the opening of the sixteenth century. Many, many people who deplored the tremendous orgy of vice and corruption which was then rampant in even the highest circles must have been ready to wipe out all the advances of the two preceding centuries. Even some of those who were unmoved by the enthusiasm of a religious revival must have been ready to subscribe to the verdict of that austere priest who passionately declared, "The whole world is in confusion; all virtue is extinguished, and all good manners; no living light abroad, no one who blushes for his vices." They may well have cursed the memory of Petrarch, who had prized so deeply his manuscripts of Homer and Plato, and longed so ardently for the ability to read them. They may well have wished that he and his followers had never spread a knowledge of the Greek language and ancient philosophy and literature throughout the Italian peninsula. But even when we read of all the evils of that time and even when we are inclined to attribute them all to the revival of learning, do we wish to turn back the pages of history and erase what the humanists accomplished? We who see the anarchy and chaos of those times only through the glass of history will confidently say no. Let us consider how three hundred years from now our present fearful falterings will be regarded. Will it be said that with the advancement of knowledge well under way and man's horizons just beginning to clear, the human race became so preoccupied with material ills that it succumbed to terror and, in the interests of security, curiosity was confined? Or will it be said that, frightened as they were and bowed down by much trouble and suffering, nevertheless in one country—the traditional home of freedom—men still retained confidence in the importance of the great intellectual adventure?

The next twenty-five years will probably answer these questions, although those who are alive may not understand the full significance of what transpires. To my mind a fair indication of the way the tide is running will be afforded by noting to what extent we are still interested in finding and supporting Andrew Carnegie's "exceptional man."

HOW CARS GO OUT OF CONTROL: ANALYSIS OF THE DRIVER'S REFLEXES[1]

By Professor YANDELL HENDERSON
YALE UNIVERSITY

A RECENT accident on a road by a lake in Switzerland—the most tragic and sorrowful event in the entire history of the motor car—challenges science. Accidents of this type are frequent. The conditions producing them exist in every modern car and every motorist. For the analysis and explanation of these conditions—particularly as concerns the reactions of the motorist—all that is needed is the application of well-established principles of neuro-physiology. Yet up to the present time no one appears to have made such an analysis.[2]

The type of accident is that in which the explanation commonly offered is that "the car went out of control." Yet in many cases subsequent examination demonstrates that the steering gear, motor and brakes were in good order.

In reality, it is the motorist who "goes out of control." Yet he acts in the only manner that his nature permits: the manner in which every human being always instinctively acts—and always will act—under the circumstances.

In all cars now, the throttle is controlled by the downward pressure of the motorist's right foot upon a pedal. Any occurrence that causes him suddenly to press down hard upon that pedal opens the throttle wide and causes the car to leap ahead with maximal acceleration. If he is then forced by his own reactions to continue to hold his foot clamped down hard upon that pedal, the car drives ahead until it collides with some object sufficiently solid to stop it or until it is overturned or until the motorist is thrown out of his seat. If he is thrown out and his foot thus removed from that pedal, the car slows down or stops. If, on the contrary, he retains his seat to the end, the speedometer is generally found to indicate a high speed at the instant of final crash. The critical feature in these accidents is, therefore, the continued pressure of the motorist's foot on the throttle pedal.

Normally the motorist regulates the speed of the car and its starting and stopping by means of several highly artificial reactions developed in his nervous system through training and experience. When speed is called for, he obtains it by a steady pressure with his right foot: an act that through all the ages prior to the invention of the motor car was never before employed by man or any of his animal ancestors to produce either rapid acceleration or continuous motion.

If the motorist wishes to go more slowly or to stop, he calls into play another much more complex acquired reaction. He draws his foot back, moves it a few

[1] Presented to the National Academy of Sciences, November 18, 1935.

[2] For a discussion of motor accidents at the British Association for the Advancement of Science, see the (London) *Times* of September 11, 1935.

inches to one side, and then presses down upon another pedal. The two acts—that by which he induces acceleration and speed and that by which he slows and stops the car—are thus closely similar in form, yet diametrically opposite in purpose.

That the human nervous system generally functions well even under these highly unphysiological requirements is indeed remarkable in view of the observations of Pavlov on "conditioned reflexes" in animals. He finds that, when two closely similar stimuli or "conditions" are used to excite quite different reactions, serious nervous disturbance may result from the "dilemma." In the motorist two widely different "conditions"—one calling for acceleration, the other for stopping—are required to excite two closely similar reactions. Yet, these two acts are seldom confused, even in emergencies. The motorist very rarely mistakes the throttle pedal for that of the brake.

What happens in serious cases of "car out of control" is rather that another reaction is called into play: a reaction so powerful that it instantaneously abolishes all the motorist's acquired or "conditioned reflexes." This reaction is as instinctive as that of a drowning man who seizes any one that tries to save him and drowns both. In the motorist the reaction concerned is the "self-righting reflex" that is excited by any sudden severe disturbance of equilibrium. It is a complex reaction in which the head, body, arms and legs are all involved. When it occurs in the driver of a car, the impulse that dominates him is to steady himself in his seat. He grasps the wheel with his whole strength. His arms stiffen, and he is as likely to steer off the road as along it. Simultaneously, and as part of the same nervous and muscular complex, he performs another act so instinctive that in most cases he is entirely unconscious of it. His legs are forcibly extended, and his feet are pressed down hard. It is the muscular act that Sherrington, who discovered it in the dog, named the "extensor thrust."

In less technical language this means that any motorist, no matter how experienced, who is suddenly and severely jolted, instantly reacts to steady himself in his seat; and in so doing he presses his foot hard down on the accelerator pedal.

If then the first jump of the car sends it along a course where it meets other jolts and bumps in rapid succession, the driver tries in vain to recover the equilibrium of his own body. And, as part of this effort, he continues to press down on the pedal and thereby sends the car completely "out of control." So far as he has time to think at all, he is amazed at the way the car behaves; yet that behavior is entirely due to the pressure of his own foot on the pedal and the grip of his hands on the wheel.

This righting reaction to recover equilibrium, and gain support for the body, is universal. It occurs in all animals. Even a newborn baby has it fully developed; and no training can eradicate its impulse. A cat, no matter how it is dropped, always twists its body around and lands on its feet. A man who slips on an icy pavement, or whose chair falls backward, instinctively tries to recover his balance. In all our ancestors through millions of years of rough-and-tumble life, this instinctive reaction has prevented many a broken bone and saved many a life. It is only now that the physiologically unwise adjustment of the pedal controlling the throttle of the modern automobile converts this instinctive reaction of personal safety into a reaction that often sends the motorist to disaster.

How completely the righting reaction may dominate a motorist is exemplified in an accident in which the following details were reliably established: At a cross-road a high-powered sport car, in which three young men were riding, struck some obstruction that gave it a severe jolt, but did not overturn the car nor break any essential part. The car then left the road, plowed six hundred feet across a field, leaving the ground at one place for twenty-five feet, and with the driver still in his seat crashed at high speed into a house.

In another accident that happened to come under my own observation, a young and inexperienced motorist in overtaking and trying to pass ahead of another car, "sideswiped" and locked with it. Both motorists then accelerated until they overturned one hundred yards further on. If, on the contrary, the power in both cars had been shut off, they would have come almost or quite to a safe stop in this distance.

In another case, directly reported to me, a lady was driving a small sedan at less than traffic speed, when a fast truck passed ahead of her. To give room she drove to the right until two wheels of her car went off the edge of the cement. In getting back on the cement, she accelerated and swerved over to the left side of the road; then still accelerating back to the right side; and finally at full speed to the left side again, where the car went off the road entirely and turned over.

It is quite certain that none of the four drivers included in these accidents could have explained why their cars behaved as they did. Nor could any of them, after the initial event, have removed the right foot from the throttle pedal. All that they were capable of doing—and in fact did—was to steady themselves in their seats by pressing down on that pedal, not merely with ordinary force, but with the whole strength of their legs.

In such cases as these there is an initial physical jolt. But even that is not necessary. In the records of accidents that I have examined, there are many in which the driver was first merely startled and re-

sponded—as every one normally does— by a momentary extensor thrust of his legs. The car jumped, thus jolting the driver, bringing his foot still more forcibly down on the pedal, and sending the car crashing into a tree, or another car, or through a railing, or off a bridge into a river. I recently saw a new car with an inexperienced driver jump forward, swerve, mount the sidewalk and smash against a telegraph pole. The perfect driver would not behave as he did; but even normal men and women often do. Many things may startle a driver who—with an apparently clear road ahead—is not paying very close attention. It may be a child or other pedestrian that suddenly appears directly in front of the car; or it may be another car cutting across or coming in from a side road. And thus startled he accelerates, instead of slowing down, and crashes into the other car or runs down the pedestrian.

On curves also a driver tends to feel himself out of balance, and often finds it hard to avoid increasing the pressure of his foot on the pedal, even when he realizes that his speed is excessive. This tendency to accelerate is one of the reasons that cars so often go off of curves and smash or turn over.

Such in brief is the explanation that physiology affords of why and how a car that is in perfect order easily "goes out of control." It reveals a hitherto unsuspected interaction between the car and human nature. We can not change human nature—not in a million years, even under the "new conditions analogous to natural selection" that (according to Professor Raymond Pearl) our automobiles are now imposing upon us. The change must be made in the cars. Yet, if it is not to meet serious opposition, it must be so slight that the motorist will scarcely notice it.

Fortunately, the "righting or equilibrium recovery reaction" itself suggests a natural remedy. The extensor thrust must itself either cut off the ignition or close the throttle, and thus slow the car. There are indeed already—as I learn—several inventions filed in the U. S. Patent Office so designed that heavy pressure upon the accelerator pedal will close the throttle. Their inventors believe that a "car out of control" indicates that the driver has mistaken the accelerator for the brake. Be that as it may; any such device is open to the decisive objection that many motorists, when overtaking and passing ahead of another car, are accustomed to press heavily on the accelerator. If, in doing so, they happened to close the throttle, the result might be a head-on collision with a car going in the opposite direction.

It seems to me, therefore, that it will be best to leave the right foot to do its worst, as at present; and to arrange for the left foot to counteract it and provide safety. For this purpose there should be another pedal for the left foot at the spot where that foot ordinarily rests when not applied to the clutch. Moderate pressure upon this safety pedal might blow the horn, as a means of accustoming the motorist to the use of this pedal. Heavy pressure on it should either counteract the pressure of the right foot on the accelerator and allow the throttle to close or it should turn another butterfly valve in the carburetor and shut off the power. Then, under an extensor thrust, the car would slow down instead of accelerating out of control.

It is one of the characteristic and reliable features of the extensor thrust of the legs that the two legs are always pushed forward and downward together. The thrust of the left foot affords, therefore, a reliable means of making the equilibrium reaction a means of safety, as it always has been in the past, instead of an ever-present cause of danger as it now is. It must do this by closing the throttle, not by cutting off the ignition; for interrupting the ignition with the throttle wide open would produce dangerously violent explosions in the muffler. A connection between the safety pedal and the accelerator or directly between the safety pedal and the carburetor involves no considerable mechanical difficulty.

Finally, in order to form at least a rough estimate of the importance of eliminating the "car out of control" factor in automobile accidents and fatalities, I have availed myself of the courteous permission of Mr. Michael A. Connor, Commissioner of Motor Vehicles, to examine the records of the State of Connecticut for the year 1934. Excellent as are the Connecticut statistics, neither these statistics nor any others contain as a separate class the "car out of control" accidents. The reason is, of course, that the peculiar feature of these accidents has not heretofore been realized.

It was necessary, therefore, to study the details of each accident, and in order to save time, the examination was confined to those accidents from which deaths resulted: 447 accidents, 470 deaths. It further appeared that for the accidents in which a pedestrian was the victim, the records generally are rather meager as to the behavior of the car. There are, however, enough cases in which the car mounted the sidewalk or went off its course to justify belief that the "out of control" element may be as important in accidents in which pedestrians were the victims as in those that killed only motorists.

The latter class of accidents which, with the aid of my assistant, Dr. L. A. Greenberg, I have studied in detail, included, during the year 1934, 191 fatal accidents. Among them we find at least 19 in which the accounts indicate clearly that the "car went out of control" essentially as described in this paper. The

details of these cases are very instructive. In six the driver suddenly saw another car directly in front of him and accelerated. In three, he lost control on a curve; and in three more he first touched another car or avoided a pedestrian, and then accelerated wildly and crashed fatally.

On this basis, and until fuller data are available, the element of "car out of control" may be taken as about 10 per cent. of all serious automobile accidents. Perhaps when this element is more generally looked for, it will be found in much larger percentage. And, if this estimate is correct, the addition of a safety pedal to the present controls of our cars should effect a corresponding saving of life.

Whatever the percentage, this is certain: Until all cars are fitted with a safety pedal or some equivalent device, accidents similar to that referred to in the opening paragraph of this paper will continue.

OBITUARY

CHARLES R. BARDEEN—1871–1935

ON June 12 there died at his home in Madison Dr. Charles R. Bardeen, dean of the University of Wisconsin Medical School. Death was due to a pancreatic lesion which was followed by liver involvements. His passing closed a life rich in accomplishment and brought a profound sense of loss to his colleagues, associates and the thousands of students in all parts of the world who had come under his influence.

Although Dr. Bardeen was born in Kalamazoo, Michigan, his boyhood home was in Syracuse, New York. The father was an educator and planned his children's education with care. Before entering college the son was sent to the Teichmann school in Leipzig, Germany, where he remained for a year. He always credited this experience with having laid the foundations for clear reasoning and a certain method of direct approach to fundamentals which later characterized all his research, teaching and public activities.

In 1889 he entered Harvard University, graduating in 1893. He was immediately attracted to the opportunities offered by a new medical school, that of the Johns Hopkins University. He entered the first class of this newly established institution and received his M.D. in 1897. Since his name headed the class roll alphabetically he was actually the first person ever to receive a Hopkins' medical degree. Among his classmates were three others who have made national reputations: E. L. Opie, W. G. MacCallum and Richard P. Strong.

Following his graduation, Dr. Bardeen was appointed assistant in anatomy at Johns Hopkins, later becoming associate and then associate professor. In 1904 he was called to Wisconsin by President Van Hise to be professor of anatomy and to lay the plans for a medical school. The founders of medical education at the university were President-emeritus Birge and Dr. William S. Miller, who in the department of zoology had already instituted certain pre-clinical courses. Dr. Bardeen was the founder of the medical school. In 1907 the legislature authorized the establishment of a two-year school and the professor of anatomy became Dean Bardeen. Around himself he collected a strong faculty. All the students were forced to do their clinical years at other institutions, but this quickly established the fact that unusually well-prepared young people were coming from Wisconsin. With the building of the Wisconsin General Hospital the full four-year medical course was established in 1925. Following this Dr. Bardeen secured the erection of the Service Memorial Institutes, the Student Infirmary and the Orthopedic Hospital.

In 1932, in honor of his twenty-fifth year of service as dean of the Medical School, the University of Wisconsin bestowed on him the LL.D. degree. At a banquet attended by many representatives of neighboring institutions, colleagues and students his portrait by Grenhagen was unveiled.

Dr. Bardeen was a scientist, an educator and an administrator. To these three fields of activity he brought enthusiasm and rare judgment. He thought continually of the problems confronting the physician, the student and the patient. He never spared himself and he was as free of ostentation as is humanly possible. The many honors that came to him were thus tributes to his real ability.

Dr. Bardeen's publications make up a list of ninety-six titles. The papers fall into two groups; those which are strictly scientific reports and those which deal with medical education. Among the former group are several that have far-reaching significance. His earliest work had to do with the changes following superficial burns and his observations are still quoted by all students of the subject. Many titles have to do with developmental and experimental morphology. He early made use of the x-ray and was one of the first in this country to study the effect of this form of energy on living cells. His scholarly work on the "Height-Weight Index of Build in Relation to Linear and Volumetric Proportions and Surface-Area of the Body" was published by the Carnegie Institution. This, as well as his study on the relation of heart size to body, might have opened up many physiological and clinical problems. He first proposed determining the size of the heart from its x-ray silhouette, a method