On the Phenomenon of Sudden Death in Animals and Man

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"VOODOO" DEATH—that is the title of a paper published in 1942 by Walter Cannon.[1] It contains many instances of mysterious, sudden, apparently psychogenic death, from all parts of the world. A Brazilian Indian condemned and sentenced by a so-called medicine man, is helpless against his own emotional response to this pronouncement—and dies within hours. In Africa a young Negro unknowingly eats the inviolably banned wild hen. On discovery of his "crime" he trembles, is overcome by fear, and dies in 24 hours. In New Zealand a Maori woman eats fruit that she only later learns has come from a tabooed place. Her chief has been profaned. By noon of the next day she is dead. In Australia a witch doctor points a bone at a man. Believing that nothing can save him, the man rapidly sinks in spirits and prepares to die. He is saved only at the last moment when the witch doctor is forced to remove the charm. R. Herbert Basedow in his book *The Australian Aboriginal*[2] wrote in 1925:

> The man who discovers that he is being boned by an enemy is, indeed, a pitiable sight. He stands aghast with his eyes staring at the treacherous pointer, and with his hands lifted to ward off the lethal medium, which he imagines is pouring into his body. His cheeks blanch, and his eyes become glassy, and the expression of his face becomes horribly distorted. He attempts to shriek but usually the sound chokes in his throat, and all that one might see is froth at his mouth. His body begins to tremble and his muscles twitch involuntarily. He sways backward and falls to the ground, and after a short time appears to be in a swoon. He finally composes himself, goes to his hut and there frets to death.

Cannon made a thorough search of reports from many primitive societies before he convinced himself of the existence of voodoo deaths. He concluded:

> . . . the phenomenon is characteristically noted among aborigines—among human beings so primitive, so superstitious, so ignorant, that they feel themselves bewildered strangers in a hostile world. Instead of knowledge, they have fertile and unrestricted imaginations which fill their environment with all manner of evil spirits capable of affecting their lives disastrously . . .

Having, after a painstaking search of the literature, convinced himself of the reality of this phenomenon, Cannon next addressed himself to the question "How can an ominous and persistent state of fear end the life of man?" To answer this question he had recourse to his experimental observations on rage and fear in cats. He believed that while rage is associated with the instinct to attack and fear with the instinct to flee, these two emotions have similar effects on the body. Thus, when either of these instincts is aroused the same elemental parts of the nervous system and endocrine apparatus are brought into action, the sympathicoadrenal system.

If these powerful emotions prevail, and the

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bodily forces are fully mobilized for action, and if this state of extreme perturbation continues in uncontrolled possession of the organism for any considerable period, without the occurrence of action, dire results may ensue.

Thus, according to Cannon, death would result as a consequence of the state of shock produced by the continuous outpouring of adrenalin. Voodooed individuals would, therefore, be expected to breathe very rapidly, have a rapid pulse, and show a hemoconcentration resulting from loss of fluids from the blood to the tissues. The heart would beat faster and faster, gradually leading to a state of constant contraction and, ultimately, to death in systole.

Cannon expressed the hope that anyone having the opportunity to observe an individual in the throes of voodoo influence would make observations on respiratory and pulse rates, concentration of the blood, etc., to test this theory.

I bring this up here not because I have had opportunity to examine human victims—I have not—but because I have observed what may be a similar phenomenon in rats and because our studies may throw light on the underlying mechanisms of sudden unexplained death in man, not only in voodoo cultures. We are still actively at work on the problem and consequently this communication must be considered simply as a report of work in progress.

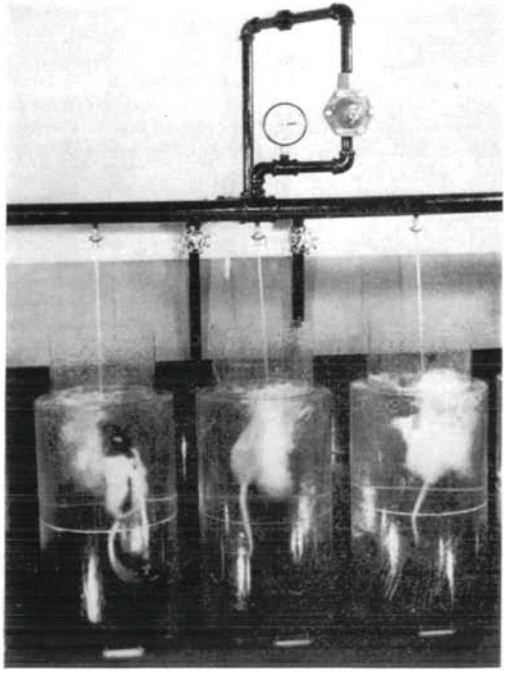

Fig. 1. Glass swimming jars, water jets, cold and hot water faucets, pressure gauge, and pressure regulator.

As so often happens, this phenomenon was discovered accidentally, as it were, during the course of other experiments. The first observation was made with Dr. Gordon Kennedy in 1953 while studying the sodium metabolism of rats on very high salt diets. To determine the amount of sodium excreted, three animals on a diet containing 35 per cent NaCl were kept in metabolism cages over large glass funnels. The urine was collected in a cylinder. To prevent contamination of the urine with this salt-rich food, the food-cup in each cage was placed at the end of a passageway, as far as possible from the neck of the funnel; however, despite our precautions, food was still dragged over the funnel, apparently on the whiskers or hair of the snout. In a further attempt to prevent this contamination the whiskers and hair were trimmed away with electric clippers. One of the three rats at once began to behave in a very peculiar manner, incessantly pushing its snout into the corners of the cage or into the food-cup with a corkscrew motion. Although before the clipping procedure it had seemed entirely normal, eight hours afterwards it was dead.

This observation was recalled a year or two later, while we were studying differences in the response to stress of wild and domesticated Norway rats. For these studies we measured endurance by means of swimming survival times, using specially designed tanks—glass cylinders 36 inches deep, standing inside glass jars 8 inches in diameter and 30 inches in depth (Fig. 1). A jet of water of any desired temperature playing into the center of each cylinder precluded the animals' floating, while the collar of the cylinder itself prevented escape. The study was started with observations on our domesticated rats. Figure 2 shows the relationship between swimming time (drowning) and water temperature. The ordinates show average (7 rats at each point) swimming time in hours, and the abscissas water temperature in degrees Fahrenheit. As can be seen, the average survival times were directly related to the temperature of the water; thus, the swimming times ranged from 10-15 minutes at 63-73° F., to 60 hours at 95° F., to 20 minutes at 105°.

The significance of this average curve was greatly reduced by the marked variations in individual swimming times. At all temperatures, a small number of rats died within 5-10 minutes after immersion, while in some instances others apparently no more healthy, swam as long as 81 hours. The elimination of these large variations presented a real problem, which for some time we could not solve. Then the solution came from an unexpected source—the finding of the phenomenon of sudden death, which constitutes the main topic of this communication. On one occasion while I was watching rats swim it occurred to me to investigate the effect of trimming the rat's whiskers on its performance in water. Would a rat swimming without whiskers show the peculiar behavior of the original rat in the metabolism cage?

Our observations were started with twelve,

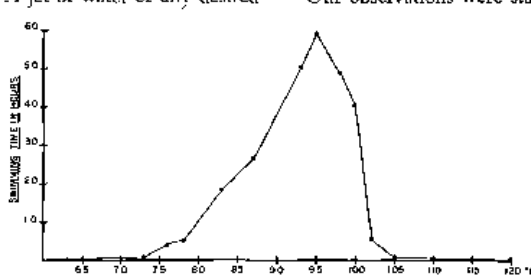

Fig. 2. Curve showing average swimming time (end point, drowning) of unconditioned tame domesticated Norway rats with relation to water temperature. Averages for 7 rats at each point.

tame, domesticated rats. Using electric clippers, the whiskers and hair of the facial area were trimmed before the animals were placed in water at 95° F., a temperature at which most intact, control rats swim 60 to 80 hours. The first rat swam around excitedly on the surface for a very short time, then dove to the bottom, where it began to swim around nosing its way along the glass wall. Without coming to the surface a single time, it died 2 minutes after entering the tank. Two more of the twelve domesticated rats tested died in much the same way; however, the remaining 9 swam 40 to 60 hours.

Five of 6 hybrid rats, crosses between wild and domesticated rats, similarly treated, died in a very brief time. We then tested 34 clipped wild rats, all recently trapped. These animals are characteristically fierce, aggressive, and suspicious; they are constantly on the alert for any avenue of escape and react very strongly to any form of restraint in captivity. All 34 died in 1-15 minutes after immersion in the jars.

From the results we concluded that trimming the rats' whiskers, destroying possibly their most important means of contact with the outside world, seemed disturbing enough, especially to wild rats, to cause their deaths. However, when we began analyzing the various steps involved in transferring the fierce, wild rats from their cages to the water jars without the use of any anesthetic, it became obvious that a number of other factors had to be taken into account. To evaluate the relative importance of these factors, it became necessary to follow the rats from the time they left their cages until they finally died at the bottom of the swimming jars.

Figure 3*A* shows the type of metal cage used for the wild rats. The bevelled end contains a hinged door, the flat end a sliding door. Figure 3*B* shows the black opaque bag used for catching and holding the rat. The open end is held over the sliding door at the flat end of the cage. When the sliding door is opened, the rat sees the dark opening—an avenue of escape—and usually within seconds, almost "shoots" in. The instant the rat is out of the cage its retreat is cut off by a rod pressed down across the mouth of the bag as shown in Fig. 3*C*. Figures 3*D* and *E* show how, by means of the rod, the rat is then pushed into the end of the bag, where it is firmly but gently prevented from turning. The head is located by palpation and is held between the thumb and fingers, with care not to exert any pressure on the neck, while the body is held in the palm of the hand. Over 2000 rats have been held in this way, and none has ever made an attempt to bite through the bag. The rat is then lifted and the black cloth is peeled back exposing its head and body. (See Fig. 3*F*.) Held in this way the rat

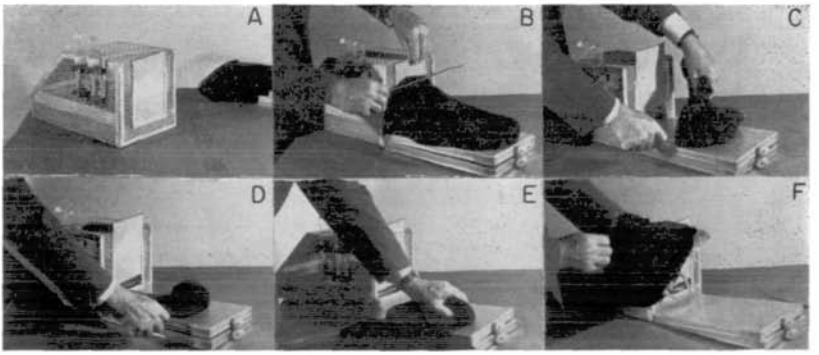

Fig. 3. Various steps involved in transferring wild rat from holding cage to black bag.

can neither bite nor escape; its whiskers can be trimmed, it can be injected, or it can be dropped directly into a swimming jar.

Thus, in evaluating the possible causes of the prompt death of the wild rats in this experiment, account must be taken of the following factors:

1. Reaction of the rat to confinement in the holding bag.
2. Reaction to being held in the experimenter's hand, while being prevented from biting or escaping.
3. Peripheral and cerebral vascular reactions to being held in an upright position. (The upright posture is reported to be fatal to wild rabbits.)[8]
4. Peripheral and cerebral vascular reactions to possible unavoidable pressure on the carotid sinus, carotid body, or larynx, exerted by the tips of the forefinger and thumb in holding the rat. (Prolonged pressure on the carotid sinus can produce syncope and even death in man as well as animals through its effect on vascular and respiratory mechanisms.)[4]
5. Reaction to the process of being clipped.
6. Reaction to confinement in swimming jar, with no avenue of escape.
7. Reaction of the clipped rats to a new situation, determined by the loss of stimulation from whiskers.
8. Respiratory reaction to immersion in water. (Diving produces marked slowing in heart rate.)[5]
9. Peripheral and cerebral vascular reactions to immersion in water at a temperature of 95° F. (Immersion in water of this temperature could produce a marked drop in pressure, resulting in cerebral anemia.)
10. Vascular reaction to nearly upright swimming posture. (Similar to, but presumably more marked than in No. 3.)

At present it appears that of all these factors, two are the most important: the restraint involved in holding the wild rats, thus suddenly and finally abolishing all hope of escape; and the confinement in the glass jar, further eliminating all chance of escape and at the same time threatening them with immediate drowning. Some of the wild rats died simply while being held in the hand; some even died when put into the water directly from their living cages, without ever being held. The combination of both maneuvers killed a far higher percentage. When in addition the whiskers were trimmed, all normal wild rats tested so far have died. The trimming of the whiskers thus proved to play a contributory, rather than an essential, role.

What kills these rats? Why do all of the fierce, aggressive, wild rats die promptly on immersion after clipping, and only a small number of the similarly treated tame domesticated rats?

On the basis of Cannon's conclusions and under the influence of the current thinking about the importance of the part played by the adrenals and the sympathetic nervous system in emotional states, and especially under stress, we naturally looked first of all for signs of sympathetic stimulation, especially for tachycardia and death in systole. Accordingly we were first interested in measuring the heart rate.

Electrocardiographic records were taken by means of electrodes consisting of short pieces of sharpened copper wire, each with a very fine insulated wire soldered to the blunt end. The pointed copper wires were dipped into electrode jelly and inserted under the skin of the two hind legs and one foreleg. They were inserted up the legs and the connecting wires were bent back up over the legs. A piece of plastic adhesive tape wrapped around the leg held the electrode and wire in place, insuring that a force exerted on the connecting wire would pull the electrode further under the skin rather than dislodge it. The connecting wires were brought together over the animal's back. In this way the rat could swim without getting itself entangled. Surprisingly, records taken under water were indistinguishable from those taken in air.

Contrary to our expectation, the EKG records indicated that the rats succumbing promptly died with a slowing of the heart rate rather than with an acceleration. Figure 4 shows portions of the underwater EKG record typical of a rat dying promptly after immer-

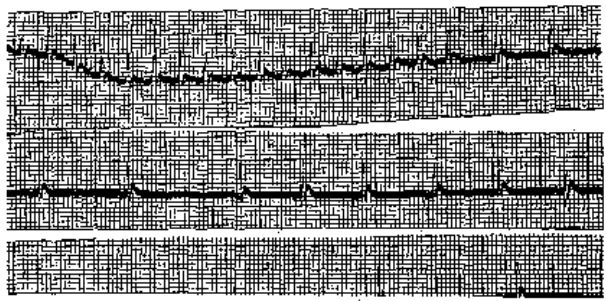

Fig. 4. Part of electrocardiogram on wild rat taken a few minutes after the rat's immersion in the water jar.

sion. Terminally, slowing of respiration and lowering of body temperature were also observed. Ultimately the heart stopped in diastole after having shown a steady gradual decrease in rate. As expected, autopsy revealed a large heart distended with blood. These findings indicate that the rats may have died a so-called vagus death, which is the result of overstimulation of the parasympathetic rather than of the sympathicoadrenal system.

It should be pointed out that the first response to stress, whether that of restraint in the hand or confinement in the water jars, was often an accelerated heart rate; only subsequently, with prolongation of the stress situation, was this followed by slowing. In some rats the latter response developed very promptly, in others not for a few minutes.

The following additional facts are in agreement with such a preliminary formulation: (1) pretreatment with atropine prevented the prompt death of 3 out of 25 clipped wild rats. By increasing the dose or by varying the interval between the injections and the test it might have been possible to achieve a higher survival rate; (2) domesticated rats injected with definitely sublethal amounts of cholinergic drugs (morphine, physostigmine, mecholyl), i.e., of parasympathetic stimulants, died within a few minutes after being put in the swimming jars. Thus, one-tenth of the LD 50 of morphine sufficed to bring out the sudden death response in these rats, in effect eliminating this distinction between domesticated and wild rats; (3) so far all the adrenalectomized wild rats tested still showed sudden-death response, indicating that the deaths were not due to an overwhelming supply of adrenalin. Thyroidectomy likewise did not prevent the appearance of the sudden-death phenomenon.

The situation of these rats scarcely seems one demanding fight or flight—it is rather one of hopelessness; whether they are restrained in the hand or confined in the swimming jar, the rats are in a situation against which they have no defense. This reaction of hopelessness is shown by some wild rats very soon after being grasped in the hand and prevented from moving; they seem literally to "give up."

Support for the assumption that the sudden-death phenomenon depends largely on emotional reactions to restraint or immersion comes from the observation that after elimination of the hopelessness the rats do not die. This is achieved by repeatedly holding the rats briefly and then freeing them, and by immersing them in water for a few minutes on several occasions. In this way the rats quickly learn that the situation is not actually hopeless; thereafter they again become aggressive, try to escape, and show no signs of giving up. Wild rats so conditioned swim just as long as domestic rats or longer.

Another observation worthy of record concerns the remarkable speed of recovery of

which these animals are capable. Once freed from restraint in the hand or confinement in the glass jars, a rat that quite surely would have died in another minute or two becomes normally active and aggressive in only a few minutes. Thus, in order to measure the maximum swimming time, we now try to free the rats of all emotional reactions to restraint or confinement by successively exposing them to these situations and freeing them several times beforehand. In this way we have succeeded in eliminating most of the individual variations and are now obtaining quite constant, reproducible, endurance records for both domesticated and wild rats.

It is interesting that a few wild rats have also been protected by pretreatment with chlorpromazine, without other "conditioning."

That the wild rats as compared to the domesticated rats seem much more susceptible to this type of death would suggest that they have a higher vagus tone. In agreement with this thought are the well-known observations that vagus tone is higher in healthy, vigorous individuals than in weaker ones; also that vagus tone is higher in wild than in domesticated animals in general.[6]

Other wild animals—rabbits, shrews, and pigeons—as well as some domesticated animals —ewes—are known to show a sudden-death response; whether of the same kind as we have described here is not known at present.

How can these results be applied toward the understanding of the voodoo-death response in man? Apparently the "boned" victim, like the wild rat, is not set for fight or flight, but similarly seems resigned to his fate —his situation seems to him quite hopeless. For this reason we believe that the human victims—like our rats—may well die a parasympathetic rather than a sympathicoadrenal death, as Cannon postulated.

Like the wild rat, primitive man, when freed from voodoo, is said to recover almost instantaneously, even though he had recently seemed more dead than alive. These observations suggest that the sudden-death phenomenon may be a one-time occurrence both in rats and man—in any particular circumstances, ending either in death or in immunity from this particular kind of death. In human beings as well as in rats we see the possibility that hopelessness and death may result from the effects of a combination of reactions, all of which may operate in the same direction, and increase the vagal tone.

There is the further suggestion that the incidence of this response varies inversely as the degree of civilization, or domestication, of the individual, since it occurs more frequently in wild than in domesticated rats and so far certainly has been described chiefly in primitive man, that is to say, in creatures living in precarious situations.

However, some physicians believe that this phenomenon exists also in our culture. Thus, according to Cannon, Dr. J. M. T. Finney, the well-known surgeon at the Johns Hopkins Hospital, apparently believed in it, since he absolutely would not operate on any patient who showed a strong fear of operation. Many instances are at hand of sudden death from fright, sight of blood, hypodermic injections, or from sudden immersion in water.

During the war a considerable number of unaccountable deaths were reported among soldiers in the armed forces in this country. These men died when they apparently were in good health. At autopsy no pathology could be observed.[7]

Of interest here also is that, according to Dr. R. S. Fisher, Coroner of the City of Baltimore, a number of individuals die each year after taking small, definitely sublethal doses of poison, or after inflicting small, nonlethal wounds on themselves; apparently they die as a result of the belief in their doom.

Summary

A phenomenon of sudden death has been described that occurs in man, rats, and many other animals apparently as a result of hopelessness; this seems to involve overactivity primarily of the parasympathetic system. In this instance as in many others, the ideas of Walter Cannon opened up a new area of interesting, exciting research.

References

1. Cannon, W. B. "Voodoo" death. *Am. Anthrop.* 44:169, 1942.
2. Basedow, H. The Australian Aboriginal. Adelaide, Australia, 1925.
3. Best, C. H., and Taylor, N. B. *Physiological Basis of Medical Practice.* (Fifth Ed.) Baltimore, 1950.
4. Weiss, S. Instantaneous "physiologic" death. *New England J. Med.* 223:793, 1940.
5. Irving, L. The action of the heart and circulation during diving. *Tr. New York Acad. Sc.* 5:11, 1942.
6. Clark, A. S. *Comparative Physiology of the Heart.* London, Cambridge, 1927.
7. Moritz, A. R., and Zamcheck, N. Sudden unexpected deaths of young soldiers. *Arch. Path.* 42:459, 1946.

International Congress of Child Psychiatry

Preliminary Announcement

The next International Congress of Child Psychiatry will take place in Lisbon in the summer of 1958. The present tentative plans are to hold the meeting on June 16 to June 21, 1958. The general theme of the Congress will be "Psychological Problems of Children from 6 to 10 Years." Outlines of proposed contributions should be submitted *before June* 30, 1957 to:

Mrs. Elizabeth E. Irvine, Secretary-General
International Association for Child Psychiatry and Allied Professions
14 Belsize Square, London, N.W.3, England.