LIGHTNING, LIGHTNING-STROKE AND ITS TREATMENT

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LIGHTNING, LIGHTNING-STROKE, AND ITS TREATMENT

BY

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TO THE MEMORY OF

MY FATHER

WILLIAM HENRY SPENCER,

M.D.CANTAB., M.R.C.P.LOND.

WHO INTRODUCED AND GAVE TO HIS PROFESSION

THE FIRST BINAURAL STETHOSCOPE

FOREWORD

DURING an unbroken period of twenty-five years, whilst holding the appointment of Government Medical Officer in a large rural district in the Eastern Transvaal, frequent and serious catastrophes by lightning called for my presence, in order that I might qualify myself to give evidence at inquests in the large number of cases where such was called for.

It was this fact which led me to give the subject very serious attention in the early years of the present century. The Transvaal has long been considered to be the "Home of the Thunderstorm," and my own experience leads me to the conclusion that the designation is not unmerited.

My study of the subject was greatly assisted by the perusal of articles in the *Transvaal Agricultural Journal*, appearing during that time over the names of Dr. R. T. A. Innes, the Director of the Transvaal Observatory, and Mr. H. E. Wood, M.Sc., F.R.A.S., who has since succeeded Dr. Innes in the important post of Director. I here acknowledge with a keen sense of gratitude my

friendship with these gentlemen and also much assistance given me by them both.

Many years ago, I was advised by Dr. Innes to publish these investigations; but it is only now, with the bustle of more active life behind me, that I find myself with sufficient leisure to put in order for publication my many notes, records and conclusions.

While admitting that the theories of causation of lightning phenomena may perhaps be considered as outside the province of a medical man, I have thought it of importance to include some observations regarding them in order to elucidate its action and the injuries it produces.

Remembering my own difficulties in obtaining information on the subject in bygone years, I trust that this contribution to the literature dealing with lightning and lightning-stroke may be of use to others of my profession.

H. A. SPENCER.

"Ingleside,"
Wynberg,
Johannesburg.
November 4, 1931.

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LIGHTNING, LIGHTNING-STROKE, AND ITS TREATMENT

CHAPTER I

ATMOSPHERIC ELECTRICITY, ETC.

I HAVE thought that it would be of some interest and assistance to preface my remarks on the clinical aspect of lightning-stroke with some explanatory comments on the phenomena of lightning causation and discharge. In this connection, much that in the past was a matter of scientific speculation has in recent years been put on a sounder footing, the difficulties attending observation of and research into the mysteries of great altitudes having been largely overcome by the invention of the aeroplane and to some extent also by the automatic records brought back to earth by liberated balloons.

Atmospheric Electricity.

A constant supply of electricity is residual in the higher altitudes and more or less insulated there by the degree of dryness of the intervening

air. It is kept constant by the friction of wind and the continual evaporation of moisture upon the earth's surface.

Clouds floating in the atmosphere receive their electrification from this residual supply, off-loading, when surcharged, from one to another, and to the earth, in flashes of lightning. In 1749, Benjamin Franklin demonstrated the electrification of thunder-clouds by conducting the electricity from them along a wire attached to a flying kite, getting sparks at his end of the wire; later on, scientists abroad, when imitating this experiment, drew from thunder-clouds electricity of sufficient voltage to electrocute more than one of the experimenters.

Cloud Formation.

Invisible moisture rising from the earth into higher altitudes, and meeting there ever-decreasing temperature, is condensed into visible moisture, or vapour and cloud. When electrified, clouds are still further condensed and, becoming heavier, tend to subside again to earth. Clouds are thus condensed moisture become visible, and in the higher altitudes may contain frost and snow and ice, sustained and floating in space owing to rarefaction.

The electricity of clouds is drawn to the surface by induction of others near by and by the earth, enveloping them in a superficial layer; in this condition, some clouds attract and coalesce with others, while some repel each other. When thunder-clouds gather overhead and a storm is imminent, the attraction and repulsion described may often be seen in the activity of clouds rushing together, scattering or flying asunder.

Effect of Electricity on Moisture.

The effect of electricity on moisture may be watched in a fountain playing into a basin and is similar to what occurs in the higher altitudes. If the fountain jet be regulated until the water rises as fine as vapour, it will be seen, but not heard, to fall back into the basin with a barely perceptible splash; the drops of water composing it and constantly colliding with each other, will not coalesce on impact, but will rebound. If an electric discharge is directed towards the jet, it will at once contract into a compact stream of big drops which can be heard as well as seen falling back into the basin, the *slight* electrification of the water-drops causing their coalescence as they collide. When the electricity is brought closer to the jet and this is *strongly* electrified, the drops composing it will

mutually repel each other and scatter the stream in all directions.

At the beginning of a thunderstorm, it is often noticeable that a few big drops spatter down until a flash of lightning falls near by, when down comes the rain in torrents: the repulsion of strongly electrified drops of rain, partly neutralised by the flash, causes them to become changed to weakly electrified raindrops which coalesce on impact with one another. With every flash of lightning during a thunderstorm, the rain descends more heavily than before.

Earth Electricity.

The accepted explanation of the electricity residual in higher altitudes and of the formation and substance of intervening clouds will go some way towards answering such questions as: Whence comes the electricity which we periodically experience as lightning? Under what conditions and how conducted does it approach the earth?

This is not all, however, for the earth also has its residual electricity, and this is acted upon by that in the atmosphere which induces electricity in the clouds. Atmospheric electricity may as a rule be said to be positive, whilst that residual

and induced upon the surface of the earth is found to be negative. Indeed, every solid body, and not only the earth, may be considered to be charged with electricity which at once splits up into positive and negative kinds upon the approach of another electrified body, each body inducing in the other, and drawing to the surface contiguous to it, the opposite kind of electricity from that which it presents.

In connection with cloud and earth electricity, a highly charged cloud (P) approaching and moving above the surface of the earth (N) will attract the negative electricity of the earth, which may be imagined as following beneath the cloud as it moves, ever trying to reach and neutralise the cloud-charge. This earth electricity may be thought of as running up every projection skywards—*e.g.*, mountains and hills, spires and chimneys, tall trees, etc.—in its course over the earth, beneath the clouds. By some such projection, the negative electricity of the earth may be brought so close to that in the cloud as to neutralise the latter, without any gap to be jumped by a spark—*i.e.*, lightning. To assist this silent neutralisation is the object of all modern so-called "lightning-conductors."

CHAPTER II

THE PROTECTION OF BUILDINGS AGAINST LIGHTNING

THE old-time "lightning-conductor" erected upon buildings to protect them against lightning-stroke usually consisted of a solid half-inch iron rod which ran from the ground up the wall of the building to some pinnacle pointing skywards; its function, to put it crudely, was to arrest any flash of lightning *en route* to the building and conduct it safely and harmlessly to earth, there to be neutralised by the electricity of the earth. Modern conductors, however, are intended to convey earth electricity (N) cloudwards, in as large a quantity as is possible, with the object of silently neutralising clouds (probably surcharged with electricity (P)) passing overhead, and so avoiding the gap between cloud and earth which, but for this, means a flash of lightning.

It is well known that soft metals best conduct electricity—in fact, copper, bronzed to prevent weathering and erosion, is now invariably used for conductors; it may be less well known, how-

ever, that the surface alone of metals conducts the current and not their substance. Therefore, when it is desired to conduct current in large quantity it becomes necessary to increase the surface in the conductor, and to do this the cable is composed of a large number of fine copper wires, plaited, woven and interlaced into flat cable conductors of whatever width may be desired. The usual width of these is an inch or two, but they are sometimes made three and four inches wide. At each end of such cables the small wires are unravelled and spread into a brush formation.

The aerial brush of a cable of this description should project well above the highest point to which it is taken ; rightly, it should stand up about three feet, but often it is too flexible to stand up more than a foot. From this brush is thrown off into the air above the earth electricity which is being collected by the brush at the other end of the cable and which is drawn up the cable by induction from the clouds. The more highly-charged the clouds above and the greater the tension of the earth-current in the cable, the more will be thrown off to neutralise the surcharge ; for whilst negative current is rushing upwards towards the clouds, the positive current in and around the clouds dips down towards the earth,

definitely lessening the distance between them until they meet and silently neutralise.

Equally important is the earth brush of the cable, since if not treated correctly and scientifically it renders the conductor quite useless. This earth brush must be buried in the ground to a depth of from two to three feet, the ground around it being kept thoroughly damp (at least throughout the season for thunderstorms), or the brush may with advantage be taken direct into running water. This end of the cable has been housed successfully in a small concrete tank through which water always ran, keeping it full, and also sunk into earth beneath a storm-water drain; in both positions its activity was beyond question, as current could be heard escaping under tension up the cable.

Another important consideration when fixing such cables is the avoidance of all acute angles in taking the cable up the wall of the building, as current under tension will assuredly jump off at such elbows. The fastenings of the cable to the wall must, of course, be well insulated.

When surcharged clouds (which may off-load at any moment) are passing low over an efficient conductor of this type, the tension of induced current rushing up the cable from the earth may

be so high that a sound as of escaping gas—a hiss that waxes and wanes as clouds of varying tension float over it—will usually be heard. It is rather alarming to find oneself standing beside a conducting cable which suddenly begins to hiss loudly as a heavy, black thunder-cloud sweeps overhead.

The Hissing of Electricity under Tension.

Three very efficient cable conductors were erected a number of years ago at the Transvaal Observatory, which crowns the peak of a ridge close to Johannesburg. Referring to the hissing noise caused by escaping earth-current under considerable tension during thunderstorms, the Director once told me that it was quite alarming and eerie to be near the cables at such times, nor did it in the least assuage this feeling of alarm to know exactly what was happening in them.

Although in so prominent a position and visited every summer by numbers of very violent thunderstorms, no flash of lightning has struck the Observatory during the many years these cables have been in use, as Dr. Innes reminded me recently.

A newly built gaol in the Transvaal was, upon completion, efficiently protected against lightning

by a flat cable of copper wires, an inch in width, which ran up the outside wall beside the large double doors giving entrance to the gaol and was carried up to a peak above the porch, where the aerial end of it was brushed. The earth brush was sunk into the ground beneath a storm-water drain, where it would remain wet throughout the summer months, when thunderstorms are prevalent. I visited this gaol almost daily for several years, and on many occasions whilst waiting at the door for admission when heavy thunderstorms were hurtling by overhead, I have been startled by a loud hissing sound in the cable affixed to the wall, about six feet from where I was standing; the hissing would wane or wax loud in a very marked manner as some cloud came overhead or passed on again, the differences of sound being apparently due to the amount of the cloud's electric charge or surcharge. The warders attributed the hissing to "lightning escaping down the cable" and were so alarmed and apprehensive that they refused to approach the front entrance at times of threatening thunderstorms; instead, they sought admittance at the back of the gaol, where there was no cable!

I feel sure that this phenomenon must produce at least a feeling of apprehension in all who stand

near enough to a cable to hear it, even when they are acquainted with the cause.

The "Impulsive Rush" of Lightning.

Reference has been made to the positive electricity of the clouds approaching the earth when the intervening air is sufficiently moist to assist this; under the same conditions, the negative current from the earth has similarly been detected close to the clouds. It must, however, be realised that at times neither natural nor artificial conductors can effect silent neutralisation or prevent lightning; for when an already surcharged cloud receives a further charge which it cannot hold, it will, against the resistance of non-conducting air, instantly off-load its whole charge to earth in a flash of enormous potentiality. This is the flash of lightning described by Sir Oliver Lodge as the "impulsive rush"; against it, no known conductor is of the smallest avail.

Lightning has sometimes been described in the Press as having struck from the ground skywards, "apparently from holes in the ground," as one man put it. Such an occurrence has never been mentioned by any authority upon meteorology and may therefore be considered impossible.

CHAPTER III

THE FLASH OF LIGHTNING

CONSIDERATION of what takes place in the atmosphere as a flash of lightning passes through it will throw considerable light upon the injuries produced and the havoc sometimes wrought when animate and inanimate objects act as conductors. The general impression of the cause of these phenomena remained ambiguous and vague until Sir Oliver Lodge explained it and simplified the problem.

Bursting from a cloud and travelling with the velocity of light at 186,000 miles a second, the electric current rends a track to earth through the resisting air by the shortest route, friction against the particles of air superheating and raising them to incandescence. What we know as *lightning is the incandescent track of this electric current* through the atmosphere. *The flash really consists of a number of streaks*, a leash of incandescent filaments.

Photographs of lightning flashes have been taken frequently of recent years and reproductions of them published. From these we learn that what

appears to the naked eye as a single streak of lightning really consists of a number of streaks, and that they branch and rebranch in a network of incandescent filaments between the streaks, exactly as seen reproduced in arborescent burns upon the skin of some of the people struck by lightning.

Other results attending a flash are : (*i.*) instant *expansion and repulsion of the air* in contact with each streak and filament of current comprising the flash, and (*ii.*) the loud report caused by the recoil of the mass of air repelled all along the track of the flash, which is known as thunder. The tremendous thrusting force of such a leash of current through the atmosphere becomes very appreciable to us in the almost stunning report, and often by the very shaking of the ground beneath our feet when a flash falls in our vicinity.

The Varying Colour of a Lightning Flash.

At the time when "dry" thunderstorms are prevalent in South Africa, occurring week by week without rainfall—*i.e.*, at the end of winter and the beginning of spring—the atmosphere still suspends the finely divided dust blown up by the regular winter winds during several dry months. This dust bank extends into the

atmosphere for a considerable height, becoming evident, soon after the sun begins to decline each day, in the peculiar yellow light thrown over vegetation, etc., in the countryside. This yellow light deepens in tint, becoming first orange and then red as the sunset approaches and quite a sanguinary red just before the sun drops below the horizon. The dust producing these tints varies in accordance with the nature of the land from which it has been lifted by the wind: yellows and reds of ochres, reds of iron oxides and blacks of vegetable moulds.

The lightning striking to earth at this time of year and before showers have washed the winter dust out of the atmosphere is often seen to be of a marked yellow tint, and has frequently been described as red; and this is no doubt also due to incandescence of the dust suspended in the air, through which the flash passes. Once the atmosphere has been washed by rain the white light of the flash again obtains.

Extraordinary Effulgence of a Flash of Lightning.

Since photography succeeded in revealing the constitution of a flash the intense vividness of the light emitted is better understood. It is not un-

usual to be momentarily dazzled and "half blinded" by a flash of lightning at night, but the following unusual occurrence much impressed this vividness upon me.

During 1889, whilst encamped with British troops near the Valsch River Bridge, in the Orange Free State, I lay in my tent early one afternoon all but overcome by the almost insupportable closeness which precedes a thunderstorm. The short curtain (the "flies") hanging from the canvas wall of the tent to the ground was rolled up all round to invite a breeze, but the heat was unrelieved, and I looked out upon black clouds, lowering and rolling overhead and producing a gloom as of declining day. A few great drops of rain falling upon the canvas set me lowering the flies as quickly as possible; this was just completed and I was still kneeling up to the tent wall with my face towards the canvas when, with a crash that shook the ground, a great flash of lightning fell about 150 yards away, exactly opposite me. So vivid was the light in that moment that the canvas wall in front of me was transparent for the instant, and through the canvas I saw the flash strike to earth close to some blanket bivouacs and several khaki figures thrown back from it. The glimpse was instan-

taneous and showed me just where the flash fell, near bivouacs which had been erected since I retired to my tent. Hurrying to the door of the tent and looking towards the spot seen through the canvas, I saw the bivouacs and found that other khaki figures were hastening to the assistance of those lying upon the ground near the foremost shelter. Several of us joined them and gave what help we could. No rain fell, save a few isolated drops, and the clouds passed over very quickly, as so often occurs at the time of the year when dry storms are prevalent.

Returning home one night in the Transvaal, in a Cape buggy with a pair of good mules, my wife and I found the darkness so accentuated by the black clouds of a threatening thunderstorm, and the air so full with the feeling of electricity, that we felt a storm might burst upon us at any moment. We were still three miles from our village and nearing the end of a long journey, the mules, with their night-sight—for we travelled without lights in those days—finding their own way home upon a well-known road. Suddenly a flash of lightning of extraordinary vividness struck to earth away on our right, apparently a few miles away, and was followed by a deafening crash of thunder. In that instant, the whole

countryside was lit up and every pebble in the road revealed, far more distinctly than in the brightest sunlight; the mules, who had been closely watching the road as they trotted, fell back upon their haunches, throwing up their heads as though the road had risen and struck them. Had they not been tired, dazzled by the glare, and blinded by the succeeding inky blackness, a stampede might have resulted; as it was, a little talking to whilst they regained their night-sight reassured them, and soon they again moved forward towards the village. The storm passed over without any rain falling. Next morning, I was summoned to a tent in which seven men had been found struck by that flash; it was six miles away from the spot we had been driving over when the flash fell.

CHAPTER IV

INJURIES PRODUCED BY LIGHTNING-STROKE

FROM what has been said about a flash of lightning, it will be obvious that there are four elements in the flash, each producing characteristic injuries in the human beings struck by it. These four elements are:

1. The direct effect of the electric current.
2. Burns caused by the superheated air in contact with it.
3. Effects of the expanded and repelled air around the flash, seen wherever the smallest streak of lightning penetrates and especially in the rupture of clothing worn.
4. The "sledge-hammer blow" given by the compressed air pushed before the current.

These will be taken *seriatim*, as there is a good deal to be said about each one.

1. The Direct Effect of the Electric Current.

The current in a flash of lightning is of enormous voltage, but its effect upon man differs in no way from that emitted by an electric generator. This effect is seen upon the nervous system and

the muscles of the body, the varying degree of effect suggesting that the person concerned receives sometimes the whole flash, sometimes only a streak of the leash composing the flash. A high degree of shock, which may instantly electrocute the man, is produced upon the brain and general nervous system ; lesser degrees of shock are seen in those cases where stunning or a transient insensibility only is produced, from which patients recover without the assistance of treatment.

As it is never possible to gauge the severity of the shock produced in a man lying insensible from lightning-stroke, every case should receive the same treatment, begun as early as possible and continued as long as the slightest reaction is obtained. As a result of energetic and persevering treatment such as this, cases are on record of the recovery of patients who were to all intents and purposes dead.

The shock produces instantaneous anæmia of the brain, due to sudden, spasmodic contraction of all cerebral arteries, the muscular fibre in their coats being firmly contracted ; the heart suddenly and forcibly contracts and remains in that state until death supervenes or until, stimulated by the return of a little blood into its cavities, passive dilatation begins to occur. This contraction of

the heart forces its contained blood into the lungs, from whence its return to the heart is assisted by artificial respiration. Respiration ceases owing to the medulla and spinal cord becoming similarly bloodless. The voluntary muscles throughout the body and some of the involuntary—*e.g.*, the heart and arterial muscle fibres—contract suddenly and firmly. The flexor muscles being invariably more developed and stronger than the extensors, the limbs become firmly flexed and remain so for some time. Instances of this latter condition are occasionally recorded in those working near highly charged wires and inadvertently connecting with them; being electrocuted, they remain for some considerable time suspended to the wires by firmly contracted flexor muscles of arm or leg.

2. The Burns caused by a Flash.

Where the electric current of a flash of lightning runs over the skin of a person, a superficial burn, mapping out the course it took, is produced as a result of an instant's application of the air superheated by contact with the current. The burn consists of a red streak upon the limbs or body, of which the epithelial layer only is found to be charred or scorched—the heat evidently passing

over the skin at tremendous speed and in so doing producing what is aptly described as "the brush-burn of lightning." It heals rapidly, without scarring, upon survivors from lightning-stroke. In some cases, it is distributed in a most extraordinary manner, like filigree or arborescence; this is characteristic of lightning-stroke alone.

The "brushburn" of lightning may be divided into:

(*a*) Linear burns, which vary in width from $\frac{1}{8}$ inch to 1 inch.

(*b*) Arborescent and filigree burns. These indicate a severe stroke by a considerable streak of current, and are invariably seen upon those electrocuted.

(*c*) A surface burn, found beneath metals worn or carried by the person struck—*e.g.*, belt-buckles, watches, cigarette cases, money, keys, etc. This is not a linear burn, and is slightly more severe and extensive than is (*a*).

(*a*) Linear burns smart considerably for a little time after their infliction, if not smeared over with an unguent to exclude the air. In twenty-four hours they begin to be a light brown, and ultimately disappear entirely. Where this burn is broad, as in one I witnessed, which was more than an inch in width, it has probably been pro-

duced by more than one streak of current coursing over the skin.

(*b*) The counterpart of these filigree or arborescent burns may be seen in many of the photographs of a lightning-flash in the sky; in these, fine threads and streaks of current are seen to interweave to produce a network of filigree and arborescent appearance, exactly as seen upon the skin of those struck down by lightning. Numbers of sufferers have been found showing this very striking and extraordinary appearance of burn. I was never able to resuscitate anyone so badly burned as this.

(*c*) This burn is more or less irregular, and about the size of the metal object causing it. It occurs only under metals and is always isolated, not connected by streaks of burn. It can be attributed to some metal buckle, fastening or object, such as sock-suspenders, metal buttons, pocket knife, hooks of waist-belt, money, keys, watch and key chains, and similar objects, carried on the body of the person when struck. The clothes are often burnt into a hole over such objects, the objects themselves invariably being slightly fused and melted at one spot; and immediately beneath the fused metal the burn will be found. A blister is also generally seen where these

burns under metals occur, the greater severity of this form of burn being no doubt produced by the fusing of the metal.

All these various burns would be treated in the same way as ordinary burns, and protected from the air by some ointment as soon as possible.

3. Effects of the Expanded and Repelled Air in Contact with the Current.

When a flash of lightning strikes into a cavity anywhere, great mischief is produced by the expansion and repulsion of the air contained in it. Thus, when trees are struck, the hollows are blasted. Similarly, holes in the ground are blown open, masonry is moved from its position, enormous blocks are shifted and even dislodged from their place by the sudden expansion of the air beneath, around, or in them.

The effect of lightning-stroke upon the boots, clothing, etc., worn by those struck is very characteristic, and is entirely due to the expansion and repulsion of the air in their fabric, which bursts them asunder over or in the track of the flash. The result is remarkable, as the following case shows :

A young farmer, hoping to escape an impending thunderstorm, was hurrying on foot to his

homestead near by when he was overtaken by heavy rain and forced to seek shelter beneath some tall gum trees close to the farmhouse; he waited there, standing with his back about a foot from the trunk of one of them. This tree was immediately struck by a flash of lightning which ran down its bark to the ground, on its way to earth striking the man standing beneath it.

The man was struck upon the back of the head, his body being hurled nine yards away, where it was found, practically naked, his clothes, which were in shreds, trailing back to where he had stood beneath the tree. A hole in the back of his hat, about the size of a crown, was found to coincide with a lump upon the scalp, showing where he had been struck. From this spot, the current had coursed down his neck to his back, filaments of the current running down both arms to his hands and from these to the legs and to the ground. Arborescent brushburns mapped out the course of the current from the neck to the heels, with burns beneath his watch, pocket knife, and various metal buttons and buckles. His clothing was in shreds, having been burst over every streak of current; the edges of the bursts were ragged, with projecting threads, and smelt of singeing, but showed no sign of scorching any-

where; any charred threads must have been blown off the edges of the rents by the explosive expansion of the air in the fabric. His belt had been burst from his body and his sock-suspenders from his legs; his socks were burst down the back, his boots had also been burst and thrown off his feet.

He was dead when found, and no effort was made to resuscitate him.

4. The Compressed Air pushed before a Flash of Lightning.

Survivors able to remember being struck by lightning speak of a tremendous blow which bereft them of consciousness. This blow was believed to be delivered by the current or the lightning until Sir Oliver Lodge explained that electricity *per se* could deliver no blow and that this blow was given by the highly compressed air pushed before the current, or before the streaks of electricity travelling through the atmosphere.

A robust young farmer of twenty-eight was one afternoon using a one-horse cultivator over ploughed land when a thunderstorm came up. He wore a hat, shirt, trousers held in by a belt, socks, sock-suspenders, and boots. When rain began to fall he took off his shirt, pulled his hat well over

his eyes, and continued his work, stripped to the waist.

His elder brother returned to the house when the rain began and had just entered the doorway when a very vivid flash of lightning startled him, and a crash of thunder shook the ground. Rain now fell very heavily, and as the younger brother did not return from the field he went out to look for him. At the stable door he found the horse, still harnessed to an overturned cultivator, which it had evidently dragged back unguided from the field, and following the track made by the overturned cultivator the elder man came upon the younger, lying upon his face, apparently dead and almost naked, his trousers stripped from his legs but still hanging on to one foot by a bit of lining. There was evidence that his body had been dragged some yards from the place at which he had been struck and where his hat and boots still lay. The body was pulseless, pale, and cold, no respiratory movement being apparent, and, imagining him to be dead, the brother summoned the assistance of natives to carry the body to the house. The ground over which they had to pass was very rough and the shaking that inevitably resulted appeared to assist in the young man's resuscitation, some colour returning to his face.

On laying him down in the house they saw that he was breathing; he remained insensible, however, and after a while a neighbour rode into the village to summon me.

This man arrived during another thunderstorm and found me amputating a limb in a small house upon the outskirts of the village, the door open to give extra light; lightning was flashing and thunder crashing outside and it was almost impossible to hear his message. While I proceeded with my work he told me of what had happened, that the man was breathing, had regained his colour, and that his pulse appeared to be good, but that he was still insensible. Unable to leave the case I was engaged upon, I sent the messenger back with eight gr. 1 tabloids of calomel, instructing him to crush them and shake them on to the patient's tongue and wash them down with a teaspoonful of water. I was to visit the patient as soon as I could; but thunder, lightning, and heavy rainstorms persisted throughout the night, so that it was seven o'clock next morning before I reached his side.

The calomel had been given as directed, and about an hour afterwards the patient had opened his eyes and tried to formulate a remark; he had appeared annoyed that he could not do so, and

gave up trying to talk, signifying by signs that he had a very severe headache. He had drowsed through the rest of the day and throughout the night, and, thanks to the calomel, was able to record much relief to the headache before he dozed off again.

On my arrival he was easily aroused, appeared quite sensible, even able to smile as he told me that his head was better and drew my attention to a hard lump of effused blood at the back of it, beneath the scalp. He had still some difficulty in remembering his words, but told me that he knew nothing save that a "smashing, sledge-hammer blow" on the back of his head had "knocked him out."

His body showed only one brushburn, this appearing amongst the hairs on the back of his head and extending a little way down his neck; he had a few surface burns around the waist, beneath his watch and knife, which he had worn upon his belt, beneath the buckles of the belt itself, the buckles of his sock-suspenders, his keys, and a metal button here and there; all of these objects showed marked evidence of fusing upon their surfaces.

His soft felt hat was found to have an irregular hole, half an inch in diameter, in the back of the

crown; the edges of the hole showed no signs of scorching but smelt of singeing. The position of the hole in the hat corresponded to the lump upon the back of the patient's head, produced by the blow from the compressed air pushed before the flash. The leather belt he had worn was burst down the back and thrown from his body, the trousers showed a burst down each leg from the waist, socks and boots were burst down the back and showed the usual ragged edges; as regards the boots, it was as though a blunt knife had been thrust out through the leather.

No doubt his wet condition—rain must have been literally running off his body at the moment of the stroke—saved his life by conducting the current readily to earth. He was left without burns other than those beneath metals.

He refused nourishment for several days, taking only a little water, and slept continuously day and night. It was not difficult to arouse him, however. Whenever he was awake he complained a good deal of the aching of his head, and a few days after the injury I discovered that he had been quite deafened in the ear nearest the blow. His gait, too, was rather unsteady, though he moved about very little for a fortnight; his speech also remained slow, and he had difficulty

in remembering words and names for a number of weeks, during which time his head continued to worry him, aching upon the slightest exertion or movement.

Eight years later, there was no improvement in the hearing, and his brother described him to me as being very different from what he had been before the stroke. His speech was still slow and hesitating and he obviously had some difficulty in remembering words in general use. He had lost all his former cheerfulness and had become consistently morose and pessimistic.

I have no doubt that in this case the brain was definitely injured, both at the spot where the blow fell and, by *contra coup,* in the frontal region opposite. There must have been considerable bruising and also, I believe, a definite lesion of the superficial nervous layer of the brain. I even conceive it quite possible that the skull was fractured, perhaps into the middle ear on the side in which hearing was lost. He must have received a direct and terrific blow as he stood up in the open upon the hillside, and I was surprised that there was no visible lesion and no break in the skin where his head had been struck.

CHAPTER V

CONDITION CHARACTERISTIC OF DEATH FROM LIGHTNING-STROKE

THE attention of country magistrates is constantly drawn to the dead bodies of natives found upon the veldt, and it becomes necessary for them to decide as to the cause of death, whether it be from natural causes, from accident (such as lightning-stroke) or from violence. In such cases, the district surgeon is called in to give his opinion, and this makes it necessary that he should know, among other things, what are the characteristics of death from lightning-stroke. These are as follows :

1. When the head is struck (as is invariable), a lump of effusion beneath the scalp is very evident, generally upon the back of it. There will be no abrasion of the skin over it, as when caused by weapons of wood, etc.

2. Streaks of brushburn will be found upon the skin of the body in the neighbourhood of the original blow, appearing dark brown or black in natives, and red, a dusky red, in Europeans. The characteristic arborescent burns, like a reproduc-

tion of vegetation or filigree work, may be detected in places.

3. The body will be more or less stripped of the clothes worn at the time of the stroke, and these will be found lying near by, with the hat (if worn), and will show in the material bursts of the nature typical of lightning-stroke.

(*a*) These rents will smell of singeing, and some evidence of scorching may be seen on the edges.

(*b*) Leather boots, shoes, and belts will be found burst in the characteristic manner, generally down the back, and will be found lying near the hat.

4. Circumscribed burns will be found wherever metals were worn: beneath metal buttons on clothes, buckles of belt, etc.; and where such metals are found they may be seen to be slightly fused.

General Considerations.—The body will be well nourished, showing no sign of wasting, as from tuberculosis, etc., or as in death from sickness.

The body of a native was reported to be lying upon a hillside three miles from the village, under conditions considered to be suggestive of murder after a severe struggle. A native constable recognised the body as that of a man discharged from the local gaol early the previous morning,

on completion of his sentence, whom he had seen set off to walk to his kraal, sixty miles away, wearing a suit of store clothes and a soft felt hat, and carrying his old clothes, boots, etc., in a bundle slung over a stick carried across his shoulder.

The body lay upon the face; there was a suggestion of general flexion about all the limbs and the fingers of the hands. This condition was evident in the muscles of expression, the lips being parted in a grin (*risus sardonicus*) from contraction of the muscles concerned. A lump of effusion beneath the scalp was found upon the side of the head, but no abrasion of the skin over it as in the case of lumps caused by blows from sticks, etc. His body showed brushburns down the neck on to the back and limbs; arborescent burns were upon his back and small round burns where metals had been worn. His clothes had been torn to shreds and mostly off his body; his hat was not beside him, but clothing from his body and from the bundle he had carried over the stick was scattered all around, boots among them. A belt he had worn was burst in the manner characteristic of lightning-stroke and lay near by. The hat was found later, among some rocks, where it had evidently been carried by a gust of wind; it was

holed, in the manner typical of lightning-stroke, on one side of the crown, the hole corresponding to the scalp effusion. Evidently a streak of the current had rent open and scattered the bundle of clothing. The boots were not burst; the man had been walking barefoot when struck.

The evidence was complete of his having been struck by lightning as he toiled up the hillside the previous day, when a thunderstorm could be remembered to have fallen in that vicinity.

The very vivid flash which was described under the heading of *The Effulgence of a Flash of Lightning* as having struck a tent six miles away from us had a serious outcome. At the spot in question, alongside the railway line, five Europeans occupied a tent, being engaged all day at work upon the track. On this particular night, two lads riding push-bicycles without lamps found the way so dark—the sky being overcast by an impending thunderstorm—that they were unable to see the road from their saddles and had to dismount and push their bicycles. They were relieved to see a lighted tent not far from the road, and made their way towards it. Men personally known to them were among its occupants, and these, appreciating the lads' fear of lightning during the dry storm period, easily per-

suaded the two to stay in the tent with them until the storm had passed. The bicycles were thereupon brought into the tent and lashed to the tent-pole as high up as they could be got in the bell-tent; this gave more room for the legs of those lying or sitting up around the walls.

These arrangements were scarcely completed when the tent was struck by the great flash of lightning which had nearly blinded our mules and ourselves as we drove homeward six miles away. The tent was struck in the usual place, beside the peak, a hole being burst in the canvas there. The current ran down the tent-pole, but was checked and broken up by the slung bicycles into a veritable rain of electric sparks, which filled the tent, killing most of the inmates and severely burning every one of them, in the eyes, over their faces, and over every exposed part of their bodies. All were rendered unconscious. Next morning, a ganger, walking down the track to see why they were not at work, found them all lying, apparently dead, in the tent!

On my arrival a little later, I found that three of the men were dead. The other four, though still insensible, showed some evidences of life, and when moved groaned as though experiencing great pain. We succeeded in resuscitating all

four, but they were unable to see anything, their eyes being flecked closely, inside and outside the lids, with small burns, as also were their heads and faces. All were suffering very great pain. One of the four died from shock and exhaustion during the day; another, who survived for some months, also died without recovering his sight.

The two survivors used to come into the village now and then, and were examined by myself once a year for a renewal of their pensions. They were quite blind, from cicatrisation of corneal burns, and had to be led about by their children. From these two, much of the above detail was gleaned; one of them said that with the flash his hand went up to his eyes and the last thing he glimpsed between his fingers was the tent full of sparks, "like a rain of fire." One of these men died later, but the other was still alive after eight years.

The bicycles were badly fused from end to end; the tent was not set on fire, though holed, presumably from small bursts, in many places.

CHAPTER VI

CASES OF HUMAN INJURY CAUSED BY LIGHTNING-STROKE

THE incident recorded in a previous chapter in connection with the very vivid flash of lightning seen through the canvas wall of a tent at the Valsch River Bridge, in the Orange Free State, had in it elements of much clinical interest.

On that occasion, a squad of soldiers had just been brought down by a sergeant from the top of a steep hill overlooking the bridge, and had been dismissed on reaching an encampment of blanket bivouacs at the foot of the hill. While the men dispersed to their bivouacs to dispose of their rifles, the sergeant remained at the open entrance of the first bivouac, talking to the man lying down within, and leaning upon his rifle, which had the bayonet still fixed to it. Two or three of the men had just returned to the sergeant and were standing near by, when the flash of lightning fell amongst them, striking the sergeant and his rifle, bursting off his clothes, and hurling the rifle some ten or twelve yards away. The group of men standing near were also repelled,

all of them being thrown backward and falling to the ground, where they were soon rolling about in a confused, semi-conscious condition, groaning with the pain of the agonising contraction of muscles produced by the conduction of the current to their bodies. Their clothing was not burst and none of them showed any brushburns. The man lying in the bivouac had also been electrified, but not struck, and was found to be insensible. He was carried into the open, where willing helpers were soon at work rubbing upwards the limbs of all the sufferers, giving them some relief, and before long all but one were sufficiently recovered to be helped to make their way to the field hospital.

The sergeant was the only immediate casualty. His soft felt hat, clothes, stockings, and boots were burst off and flung away from his body, leaving him lying naked. Brushburns extended in lines from his hands, up the arms, to the body; there was a contused lump upon the back of his head (corresponding to a hole burst in the hat), from which other linear brushmarks ran down the neck to the shoulders; the shoulders gave the impression of having received another discharge of the current, for here, and down the back, brushburns occurred in arborescent and filigree

markings. The clothes, which were lying near by, showed bursting of the sleeves in shirt and tunic, the backs of both being literally in shreds and tatters. The rifle he had held at the time he was struck showed extensive evidence of superficial fusing and charring of metal and wood, from the point of the bayonet to the butt.

For some time, attempts were made by relays of willing men to resuscitate the sergeant, but without the slightest result. The electrified men were able to use their muscles and get about again in from two to six days, but the man who had been electrified when lying in the bivouac talking to the sergeant died a few days later in hospital—from weak heart and shock, I understand. This man's clothes showed no bursts, and his body was without brushburns, but he had had to be conveyed to hospital as he was evidently suffering great pain, in the muscles of the back especially.

I was approaching the village on horseback one afternoon at the end of the dry winter months, and hoping to reach home before a threatening thunderstorm broke, when a vivid flash of lightning suddenly struck to earth about a couple of hundred yards behind me. I distinctly heard the hiss of it through the dry atmosphere, followed by

a terrific crash of thunder which caused my horse to plunge violently. Remembering that I had just ridden past a few isolated native huts on the hillside, beside the road where the flash seemed to have struck, I glanced over my shoulder and saw smoke rising from the point of one of them. Having succeeded in controlling my horse, I rode to the hut, which was by then in flames. Natives from the other hut were carrying out from the burning structure a very young baby, apparently dead, and a native girl of about thirteen who was unconscious and still in a state of general flexion. Rushing into the hut to bring out anyone else left within, I had only time for a very cursory glance around before assisting to remove into the open a young Zulu mother who appeared to have had her meagre garments stripped from her body and to have been struck dead. In a very few minutes the roof of the blazing hut fell in.

Going into the next hut, I found that the recently-rescued baby had just begun to whimper ; ultimately it recovered entirely. Artificial respiration was at once commenced upon the girl and woman, by the latter's husband and brother, but without result in the case of the woman. The girl, whose clothes were intact and whose body showed no brushburns, soon began to breathe,

and then to cry out with the pains and cramps in her muscles; a native woman succeeded in relieving her by massage of her limbs. Fortunately, the girl had only been electrified.

A native described to me how they found the baby in the girl's lap, held firmly to her body by tightly flexed legs as she sat huddled up in a heap against the wall of the hut. From what the girl was able to tell when she recovered, it seems that the woman was nursing the baby when she was struck, that the baby was repelled and flung against the chest of the girl, and that the girl was repelled in turn and flung against the hut wall, where she subsided. Some sort of garment was still upon the baby when found, and as the child was only a week old and showed neither bruise nor burn it seems evident that its life was saved by the peculiar manner of its fall.

The brushburns upon the body of the Zulu woman were rather remarkable. The superficial charring of the skin was linear all over the body, and there was no arborescence; the lines were black, about three times broader than those usually seen, and appeared to run from the side of the face nearest the pole of the hut, over the body to the feet. The woman was very fat, and in every crease and fold of the skin over the body

and limbs—which must have been more than moist with perspiration when the woman was struck—ran a brushburn. One of the broadest lines of burn ran down the front of the chest and abdomen, a branch from it running across the chest, beneath the breasts, making a well-marked cross.

No rain fell in connection with this electric storm and the hut was burnt to the ground in a short time.

Ten years later, a native in this neighbourhood, remembering the occurrence, told me of the survival, without further trouble of any sort, of the baby and the young girl. He did not forget to remark also upon the extraordinary black cross upon the woman's body.

On another occasion, I was riding to the same village and along the same road, descending the hill to the river, and again hurrying to reach home before a threatening thunderstorm in front of me broke. Below me, at the foot of the hill, ran the river, precipitous rocks and banks upon the near side, but across it a flat expanse of ground running back a considerable distance, and upon this, several hundred yards back from the river's edge, stood a native rest-house, where those who walked in from their up-country staads found shelter while

waiting for the train which would carry them to the Johannesburg or other mines, where they worked.

As I rode forward down the hill, I watched several natives bathing in the river below me, and as I looked I saw raindrops begin to fall upon the surface of the water. Instantly all the natives in the water hurried for the bank, up which they scrambled, and snatching up their various bundles of clothing they tucked them into the hollow of their bodies and ran for the rest-house, with heads and bodies bent against the driving rainstorm. There seemed to be three or four natives running one behind the other.

The next moment, with a crash of thunder, a flash of lightning drove with the rainstorm across the flat towards the river, and the running boys disappeared for a second in a hazy flash which appeared to me to pass above them *en route* for the water behind. From my position on the hill-side, nearly a quarter of a mile above the happening, it was not clear to me whether the flash or the streaks composing it struck the running natives, but what I did see was that the bundles of clothing were flung from them and that they themselves were lying motionless upon their faces.

To reach the flat where the natives had been

struck down was some way round by road, across a bridge and back along the river bank, and by the time I arrived at the rest-house the first two natives had been carried in unconscious, laid upon the floor as dead, and covered with a blanket. The third, who was just being carried in, was, however, groaning lustily with the pain of cramped and contracted muscles. Other natives were set to rub this boy's limbs in the proper manner; he showed a single brushburn upon the front of one thigh, but was soon sensible, and acutely conscious of recently wrung muscles. The two who had been thought to be dead were resuscitated in the course of half an hour by artificial respiration.

The boy who had been running first had a lump of contusion upon the top (back) of his head, from which a brushburn ran round the back of his neck towards the chest, where it disappeared—either conducted to earth by the water running down his body, or, as I suspect, "spit off" his bent back on to the following boy, for the second boy had a brushburn on his back which appeared to begin at the root of his neck and to disappear just below the shoulder-blades. This second boy gave no trouble, but was soon breathing well, was conscious, and very voluble in voicing his muscular discomforts. The first boy struck, however, gave an infinity of

trouble ; he had a neurotic heart, without apparent lesion, and though he was resuscitated after a couple of relays of natives had pumped away at his chest, his heart failed two or three times and had to be restarted by further chest-expansion exercises. As he appeared at last to have recovered, though not yet properly conscious, I took advantage of a lull in the storm to ride on to my home, leaving the patient to the care of his confrères ; but alas for the zeal and perseverance of the average native, after I left the heart flagged once more, the boy was allowed to die that time, and remained dead ! Though still feeling sore, the two survivors were able to proceed to their mine by train the next day.

A matter which interested me in connection with these natives was their insistence that they had been knocked down by a blow ; when asked by whom they had been struck, however, they shook their heads. Both persisted in their statement that they had been felled to the ground, although they could not say by whom or by what.

CHAPTER VII

TREATMENT OF THOSE STRUCK BY LIGHTNING

THE person struck by lightning lies motionless and insensible; no pulse is to be felt at the wrist, respiration is suspended or has ceased, the face is pale, and the man is, to all appearances, dead.

Commence artificial respiration at the earliest possible moment, and to assist this:

1. Avoid any crowding around the patient. Admit all the fresh air possible.

2. Turn the head to one side and keep it in this position while you work; this will prevent the tongue from falling back and occluding the windpipe.

3. Your efforts will be materially assisted by laying the patient flat upon his back, with something in the nature of a pillow beneath the shoulders only; the head will then lie a little lower than the body.

These preliminaries adjusted as quickly as possible, take up your position behind the patient's head and proceed to work. First seize the man's arms by the wrists and pull them back quickly above his head, then take a fresh grip of the forearms, just beyond the wrists, and stretch

the arms back towards you as far as they will readily come, lastly bring them quickly down on to the chest, bending them at the elbows as you come, so that the arms fall on to the chest beneath the forearms, and with your whole weight behind you press the arms on to the chest. If these movements are carried out properly and energetically, you should hear something in the nature of a groan as the air is forced quickly out of the chest up the windpipe. Waste no time over this, but quickly bring the arms up above the head once more and give the same final stretch of the limbs up towards you before again flexing them upon the chest. If this extension is properly carried out to the utmost, you should hear the air entering the lungs with a sound as of a gasp. Continue these motions as long as necessary, losing no time in moving the arms up and down, but pausing at the end of the upward pull and again as your weight is applied to the chest through the arms.

By drawing up the arms to the utmost, you expand the chest, which then fills with air; by pressing upon the chest with the arms you empty it of air. Thus these motions cause an imitation of normal respiration. In pressing the air out of the lungs you also press blood from the engorged lungs into the heart, and as soon as its dilation is

thus forced it begins to pulsate normally, if there is any life in the patient, the natural stimulus to the heart's contraction being its dilation with blood.

It cannot be too widely known that by means of artificial respiration, intelligently and energetically applied, thousands of people who appeared to be dead have been brought back to life. In lightning-stroke casualties I have myself seen innumerable seemingly hopeless cases recover through such effort.

If the work of resuscitation is necessary for a long time, do not despair, but when personally unable to continue the work let others carry it on. When respiration first begins to reassert itself it is liable to stop again, and if this happens the motions described must be restarted and continued until respiration is fully and normally established. Partly resuscitated cases have been lost through want of perseverance at this stage.

When a man recovers, he groans and squirms with the pain of cramped and contracted muscles all over his body, and bystanders should here be asked to rub the legs upwards to relieve this and to assist the return of the circulation. As the circulation begins to return, the face becomes flushed and suffused.

The following illustration of the tonic contrac-

tion of muscle caused by the electric current in a flash of lightning is from my own experience.

An elderly gentleman and his son were walking arm in arm one night, outside their hotel, on the outskirts of a village in the Transvaal, when a flash of lightning struck the ground about two hundred yards away from them, just as they were walking over an outcrop of ironstone. They received a shock which threw them to the ground locked in each other's embrace, and rolled about upon the ground for some minutes, unable to disentangle themselves or to call out. Finally, some people outside the hotel, thinking they were fighting, separated them and assisted them to their feet, still unable to explain what had occurred.

Arriving on the scene soon afterwards, I found that they had regained their power of speech and were able to discuss the occurrence. They explained that their legs had suddenly ceased to support them and they found themselves rolling upon the ground with flexed limbs which they were unable to straighten or to disengage from each other. Although the people standing upon the hotel verandah, ten yards from them, had felt no shock, they had both come to the conclusion that they must have been electrified in some manner by the flash of lightning which they had

witnessed. Neither of them showed any brush-burns or other evidences of having been struck by lightning, but their muscles were very cramped and sore; the father told me that he could feel every muscle throughout his body.

Next morning, on visiting the spot where the lightning had struck the ground, I found an outcrop of ironstone similar to that outside the hotel; as I was able to trace it across the intervening ground without difficulty, it must have been continuous.

This was one of the dry electric storms which occur so regularly before the rainfall sets in. No rain fell on this occasion.

CHAPTER VIII

THE CONDUCTION OF LIGHTNING

NEARLY all the casualties from lightning-stroke in the Transvaal occur during the season when dry thunderstorms are prevalent. At this time of year, when the cold, frosty weather has passed and the heat by day steadily increases, clouds in ever-growing number appear in the sky which for months has been cloudless. An afternoon comes when, banking up in a few hours, heavy black clouds cover the zenith and betoken a possible thunderstorm. Many afternoons may come and go before this prediction is fulfilled, although at night lightning may be seen striking from cloud to cloud in the higher altitudes. Then one day, with a hiss and a crash of thunder, a tremendous flash of lightning thrusts through the dry air to earth, striking a tree, hut, tent, or house, perhaps a travelling cart and horses or waggon and oxen. It may strike down a chimney, in through an open door or window, and, not uncommonly, in at the back door, down the passage and out through the front door!

The vagaries of these impulsive discharges,

which disregard conductors and appear to follow no regular course, are amazing, With a church steeple or a high tree near by, a small tent, a tiny cabin, or a child in the street, will be struck. In consequence, the lightning from these dry storms strikes terror in those living in open and isolated parts of the country. For hours before the flash strikes, the atmosphere is hot and breathless, very still and electric, sounds being heard at, and reverberating from, long distances with singular clearness. It fills usually stout-hearted people with a nervous dread, an anticipation of impending tragedy; streets are deserted, vehicular traffic is suspended, people retire to their houses and shut themselves in, awaiting the arrival of a phenomenon imperfectly understood.

Happily, those who have studied electricity and have some understanding of its apparent vagaries, distilled generally from experience as well as from reliable reports of different happenings, have much to tell of precautions which, were they but duly regarded, would allay this nervous dread and prevent many a casualty.

Conduction by Hot Air.

There is ample proof of the dictum of Dr. Innes and others able to speak with authority that

a track of hot air offers more ready conduction to a flash of lightning bursting through dry air than does the cooler, more condensed air in its neighbourhood. It explains the vagaries of lightning: in striking down a chimney when a fire is burning in the grate, in entering through open doors and windows conducting a stream of hot air out of a house considerably overheated within by radiation from an iron roof, and in following the track of eighteen or twenty hot, sweating oxen drawing a waggon, or horses drawing a cart. In the case of a vehicle travelling through an atmosphere of disturbed air, which would be in motion for some time afterwards, the track left by the breathing, sweating animals would be more moist and heated, and therefore less dense, than the dry, still, cooler air in its neighbourhood. The smell of sweating oxen and horses attached to moving vehicles is evident for forty or fifty yards behind them, and even farther away than that.

It is quite a common occurrence in the Transvaal for oxen drawing a waggon to be struck while travelling along the country roads during the dry period. As a rule, farmers out-span just where they are when overtaken by a thunderstorm, tie the oxen to the *disselboom*, or pole, and themselves lie beneath the waggon till the storm has

passed. Such precautions are, however, sometimes disregarded in an effort to reach shelter before anything happens, and dire results not infrequently follow. The waggons are of very hard wood, and contain a good deal of iron, in bolts, bands, and bindings, while to the end of the *disselboom* is attached a long, heavy chain to which the oxen are attached in pairs, at intervals, by means of yokes.

On two occasions I came across waggons in the district of which the oxen had been struck by lightning "running beneath the waggon and along the trekchain"—as one farmer described it—killing some of them, rendering others temporarily insensible, and burning others upon their sides, which had been in contact with the chain. In both instances I concluded that the hot-air track had been responsible for conduction of the flash. At the time of which I write, this part of the Transvaal was, over very large areas, without tree or bush for many miles; it was merely grassed, and there was nothing to assist the conduction of a flash of lightning bursting from clouds over these areas, except possibly a travelling waggon, with its long track of hot air trailing behind it as it moved. It was invariably during the dry-storm period that these lightning accidents

occurred to vehicles, no rain falling to conduct or spread the flash and thus minimise the danger.

In isolated farmhouses, and especially in cabins and such places, it is quite exceptional to find fireplaces in any room, except the kitchen, which is usually a small lean-to outside; and throughout the season for such occurrences as thunderstorms, fires would only be in use there during the preparation of a meal. In country districts of the Transvaal it was rare to hear of lightning being conducted down a chimney into a house, no case coming to my knowledge; such an entry of lightning into a house was, however, read of at intervals. As is well known, the heat beneath the galvanised iron roofs of the average country house is terrific during the circulation of the sun through the zenith and insupportable to any form of life immediately beneath the roof; this superheated air pours out into the open through any available apertures, such as doors and windows, thus providing a track of conduction for any flash of lightning in the vicinity, into the house and out again, often enough without doing any damage, though occasionally quite the reverse. This method of entry of a flash is very common in country houses.

On one occasion, at a small farm in the district.

my wife and I witnessed, at uncomfortably close quarters, the passage of a flash of lightning through the house, fortunately without any ill results. The necessary duties which took me to the farm being completed, I was approaching the house with the farmer when a thunderstorm began to break, and we were not more than twenty-five or thirty yards from the back door of the house when a flash of lightning fell close to it. Entering the house by this door a moment or two later, we were struck by the strong smell of sulphur or, perhaps, of ozone—possibly a little of both—in the passage running through the house, from back to front. We found our wives in a small room off this passage excitedly discussing the action of a flash of lightning which they had seen, from the open door of their room, pass down the passage and out through the open front door! It was a very hot day, and especially hot inside the house, and hot air was no doubt pouring out through the open front door, the wind preventing its exit by the back.

Another such case, unfortunately attended by a casualty, came to my notice in the same district at about the same time. It occurred in a small, low cabin dumped down upon an extensive flat—without a tree or bush in sight for miles—and

occupied only by a man and his wife. A third of the one room the walls enclosed had been partitioned off into a bedroom, the flimsy partition reaching to the height of the walls, above which was the peaked roof, open to both rooms. In the bedroom stood a large iron bedstead, its head to the end wall, its side a few feet out from the back wall in which was a small window-aperture, about $2 \times 2\frac{1}{2}$ feet in size, unclosed in any way ; this aperture was about 2 feet beyond and a little above the foot of the bed, and on its right side. The cabin was roofed with corrugated iron sheeting.

It was a very hot, close day, with a thunderstorm almost overhead, and superheated air from beneath the roof would be pouring out into the open through the window-aperture. Overcome by the heat, the two occupants lay upon the bed, the wife, still clad in her dress, upon the right side, with the window-aperture a foot or more beyond and above her feet, and her husband, stripped to the waist, upon the left, with his back towards her.

Suddenly, a flash of lightning struck behind the house, possibly splashing off the iron roof, past the window, to the ground ; from there, striking obliquely through the small window-aperture in the back wall, it passed over the woman's feet,

bursting the sleeve from her left arm and burning the arm in passing, and striking the man in the middle of the back hurled him off the bed on to the floor—a corpse. The husband was thus electrocuted as he slept. The wife was awake at the moment of the flash and saw it enter the aperture and pass over her, but she remembered no more.

The woman showed only one linear brushburn, obliquely across her left arm. The man's back had arborescent burns across it, running round the sides towards the front. Some of the current was probably conducted by the iron bedstead to the floor, which was of stamped earth, made very smooth. The quilt upon which the two had rested was seen to be burst in several places around where the man had lain when struck.

Still other cases illustrative of conduction of lightning-flashes by hot-air currents came to my notice from time to time. One in Natal, occurring in the midst of native unrest and on the eve of a native rebellion, was nearly mistaken for a murder and almost precipitated retaliation by Europeans.

A country storekeeper entered his front door just as a flash of lightning swept through the open back door and down the passage. It met him full, and he was found lying dead just inside the front door, with, as the district surgeon described it,

"a large hole in his head." The man's native servants had left without notice and he had sent his family away to the nearest town for safety, so that no one appeared to have witnessed the accident. Fortunately, one old servant, who had remained loyal, came forward at the eleventh hour and described how he had seen a flash of lightning enter the back door just as his master opened the front door, and how, terrified at finding his protector dead, he also had fled. The case, authenticated by a medical man, interested me much, as showing a thing which I had not yet seen, namely, a definite rupture of the surface where the man had been struck.

In one of his instructive articles, Dr. R. T. A. Innes laid down certain rules for the safety of those living in isolated country places. These rules, which are as follows, cannot be too widely circulated :

When thunderstorms threaten, occupants of houses should avoid loitering in the line between two open windows, two open doors, an open door and window, or a fireplace and window or door. In all probability, hot air will be leaving the house by all these routes.

Driving quietly down a hill towards the village, one afternoon, when threatening clouds had

begun to drift up overhead, I noticed a Cape buggy drawn by two horses some little distance ahead of me and upon the same road. A flash of lightning in the neighbourhood seemed suddenly to remind the occupants of the buggy of dreaded possibilities, for the horses were whipped up into a canter and all speed made for shelter. They had proceeded perhaps a further half-mile when another flash of lightning appeared to me to fall some distance behind them, and I was amazed to see the cart topple over and the occupants thrown out.

When I reached the cart, men and horses were lying still. Efforts were made to resuscitate the two men, but without avail, both having been electrocuted. Both men showed brushburns upon face and neck and upon the arm contiguous to each other, which suggested that the flash had passed between them. Over these burns, clothes were burst in the usual manner.

Evidently the flash of lightning had passed through the opening at the back of the hood as well as beneath the cart to the two horses. I conceived at the time that increasing the pace of the horses just before the flash came to ground must have provided a track of hot, moist air from the sweating horses, and set that air in motion.

and that this conducted the lightning to the cart, which might otherwise have escaped it altogether.

In a large camp of some hundreds of tents, of which I was in medical charge some years ago, numbers of cases occurred in which flashes of lightning were conducted to tents by tracks of hot air emerging from the ventilators around their points. Such occurrences happened under only two conditions: (*i.*) Where overcrowded tents were kept closely fastened up, and (*ii.*) where empty tents were kept closely fastened up. With regard to (*ii.*), investigation showed the heat in these tents to be quite insupportable when first thrown open, and such heat must have been escaping through the ventilators under some tension while the tents were closed. It was apparently fear of the lightning which led to tents being closely fastened up when storms threatened, those concerned being unaware that in doing this they were but decreasing the tents' chances of safety. No tent kept habitually well ventilated was ever struck by lightning, even when it was considerably overcrowded.

The experiences in this connection in the camp referred to will be dealt with in a later chapter.

Conduction by Wood.

Wood is a bad conductor, because offering resistance to the ready conduction of electricity upon its surface.

Wherever air-containing cavities occur in trees, and give conduction to lightning, the incandescent sheath, expanding and repelling this air, will burst the cavities. Trees blasted by lightning are always found to have had cavities in their trunks occupied by air, the sudden expansion and repulsion of which burst the wood asunder. Lesser degrees of splintering often occur, in similar circumstances, in fissured and cracked wood.

Great trees, sound and in full foliage, sometimes give conduction to lightning, which runs down the trunk to the ground, scorching and drying up the sap beneath and in the bark. This injury extends to roots, root filaments and fine rootlets, all of which are seared, the tree consequently dying soon after. The apparently sound trees everywhere seen standing stark and bare amongst their fully foliaged fellows have invariably been struck by lightning in this manner.

A police Post which stood halfway up a mountain in my district in the Transvaal had as neighbours two very large, fine, blue gum trees, com-

puted to be about sixty years old. The two stood close together, and alone, no other trees growing upon that side of the mountain. Visiting the Post one day I was struck by the dull, lustreless appearance of the leaves of one of them, and was told by the sergeant that he had seen that tree struck by lightning the previous day, during a heavy storm. A week later, all the leaves of this tree hung dry and dead ; then came days of wind which stripped the tree of its foliage and left it standing stark and bare, in great contrast to its fellow, green with leaves through summer and winter. Two years later, the same fate overtook this other tree ; it was impossible to see any evidence whatever of the tree being seared or scorched, but the foliage died in a few days, and soon this tree, too, had lost every leaf. The two stood naked there for a few years and were then cut down. A section of the dead trunk which was examined gave no indication to the eye as to how lightning kills trees so promptly.

A large number of wooden tent-poles which have conducted lightning-flashes to earth have been carefully examined, but have shown no evidence of the part they have played. Tent-poles, however, are always of sound, hard wood, polished and very smooth, with iron ferrules at

intervals for disconnection. They are painted a reddish-brown to preserve them, with a paint made of an oxide of iron, and it is likely that such paint would allow a freer conduction than a non-metallic one. For this and other reasons, a tent-pole offers less resistance, although of non-conducting wood.

Conduction by Water.

Rain is probably the usual conductor of lightning to earth, and is a ready one. Upon this fact depends the safety during a storm of many buildings, possibly of vehicles upon the road, and certainly of persons on foot, any of which have survived being struck. Water pouring over and from things distributes the current and carries it to earth without resistance, and therefore without damage.

The Earth as a Conductor of Lightning.

Upon reaching the ground, a flash of lightning is probably at once neutralised by the earth-electricity (N). Search has many times been made, and the spot at which a flash went to earth examined, but no disturbance of the soil or other evidence of any kind has at any time been found

sufficient to explain the mode of its disappearance. When ground is moist or wet, the current may often be conducted by this to persons moving or standing in the vicinity, and they become electrified for a moment, as already explained. In such cases, painful contractions of the muscles are produced, but no blow is felt, as in direct stroke, nor are burns or streaks of burn or signs of bursting in the clothing to be found.

Some years ago, in a book collating cases of lightning-stroke, I read of a casualty considered to be extraordinary and undoubtedly due to lightning-stroke. The facts related were : An old labourer who was nearly blind was working with a number of other men and women in a large field when a flash of lightning from an approaching thunderstorm sent them all scurrying for shelter, leaving the old man behind them. Knowing that he could not find his way to shelter unaided, the old man remained in the middle of the field, but dropped to his knees in prayer. As the storm passed over the spot, a flash of lightning was seen to fall somewhere in the field, and when the storm was over and the labourers returned they found the old man still kneeling on the ground. One of them went up to him and laid a hand upon his shoulder, but the body toppled forward and the

man was found to be dead. His death was considered to be due to lightning-stroke. But had lightning-stroke been the cause, the blow from the compressed air pushed before the current would have thrown the old man upon his face, even if it had not, as invariably happens, blown his body to a distance of some yards. His clothing would also have been burst from his body, and the body borne arborescent burns and streaks, of each of which no mention whatever is made, although they would scarcely have gone unmentioned had they existed. No, the old man was not struck by lightning, but then neither was he electrified by ground conduction of a flash, for had he been so the quite involuntary contraction of muscles would have thrown him into contortions. It seems probable, however, that he died from syncope, fear of his situation having inhibited a weak, senile heart.

Lightning and Grass-thatched Huts.

All native huts in South Africa are thatched with coarse grass, the roof being conical and upheld by a central pole which fits into a cone at its point. These huts are frequently struck by lightning on one side of the point, and it may be that hot air, percolating through the thatch at

this spot, assists in conducting the flash to the pole and so to the ground.

At night, the hut door will be tightly closed; the inmates will be lying with their heads beneath the blankets, breathing their own breath again and again; and if the night is at all cold there will be a fire in the middle of the floor.

When the thatch is wetted by a storm of rain, a flash striking the roof will no doubt be distributed by wet thatch to the walls, and carried by wet walls to the ground. When the thatch is dry, however, a ragged hole is burst through it at one side of the point, and through this the flash runs to the pole and thence to the ground, the incandescent sheath of the flash invariably setting the grass alight somewhere around the margin of the hole, so that the whole of the thatch is burnt off the hut within a few minutes. Unfortunately, these accidents frequently happen at night, with the consequence that the inmates, stupefied by foul air, fail to awaken, and are either suffocated by the smoke or burnt to death by the falling in upon them of the blazing roof. Dry thatch, of course, burns like tinder.

Conduction by Galvanised Roofing.

As was said in a previous chapter, it is the *surface* of metals which conducts lightning, not their substance. This fact makes roofs of galvanised iron a definite protection against lightning-stroke injury to those living in countries where thunderstorms and lightning are prevalent during certain periods of the year, for the conduction by this type of roofing is extremely rapid. Thus, when such a roof is struck, the iron instantly distributes the current to the guttering around its margin, where water-pipes conduct it to earth, to water-tanks or to running water in the gutters.

Dr. R. T. A. Innes pointed out, in one of his valuable articles, that it is most important to have the water-pipes connected with the ground by means of a strip of metal fastened to the pipe at one end and sunk a little way into the ground at the other end, as this obviates the mischief liable to occur where the flash has to jump an interval.

CHAPTER IX

BELL-TENT CONDUCTION OF LIGHTNING

TO occupy a bell-tent in the open during the time of the year in which thunderstorms are prevalent is undoubtedly to run a very definite risk, experience showing that tents of this particular shape and construction are frequently struck by lightning, whether they are occupied or empty and fastened up.

In an unusually large experience of camps, I have not known tents of other shapes struck by lightning, although these—*e.g.*, marquees, E.P. tents, patrol tents, etc.—are provided with much larger ventilation apertures than bell-tents.

Fortunately, the danger of the bell-tent is now almost generally recognised, and for a good many years it has been customary for those in charge of camps to issue warnings to occupants to be careful to avoid contact with the tent-pole during thunderstorms and to avoid hanging things upon it at such times.

In South Africa, during the period of dry storms antecedent to the onset of the rainy season, the ground (to which all tents must be pegged) remains exceedingly dry and ineffective

in the matter of conduction of earth-electricity to the points of tents; moreover, when paragrails were tried throughout the champaign country, it was proved that the conduction of earth-electricity to the summit of the cables, in quantities to be of any use whatever, depended upon the lower end of the cables being kept either in water or in very wet earth. It may therefore be said that at this time of the year the bell shape of tent is unable to assist in the neutralisation of the electricity in the surcharged clouds passing overhead. It would, of course, be quite a simple matter to supply cables of plaited copper wires for fastening lightly to tent-poles, the brushed lower end of which would be buried beside the pole and well watered when necessary for it to act, and the brushed top end fastened so as to project above the point of the tent.

As already mentioned, the danger of these bell-tents lies in the constant track of hot air pouring through the ventilators around their points and streaming cloudwards, for this acts as a ready conductor of any lightning that may be thrown by surcharged clouds into the atmosphere in the vicinity of the tents. If a cable carried up the pole of a bell-tent were not always thoroughly effective in neutralising cloud-electricity it would

at least give a flash of lightning safe conduct to the ground.

What may happen when a bell-tent is struck by lightning is well illustrated in the following example :

A military bell-tent had been pitched alone, out upon the village commonage, about two hundred yards beyond the nearest house. It was to be the orderly tent of a small force arriving in a few days' time to camp in the vicinity. About sixty yards from it, on one side, stood an avenue of young blue gum trees ; otherwise, only bare veldt lay around the tent for a mile or more.

One sultry afternoon, when thunder-clouds lowered overhead, an officer sat inside the tent at a four-foot trestle table which was pushed up against the tent-pole ; the table was of the usual military pattern, bound with iron around the edge and standing upon iron trestles. On the officer's left was the tent door, loosely brought together in momentary expectation of a heavy thunder-storm ; on his right, two subalterns sat upon a long, iron-bound, wooden box, facing him, their backs to the canvas ; directly opposite him, upon the far side of the tent-pole, stood a very stout sergeant, making a report and periodically putting out his hand to grasp the pole.

A clap of thunder not very far away warned them that the storm was arriving overhead, and there was some talk as to what happened when tents were struck by lightning. The precaution was taken to remove the trestle table a few inches away from the pole, and the sergeant was warned not to touch the pole, as a flash might run down it.

Evidently, the thought that the tent might be struck somewhat unnerved the sergeant, for he again put his hand out and grasped the pole. At that instant, with a tremendous crash, a flash of lightning burst a hole in the point of the tent and ran down the pole to the ground. The sergeant was thrown back against the tent wall, where he subsided, an insensible, inert heap, upon the ground. The officer was also thrown back against the canvas, the table on top of him, and lay there insensible for perhaps ten minutes. The two subalterns, evidently only electrified, had all their muscles strongly contracted, so strongly that, as each averred of the other, an involuntary grunt was forced from them by the contraction of their chest muscles ; neither of them lost consciousness, and on my arrival a few minutes later they were able to describe exactly what had happened, from beginning to end.

The thunder, and something striking the point

of the tent, drew their eyes upwards, and they found themselves looking at daylight through a hole near the point. Through this hole, lightning flashed down the pole, with crackling sounds (probably caused by expanded air collections in the pole), ran round the trestle table, throwing it back from the pole and causing it to push the officer against the canvas. The two subalterns did not see the lightning actually strike the sergeant; all they saw was that he had grasped the pole a fraction of a second before, and fell back as the flash appeared. They seemed to think that the table had struck the officer upon the head and rendered him unconscious; but when I saw him, the burst sleeves and streaks of brushburn upon his arms showed me that they had been in contact with the current, and, indeed, he was himself able to remember that at the moment the tent was struck he had been holding the sides of the table with his hands, thinking that as it was two or three inches away from the pole it was safely insulated.

The sergeant had been electrocuted and all efforts to resuscitate him failed. His clothes were all but burst off him, a little still hanging to his right arm; the left sleeves of his tunic and shirt were burst up to the shoulder, as were all items of

clothing on the left side of the body; belt, breeches, leather gaiters, boots and socks, were all burst off his body. His left side showed a number of streaks of brushburn, with arborescent burns in small amount. (Stout people like this sergeant, who have fatty hearts, are occasionally resuscitated, but in my experience they succumb after a few days from syncope, the shock to the heart nerves proving too severe.) The officer soon recovered, but felt very sore in his muscles; his burnt hands and arms remained very painful for a day or two. The subalterns also felt very sore in their muscles for some days; their bodies showed no evidences of brushburns, nor was their clothing burst.

No rain fell in connection with this storm. The tent was immediately removed from the spot at which the tragedy had occurred, the impression existing that some iron-bearing rock below ground had, in spite of the possible tree conductors a few yards away, attracted the flash of lightning; this impression was, however, proved to be erroneous in after years. The camp was pitched upon the hillside a mile away, where, unfortunately, other casualties from lightning-stroke occurred before the dangerous season had passed.

CHAPTER X

EXPERIENCES OF LIGHTNING IN A LARGE CAMP

IN 1901, during the Boer War, large numbers of starving and fever-stricken people were continually brought in from the surrounding district to the Transvaal village where I was stationed. At first they arrived in scores, but soon they came in hundreds. They were housed in bell-tents, erected for their accommodation upon an expanse of level ground near the railway station, and forming a large camp.

The military, who erected the tents and laid out the camp with their usual precision and efficiency, saw to it that there was no crowding of the tents, that ample space was allowed between the rows of tents and between the tents in each row. This camp was soon accommodating 8,000 people, and it maintained that number throughout its existence, despite off-loadings into camps in other parts of the country. For over a year, my entire days were occupied in attending to the needs of the people in this, the first Refugee Camp in the Transvaal, my experiences in connection with lightning-stroke during that period being very varied and extraordinary.

When the season for electric storms arrived, upon the cessation of the dry winter months and with the approach of spring, tents were constantly struck by lightning, always near the ventilators at their points, a ragged hole about six inches in diameter being burst in this position. The fact that, amongst the hundreds standing around, the tents struck were invariably those kept closely fastened up during threatening storms and, despite stifling heat, crowded with people from other tents, was most significant, and for some time caused me much thought and speculation. But I soon became aware that empty tents were also frequently struck, in fact, more often struck than those in occupation, and this was a thing which puzzled me until investigation showed that the empty tents accumulated very great heat when they were closely laced up awaiting occupation, heat which the ventilators were quite inadequate to remove from day to day. When such tents were first opened, the heat within them was stifling and insupportable. It became evident to me that empty tents offered the same conduction conditions as did overcrowded tents; and this suggested the possibility that the hot, moist air streaming through the ventilators of these tents into the dry atmosphere without provided a track

of ready conduction non-existent in well-ventilated tents—a fact later corroborated by Dr. R. T. A. Innes in his published articles.

Refugees throughout the camp were warned against the overcrowding of tents when storms threatened, against closely fastening them up on these occasions, and against touching the tent-pole or allowing anything to come in contact with it at such a time. Unfortunately, when these electric storms became imminent, the women refugees continued to crowd into single tents, there to sing hymns and pray, though the marquees used for religious services were at their disposal on these occasions. In all my experience I have never known a marquee to be struck. When struck by lightning, no tent was ever set on fire in this camp, though evidences of singeing, to an insignificant extent, were invariable, somewhere upon the edges of the hole at the point.

Upon one occasion, eighteen women and one man, a Scripture reader, had all crowded into one ordinary bell-tent when an electric storm threatened. The reader read prayers, and they all sang hymns, endeavouring by vocal activity to allay their terror of lightning. Describing the situation to me later, one of those present said that they were packed in the tent like sardines,

pressed against the pole and the canvas, and quite unable to move in the almost insupportable heat. The door-flaps were overlapped and loosely fastened from inside, so that a stream of very hot, moist air must have been escaping under tension through the small ventilators.

During the singing of a hymn, a terrific crash of thunder was heard overhead, and a flash of lightning struck the tent—and struck this tent alone, though it was standing amongst scores of others. As the flash ran down the pole to the ground, the tightly packed mass of humanity appeared to be repelled from the pole towards the canvas walls; the tent rocked this way and that, and finally fell over with its almost solid content, most of whom were insensible. The hymn had stopped abruptly, and as the thunder rolled away there was dead silence; it was this silence which led to investigation and to the alarm being given.

By this time a number of the electrified women were recovering consciousness; eight others appeared to be severely injured, and of these it was found impossible to resuscitate three, who had been in contact with the pole and had been electrocuted. Many of the women were found to have brushburns on arms, shoulders, chests or backs, and in every case the sleeve or dress which covered

the part burnt was burst. Three women had limbs fractured through insensible women being thrown forcibly against them, and in one case by a blow from the falling pole. Several of the women were very stout and had evidently fatty hearts, and these were insensible from shock and syncope, two of them dying a few days later, though successfully resuscitated at the time of the accident; none of these showed brushburns or burst clothing.

Much interesting information was afterwards given by those who had recovered from simple electrification. Two of the women who had been electrocuted had been pressed against the tent-pole by the crowd and unable to move at all. Another woman had held on to the pole with one hand, her elbow crooked and pressed firmly against her neighbour's chest; the current had run along this woman's arm as far as the elbow, and burnt her; the one who was leaning against her elbow had received this charge in her chest and been thereby electrocuted.

Late one night three men arrived at the camp from the outside district, exhausted with travel and half starved. They were fed, blankets were issued to them, and they were apportioned one of the several empty, fastened-up tents, being

warned (as the sky was overcast and a storm threatening) not to come in contact with the tent-pole. They flung themselves upon the ground in their blankets, but a few minutes later one of them, who was an epileptic, had a seizure; the other two rose at once, controlled him and attended to him until the fit was over, when, discovering that both his legs were touching the pole, they moved them away, one leg on each side of it, and left him sleeping upon his back in this position. Before they could close their eyes, however, they were again aroused, this time by an unexpected crash of thunder directly overhead; the tent rocked from the blow upon its point, and both men saw a flash of lightning run down the pole to the ground between the feet of the sleeping man; they described later how he flung his legs out farther from the pole and then lay very still. On examining the man, they found him unconscious and no longer breathing; imagining him to have been killed by the flash, they first covered his body with his blanket and then, picking up their own, they fastened up the door-flaps and went to a neighbouring tent, where they slept during the remainder of the night.

Early next morning the two men reported the death of their mate by lightning-stroke, and,

being acquainted with the facts upon my arrival, I went to make an inspection of the tent and the body. On being shown the tent in which the tragedy had occurred, I noticed the ragged hole through the canvas at the point, so characteristic of lightning-stroke, but when the tent was opened I found that the man supposed to have been killed was not only breathing, but was also groaning, and moving his body and limbs! He was at once removed to hospital, and an examination revealed no signs of brushburn, either upon feet, legs, or body, and no burst garments. In a little while he recovered completely from the electrification he had experienced; unfortunately, it did not influence his epilepsy.

Cases of suspended animation similar to the above came to my notice upon numerous occasions. Those recounted here serve to emphasise the possibility of resuscitation some time after an individual has been struck and when he is apparently dead. It would appear that slight stimulation of the heart is often sufficient to restart its action. In the case just described, I consider it possible that the weight of the blanket covering the chest and body of the insensible man had been sufficient to produce a feeble contraction of the heart, and that this continued and became stronger

as circulation in the medulla (where the respiratory centre is situated) returned, finally establishing respiration.

It is probable that such suspended animation and its re-establishment is rendered possible by the presence of nerve ganglia in the muscular walls of the heart which enable that organ to continue to act for some time after being cut off from contact with the brain ; consequently it is possible to stimulate the heart to action, even though the brain is dormant or dead owing to total stagnation of circulation, and to keep it acting by repeated stimulation until brain-circulation is re-established. When it proves impossible to resuscitate an individual struck by lightning, it is probable that these heart ganglia, as well as all other independent ganglia, have shared the severe shock suffered by the brain, the largest ganglia in the body.

On three separate occasions in this camp it was reported to me by thoroughly reliable men that, during a thunderstorm the previous night, they had, as they lay in bed, seen a flash of lightning run down their tent-pole to the ground. Each had had his attention drawn to the point of the tent by the bang of the burst fabric as the flash penetrated the canvas and reached the pole. I was shown in the morning the unmistakable hole

in the canvas, a hole which was known to us not to have been there the previous day. In each case, the adults had occupied iron bedsteads, and care had been taken that nothing hung upon the poles when they retired for the night; in two of these instances, children slept upon the ground upon improvised mattresses of a non-conducting nature, and had slept soundly throughout the occurrence; in another instance, the man's wife had also slept through the phenomenon.

Sometimes inmates of tents would point out to me the well-known hole in the point, which they had noticed on awakening in the morning but which had not been there overnight; they presumed that it had been caused by lightning striking the tent, but they knew nothing of the occurrence, having slept soundly throughout the storm. On one occasion, I pointed out to the inmate a hole in the point of his tent, asking him what had caused it, and found that until that moment he had not seen it, but he knew that it had not been there when he retired the previous night; he was considerably astonished when told to what it was due, as he and his wife and two children had slept peacefully throughout the night.

A number of military camps were scattered about this village in the Transvaal, and from time

to time some of these had tents struck by lightning. One, in particular, seemed to be struck more often than others, and when one of the officers informed me that when one tent was struck men in neighbouring tents also felt the shock, I suggested the presence of a layer of ironstone (known as *oudklip*) just below the surface, and recommended the removal of the camp to another site. The recommendation was carried out, and no other tent was struck during the rest of the dangerous season. Some years later the site occupied by this camp was built upon, and I was interested to see the layer of *oudklip* which lay just below the surface and which had to be removed before houses could be built there.

CHAPTER XI

THE IMMUNITY OF MOTOR VEHICLES FROM LIGHTNING-STROKE

I THINK it is now generally accepted that all motor vehicles are immune from direct lightning-stroke, though the reason for this is still a matter of speculation. Motor-cars travelling in the country districts during the thunderstorm season are often literally in and out of these storms, with lightning playing around them. The commotion they produce in the atmosphere when travelling and the long track of heated gas (containing a definite amount of inflammable petrol) they leave behind them provide ideal conditions of conduction for a flash of lightning seeking the ground in a non-conducting atmosphere; yet the case of a car being directly struck is never reported.

The theories anent the immunity of motor-cars are as follows:

1. That motor vehicles are insulated by their rubber tyres, which are incapable of conducting earth-electricity into the atmosphere, and therefore also incapable of conducting atmospheric electricity to earth.

Yet the earth-cable of every car is fastened to the chassis, and obviously conveys the repelled

electricity to earth *via* the tyres, or the car would not go. (When it becomes loose or detached it makes trouble, or the car stops.)

2. It has also been widely repeated that motor vehicles, being constructed almost entirely of metal, offer distribution and ready conduction to lightning striking them. Those who advocate this theory think it possible that motor vehicles are struck more often than even their drivers are aware.

But it is difficult to believe that the blow delivered by the point of lightning and made by the compressed air pushed in front of the flash could not burst holes in the fabric covering these vehicles or, entering the car sometimes from the side, knock insensible an occupant.

A few cases of motor-cars struck by lightning have been recorded from time to time in the Press, but those with which I am personally acquainted were all indirect strikes off a house or tree on to a car, and thus really a splash off some other object struck in the vicinity.

A motorist in Johannesburg, overtaken in the streets by a deluge of rain from a thunderstorm, was hurrying to reach a garage, his car running water from end to end, when, in turning the corner of a street, the hood of his car came within two feet of a verandah overhanging the pavement and belonging to a house which was struck by light-

ning just as he passed. The flash ran down its wet walls to the verandah, from which it splashed on to the front corner of the car's hood, ran down the windscreen-support to the bonnet, then to the mudguard and so to the front wheel. The driver saw the route followed by the flash, but felt not the slightest electric shock. On reaching his garage he found that he could trace the course of the current by a slightly scorched streak on the Ducco paint which ran down the side of the hood towards the wheel; as he could trace it no farther it seems probable that it had been conducted mostly by the water streaming from the car.

A friend and I once spent an alarming half-hour in a motor-car on the top of a mountain, when we were fully exposed to one of the heaviest thunder-storms we had ever experienced. Every effort had been made to reach the level ground at the summit before the storm broke, but rain began to fall when we were but a few score yards from our goal, and in a very few minutes a torrent of rain-water was rushing down the road and breaking like a wave over the top of the radiator. Unable to proceed, we were obliged to draw up the car on a little elevation at the roadside and remain there, without stick or stone of shelter, while the storm raged around us. The ground shook with the

crashing thunder; lightning appeared to be playing round the car and often uncomfortably near, but with the densely falling rain (heavy enough to blot out everything around us) it did not lack for conduction, and I imagine our immunity to have been due to this fact.

A certain amount of immunity from lightning-stroke is undoubtedly due to the ability of motor vehicles to dodge thunderstorms by travelling at a speed never even dreamed of with horse-drawn conveyances. By such means a driver can often maintain his car in safety behind, before or to one side of a storm in sight.

On one occasion, when visiting an outlying village in my district, I noticed that a dense black thunderstorm, with thunder and lightning already in play, was approaching the village, and was travelling in such a direction that it must inevitably follow the route I should presently have to take for my return journey. My duties were quickly completed, the curtains of the car adjusted, and all made ready for bad weather. The storm reached the village before we could leave, but ere we had gone a mile we had left it behind us and were travelling over dry, dusty roads, the storm following and blotting out hill and kopje one by one behind us. Not a drop of rain fell upon the car,

though thunder growled and lightning flashed behind us throughout the whole of the return journey. A bare quarter of an hour after we had reached home, the storm that had followed us broke over the house and the neighbourhood, its fury lasting for over an hour. On many other occasions also we have successfully dodged a thunderstorm by means of speed.

One hot spring morning, while travelling by car over very bare country up on the Highvelt, very much exposed to the vagaries of the elements, my companion and I saw a thunderstorm some distance ahead, travelling in the direction we ourselves intended to take. As we drew nearer, it was possible to see hailstones falling on to and rebounding from the surface of the road, and on getting within range we received a jagged piece of ice upon the hood of the car. The roar of the storm ahead, the whiteness of the surrounding country, and the cold of the ice upon the ground, were most marked and extraordinary. Speed was slackened, and the storm allowed to pass ahead again before we proceeded on our journey. Soon we had the gratification of reaching dry roads and warm weather once more. The lightning travelled before us, never a menace to the car that followed.

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