	0.05	Respiration partially controlled.
5	1918	S. B. G.	19.1–19.55	Left supraclavicular fossa.	1.95	" "	0.6	Respiration not controlled.
7	1918	S. M.	17.6–18.8			Oropharynx.	0.9	Respiration partially controlled.
4	1918	S. M.	19.3–20.6	Left supraclavicular fossa.	0.7	"	−1.2*	Respiration not controlled.
22	1920	S. M.	18–19	Forehead.	0.1	"	0.4	Respiration controlled.
23	1920	S. B. G.	17 (approximate).	"	−0.3	Right tonsil.	1.2	" "
11	1920	S. M.	16–17	"	0.1	Nasopharynx.	0.55	" "
10	1920	J. C. McK.	19.2–20.3	"	0.15	"	1.1	" "
4	1920	S. B. G.	14 (approximate).	"	0.2	Left inferior turbinate.	2.0	" "
2	1920	A. G.	16–17	"	0.25	" " "	2.2	" "
7	1920	S. B. G.	16.5 (approximate).	"	0.2	" nasal septum.	2.1	" "

9	1920	A. G.	16.5–16.8	Forehead.	0.4	Left middle meatus.	1.25	Respiration controlled.
3	1920	M. F. W.	16.5–18	"	−0.02	" " "	1.5	" "
8	1920	S. M.	17 (approximate).	"	0.2	Right inferior turbinate.	0.3	" "
24	1920	W. R. M.	17–18	"	0.25	" nasal septum.	5.0 (approximate).	" "
6	1920	S. M.	17–18	"	0.2	" " "	0.6	" "
5	1920	F. J. C.	18–18.5	"	0.1	Left " "	1.1	" "
21	1920	S. M.	18.5–18.8	"	−0.2	Air of postnasal space.	−0.65	" "
20	1920	G. D. S.	19.8 (approximate).	"	0.2	" " " "	0.6	" "

Average maximal temperature depressions caused by reflex vasoconstriction in response to chilling of body surface by disrobing warmly wrapped subject: skin at base of neck, 1.74°C.; skin of forehead, 0.13°C.; mucous membrane of palate and oropharynx (omitting Experiment 4, 1918), 0.82°C.; mucous membrane of nasopharynx, 0.83°C.; mucous membrane of nasal cavity, 1.78°C.; mucous membrane of palatine tonsil (one experiment), 1.2°C.

* In those experiments in which the temperature rose instead of falling with unwrapping, the point of maximum rise is preceded by a minus sign.

value of stimulation requisite to bring about reflex peripheral vasoconstriction, and it has been possible by this means to demonstrate a difference between the threshold of the vasoconstrictor reflex to the skin of the forehead on the one hand, and to the skin at the base of the neck and to the mucous membranes of the nose, throat, and palate on the other. Such mild chilling caused vasoconstriction and depression of superficial temperature in the skin of the supra- and infraclavicular fossæ and in the mucous membranes of the palate, tonsil, oropharynx, nasopharynx, and nasal cavity. In fifteen experiments in which its effect on the skin of the forehead has been observed, on the other hand, a slight rise in temperature in three instances, rather than a fall, was observed in the interval during which the subject was unwrapped but not exposed to the draft of the fan; of the other twelve experiments, in about half the relation between temperature fall and unwrapping was uncertain, and the slight depression observed may have been due to accidental variation; in the remainder the temperature fall seemed clearly to be referable to the slight chilling, but was very small, 0.1–0.25°C. Under the stronger stimulation of chilling with the fan the forehead showed clear-cut vasoconstriction.

It is quite probable that the figures given in Table I, for mucous membrane temperature fall in the palatine-oropharyngeal group, are somewhat larger than they should be; these experiments were performed before we realized that the involuntary deepening of respiration with chilling necessitated careful respiratory control.[12]

A single experiment,[13] not included in Table I but the results of which seem sufficiently clear-cut to warrant acceptance, was performed in 1918 with one thermopile on the normal skin of the thorax and the second upon the scar at the site of a breast amputation performed about 3½ months previously. The subject was chilled merely by unwrapping from the waist up at a room temperature of 15.65–16.35°C. The scar temperature fell 1.8°C., the skin temperature 2.6°C. in 5 minutes.

From the above data it seems safe to conclude that the threshold of the vasoconstrictor reflex in response to chilling of a distant cutaneous

[12] Mudd and Grant,[1] p. 69.

[13] Mudd and Grant,[1] Experiment 25, p. 94, and Fig. 14, middle curves.

area is higher for the skin of the forehead than for the skin of the covered portions of the trunk and the mucous membranes of the nasal cavity, postnasal space, throat, and palate.

Local Differences in the Recovery of Blood Supply upon Rewarming after Chilling.

Skin and mucous membrane blood supply is diminished in the sites studied as a quick reflex response to sudden cutaneous chilling, and is increased in prompt response to rewarming. But the recovery of blood supply has not typically been complete in any of the mucous membrane sites studied except the palatine tonsils. Two questions remain therefore to be answered: (1) To what degree is blood supply fairly promptly restored in the several sites under consideration? (2) What is the duration after cessation of chilling of the ischemia of the mucous membranes?

It is perhaps worth enumerating instances of the difficulties which beset an attempt to answer these questions and make us offer conclusions with extreme diffidence. We can never be perfectly certain that the conditions of application of the thermopile tips are identical before chilling and during rewarming a half hour or more later. Although the respiration charts are kept and studied, it is impossible to be sure that the respiratory ventilation of the mucous membranes remains constant within sufficiently narrow limits to make temperature differences of one- or two-tenths of a degree, separated by a long interval of time, significant. It was impossible to rewrap the subject precisely as he had been wrapped before the experiment. Superficial temperature and vasomotor tone do not run precisely parallel over such long intervals of time as are here under consideration. The variability in degree of recovery among the experiments is such that much more data than are available would have to be accumulated in order to form a basis for precise quantitative conclusions. Finally, we cannot be sure to just what degree such fine details of reaction as are now under consideration, duplicate, under experimental conditions, reactions as they would occur under natural conditions.

However, it is possible, with the above reservations always in mind, from analysis of the available data to derive a mathematical expression which expresses in some degree satisfactorily the relative tendencies of skin and mucous membranes to recover their blood supplies upon rewarming after cutaneous chilling, and this is done in Table II.

TABLE II.

Recovery of Blood Supply at Various Sites upon Rewarming after Chilling of the Body Surface.

Experiment No.	Year.	Subject.	Mucous membrane site.	Maximum mucous membrane temperature fall.	Maximum mucous membrane recovery.	Time required for maximum recovery.	Maximum skin temperature fall.	Maximum skin recovery.	Time required for maximum recovery.	Duration of experiment after wrapping.
				°C.	*°C.*	*min.*	*°C.*	*°C.*	*min.*	*min.*
15	1918	S. B. G.	Soft palate.	1.5	0.8	11	0.25	0.45	12.5	15.5
18	1918	A. G.	“	1.9	0.65	15.5	2.35	1.75	9.5	17
19	1918	S. M.	“ “	0.8	0.2	6.5	2.0	3.0	9.5	14.5
12	1919	A. G.	“ “	0.8	0.3	8	2.4	2.1	23	25
13	1919	S. B. G.	“ “	0.75	0.6	12	2.1	2.3	5	19
Average. Recovery index = 0.42				1.15	0.5	10.6	1.8	1.9	11.9	18.2
16	1918	S. M.	Oropharynx.	1.5	1.3	18	3.3	3.9	14	18
17	1920	G. D. S.	“	1.2	0.5	22.5	3.2	3.0	24.5	44
19	1920	W. A. H.	“	1.4	0.9	38.5	1.5	1.25	42	47.5
Average. Recovery index = 0.64				1.3	0.9	26.3	2.7	2.7	26.8	36.5
21	1918	S. M.	Nasopharynx.	1.8	1.45	6	1.95	1.85	4	13
10	1920	J. C. McK.	“	1.8	1.3	7.5	2.3	2.0	13.5	32.5
11	1920	S. M.	“	1.4	0.5	3.5	2.1	1.7	24.5	25.5
12	1920	W. A. H.	“	1.1	1.6	33	1.3	1.2	6	36
13	1920	G. D. S.	“	1.7	1.1	21	1.65	1.55	21	42.5
14	1920	S. M.	“	1.0	1.1	3.5	0.7	1.0	3.5	22.5
15	1920	S. M.	“	0.7	0.4	3	1.0	0.8	8	10
16	1920	W. A. H.	“	0.7	0.45	16	2.0	1.8	20.5	21.5
Average. Recovery index = 0.84				1.3	1.0	11.6	1.6	1.5	12.6	25.4
20	1918	S. M.	Left tonsil.	1.2	(3.9)*	7.5	2.0	1.8	5.5	20
				1.3	1.5	13	0.9	1.45	8	13
1	1919	W. G. E.	“ “	1.9	3.6	36.5	3.1	3.1	38	42.5
3	1919	S. B. G.	“ “	1.0	0.95	7	2.4	2.3	7	35.5
5	1919	S. B. G.	“ “	1.7	1.5	3	4.1	3.6	5	6
23	1920	S. B. G.	Right “	1.5	1.0	7.5	2.0	1.4	9.5	11.5
30	1920	A. L. E.	“ “	0.3	2.35	5.5	2.9	3.3	23	
31	1920	S. B. G.	“ “	1.2	1.2	3.5	1.1	0.8	14.5	15.5
Average. Recovery index = 1.66				1.25	2.0	10.4	2.3	2.2	13.8	20.6

* Interpreted in 1918 as an experimental error; now regarded as probably representing a true reaction of hyperemia.

TABLE II—*Concluded.*

Experiment No.	Year.	Subject.	Mucous membrane site.	Maximum mucous membrane temperature fall.	Maximum mucous membrane recovery.	Time required for maximum recovery.	Maximum skin temperature fall.	Maximum skin recovery.	Time required for maximum recovery.	Duration of experiment after wrapping.
				°C.	°C.	min.	°C.	°C.	min.	min.
2	1920	A. G.	Left inferior turbinate.	6.3	6.6	37.5	3.9	3.5	24.5	49.5
3	1920	M. F. W.	Left middle meatus.	3.3	4.5	12.5	1.3	1.1	10	30
4	1920	S. B. G.	Left inferior turbinate.	6.5	4.65	9	2.3	2.2	10	24.5
6	1920	S. M.	Right nasal septum.	3.65	1.2	2.5	2.9	2.4	28.5	36.5
7	1920	S. B. G.	Left nasal septum.	4.15	3.5	27	1.3	0.5	2.5	40.5
8	1920	S. M.	Right inferior turbinate.	6.6	3.9	8.5	3.0	1.7	7.5	28
9	1920	A. G.	Left middle meatus.	5.5	1.45	11.5	1.8	1.45	8	30
25	1920	S. M.	Right inferior meatus.	1.0	0.4	3	2.3	1.4	10	14
28	1920	A. G.	Right middle turbinate.	4.0	2.8	8	1.5	1.4	2	9
Average..............................				4.6	3.2	13.3	2.25	1.7	11.4	29.1
Recovery index = 0.92										

In all the experiments in Table II respiration was controlled and the site of skin application was the forehead. From the data tabulated the percentages of skin and mucous membrane recovery are readily computed, and from these the recovery index according to the following formula:

$$\frac{\frac{\text{Mucous membrane recovery}}{\text{Mucous membrane fall}}}{\frac{\text{Skin recovery}}{\text{Skin fall}}} = \frac{\text{percentage mucous membrane recovery}}{\text{percentage skin recovery}} = \text{recovery index}$$

The "recovery index" is thus an expression of the tendency of the mucous membrane to recovery of its blood supply referred to that of the skin taken as unity, and at least eliminates in considerable degree effects due to chance differences in the rewrapping of the subjects, and to alterations in general blood temperature and pressure.

Even though we bear in mind, then, all the reservations above, we believe that study of Table II necessitates again the conclusions which we reached from these and other data in 1918[14] and again in 1919;[15] namely, that palate and oropharynx have in our experiments exhibited considerably less tendency than the skin to regain their blood supply on rewarming after chilling, and remain for some time at least somewhat ischemic; and that the palatine tonsils have exhibited greater tendency than the skin to recover blood supply after cessation of chilling, and in several instances have become actually hyperemic.[16] The nasopharynx and nasal cavity, although the available data are hardly sufficient to be conclusive on this point, seem to occupy an intermediate position, and have, on the average, exhibited only a little less tendency than the skin to recover blood supply. The skin has sometimes regained a little more than its control blood supply, sometimes a little less; on the average it has returned about to control conditions; its temperature recovery for the 33 experiments tabulated has been 92 per cent.

Only a few experiments have been sufficiently prolonged after rewrapping to throw much light on how long the mucous membranes may remain ischemic. The following experiments (Table II) are probably most significant in this respect.

Experiment 13 (1920), nasopharynx (Text-fig. 13); maximum normal temperature recoveries of 67 per cent for mucous membrane and of 94 per cent for skin, reached in 21 minutes from the time of rewrapping. Temperatures were elevated by amyl nitrite, but thereafter returned to about the levels indicated. Duration of experiment after cessation of chilling, 42.5 minutes. Recovery index = 0.71.

Experiment 17 (1920), oropharynx (Text-fig. 13); maximum normal temperature recovery of 40 per cent for mucous membrane, reached in 22.5 minutes, and of 94 per cent for skin in 24.5 minutes. Rise with amyl nitrite; return thereafter to about levels indicated. Duration after cessation of chilling, 44 minutes. Recovery index = 0.43.

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[14] Mudd and Grant[1], p. 74.

[15] Grant, Mudd, and Goldman,[2] p. 93.

[16] This reaction of tonsillar hyperemia with warming has also been found by Azzi (Azzi, A., *Riforma med.*, 1921, xxxvii, 175) in experiments in which he repeated, confirmed, and extended our studies upon the tonsils.

Experiment 19 (1920), oropharynx; maximum temperature recovery of 66 per cent in 38.5 minutes for mucous membrane, and of 83 per cent in 42 minutes for skin. Duration after cessation of chilling, 47.5 minutes. Recovery index = 0.79.

It seems probable that a slight loss of body heat after cessation of chilling[17] may have accounted in part for the failure of the temperatures to rise higher, but this should affect skin and mucous membranes practically equally and could not account for the low recovery index of the mucous membranes.

DISCUSSION.

Tschalussow[18] inserted a tube, wrapped with vaseline-soaked cotton and connecting with a tambour, into his anterior nares, and packed his posterior nares. With his nose thus acting as a plethysmographic chamber, he studied the effect of various stimuli, as follows: (1) insertion of the legs half-way up the shin in water of 18°C.; (2) immersion in water of 40–41°C.; (3) electric stimulation; (4) needle pricks; (5) scratching of the skin of the lower extremity. All the stimuli resulted in essentially one effect—contraction of the nasal vessels. The most clear-cut and constant effects were given by the cold water.

Schade[19] has tabulated the reflex effects of chilling and the reactions to adrenalin administration upon the various organs within the motor distribution of the true sympathetic nervous system and finds the two, qualitatively at least, practically identical. Although we have made no attempt to study adequately the reaction of the mucous membranes to adrenalin, the one instance which was observed and recorded in 1918[20] showed a transient fall of 2°C. in the temperature of the palatine mucous membrane of a dog with adrenalin, and the rapid loss of body heat in the anesthetized animals was temporarily checked by adrenalin injection, doubtless due in part to cutaneous vasoconstriction. Further study would probably confirm this reaction of mucous membrane ischemia with adrenalin, since the vasoconstrictor fibers for the head are contained in the cervical sympathetic nerve.[21] The reactions to cutaneous chilling we have demonstrated thus constitute one more illustration of the reflex stimulation of the motor elements of the sympathetic system through chilling of the body surface.

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[17] Mudd and Grant,[1] p. 66.

[18] Tschalussow, M. A., *Arch. ges. Physiol.*, 1913, cli, 540.

[19] Schade, H., *Z. ges. exp. Med.*, 1918–19, vii, 355; *Münch. med. Woch.*, 1919, lxvi, 1021.

[20] Mudd and Grant[1], p. 60.

[21] Schäfer, E. A., Text-book of physiology, Edinburgh, 1900, ii, 141. Nagel, W., Handbuch der Physiologie des Menschen, Braunschweig, 1909, iv, 405.

The relation of this work to the excitation of upper respiratory infection has been fully discussed elsewhere[22] and we will not consider it here beyond reaffirming our belief in the probability of the hypothesis that the mucous membrane ischemia incident on prolonged or excessive chilling, especially if combined with overfatigue or loss of sleep or other cause of lowered resistance, may mediate infection by the indigenous pathogenic microorganisms.[23]

SUMMARY.

Devices are described by means of which the terminals of thermopiles may be held in stable apposition with the mucous membranes of the nasal cavity and postnasal space and local temperature variations thus followed.

Chilling of the body surface has without exception caused depression of the temperature of the nasal mucosa surface, amounting in some instances to as much as 6°C., and indicating marked reflex vasoconstriction and diminution of blood supply. With rewrapping, partial recovery of blood supply promptly occurs, although recovery has been incomplete within the duration of the experiments in ten of twelve instances.

Application of the wires within the nasal cavity has usually caused pain and discharge of clear mucus, sometimes also lacrimation and sneezing. The rhinorrhea has occurred both on the side directly irritated and on the opposite side, although on the former more abundantly, and has apparently been little if at all affected by the diminished blood supply and shrinkage of the mucous membrane incident to chilling the body surface. Discharge from the nose has been at most a rare occurrence in experiments in which the nasal mucosa was not directly irritated.

The temperature of the nasopharyngeal mucosa surface has also been depressed, typically between 1° and 2°C., with chilling of the

[22] Mudd, S., Grant, S. B., and Goldman, A., *J. Lab. and Clin. Med.*, 1921, vi, 175, 253, 322; *Ann. Otol., Rhinol. and Laryngol.*, 1921, xxx, March number.

[23] The chilling in our studies has always been sudden. Under circumstances in which it is very gradual, as for instance when a person sleeps in a bedroom the temperature of which falls slowly through the night, as Dr. F. C. Shattuck has suggested to one of us, we should expect less vasomotor reaction and less disturbance of the normal distribution of the blood.

body surface. This depression has also been shown to have local reflex vasoconstriction and ischemia as its basis. With rewrapping, prompt return toward normal occurs, but here also recovery of blood supply has in the majority of instances not been complete within the duration of the experiments.

The thresholds of the chilling vasoconstrictor reflex to the mucous membranes of the nasal cavity and postnasal space, tonsil, oropharynx, and palate and the threshold of the reflex to the skin of the trunk have been found to be lower than the threshold of the like reflex to the skin of the forehead. Disrobing the warmly wrapped subject in a room a little below ordinary room temperature has been found sufficient to cause marked vasoconstriction in the sites of the former group, but only slight or no vasoconstriction in the forehead.

A number of instances of cold or sore throat occurred among the subjects of the experiments, in several instances correlated with somewhat interesting bacteriologic findings which will be described elsewhere.[24]

It is a pleasure to thank the friends whose aid as subjects has made the present study possible.

[24] Goldman, A., Mudd, S., and Grant, S. B., *J. Infect. Dis.*, 1921, xxix (in press).