employed, as in the year 1855 or 1856 he brought out a rifle which he called the "Express Train," and the word "Express" has since been pretty generally used in referring to low-trajectory rifles. I would not therefore like to claim the entire credit of be ng the first to introduce these rifles, as, if Mr. Purdey was working them out at the same time, he is entitled to a share of the credit. I may say that when I made my experiments I had not heard anything of Mr. Purdey's, and, so far as I know, no other maker had brought out a similar kind of weapon at that time.

With regard to the minimum muzzle velocity that should constitute a rifle an "Express," I agree with you, that it should not be fixed at less than 1600ft. per second. With the ·450 rifle, 5 drams of powder, and my ordinary Express bullet, a velocity of about 2000ft. is developed, which I think is about the maximum that can be obtained.

I do not know whether you will be dealing with anything but sporting rifles, but may just mention that I was very early in the field with a long range-rifle. In 1852 I carried out some experiments in presence of the late Mr. Ellis, M.P., and Capt. Horatio Ross, at Bells Mills, Edinburgh. The rifling which I used was three shallow segmented grooves, and the trials were so satisfactory that the results were communicated to the War Office, and in 1853 the Enfield rifle rifled, on the same principle, was produced.

5.—By Mr. F. OSBORNE.

If we look back at the sporting rifle for dangerous game about and a little before 1870, we may be enabled to realise most of the qualifications a perfect Express rifle should have. At the period sporting rifles were mostly of large calibre, ranging fr 24 to 12 bore as a rule, and constructed to fire either a sph ball with a slow pitch of rifling, or an explosive shell, elongated bullet with necessarily a more rapid spiral. systems were found to be unsatisfactory; the forme giving a flat trajectory to about 80 yards, require beyond that range, and in the matter of accuracy was far from perfect. Its killing powers, unless us of powder not to be borne in *portable* rifles, le of the explosive shell—a costly, complicated, a an unsatisfactory arrangement. The elongat their quick turn, were much more accurate even at considerable distances, and in this had a marked superiority over their rivals, but were much inferior to them in the matter of trajectory, requiring an elevation for every 50 yards; in killing power, in most cases, they were deemed inferior to the rifles using the spherical ball, unless treated in exactly the same way.

The term "Express," and the kind of rifle to which it applies, owe their existence mainly to the description of bullet used—a bullet so light as to admit of enormous powder charges being burnt behind it without producing an unbearable recoil even in easily portable rifles—a bullet that can be used in small calibres without diminishing its killing power, retaining all the flatness of trajectory and accuracy of diagram peculiar to those calibres, and yet, on striking the game, capable of inflicting the severest wound in consequence of its change of form upon impact, and an expansion exceeding in size and lacerating power the old 12-bore ball.

We may here remark that these old systems of rifles would have been much more effective if their weight could have been increased; this rather points out the first consideration to be attended to in defining a model Express rifle—its weight. No Express rifle can be worthy of the name as a thorough all-round weapon, combining the greatest destructive power with general handiness, that exceeds say at most 10lb. Why? Because the military authorities, after immense experience, have concluded that 9lb. is sufficient for the soldier's rifle; so, taking the average sportsman, his physique and his impedimenta, into consideration, the most we can allow is an extra pound. This point conceded, we can proceed to dispose of the remainder by insisting upon the initial velocity of the bullet
eing not less than 1800ft. per second, more if possible; a rifle
t does not approach this, the key of the Express system, places
out of the scope of our investigations. Why? Because
such a bullet starts at such a velocity, or thereabouts, upon
when fired from the extreme sporting ranges its striking
ld be so impaired as to prevent the complete change of
characteristic of the perfectly acting Express bullet.
oint to be considered is the trajectory. It will be
wledged by sportsmen that to be relieved in great
trouble of judging distance and adjusting sights,
alue in the field; no rifle enables us to dispense
ments so completely as the Express, and this

only to a partial extent, and to a moderate range, which may be taken for its extreme limit as 150 yards. Any rifle capable of being used at all ranges up to that distance with one fixed sight and aim, without the vertical deviation from bullet drop seriously impairing the value of its diagram, must exhibit one of the finest qualities of the Express, provided that no undue decrease in its destructive power, or increase in its recoil, be caused by the means taken to obtain this excellent feature in a sporting rifle.

I may illustrate my views on the trajectory of a typical Express rifle when I say that from 50 yards to 150 yards there should not be a greater bullet drop than 5in. or thereabouts.*

As to accuracy of fire, the conditions already enumerated as essential to the Express are considerably at variance with those that should exist in a rifle intended to give a high degree of accuracy; still, for a limited number of shots the Express rifle is fairly accurate. No conditions of sport could arise where any *number* of consecutive shots would require to be fired; and even with the heaviest charge used, seven or eight shots can be fired in succession without a serious amount of error becoming apparent.

My idea of the standard of accuracy necessary to an Express rifle is, that it should place its shots in a 6in. circle, or thereabout, from the 150 yards range when fired under fairly favourable conditions. It should be here noted that by ringing the changes on the constituents of the Express system, either the calibre, weight of bullet, charge of powder, &c., rifles can be constructed to give special prominence to either one or other of those features whose judicious combination result in the production of a perfect arm: thus, the power of the rifle may be developed at the expense of its recoil, accuracy, and trajectory; or its accuracy may be augmented by the sacrifice of a portion of its power, &c.

To sum up: An Express rifle should be of moderate weig' certainly not exceeding that of the service rifle by much more a pound. The recoil of the rifle should be measured by th standard, and should not much exceed that of the serv' The rifle must fire a bullet capable of considerable expansion on impact, producing a severe and dangerous should also fire a solid bullet, giving great penetratior the sighting for which at, say, 100 yards should ag the Express projectile: the initial velocity of

* Note by Sir H. Halford: Impossibl

1800ft. per second, or thereabout. The trajectory should not show a greater bullet drop than 5in., or thereabout, from 50 to 150 yards. The accuracy should not give a much wider group than one of 6in. diameter when fired from the 150 yards range. Of course, in the matter of trajectory and accuracy we should take as an illustration the performance of a *single* rifle, for obvious reasons; though, when perfectly regulated, the double rifle is not so far behind the single as may be generally believed. I am aware that in some of the figures by which I have attempted to illustrate the work of an Express rifle, I am somewhat behind the degree of excellence already supposed to be arrived at by some advanced rifle makers, but I prefer that it should be so.

6.—By Mr. H. Holland.*

A minimum of 1600ft. per second initial velocity, and a maximum of 2000ft., would probably include all kinds of rifles called Expresses. The proportion of powder to lead required to produce these velocities would range from 1 powder to 4 lead for the lower velocity, to 1 to 2 for the higher.

I consider for the ordinary bores, say ·450 and ·500, the velocity of from 1700ft. to 1800ft. per second is that most likely to give the best results, combining great accuracy with flatness of trajectory. To obtain these results, I use a charge of not less than 1 powder to 3 of lead, with a minimum of 4dr. powder in the ·450 bore, and 5dr. in the ·500 bore. With these charges we have been able to obtain great accuracy at the longer ranges, at which many Expresses fall off very seriously.

Such a high velocity as 2000ft. per second can only be obtained by using very light bullets and very heavy charges of powder, always at the sacrifice of accuracy and penetrating force.

There is some difficulty in getting a definition of "Express" by either initial velocity or proportion of powder to lead, without at the same time fixing a minimum charge of powder. For example, if initial velocity only be taken as the standard, a very short light bullet, fired with a moderate charge of powder, giving a high initial velocity, might be used, which would so rapidly lose speed that at 150 yards the *fall* would be so great as to take the weapon altogether out of the Express class.

* These remarks have been considerably altered and added to since they were first issued.

A charge of 1 powder to 4 lead is sometimes considered an Express rifle charge. Under certain conditions this may be correct; but it cannot be taken as a gauge of an Express unless a minimum charge of powder be given at the same time. A low trajectory is only one of the *desiderata* of a satisfactory sporting rifle. I consider that the most important features are—(1) accuracy of shooting, and killing power; (2) low trajectory; (3) such freedom from fouling as will allow of a series of shots being fired without any falling off in accuracy.

1. Accuracy.—Not only should an Express make a close diagram at short ranges, but, if properly constructed, and the bullets and charges correctly proportioned, this should be obtained even with a double-barrelled rifle at 150 and 200 yards. A ·450 deer-stalking Express should place a series of ten shots, at any rate, into a 6in. square at 150 yards.

2. Trajectory.—It is pretty generally known that a good Express will give a trajectory of about 3½in. to 4in. up to 150 yards—which is practically all a sportsman can desire upon this point. Complaints are often made that Express rifles shoot high. This is frequently the fault of sportsmen themselves, who demand the impossible, viz., a flat trajectory to 200 yards—a demand constantly being made. The result is, that some makers, to meet this demand, sight the rifles for these gentlemen with the first sight cut to the 200 yards range; consequently they shoot many inches high at those ranges at which perhaps most game is killed, viz., from 50 to 100 yards. I consider that an Express should be sighted correctly at 100 yards—certainly not high; as I have always been informed by many of the best and most experienced sportsmen, that a large proportion of the game missed is lost through shooting over the object. Even when a rifle is correctly sighted at 100 yards, there is always the risk of the sportsman not taking a sufficiently fine sight, or not getting down to the bottom of the notch of the back sight, or even of the rifle "jumping" if rested upon any hard substance. How much greater, then, is the risk of this if the rifle is sighted to shoot some inches high at this range!

3. Freedom from Fouling.—As to this point, all that is required is that the rifle shall not need wiping out, in order to keep up its original accuracy, for ten successive shots.

REMARKS ON THE ABOVE "OPINIONS ON EXPRESS RIFLES."

By Mr. METFORD.

Regarding the question of what should be reckoned as Express speed, I think your 5in. really as good as need be. All I wanted to prove was that, by experiment, I got this within a fraction of an inch by 4 lead and 1 powder, which gives about 1600ft.

You see there is (at least to my mind) a real practical value in thus making it a proportionate affair of powder and lead, for, in many matches in India, I believe, there are prizes for Expresses; of course, Express loaded. Now, if either initial or terminal velocity, or, again, the drop, whether between 100yds. or 150yds., or from initial line, be taken as standard, who is to prove whether Express was or was not used? Few people have speed instruments, and the amount of wrangling over drop would be interminable; but any-one can readily and unmistakably test the proportion of powder and bullet.

You say, "what is the sportsman's outside distance?" I am told by my friends, Sir H. Halford and H. Evans, of Jura Forest, that most shots are taken within 100yds. I have poured into my ear wonderful shots at 200yds. and more, but I take it that no one need bother about such a range; 150yds. is about the general extreme. Your letter puts this question:

What terminal velocity at 150yds. do you consider would correspond with a drop of little more than 5in. between 50yds. and 150yds.?

Do not you mean between 100yds. and 150yds.? Your paper of Feb. 20, 1883, says, p. 2 (nearly at end), 5in. from 100yds. to 150yds.

I see that the charge I used in the experiments which guide me in this matter would give about 1600ft. per second, and at 150yds. give 1225ft. per second.

My trajectory drawing tells me as follows: Sight set true for 100yds. at 50yds., bullet about 1¾in. nearly above line at 150yds., about 5in. below, weight of bullet, 360grs.

Possible error would be limited to something not worth recording, but say ¾in. of the latter; not that I have any belief that I have made a ¾in. error. My speeds were taken, not from computation from mean speeds, as taken by cutting two wires, or breaking two connections, but by a ballistic pendulum, the special idea of which was suggested to me by my friend William Froude some years since, and the design of which I worked out myself, and which had his approbation. It is so delicate that it will show the variation in speed caused by putting two  wads behind the bullet instead of one.

With it I get actual velocities right off; and this without there being any necessity for striking the pendulum in its axis, which was the old trouble. It is a peculiarly charming instrument for ascertaining actual striking speeds as one retires back and back.

I have been now using it for the last twenty years, I think it is, and I believe it to be most decidedly superior to any of the instruments now in vogue for small arm work.

By Mr. HENRY.

I still adhere to the opinion that no rifle should be designated "Express" which does not give an initial velocity of 1600ft. This is the minimum, but of course the greater the velocity that can be developed the better, provided accuracy can be maintained; and I think I can show that great accuracy is not incompatible with a very high initial velocity—say of fully 2000ft.—derived from using a small bore with a slow spirality of rifling, or large charge of powder and a light bullet. In proof of this I inclose diagrams made with a ·450 gauge single rifle, taking 136gr. (5dr.) C. and H. No. 6 powder and a hollow-pointed bullet weighing 270gr., using the standing sight only, and taking the sight as nearly as possible in the same way (*not* fine and full) up to 150 yards. By taking the foresight full, the standing sight is good for all practical sporting purposes to over 200 yards. At 100 yards you will observe that the rifle shoots into 3in. That this is not an exceptional rifle, but what I am in the habit of turning out, both single and double barrelled, I would refer you to such well-known sportsmen as Capt. Horatio Ross, Mr. Edward Ross, and "Rohilla," and if necessary to many others. I inclose a letter from Capt. Ross, written so far back as June, 1876, giving the results of some experiments made by him, with the assistance of the well-known rifle shot Mr. Wm. Ferguson, of Inverness, with a ·450 gauge 5dr. rifle, which letter you are at liberty to publish.

"DEAR MR. HENRY,—I yesterday gave the 'Queen of the Forest' a severer trial than I ever did previously.

"I was anxious to take advantage of the rifle range and target here, to ascertain exactly what its trajectory really is. I got Mr. Ferguson to assist me, as I consider him to be one of the most careful painstaking rifle shots we have.

"We began at 100yds., and fired shots at 130, 150, 180, 200, 220, 230, 250, 275, 300, 325, 350, and 400 yards.

"We aimed at the same spot as at 100yds. up to 250yds., using the first sight. We found that up to 230yds. there was no perceptible drop.

"At 250yds. we had to put up the flap sight, which gave very satisfactory results as far as 350yds., after that, at 400yds., we found the drop considerable and sudden.

"Mr Ferguson said that, until he had shot this rifle, he had no conception that it was possible to make a rifle which, up to 230yds., had such a flat trajectory.

"Yours very truly,

(Signed) "HORATIO ROSS."

Some sportsmen prefer a heavier bullet, and with the above rifle and charge there is no difficulty in increasing the weight to, say, 350 or 360gr., and yet retaining a trajectory sufficiently low for all practical sporting purposes, using the standing sight only, to 150 yards. I consider the light bullet, however, best for use against soft skinned animals, from deer up to and including tiger, as, owing to its greater velocity the smashing power is enormous; but for tough skinned and large boned animals the heavier bullet is, owing to its greater penetration, to be preferred.

Inclosed is a note of the various gauges of, and charges used with "Express" rifles.

To show the striking power of the "Express" bullet I forward a steel bullseye, $1\frac{1}{4}$in. thick, from my target, with a hole about 3in. by $3\frac{1}{2}$in. driven right through the solid steel; also part of a steel bullseye, 3in. in diameter and 2in. thick, knocked to pieces by the bullets.

In my previous notes I stated that my early experiments with a low trajectory rifle were made with one of ·451 gauge. This is, of course, as we measure now, but at that time only the gunmakers' gauge was used, according to which the bore would be about 50.

In connection with my former remarks on long range rifles, I may mention that in the year referred to (1852) I tried some experiments at Dalmeny Park at 1000 yards, and at a target placed on Cramond Island in the Firth of Forth at 1600 yards, shooting from the shore. I will not say that the shooting was good, as the gauge of rifle, viz. 25 or ·577, was too large, and the spirality of rifling—as we have since ascertained—was too slow to give accuracy at these long ranges, but a note of such a thing having been done may be interesting as recording one of the earliest attempts at long range shooting since so wonderfully developed.

To show the great accuracy that can be obtained with the long range rifles of the present day under favourable circumstances, I inclose two official diagrams made at Enfield with a Martini-Henry rifle and Henry ammunition at 500 yards, giving the surprisingly low mean radials of under 2in. and 3in. respectively. These are supposed to be the finest diagrams ever made.

By Mr. F. OSBORNE.

Weight of Rifle.—I find that I am alone in noticing this important point. Where would shot-gun definitions and comparisons be if this matter was not attended to?

Initial Velocity.—In this matter I find myself considerably more exacting than anyone else, but point to the following remarks in support of my views. Mr. Metford in his second paragraph says, "speed is valuable," "as the smashing power increases in the square ratio of speed, not merely with the speed." Sir H. Halford gives a table of *four* kinds of Express rifles (in which the latter kind would certainly be struck out as an Express), *two* of the remaining three have velocities of 2000ft. and 1830ft. each. Mr. Henry also gives an express with 2000ft.

Range Trajectory or Bullet Drop.—In opposition to Mr. Rigby, I fail to see why the 200 yards should enter into the question at all, as I do not think it possible within ordinary proportions, to construct a rifle giving a decent up and down group from 25 yards to 200 yards *with the same sight.* Mr. Metford says, in his fourth paragraph, "most shots are under 100 yards," &c. Mr. Henry also appears to indicate 150 yards as the Express limit. Sir H. Halford also prefers to give 100 yards as the range for diagrams, though he makes two statements about bullet drop that I fail to reconcile. First, "the fastest Express (drop) is 16 inches" (between 100 and 200 yards). Again, "gunmakers sight their *rifles 6in. or more* high at 100 yards. This at 200 yards will make a rifle shoot only 4in. low." [NOTE.—This gives a total drop of 10 INCHES between 100 and 200, as against 16in. as stated in the previous paragraph. He has in a previous sentence expressed himself in favour of rifles being sighted 3 INCHES HIGH at 100 yards. Either, or any, way he is, I take it, against the 200 yards range being included.]

With regard to Mr Metford's table of trajectories, &c., I note that he gives for bullet drop with 1900ft. initial speed 5in. nearly at 100 yards, the air resistance *not* being taken into account. Has the effect on the bullet drop of recoil, or "jump" of rifle acting the other way, been taken into account? A very illustrative experiment bearing on this point is given in Sir J. Whitworth's book "Guns and Steel" (Longmans, 1873), pp. 60, 61.

BULLET DROP.—I find the value I give for bullet drop between 50 and 150 yards much within the values indicated by Messrs. Rigby, Metford, and Sir H. Halford; but, as I have obtained my data from actual practice in firing rifles with sporting sights, I cannot materially alter my figures, though a certain amount of error may have crept in, owing to the practical difficulty of aiming exactly alike at all three ranges at the same bulls-eye, with ordinary sporting sights.

ACCURACY.—We seem to be on all fours on this point, or nearly so. Mr Metford's standard for single Express at 100 yards "should be covered by the *fist*," is sufficiently easy, though why *ten* shots? Such a number would be likely to lead to error unless some amount of time lapse between shots to prevent overheating. I suppose Sir H. Halford's diagrams are those of single rifles only, especially with the lighter charges.

RECOIL.—No one notices this feature, practically a most important one, as, if a rifle cannot be used with something like comfort, its other good points are rarely brought out. I fail to see, therefore, how Sir H. Halford can lay down weights of charges without weights of rifles to correspond. I have always considered the two as having an extremely intimate connection.

SOLID BULLETS.—An account of a successful use of solid bullets with Express rifles appeared in the *Field* in November, 1879, therefore I am in no way responsible for their introduction, though I can understand their possible value against very refractory-hided animals, &c.; but this matter can wait.

To conclude: In deference to the general leaning towards admitting rifles as "Express," with moderate or comparatively low velocities, I think we might put the minimum at 1800 or 1750ft. instead of 1900ft.—*not less*, as I think it will be well to exclude from the strictly "Express" class proper, either "Miniature Express" on the one hand, or "Miniature Cannon" on the other. As to the *bullet drop* between 50 and 150 yards being *4in. or thereabout*, I mean by this—from the centre of group made at 50 yards, to centre of group made at 150 yards, rifle fired from shoulder rest, aiming as near as may be at same spot, the sight being adjusted to suit the 100 yards range. An inch, or even two, may be added to this, but I see no reason why any greater addition should be made.

Yours faithfully,

FRANK OSBORNE.

EDITORIAL COMMENTS ON THE CORRESPONDENCE.

It will be observed that there is a considerable disagreement among the above high authorities as to the exact limits of the requirements necessary to constitute "an Express." Sir H. Halford, Mr. Metford, and Mr. Henry consider 1600ft. muzzle velocity sufficient for the purpose, while Mr. H. Holland and Mr. Osborne contend for 1750 or 1800ft. in an ordinary Express. This high velocity is required for two purposes—first, to insure sufficient expansion of the bullet in the flesh of the animal shot at, and consequent smashing power; and, secondly, to obtain so low a trajectory as to make one sight answer, "fine or full," at any distance up to 150 yards. Now the amount of smashing power required it is not easy to settle, but the trajectory and accuracy form matter for experiment, and to obtain a public demonstration of what can be done, I instituted a public trial last autumn, which may be considered to have settled the question beyond dispute. It was then shown that even with a muzzle velocity of 1750ft., the above requirement was only just obtained, so that I think it may be fairly laid down that an Express rifle ought to possess that speed, especially as it was found to be consistent with as great accuracy as can be desired. Finally, therefore, I propose to define the Express as a rifle with a trajectory not exceeding four and a half inches at 150 yards, for which a muzzle velocity of at least 1750ft. per second is required. This velocity is obtainable with charges of powder varying from 1 to 2 of lead to 1 to 3½, according to the bore, and with such accuracy as to insure hitting a vital part—*ex. gr.* the heart or head—at 150 yards. For further particulars on this point, I must refer my readers to the report on the Rifle Trial of 1883, hereafter given.

WHAT IS A SPORTING RANGE?

In different countries, with various kinds of game, the conditions under which the latter are pursued for purposes of sport will be such as to preclude any hard and fast rule on the subject. In this country, at all events, 150 yards may be regarded as the maximum distance at which game is shot at, and, no doubt, the average is considerably within a hundred yards. In India, according to both Capt. Forsyth and Sir S. Baker, the same rule applies. The former, in reference to jungle shooting, writes: "One half at least are shot at under fifty yards, three-fourths under seventy-five yards, and all, without an exception, under one hundred yards; that is to say, these are the distances at which animals are usually killed in jungle shooting." This is the general opinion of sportsmen; but for work on hills and other open situations, when "bright moments" occur, a shot at 150 yards may sometimes be made. Beyond this distance, the difficulties connected with judging distance correctly, the effect of wind, and the consequent liability to hit without killing the game, and thus send it off to a lingering death, will generally make the good sportsman pause, and will lead to an endeavour to get nearer, even at the risk of losing his shot.

Mr. Van Dyke, who is the best and most reliable modern

American authority, sums up a very well argued chapter on this subject in the following words: "For the last three years, my rule has been to shoot at nothing beyond 150 yards, if there is an even chance of getting closer to it, and not to shoot even that far if there is a fair prospect of shortening the distance. I fully believe I have gotten more deer by it. I certainly know that there have been fewer broken-legged cripples. For deer and antelope on the plains, fifty yards might be added to this distance; for elk, another fifty yards; and for buffalo, another fifty. Beyond this point, you had better make it a rule to get closer"* (pp. 317-318).

But in Southern Africa, where game has been, and still is, more plentiful, though wilder, than in India or Great Britain, a much longer range is desired, and especially by the Boers, who are not contented with a rifle unless it will perform well up to 800 yards. This can only be used for pot-shots at herds of deer; but there is no doubt that at 400 and 500 yards, with their fine power of sight, they do often kill game at such distances. Consequently, before the definition of a sporting range can be given, the locality where the rifle is intended to be used must be ascertained. In deciding on the proper range of a rifle, it must not be forgotten that the longer ones can only be obtained at the sacrifice of trajectory, which is increased from 4½ inches at 150 yards in the Express, to about double that amount in the Martini-Henry and still more in the Enfield. The South African rifle is thus, of necessity, much less useful at short ranges than the Express; because, not only must the exact range be ascertained—which is a difficult matter—but the sight must afterwards be altered to suit it, with a sacrifice of time, or the game will not be bagged with anything like the certainty which the sportsman desires.

* "The Still Hunter," by Theodore S. Van Dyke. New York: Fords, Howard, and Plunkett; London: Trubner and Co.

CHAPTER III.

RIFLING MACHINES.

MESSRS. GREENWOOD AND BATLEY'S AND MESSRS MUIR AND SONS' RIFLING MACHINES.

MESSRS. GREENWOOD AND BATLEY'S RIFLING MACHINE.

IN proceeding to describe the mechanical details connected with grooving rifle barrels, I must refer my readers to the frontispiece of this volume, which is a representation of a modern rifling machine by the celebrated firm of Greenwood and Batley, of Leeds. It is a substantial structure, some twelve feet in length, the left foot being some six inches lower than the right one, giving such an inclination to the entire machine as has been found necessary to insure the flow of lubrication down the barrel during the cutting process. As shown in the illustration, the machine is arranged for operating upon *single* rifle barrels only; *double* rifle barrels require some changes in detail in no way affecting the general principle of the machine. The inclined "guide bar" in front of the machine is used to give the amount of twist or degree of spiral desired in the groove to be cut. One end can be moved only upon the fixed centre shown on the right; the other end can be adjusted to any desired angle within the scope of the machine by means of the slotted arm to which it is fastened. The main slide or "saddle" receives its motion up and down the "bed" from the central main screw, this being driven from the pullies at the extreme right; their motion is transmitted through gearing not visible in the engraving. The vertically working toothed "rack" carried by the saddle is engaged at its lower end with the guide bar; consequently, as the saddle travels along the bed, an amount of motion is imparted to the rack varying in proportion to the inclination given to the guide bar. As shown in the illustration, a considerable amount of this motion is imparted to the rack; consequently a quick twist would be thus cut in the barrel operated upon. If the lower end of the guide bar was raised in the slotted arm until more nearly parallel to the path of the saddle, of course the motion of the rack would be much less, resulting in a slower twist being imparted to the grooves. The motion of the rack thus obtained is converted into a circular one of the "spindle" (situate across the upper part of the saddle) by means of the small spur wheel or pinion upon it gearing into the rack. This spindle carries the "cutter rod" with tool holder attached, to which latter, by the means I have endeavoured to explain, is imparted the compound motion required in grooving the barrel. The barrel is held in a "chuck" or holder, in this case possessing the power of self-centering its work, and carrying a division plate with the same number of equi-distant notches as grooves are intended to be cut; thus enabling the chuck to be moved round and secured while each succeeding groove is operated upon. Above the chuck is placed the vessel holding soapsuds or other substance used to cool and lubricate the cutting tool when at work. The breech end of the barrel being secured in this holder, the muzzle end is steadied in an arrangement shown in the engraving—care being taken that the barrel so held is duly coincident with the spindle carrying the tool holder; this latter is then passed down and through the barrel—the cutting edge of the tool being prevented from coming into contact with the bore by the means described in treating the full-sized sketch of the "cutter box." To the "feed screw" of the cutter box is then attached the small "back rod" seen at the extreme left of the machine—the use of such rod being to control and regulate the amount of "cut" put upon the tool by the operator. The wheel gear and indicating dial through which it passes are the means of effecting this end—in some cases automatically by the machine, but in this case, and generally, by the man in charge, who functions this apparatus by means of the hand-wheel just in front of and below the grip wheel of the barrel holder. The back rod has a spiral groove cut along it of the same "pitch" or degree of twist that the barrel groove is intended to have; it slides freely through the hollow shaft at the extreme left of the machine. A stud or key inside this shaft engages in the groove in the rod, so that when the shaft is rotated the rod also turns, though the longitudinal motion of the rod through the shaft is not interfered with; thus, as the cutter passes up and down the barrel the back rod follows it in exactly the same spiral path. It must be noted that the cutting work is done by the upward (from left to right) travel of the saddle; therefore, when this latter is down or near the breech end of the barrel, the cutter has passed beyond and out of the muzzle, and is ready to be so adjusted as to cut a shaving from the bore. By turning the hand-wheel connected with the back-rod mechanism, the operator withdraws the feed screw in the cutter box a determinate amount (registered by the finger on the back-rod shaft upon the fixed dial plate), thus allowing the cutting tool to rise in its bed and protrude into the bore of the barrel; the machine is then put in motion, the tool being drawn through the barrel and delivering its shaving upon passing out of the breech end, the machine stopping at the same time. This process is repeated until the groove is the correct depth, when the barrel chuck is moved to its next division, and so on until the barrel is finished.

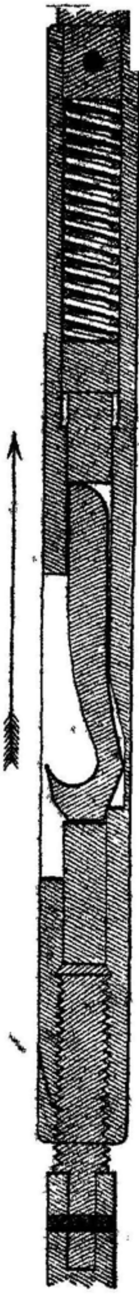

Fig. 5

I have, so far, only described that plan of grooving rifle barrels, in which a uniform twist is produced. When a varying spiral is required, the guide bar has to curve so as to approximate to the desired variation in twist of groove, and the arrangement for cutter, feed, &c., modified accordingly. When a varying depth of groove is to be produced, the desired end is obtained by modifying the pitch of spiral groove cut in back-rod, so that it shall disagree to a certain extent with pitch of twist in barrel; thus, during the passage of cutter through the barrel, the back rod is operating on the feed screw with the result of increasing or decreasing the amount of cut applied. The accompanying sketch shows in section a cutter box or tool holder, used with this machine, attached to the cutter rod at one end, and with the back rod in connection with the feed screw at the other end. The cutting tool fits in a slot cut in a cylindrical box (this fitting the bore of barrel to be rifled), and rests with an inclined face or bearing, upon a step, also abutting against the feed screw, and kept firmly in its place by the strong spiral spring shown in the forward end of the box. When the feed screw is withdrawn, the pressure of the spring causes the tool to follow, consequently raising it by the action of the inclined face upon the step in the box; when the feed screw is reversed, of course the cutter moves forward and sinks in its recess.

I must here mention that this admirable system of cutting the grooves in rifle

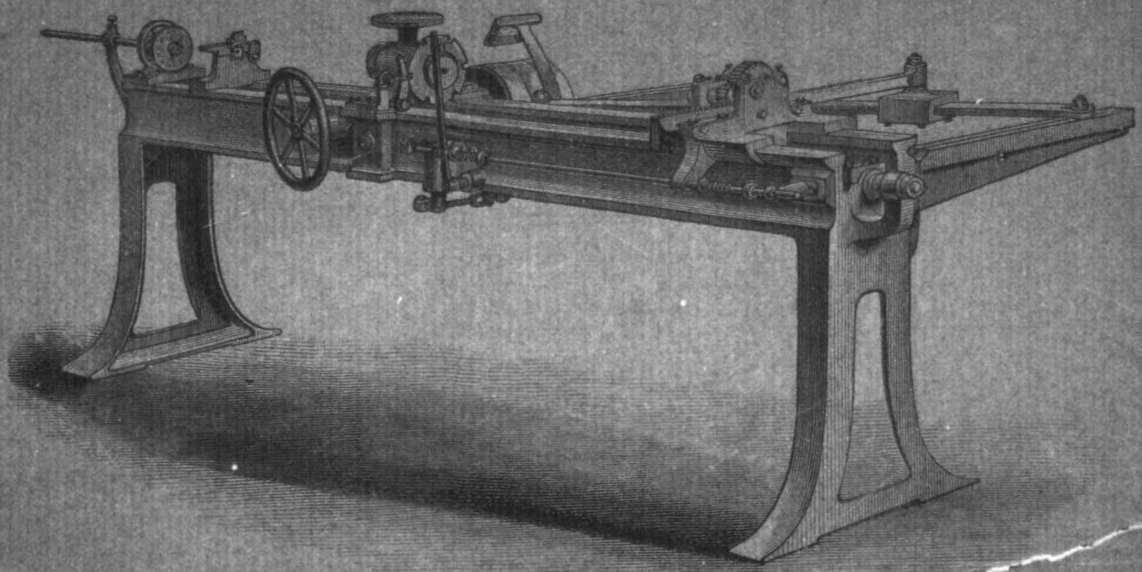

Fig. 6. Messrs. Muir and Son's Rifling Machine.

barrels was patented by Manceaux, a French gunmaker, as early as 1852, in almost as complete and perfect a manner as practised at this present day; his specification containing, among ideas now considered old-fashioned and valueless, some shrewd approximations to what has long since then been deemed advanced views in rifle manufacture. I can only just allude to the old method of groove cutting formerly practised in this country, and even now in use for some kinds of rifle barrels in the United States: I mean the plan of scraping out the cut with a file-like tool or "float" attached to a twisted rod of the desired pitch; this was worked up and down the barrel some considerable time, by hand as a rule, the rod fitting in a suitable socket, so that the "float" should copy the twist of rod inside the barrel. The process was imperfect and tedious, and has almost disappeared before Manceaux's superior method.

Messrs. Muir's Machine.

Another machine in very general use is by Muir and Son, of Manchester, who have forwarded to me the following description, together with a photograph of it, which Mr. Butterworth has carefully engraved (see Fig. 6).

The above machine is designed to rifle or cut spirals in gun barrels of almost any pitch or form of section. It is all self-contained, and does not need a driving apparatus, with the exception of one pulley on a line shaft. The barrel to be operated upon is fixed at the breech end into a dividing chuck, the muzzle end being supported by a suitable bracket, having a swivel cap, &c.

The rifling bar receives its motions reciprocating from a tranverse carriage, actuated by a revolving screw, driven by mitre wheels and strap. To economise time, a quick return motion is given to carriage by bevel wheels of 2 to 1. The reversing is effected by a bracket on carriage coming into contact with stops fixed to a rod of suitable length for a minimum or maximum traverse. This rod is coupled up to a series of levers to the strap fork—the motion of the carriage causing the strap to be moved from one pulley to another for the reverse motions as on a planing machine. To give the twist or spiral, the rifling bar is coupled up to a spindle fitted on a carriage, which is free to revolve or remain stationary at the operator's will; on this spindle a wheel is keyed, gearing into a split carrier wheel; this in turn gearing into a rack sliding on the carriage at right angles to the spindle. Motion is given to the rack by being coupled to a "former bar," of length sufficient for full traverse of carriage. This bar is secured by bolts to brackets projecting upon the body of machine. Grooves for the bolts run the length of the brackets, so that the former bar can be fixed parallel or at an angle to centre of machine. If the bar is placod parallel, motion is not given to the rack; but directly the bar is placed at an angle with the centre, motion is given to the rifling bar from the wheels and rack by causing the carriage to traverse.

To give equal divisions and the number required, the dividing head before mentioned consists of a hollow mandril, in which the barrel to be operated upon is fixed. On this mandril a dividing plate is fixed, with a suitable catch, &c., for holding the mandril stationary—the operation of dividing being done by the attendant; that is, when one groove is finished, he causes the mandril to revolve to the next division.

The rifling bar is bored up at one end to receive a suitable cutter, which is so arranged that, at the end of each cut, the tool can be drawn below the diameter of barrel, so as to avoid dragging or breaking the cutting edge. This can be done without stopping the machine, and is worked by suitable gearing from the centre of machine—that is, by hand wheel and mitres on the shaft running to extreme end of bed. At this end, a spur wheel gears into one keyed on to a hollow spindle on a bracket secured to bed—the spindle in this bracket being perfectly true, and in a line with the dividing head and spindle on carriage. The spindle is bored through, and receives a steel die with a square hole through, so as to allow a square bar to move freely. On the spindle nose a pointer is fixed, to indicate parts of revolution on a fixed index. The end of the bar is coupled up to a screw fitted in the rifling bar, this screw moving the tool in or out by the aid of an inclined plane on the back of the tool.

To put on a cut or withdraw the tool, and give an increasing depth, the operation is as follows: To put on a cut, the hand wheel at centre of machine is caused to revolve, the given amount is indicated by the pointer on the spindle of the feed bar bracket and the index plate. The spindle thus causes the square bar to revolve with the screw in the rifling bar. This screw in turn causes the cutter to slide up or down a projecting inside rifling bar—thus advancing or withdrawing the tool at pleasure.

For giving increasing depth to the groove, the hand wheel is held to the required number on the index plate—the square feed bar thus not having any circular motion. The screw is acted upon by the circular motion to the rifling bar; thus an increasing or decreasing depth of groove can be given according to pitch of feed screw and angle of former bar.

BOOK IV.

THEORY OF PROJECTILES, BY "T."

CHAPTER I.

INTRODUCTORY.

THE following remarks are written with the hope that they may serve to convey to non-scientific sportsmen and rifle-shots some little idea of the theoretical principles connected with the employment of fire-arms. As with many other discoveries of great importance, the invention of gunpowder was carried into practical use long before the principles underlying its employment received any great amount of scientific investigation. Even in the present day, most people who are accustomed to handle fire-arms have learnt to do so without having troubled their heads about the theory of the motion of projectiles. But practical men need not for that reason look upon theoretical studies as altogether needless. By dint of long practice and keen observation they may have become excellent shots; but, for all that, they might possibly have acquired their skill with fewer disappointments, and less expenditure of time and trouble, had they been spared the pains of finding out for themselves the origin of many little difficulties, which at first they may have looked upon as unaccountable, but which a fuller acquaintance with scientific principles might have led them to regard merely as natural consequences of pre-existing causes. And although, eventually, they may have become perfect masters in the manipulation of their favourite weapon, and able to do the right thing at the right moment, it not unfrequently happens that they do it by a sort of natural impulse rather than as the result of deliberation, and are quite incapable of giving to others a sound reason for the faith that is in them. Having, however, worked out their results in a practical way, it is not unnatural that such persons should consider it a waste of time to study the origin of facts with which they have long been familiarly acquainted.

The adepts who, by reason of their innate abilities and long experience, have got beyond the bounds of learning, are exceptional personages, for whom the following pages have not been written. Nor, on the other hand, is it imagined that the information can add to the knowledge of those rifle-shots who have already studied the subject scientifically; while such readers will readily perceive how much more concisely they could themselves set forth the same facts, and how much more clear they could render them by the use of algebraic symbols.

There are, however, many other men, not wanting in skill, who readily admit that plenty of "wrinkles" yet remain to be picked up, and who are perfectly willing to accept information, but have a mortal aversion to all mathematical formulas. To such persons more especially it is hoped that these observations may be of service; and it is for them, indeed, that these notes are mainly intended. And if they may not derive much actual advantage by the perusal, they may possibly find some recompense for their pains in the awakening of reminiscences of bygone days, when game got off scatheless, owing, as was then imagined, to unaccountably bad shooting, though, after all, it may have been mainly due to the operation of some natural law that hitherto had not come into operation in the same way within that sportsman's particular experience.

Two gentlemen, for instance, went on a shooting excursion across the Himalayas into Thibet; and in detailing their adventures in the *Field,* one of them said, with respect to the hunting of the "gooral," or Himalayan chamois, "Our first experience of this sport was most unsatisfactory, and it was a considerable time before either of us brought one to bag. At first we used to miss the most easy shots, apparently, and could not account for it in any way, for we were both tolerable shots in the plains." The conclusion they came to was, that it was owing to the nature of the ground, and the difficulty of judging distances. Possibly something was due to this; but it does not appear to have occurred to them that there was another very probable cause of error, viz., their height above sea-level; for the great difference in barometrical pressure at high elevations would alter considerably the trajectory of the bullet as compared with what it had been on the plains, for which the weapon had been sighted; and they might consequently clean miss an animal that they would have hit with certainty at the same distance, under conditions to which they were accustomed.

Here, then, is one incident which may not occur to every rifle-shot, but which, nevertheless, may be worth bearing in mind. Many other matters are equally or more deserving of consideration; so numerous are they, indeed, that it is not to be expected that they will be exhausted in these pages. Let us, however, attempt to deal with some of their most salient points.

CHAPTER II.

CAUSES THAT INFLUENCE THE FLIGHT OF BULLETS.

DIRECTLY or indirectly, a bullet is subjected to many influences, both before and after it leaves the barrel of the rifle; and each separate influence has greater or less effect according to variation in circumstances.

We have (1), as the originating cause of the bullet's motion, the gases produced by combustion of the powder; and the extent of the action of these gases will be varied, not only by the quantity of powder burnt, but by the physical condition of the compound, such as the size of the grains and the density due to the amount of pressure the "cake" has undergone in the process of manufacture, besides any difference which may occur in the proportion of the ingredients. Even when successive charges of the same powder are used, you cannot rely on getting absolutely exact results; for, although the sulphur, saltpetre, and charcoal may have been very carefully weighed, and great pains have been taken in the mixing process, the powder is, after all, only a mechanical mixture, and the proportions may vary somewhat in different parts of the same batch. Thus, our Government powder is said to be composed of 75 per cent. of saltpetre, 10 of sulphur, and 15 of charcoal; but in samples taken from the top and bottom of a barrel by Mr. (now Sir F. A.) Abel, one sample proved, on analysis, to have almost exactly 75 per cent. of saltpetre and the other only 74½ per cent.; one contained 10 and the other 10¼ per cent. of sulphur; and one had ¾ per cent. more charcoal than the other. It is not to be expected, then, that they could produce absolutely equal effects. Moreover, the evenness or otherwise of the grain of the powder may also influence the results obtained from successive cartridges; and so may any differences in the manipulation of the powder. The force, too, that will be exercised by a charge of gunpowder is not dependent merely on its weight and make; it is by no means, in fact, a fixed quantity, but varies with the degree of resistance encountered by the expanding gases. The potential force of the charges used in small arms is vastly in excess of the power actually developed under ordinary circumstances; and an increase in the resistance—whether it arise from additional weight of projectile, more rigid turning down of a cartridge case, or obstruction of any other nature—may produce a considerably increased development of the dormant powers of the explosive.

(2) Besides the direct effects produced by the force of the powder, the speed of the bullet is influenced by the friction that arises as the projectile is forced through the barrel, and likewise by the resistance of the partially-imprisoned air; for air there must be in the barrel when the charge is fired, and it cannot possibly get out of the way of the bullet. The walls of the tube prevent any such thrusting aside as would occur in the open atmosphere, and the speed of the projectile is too great to permit of air moving away in advance without undergoing condensation; so that there must be increasing compression, and corresponding resistance, as the bullet drives the air from breech to muzzle. The resistance which is due to friction would vary too, according to the nature of the rifling and rapidity of twist, as well as with the form of the bullet; for deep grooves and rapid spiral must offer more obstruction than shallow grooves and slow twist; while a spherical ball, which only touches in a narrow line at its

circumference, would move much more freely than elongated bullets, the resistance from which increases with their length, and *the extent of their hold upon the grooves.* Beyond these effects, there is the further obstruction which arises from fouling, and which varies with the powder, the nature of the rifling, and the moisture or dryness of the atmosphere. After black powder is burnt, nearly two-thirds of its weight remains as solid residue, and, although the larger portion of this is necessarily blown out of the barrel after the projectile, a considerable quantity is deposited within, especially when there are inequalities in the bore, such as deep rifle-grooves, wherein the dirt can readily lodge.

(3) Another of the influences affecting the course of the bullet is the recoil-movement, or "jump," which occurs in the gun before the shot has left the barrel. Some persons contend that no recoil takes place until after the shot has left the muzzle. Practical experience, however, goes to prove that the course of the bullet is affected by the motion of the barrel—which would be strange indeed if there were no movement until after barrel and ball had parted company; while theoretical considerations go to show that the recoil-movement must receive its initiation as soon as the bullet is set in motion, although the recoil would not be complete till after the projectile quits the muzzle.

(4) The resistance of the atmosphere, after the shot has departed from the barrel, is one of the most potent of the influences that affect the course of the projectile. Except for the resistance of the air, bullets would go on with undiminished speed, regardless of distance; and differences of size, shape, or weight of projectile would matter nothing as regards trajectory, for all that start with the same speed would follow the same curve. Under existing circumstances, however, different trajectories are caused, not only by different velocities, but by variation in shape of bullets of equal weight,

difference in size of bullets that are similar in form, and variation in weight of bullets that are alike in size—whether such variation be due to difference in density of the metal, or to some bullets being solid and others hollow. The trajectories of bullets will also be affected by variations in the density of the atmosphere, whether arising from differences of temperature and moisture, or differences of atmospheric pressure as shown by the rise and fall of the barometer in the same locality, as well as by the rarefaction of the air in high mountain regions. The longer the range of the projectile, the greater, of course, will be the effect on its flight; but spherical and hollow bullets are more sensitive to the change than heavy elongated projectiles of solid metal; and the effect would consequently be noticeable with the former at shorter distances than with the latter.

(5) The force of gravity, though here put last on the list, has far greater influence than any other in determining the bullet's course. Except for the effect of this force, all projectiles would fly in a straight line; they might be a greater or less time in reaching their object, according as they have low or high speed, but their course would be as direct in the one case as in the other. Under the influence of gravitation, however, the course never is direct, but invariably is curved, though not in the same degree; and the slower the speed, and longer the distance, the more marked is the curve.

Such being the principal influences that affect the course of bullets, it may be as well to examine a little more closely some of their effects. But, instead of taking them exactly in the order just given, it may be desirable, perhaps, to commence with the one last touched on, as some of the remarks made with respect to the action of the force of gravity may facilitate explanation when other points are touched on, and thus we may "kill two birds with one stone," or get two illustrations from one bullet.

CHAPTER III.

THE DROP OF THE BULLET.

In taking into consideration the progress of projectiles through the air, a little fact which is frequently overlooked should ever be borne in mind, viz., that from the instant the shot leaves the muzzle of the gun, it begins to drop down below the line in which it was fired; consequently, every yard, every inch, of the trajectory is curved, although to a very trifling extent at first. The "perfectly flat trajectory," too often spoken of, has no real existence: it could only be produced by the invention of a bullet able to set at defiance the laws of nature.

Some time ago, a sportsman writing to the *Field*, and recording the performance of a rifle in his possession, stated that it had a perfectly flat trajectory up to 150 yards. It probably never occurred to him to ask himself, "Why should a bullet go 150 yards in a perfectly straight line and then fall away from it?" He doubtless did not take into consideration any other fact than that he looked in a straight line along the barrel, and did not put up any sight for a range of 150 yards, whereas for longer distances he did put up a sight. The fact that the inside and the outside of the barrel were not parallel may have escaped his observation, or, if noticed, may not have caused him to reflect that, although his line of sight outside the barrel might be horizontal, and go straight to the object on which his eye was fixed, the bore, when he took aim, had an upward slope from breech to muzzle, and that therefore the bullet was not directed at the object aimed at, but at a point some distance above that object. Still less would it be likely to occur to him that, supposing there to be a difference of, say, $\frac{1}{10}$th of an inch in thickness of barrel or height of rib or plate at the two ends of a 27-inch rifle, this difference would be repeated 200 *times* in a range of 150 yards, and thus amount to 20 inches in such distance; while even more remote would be the inference that about midway in the range (or from 75 to 80 yards) the bullet would be fully 5 inches above the line of sight.

But, although it may be excusable in a sportsman to overlook such facts, and make statements similar to those above alluded to, the same excuse will scarcely avail a gunmaker if he utters assertions of a like nature; for he can hardly be unacquainted with the reason for constructing rifles with so much taper of barrel or thickness of plate as to dispense with movable sights up to 150 or 200 yards, nor can he be unaware of the effect that must be produced upon the elevation of the bullet at lesser distances. Yet it would not be difficult to find gunmakers' advertisements claiming for Express rifles a flat trajectory up to 200 yards, regardless of the fact that bullets which strike the mark would, according to their velocity, have been some 7, 8, or 10 inches above the line of sight in traversing that distance.

Such gunmakers were the subject of some animadversions by a correspondent of the *Field*, of a more observant turn of mind than the one just alluded to. He complained of the ill effects resulting from the construction of rifles in which the back sight had been made of undue height in order to produce a fictitious appearance of low trajectory at long ranges. In a rifle which he had bought, an otherwise good weapon had thus been rendered comparatively useless until he knocked out the back sight, which was contrived to show such a "flat trajectory" at long ranges that the bullet struck high above the mark at short distances.

As already intimated, an *absolutely* or *perfectly* flat trajectory (for both these adverbs have occasionally been made use of) can have no existence whatever. The most limited range must take some small space of time for the bullet to traverse; during that time the bullet drops, and the trajectory becomes curved. There is, no doubt, a vast deal of difference in the curves described by projectiles fired from different rifles, and by different bullets fired from the same rifle—the line of flight being, in some cases, very much less arched than in others. Consequently, one trajectory may be *relatively* flat, as compared with another; but beyond relative flatness we cannot go; and in considering why it is that one trajectory is flatter than another, we shall likewise see that, although the curve may be lessened, it never can be changed into a straight line.

The ordinary experiences of daily life make us all acquainted with the fact that, if we pick up any object of sufficient density—such, for example, as a bullet—and then, by unclosing the finger, leave it without support, it immediately begins to drop towards the earth. It does not remain in suspense an instant after its release, but, commencing with a slow downward movement, gains speed rapidly as it falls to the ground, and attains greater and greater velocity the further it descends. In like manner, everyone would consider it a matter of course for a weight falling from the height of the roof to give a more severe blow than if it had merely rolled off a chair or a table. But comparatively few persons take the trouble to ascertain the reason of such universally admitted facts. Most people are content to know what they cannot help knowing, without thinking of cause and effect; and when they find themselves face to face with certain facts that do not ordinarily come within the range of their experience. they are apt to overlook the real origin of unexpected results, and to attribute them to other causes, sometimes very wide of the mark.

Thus, a man who is a fair shot with a rifle that he has been accustomed to use at short distances, might become possessed of an "Express" such as has been recently alluded to, and have been told by the maker that it has a "point-blank range up to 200 yards;" for "point-blank" is another misleading expression in current use. From experience with his old rifle, up to 70 or 80 yards, he considers he knows well enough what "point-blank" means; and he is very well satisfied with the results when he tries his purchase at 200 yards. He finds, however, when he comes to use his new rifle at shorter ranges, that things do not go on so satisfactorily as he had anticipated; he fires "point blank," as he has hitherto done, at accustomed distances, and the bullet is planted some inches higher than he expected. It is not surprising that he should be put out thereby; and very possibly it may never occur to him that, whatever the distance for which a rifle is sighted, the bullet must be above the line of aim at intermediate distances, whether twenty-five, fifty, or a hundred yards. Why it must be so, however, becomes clear enough when one reflects upon the circumstances.

On making its exit from the barrel, the bullet drops as inevitably as it would do on being let loose by the fingers. So long as it remains within the bore, the ball is held up; but no sooner does it pass out from the muzzle, and consequently lose support, than the force of gravity takes effect on the bullet, and draws it downward. If the barrel be held horizontally, the shot begins at once to fall below the level of the position from which it started; but if—as usually is the case—the barrel has an upward inclination at the moment of firing, the bullet necessarily rises from the muzzle, and yet (anomalous as it may sound) the drop goes on during the rise of the projectile, to just the same extent as if the barrel were horizontal. In the one case, the bullet will, in a quarter of a second, have descended 1ft. below the horizontal line; and in the other it will, in the same time, have descended 1ft. below the "line of fire," whatever may be the angle of elevation above the horizon. A very good example of this double motion is seen when a jet of water issues from the muzzle of a garden-hose or fire-engine. The liquid, as it shoots forth, ascends more or less above the mouth of the tube, according to the angle to which the muzzle is raised; and the stream meanwhile falls from the line of projection to just the same extent as if the pipe were horizontal. The "trajectory" of the water, moreover, depends upon the velocity of the discharge, and, as in the case of the bullet, the higher the speed the flatter is the curve; but, however great the velocity, the jet can never strike an object unless the tube is directed in a line above it, and the stream between any two points is consequently always arched. In short, the jet of water presents visibly to the eye a curve similar in character, but shorter and higher, than that which the bullet describes when projected from the gun.

The rapidity of the natural drop in projectiles is neither increased nor diminished by their weight, nor by the speed with which they leave the gun: the velocity of descent is dependent on the duration of the fall, or, in other words, on the length of time the bullet is in motion—as this it is that regulates the distance and velocity of the drop.

Supposing, for instance, that a number of guns, all differing in dimensions, charge of powder, and weight of shot—varying, in fact, from the largest cannon down to the smallest rook-rifle or saloon pistol—were levelled horizontally on the top of a cliff, say, 100 feet above the sea; and that, on being fired, the whole of the different projectiles started off evenly together from the edge of the cliff; the various kinds of shot, whatever their weight or velocity, would drop into the water at the same moment—the time of fall (at 16 feet per second, without air-resistance) being 2½ seconds for the 100 feet.

And if, simultaneously with the shots being fired, other bullets were dropped in a straight line down the face of the cliff, or let run down inclined planes (without friction), they would reach the same level in the same time, although some of the shot may have been propelled a quarter or half a mile, and described curves of various dimensions, while others may have run down slopes of different angles, and others not have varied at all from the perpendicular. If, however, there were the slightest departure from the horizontal position of the bore, the speed of the projectile would tell; for the greater the velocity and weight, the higher would the projectile go, as compared with a slower and lighter bullet, before decending towards the earth—that is, supposing the muzzle pointed upwards; whereas, on the other hand, the more quickly would the shot make its descent if the muzzle had a downward tendency.

The "drop" may be said, in short, to be a definite quantity, determined by time, and entirely independent of any onward motion of the projectile. It operates to an equal extent whether the barrel points upwards or downwards or is held perfectly level, and whether the projectile is large or small.

It has been ascertained by experiment that bodies falling from a state of rest drop a fraction more than 16ft. in one second; but for our general explanatory purpose the fraction may be disregarded.* If the body starts with an upward or

* The fall varies slightly in different parts of the globe, increasing towards the poles and diminishing towards the equator—the attraction to the centre being greatest where the diameter of the earth is least, and *vice versâ*. The following will show a few differences in the amount of drop in one second:

	ft. in.		ft. in.
Greenwich	16 1·15	Trinidad, West Indies	16 0·55
Paris	16 1·09	Hammerfest, Norway	16 1·42
New York	16 0·96	Spitzbergen	16 1·52

Thus between London and New York the difference of fall in one second is downward impulse, the 16ft. will be added to or diminished from the distance it would have reached in one second, had the body continued to move unobstructedly in the same direction for that period of time. Accordingly, if a shot were fired straight up into the air, it would, at the end of one second, be 16ft. short of the height it would otherwise have attained; and, if fired down a precipice, the bullet would be 16ft. below the point to which it would have been carried by its own velocity in the course of one second.

It will be obvious that, if a body starts from a state of rest, and goes on regularly increasing its speed, it must move faster at the end of any given period of time than it did at the beginning, and that the velocity must increase with length of time. We always see a railway train start slowly; and it goes on for a time gradually increasing its speed, although the actual force applied when travelling at 50 miles an hour may be no greater, or even less, than when the train moved slowly out of the station. A continued application of the same motive force produces continually accelerated motion, unless it is counteracted by some other force; and, in the absence of such counteraction, the exercise of a constant force for equal periods of time would impart an equal increment of speed in every such period.

Such is the case with falling bodies, as exemplified in the trajectories of bullets. Here we have in action a constant accelerating force known as the force of gravity, which imparts a downward motion at the rate of a fraction more than 32ft. per second for the time the bullet is in motion, whether it be seconds or only a portion of a second; so that 8ft. velocity would be imparted in a quarter of a second, 16ft. in half a second, 64ft. in a couple of seconds, and so on.

about one-fifth of an inch, which may seem very trifling; but in a range of 1000 yards, with a Martini-Henry rifle, the total would amount to nearly two inches; and in similar ranges in Norway and the West Indies there might be a difference of drop of about eight inches—other things being equal.

A knowledge of the speed gradually attained in a given period of time would, however, afford to many people but little idea of the distance actually traversed in that time. Almost anyone, on being told that a certain train acquired a speed of three miles an hour in the first minute, and regularly increased its speed at the same rate, would at once perceive that in course of ten minutes it would have a velocity of 30 miles an hour, and that it would have double that speed in double the time. Nevertheless, it might puzzle him to say how far the train would have travelled in any given portion of the time; and he might even be incredulous if told that in five minutes, although the train would then have attained a velocity of 15 miles an hour, it would only have gone five furlongs, and that, at the end of the first minute, when moving at the rate of three miles an hour, it would not have proceeded 50 yards.

On the other hand, the fact of the train travelling nearly a mile in the course of the twentieth minute would be readily apprehended; and so would the statement that, by starting from 0 velocity and increasing regularly to 60 miles an hour, the average speed in the meantime must be 30 miles an hour.

It requires, however, but another step onwards to arrive at the fact that, with an average speed of 30 miles an hour, no more than 10 miles could be run in $\frac{1}{3}$rd of an hour, or 20 minutes; and the same method of estimation will quickly demonstrate that, as the average speed during the first minute (beginning from 0 and ending with 3) is but $1\frac{1}{2}$ miles an hour, the distance traversed in the $\frac{1}{60}$th part of an hour could only be the $\frac{1}{60}$th part of $1\frac{1}{2}$ miles (*i.e.*, 2640 yards), and therefore would not exceed 44 yards in one minute.

In the drop of bullets a similar process goes on. As already stated, the speed increases at the rate of 32ft. per second for the time occupied in the descent; hence it will be obvious that 8ft. velocity must be imparted in $\frac{1}{4}$th of a second.

It is not so apparent, however, that in this same quarter of a second the bullet would drop only 1 foot; yet, by having recourse to the method just adopted with respect to the train, it will be clear that such must be the case; for a bullet starting from 0 and increasing to 8ft. velocity would have a mean speed of 4ft., and progression at this rate for $\frac{1}{4}$th of a second could not carry the body more than 1ft. from its original position. But it is only when the periods of time are fractional that the progress seems so insignificant as compared with the speed; for the reverse is apparently the case when we get to whole seconds, as the distance then seems to increase with marvellous rapidity.

An accelerating velocity of 32ft. per second gives a drop of 16ft. in the first second, because it starts from 0 and ends at 32, and the drop is equal to the mean velocity. The next second begins with a velocity of 32 and ends with 64, so that the mean velocity is 48. The velocity and drop afterwards proceed as follows:

Time	Velocity at end of each second	Drop in the respective seconds	Total drop at end of each second
1 sec.	32ft per sec.	16 feet.	16 feet
2 ,,	64 ,,	48 ,,	64 ,,
3 ,,	96 ,,	80 ,,	144 ,,
4 ,,	128 ,,	112 ,,	256 ,,
5 ,,	160 ,,	144 ,,	400 ,,
6 ,,	192 ,,	176 ,,	576 ,,

The full second, with the rate of drop as here indicated, is, however, too large a unit of time for the sportsman's purpose, which requires, for the most part, fractions of a second to be taken into consideration, with drops of a few inches rather than hundreds of feet. Let us, then, take $\frac{1}{10}$th of a second as our unit of time, and we shall have very nearly 2 inches (*i.e.*, 1·93in.) as our unit of drop—which would be the extent of fall in a 50 yards range, with a bullet traversing the 150ft. at a mean velocity of 1500ft. per sec. On the same principle will the drop go on whatever unit may be chosen. Whether a full second, or a tenth or a hundredth part of a second, be adopted as the unit of time, the rate of progress will be as follows:

Periods of time.	Units of drop in the respective periods.	Total units of drop at the end of each period.
1st	1	1
2nd	3	4
3rd	5	9
4th	7	16
5th	9	25
6th	11	36
7th	13	49
8th	15	64
9th	17	81
10th	19	100

Taking, then, 2in. as the extent of fall in the first unit of time, the drop in the next equal period would be treble as much, or 6in. (making 8in. for the two periods); in the next equal space of time there would be five times 2in., or 10in. further fall (making 18in. in the three periods), and so on. The figures in the second column, multiplied by 2in., show the respective fall in each successive period, while those in the third column (also multiplied by 2in.) give the total of all previous periods. And, if it were possible for a bullet to pass through the air without losing speed, a shot that fell 2in. in 50 yards would fall 6in. between 50 and 100; 10in. between 100 and 150; and 14in. between 150 and 200—making 32in. altogether.

If, however, instead of a 2in. drop in the first period, any other space were taken—as, for instance, the $\frac{1}{50}$th part of an inch (or 0·02in.), which would be equivalent to the fall in $\frac{1}{100}$th part of a second—the same law would hold good. With a mean velocity of 1500ft. per sec., this drop would occur in a bullet by the time it had got 5 yards from the muzzle. In six such periods, or about 30 yards, the 0·02in. would be multiplied by 36, and amount to nearly $\frac{3}{4}$in.; and at the end of the eighth period, or 40 yards, the total fall would be

0·02 × 64, or about 1¼in. But, as before intimated, comparison of equal distances with equal times is not strictly correct, and is only assumed for facility of explanation.

The entire fall indicated in the last column of the foregoing tables will be observed to be the sum total of the drops separately indicated for the respective periods given in the previous column. Hence, 576ft. (at the end of six seconds), in the table on page 51, will be the total of the respective distances from 16ft. to 176ft.; while, in the next table, 100 (or any other number in the final column on the opposite page) will be the sum of the preceding figures in the middle column, up to the same period of time.

It is not necessary, however, to resort to this cumbrous mode of adding together the various figures in order to arrive at the required total, because the same end is obtained by the much more ready process of "squaring" the number of seconds, or other periods of time. Thus, 36 is the product of 6 by 6, as well as the sum of all the odd numbers from 1 to 11; for it will be observed that the middle column of the last table consists exclusively of odd numbers. So the figures in the third column in the first table are only the same odd numbers multiplied by 16ft. (which there is the unit of drop), and 576 in the final column is the product of 16ft. multiplied by 6 times 6.

The variation in the amount of drop in short periods of time may be better seen in the table on p. 54, where $\frac{1}{100}$th of a second and $\frac{1}{10}$th of a second are respectively taken as units of time, and are carried on for ten successive periods, so that the bottom of one column connects with the top of the next until full seconds are arrived at. In each case, the figures represent the total amount of fall at the end of the respective periods of time, but, where there are fractions, it has been thought unnecessary to work them out with great minuteness. The drop in the column for full seconds will be seen to be

100 times as great as in the previous column, and 10,000 times as great as in the column for hundredths of a second.

Number of periods.	Hundredths of a second.	Tenths of a second.	Full seconds
1	$\frac{1}{50}$ inch	2 inches	16 feet.
2	$\frac{1}{14}$,,	$7\frac{3}{4}$,,	64 ,,
3	$\frac{1}{6}$,,	$17\frac{1}{4}$,,	144 ,,
4	$\frac{1}{3}$,,	$2\frac{1}{2}$ feet	256 ,,
5	$\frac{1}{2}$,,	4 ,,	400 ,,
6	$\frac{2}{3}$,,	$5\frac{3}{4}$,,	576 ,,
7	1 ,,	$7\frac{3}{4}$,,	784 ,,
8	$1\frac{1}{4}$,,	$10\frac{1}{4}$,,	1024 ,,
9	$1\frac{3}{5}$,,	13 ,,	1296 ,,
10	2 ,,	16 ,,	1600 ,,

With the mean velocity of 1500ft. per second, one of these columns would represent "drops" occurring at intervals of 5 yards, while the others would, in a similar way, apply to intervals of 50 and 500 yards; and the last figures in the respective columns would represent the total drop in ranges of 50 yards, 500 yards, and 5000 yards (or nearly 3 miles)—the last of which, of course, could only apply to artillery. Inasmuch, however, as projectiles inevitably lose speed during their flight, and consequently the same shot can never have the same mean velocity for different distances, the above figures cannot be taken as strictly applicable to any single shot, and could only be correct if applied to a series of separate shots giving an equal mean velocity for all the ranges indicated. If, for instance, a 12-bore spherical ball had a mean velocity of 1500ft. per second over a 50 yards range, it would leave the muzzle with a speed of about 1650ft. per second, which would be reduced below 1400ft. velocity in going the 50 yards. Obviously, then, the first half of the distance would be accomplished in less time than the second half; and the extent of the drop during the first half of any given range must consequently be less than one-fourth of the drop occurring in the full range. For short distances, however, the proportions may be assumed to be approximately correct; and it will suffice to say, in round numbers, that, with a mean velocity of 1500ft. per second, there would be a drop of about half an inch in the first 25 yards, and about an inch and a half between 25 and 50, making two inches for the 50 yards. And in like manner it may be assumed that the height of the trajectory is about one-fourth of the total drop, although it is always more than one-fourth. With heavy elongated projectiles the one-fourth approximates much more closely than with light Express bullets and spherical balls; and the longer the range the less accurate is the foregoing estimate, especially with the lighter bullets.

The writer of this was asked, not long since, to define the share in the formation of the trajectory-curve which is due to gravity alone, and the share which is due only to air-resistance. Strictly speaking, the whole is directly produced by the action of gravity, although a portion is the indirect result of atmospheric resistance. The drop of the bullet (from which the curve results) is, as recently stated, a definite quantity dependent upon the time of fall. The effect of air-resistance is to lessen the bullet's speed; it thereby lengthens the time taken to traverse a given range, and the drop is thus increased, by the force of gravity being enabled to operate for a longer period of time.

In one sense, however, an answer may be given to the foregoing question. If there were no air-resistance, the muzzle velocity of the bullet would be its velocity throughout the range; by dividing the length of range by the bullet's velocity, you get the time of the trajectory; and from this the drop may be ascertained. Thus, a bullet with 1500ft. uniform velocity would traverse 500 yards in one second; and there would be a drop of 16ft. due to gravitation alone. But, in actuality, the velocity is always decreasing, and a bullet that starts with 1500ft. velocity from the muzzle would have much less velocity at the end of 500 yards; consequently it would take more than a second to traverse the distance, and therefore would drop more than 16ft. The difference between 16ft. and the actual drop will be the portion due to the action of air-resistance.

It may be said, however, that this gives no idea of the extent of the drop indirectly caused by the air in any given distance; and such a remark would be perfectly true. It is easy enough to give the vague general answer, but by no means so easy to furnish the special reply directly applicable to any particular instance. Every case must be dealt with according to its own circumstances. You require, in the first place, to know the weight and shape of the bullet, the bore, and the velocity; from these facts, by a process of calculation that will hereafter be described, you may ascertain how much the velocity will be reduced in a given distance, and therefrom you may calculate the time the bullet would take to traverse the range, and from this period of time you will deduce the total amount of drop. When you have got such particulars, you may subtract from this total drop the corresponding amount derived from the supposititious case of the bullet losing no velocity, and the difference will be the portion due to air-resistance.

The knowledge of the result in one case will not, however, necessarily afford information as to the result in another, unless the velocities are alike, and weight and bore in the same proportions in both instances. An alteration in the initial velocity will give a different result with the same bullet; an alteration in the bullet will give a different result from the same initial velocity; and several different bullets, fired with the same charge of powder from the same rifle, will give widely divergent differences. Here are the estimated results (without descending to very minute fractions) obtained from firing a solid elongated bullet, a hollow elongated bullet, and a spherical ball, each with 6drs. of powder, from a rifle of ·577 bore. The two elongated bullets had very nearly the same muzzle velocity, but the spherical bullet had about 150ft. higher initial speed than the other two. The differences at 100 and 200 yards are given with all three.

	Total Amount of Drop		Without Air-resistance		Difference	
	In 100yds	*In 200yds*	In 100yds	In 200yds	In 100yds	In 200yds
Solid bullet	$6\frac{1}{2}$in.	32in.	$5\frac{1}{4}$in.	21in	$1\frac{1}{4}$in. ...	11in.
Hollow bullet	$6\frac{3}{4}$in.	34in	$5\frac{1}{4}$in.	21in.	$1\frac{1}{2}$in. .	13in.
Spherical shot	$7\frac{1}{2}$in.	49in.	$4\frac{1}{2}$in.	18in.	3 in. ..	31in.

From the middle column it will be seen that the action of gravity, *without* air-resistance, would give least drop with the highest initial velocity, and equal drop with equal velocity though different bullets. But the other columns show the greater effect of air-resistance on the lighter bullets, and the difference produced on the spherical ball is more than double the difference with either of the others. It is obvious, therefore, that no definite rule can be laid down which would apply to all cases. The subject of air-resistance will, however, be more fully treated of in the ensuing chapter.

CHAPTER IV.

ATMOSPHERIC RESISTANCE.

THE amount of resistance opposed by the air to the passage of projectiles is truly marvellous. As a rule, however, most people have very vague notions of the force of air-currents or air-resistance. Everyone, no doubt, has some personal experience of the power of the wind, as it drives him along or resists his progress in stormy weather; but ideas as to what the pressure amounts to are usually very indefinite. We hear, it is true, after the occurrence of disastrous gales, a good deal with respect to their estimated force; and the newspapers publish statements of the amount of wind-pressure which caused the destruction of the Tay Bridge or some other edifice. We learn that the wind exerts a pressure of about 20lb. per square foot when a gale blows at the rate of a mile in a minute; that a hurricane of 80 miles an hour gives a pressure of more than 30lb. per square foot; and that, if the velocity of the wind reaches 100 miles an hour, the pressure is raised to about 50lb. per square foot.

Such air-currents, however, except that they extend over vast surfaces, are insignificant as compared with the atmospheric pressures on projectiles moving at high velocities. The hurricane of 100 miles an hour travels less than 150 feet in a second, or with not one-tenth part of the speed of bullets from many sporting rifles.

Action and reaction being equal, the pressure produced is the same, whether air rushes at a given speed against a motionless body, or the body is propelled at the same rate in a calm atmosphere, or whether movement in both serves to produce a combined velocity of similar extent; so that there would be the same atmospheric pressure on the front of a locomotive when the train runs at 40 miles an hour and meets a breeze of 10 miles an hour, as when the engine runs at 50 miles an hour and there is no wind, or when it runs at 60 miles an hour and overtakes a 10-mile breeze that is blowing in the same direction. In each case the atmospheric pressure would be the same as if the wind were blowing at the rate of 50 miles an hour and the engine were standing still; and the pressure per square foot would be about $12\frac{1}{2}$lb. In a similar manner, but with greater force, would the pressure of the atmosphere act on bullets in motion.

What may be the amount of pressure exerted by the air on moving projectiles was ascertained a few years ago by the Rev. F. Bashforth, Professor of Applied Mathematics to Royal Artillery Officers at Woolwich. He found, as the result of experiments carried out by order of the Government, that with a 14in spherical shot (which is almost exactly one square foot in sectional area) the resistance of the air produces a pressure of rather more than a ton when the shot is moving with 1400ft. velocity; and that with a velocity of 1900ft. per second the resistance is increased to more than two tons per square foot. With shot of larger or smaller sizes, the pressure, with the same velocity, is proportionate to the amount of surface the projectiles present to the resistance of the atmosphere, and consequently would be at the rate of a ton or two tons per square foot on a spherical bullet, if moving at the speeds stated; but a 4-bore bullet would only be about the $\frac{1}{200}$th part of a square foot, and one of ·500in· diameter would be about the $\frac{1}{800}$th part of a square foot, and the pressure in proportion. No wonder, when they encounter such resistance as this, that projectiles of all kinds fall off in velocity as they pass through the air.

With bullets of light weight the loss of speed is much more considerable than with heavy projectiles ; for shot of the same shape, and moving with equal velocity, meet with a resistance which, as just stated, is proportionate to the amount of surface they present to the atmosphere as they rush forward, whereas their weight, and consequent momentum, is by no means in equal proportion, but decreases at a much more rapid rate than their diminution of surface. Thus, the 14in. round shot just alluded to would weigh about $3\frac{1}{2}$ cwt., and the air-resistance would have a much less retarding effect on so heavy a mass than it would have on a 4-bore bullet of about an inch in diameter, for the weight of the 14in. shot would be about 1600 times as great as that of the inch bullet, but its surface would only be about 200 times as great. In like manner, a pellet of No. 6 shot, which is about $\frac{1}{10}$th of an inch in diameter, would be more retarded than the 4-bore bullet. Such a bullet is heavier than a thousand pellets of No. 6 shot, whereas its area of resistance is barely a hundred times as great; and while the air-resistance would depend on the diameter, the momentum, or, in other words, the "staying power" of the respective projectiles, would be proportionate to their weight. Hence, the 14in. cannon ball, with 1400ft. initial velocity, would only lose about 20ft. of its speed in the first 50 yards; and the 4-bore bullet would fall off about 150ft. in velocity in a like distance; whereas a No. 6 pellet would soon be reduced to less than half of its original speed, for if it started with a velocity of 1400ft. per second, it would, after travelling 50 yards, have little more than 600ft. velocity remaining.

Were it not for this resistance of the atmosphere, small shot would not lose speed any faster than large ones, nor spherical balls more rapidly than elongated bullets. Indeed, there would be no loss of speed at all in projectiles fired horizontally, for they would simply be drawn down towards the earth by force of gravity. When fired in a direction away from the earth they would be reduced in velocity during their ascent, owing to the retarding influence of gravitation; but the decrease would be a comparatively slow process, and the speed lost in the rise would be regained in the fall. Under such circumstances, a ball fired vertically into the air with 1400ft. initial velocity, would, whatever its weight and shape, ascend to a height of more than 30,000ft., or about six miles; and in its descent it would acquire the same velocity that it had on leaving the muzzle of the gun. Under existing conditions, however—encountering, as it does, the resistance of the atmosphere—a bullet with the initial velocity just mentioned might not rise to a quarter, a tenth, or a twentieth part of the above-named distance; and the height of the ascent would vary with the weight and shape of the projectile. In the descent, too, the shot would again encounter the resistance of the air, and instead of re-acquiring the speed it had on leaving the gun, it would reach the ground with a comparatively low velocity. It is stated, indeed, that the utmost velocity attained by the old-fashioned musket-ball during its descent to the earth, after being fired high up into the air, was but little over 200ft. a second; for the resistance of the atmosphere suffices to prevent any increase of velocity beyond a certain point, when a body descends by the mere force of gravity; but that point would not be alike with all projectiles, as it would depend upon their weight and dimensions, and consequent power of overcoming resistance.

The Form of the Bullet.

The shape of the bullet has a very great deal to do with the amount of resistance it encounters in making its way through the atmosphere. Spherical shot are ill-fitted for maintaining their velocity — first on account of the large amount of surface in proportion to weight (especially in small projectiles), and, secondly, because they are badly formed for thrusting their way through the air. Elongated shot have much more weight in proportion to the extent of surface directly opposed to atmospheric resistance, and in such projectiles, therefore, one objectionable quality appertaining to spherical balls is got rid of; but if the head of the elongated projectile be shaped like the half of a round ball, the second objectionable feature above alluded to is retained, and an elongated bullet with hemispherical head will encounter considerably more resistance from the air than will another bullet similar in size but better in form. In the hemispherical bullet there is a "bluffness" that reminds one of the full, broad bows seen in old-fashioned slow-moving sailing vessels; and as we know that the speed of ships depends largely upon the

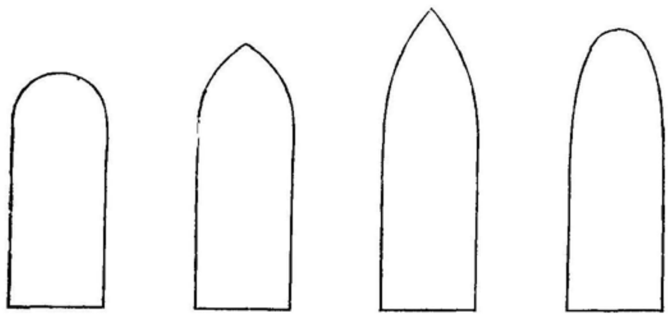

FIG. 7. FIG. 8. FIG. 9. FIG. 10.

"lines" on which they are built, so do we find the velocity of the projectile influenced by its shape. In the one case as in the other, the amount of resistance is determined, not merely by the bulk and speed of the moving body, but also by the lines or curves which that body presents to the fluid through which it has to force its way.

In the above figures are shown sections of several half-inch or ·500-bore bullets, which differ in the shape of their heads, but are alike in the body, being two diameters (or one inch) each in length, independently of head. In Fig. 7 the head is hemispherical; in Fig. 8 and Fig. 9, both heads are ogival in shape (like the pointed windows and arches of Gothic buildings), though they differ in their curves, which are formed on a radius of one diameter in the former case and of two diameters in the latter. In Fig. 10, the curvature at the shoulder is similar to that in Fig. 9, but the point being rounded off, it becomes elliptic, or, rather, hemispheroidal at the end. The bullets are shown with equal length of body, in order that the difference in shape of the head may be more obvious; but, of course, if the bullets had to be made of equal weight, the body of the longer bullets would have to be somewhat shortened.

Bullets shaped like Fig. 7 encounter considerably more air-resistance than do those formed like Fig. 8 or Fig. 9. The difference between the latter two is but trifling as regards resistance, although one is more sharply pointed than the other; and it is a curious fact, too, that the removal of the point has very little influence on the atmospheric resistance, which depends less on the sharpness of the bullet at the apex than on the nature of the curvature at the shoulder. Professor Bashforth found, as the result of experiments with elongated projectiles having heads of different shape, that the resistance to the hemispherical head (Fig. 7), at a velocity between 1100 and 1200 feet per second, was about 25 per cent. greater than with either of the other forms shown in Figs. 8, 9, and 10. He says: "The resistance to the hemispherical head was decidedly greater than that opposed to the remaining three forms. The resistance of the air to the hemispheroidal and the ogival heads varied so little that it was plain that any of these forms most serviceable in other respects might be safely adopted. The slight variations in the resistances to the three latter forms lead to the conclusion that the amount of resistance offered by the air to the motion of elongated shot is little affected by the more or less pointed apex, but depends chiefly upon the form of the head near its junction with the cylindrical body of the shot. In this neighbourhood the forms of the hemispheroidal head and the ogival head struck with a radius of two diameters are the same, and the resistances are little different."

Between the perfectly flat head and the hemispherical head there is not a very large amount of difference as regards air-resistance, though it is rather greater with the former than with the latter. It is strange, however, that with ordinary round shot there should be much more resistance than with elongated bullets having rounded heads, and more even than with flat-headed projectiles. It has just been stated that there is about 25 per cent. more resistance with bullets shaped like Fig. 7 than with the other shapes figured; and the resistance increases to about 30 per cent. with flat-headed projectiles; but with round shot the resistance is upwards of 40 per cent. more than with elongated shot like Figs. 8, 9, and 10, at the velocity previously stated, and at a lower velocity (1000ft. per second) it is about 90 per cent. more; for with change of speed the degree of the resistance does not alter in similar proportion with the different projectiles, as will be obvious from the following table, where the velocities range from 1000 to 2000 feet per second. Here the figures relating to 14in. round shot are included in order that the air-resistance on projectiles of this diameter may be regarded as "pressure per square foot," a 14in. circle being just about one square foot in area.

In the case of the bullets of ·500 bore, the last two columns will show the respective pressures on projectiles of half an inch diameter; but elongated bullets are, of course, much heavier than spherical balls of the same bore, and therefore, in order to indicate the proportion which the pressure bears to the weight of the bullet, a number is in each case placed between parentheses. Thus, in the first line, the pressure of the air on the ·500-bore elongated bullet is indicated as equal to about ten times the weight of the projectile, whereas that on the spherical ball of the same diameter is about forty times the bullet's weight. Hence it is that the spherical ball loses speed so much more rapidly.

AMOUNT OF AIR-RESISTANCE AT DIFFERENT VELOCITIES:

	With 14-inch Shot.		With ·500-bore Bullets.	
Velocity. Ft.-sec.	Ogival. lbs.	Spherical. lbs.	Ogival. lbs.	Spherical. lbs.
1000*	456	859	0·58 (10)	1·10 (40)
1100	866	1227	1·10 (19)	1·56 (56)
1200	1153	1614	1·47 (26)	2·06 (74)
1300	1453	1977	1·85 (33)	2·52 (91)
1400	1794	2361	2·23 (40)	3·01 (108)
1500	2012	2755	2·57 (46)	3·51 (126)
1600	2238	3179	2·85 (51)	4·06 (146)
1700	2483	3613	3·17 (57)	4·61 (166)
1800	2745	4055	3·50 (63)	5·17 (186)
1900	3011	4539	3·84 (69)	5·79 (208)
2000	3351	5060	4·27 (76)	6·45 (232)

For the purpose of the above comparison with ·500-bore bullets, the elongated projectile has been assumed to be double the weight of the spherical ball. Thus, supposing the latter to weigh about 200 grains and the former 400, the air-resistance to the spherical ball would, at 1000 ft.-sec. velocity, be equal to nearly 40 times the weight of the ball, whereas with the elongated bullet it would be only about 10 times the weight of the projectile; and with higher velocities the pressure would go on increasing as shown by the respective numbers. If the elongated bullets were of more than double the weight of spherical balls of the same bore—as many are—the contrast would be still greater than is here shown.

DIFFERENCES OF BAROMETRICAL PRESSURE.

It was intimated in a previous page that difference of barometrical pressure has, in some cases, a considerable effect on the amount of retardation produced by the air, and consequently on the extent of the "drop" in the bullet; and the longer the range and the lower the velocity, the greater this difference will be, while with short ranges and high speed the effect will scarcely be noticeable. Spherical balls are more sensitive to the change than elongated projectiles, and heavy bullets less so than light ones. Reference has been made in a previous page to two sportsmen who went on a shooting excursion across the Himalayas into Thibet, and who found great difficulty in hitting their game in the hill country; and, as already remarked, it seems probable that the result may have been due in some measure to the difference of the drop of the bullet in a rarefied atmosphere. What the greatest height was at which these gentlemen used their rifles is not apparent from the account of their doings. They ascended to the height of about 20,000 feet, yet it is not probable that they continued to shoot up to that elevation; but as mention is made of kakur or barking deer being found up to the height of 10,000 feet, and musk deer up to 12,000 feet, and of the party having gone in pursuit of tahr, or wild goat, at greater elevations, it may well be presumed that they used their weapons where the barometric pressure was less than 20 inches, which would be at about 11,000 feet high.* The "highest inn in Europe," on the Riffelberg, in the Alps, in the neighbourhood of the Matterhorn, is about 8500 feet high; and at this height the barometer would mark about 22 inches—a fact which may perhaps be of some little interest

* Since the above was written, two letters have appeared in the *Times* (Sept. 13, 1883), descriptive of mountain-climbing in the Himalayas, by Mr. Graham, a member of the Alpine Club, with two Swiss attendants. Writing from a camp at an elevation of 14,000ft., he says · "Boss is shooting. There is not much sport, but I was lucky enough to get a fine ounce or snow leopard. The peak Kang La, which Imboden and I ascended, is either 20,300ft. or 20,800ft., according to the two known surveys; so that I shall not return quite empty handed." And in the second letter Mr. Graham said: "We managed to bag another peak, which I have taken the liberty of calling Mount Monal, on account of the quantity of these fine birds on its lower slopes. Height, 22,326ft. by Government survey."

in connection with this subject, as chamois are still to be found in the district.

The reduction of barometrical pressure has a very similar influence upon the motion of the projectile to that which would be produced under ordinary atmospheric conditions if an addition were made to the weight of the bullet without enlarging its area or lessening its initial velocity. Under such circumstances a less amount of retardation would result from the resistance of the air. A fall in the barometer from 30in. to 29in. would be like multiplying the number of grains in the projectile by $\frac{30}{29}$, or, in other words, increasing it by $\frac{1}{29}$th of its weight; thus, in the case of the Martini-Henry bullet, raising it, in effect, from 480 grains to about 496½ grains. And if the barometric pressure diminishes to 20in., the effect would be similar to multiplying the bullet's weight by $\frac{30}{20}$, and thus increasing it by one-half, which would be similar to an increase of the Martini-Henry bullet from 480 up to 720 grains. Such, indeed, is the likeness of result, whereas the difference in cause is, that in the one case less obstruction is offered by the reduced weight of the air, and, in the other, that the power of overcoming obstruction is enhanced by the increased weight of the bullet.

The modern "Express" rifle has considerably altered the condition of things from what they were formerly; and there is nowadays much less necessity for the exercise of a discriminating judgment than there used to be when none but spherical balls were in vogue. As the Himalayan excursion already alluded to took place some twenty years ago, the rifles used were not "Expresses," and the spherical balls employed were by no means of large dimensions. The rifle carried by the writer of the narrative was only a 24-bore (almost exactly the same diameter as the ·577 Express), which, with a spherical ball, must necessarily have had a very high trajectory at the long ranges at which it appears to have been used by him; and its susceptibility to differences of atmospheric pressure must have been considerable accordingly. If this rifle gave an initial velocity of, say, 1500ft. per second, its bullet would, in a range of 200 yards, drop about 1½in. less for every inch of fall in the barometer. Supposing, then, that these sportsmen were shooting at such an elevation that the atmospheric pressure indicated on the barometer was reduced from 30in. to 20in., and that their rifles had been sighted in England, where 30in. is the normal height of the barometer, the 24-bore bullet, after a flight of 200 yards through the air, would be about 15in. higher than the spot aimed at, so that a bullet which, under ordinary circumstances, would have killed or wounded an animal, might pass clean over its back in consequence of the diminished resistance of the atmosphere.

At short distances, however, the variations of drop from this cause are so small as to be practically unnoticeable, especially with heavy elongated projectiles; but even with these the differences are more marked as the distances increase, and at long ranges they become very considerable. The difference may be said, in round numbers, to increase in proportion to the cube of increase in range, so that if the bullet were an inch high at one distance, it would be about 8in. high at double the distance. With heavy elongated bullets, such as the Martini-Henry, the proportion keeps very near to the cube; with spherical balls there is a greater ratio of difference, as will be seen by the following figures:

DIFFERENCE IN DROP OF BULLETS WITH 1 INCH DIFFERENCE IN BAROMETER (29″ AND 30″).

	At 100yds	At 200yds	At 400yds	At 800yds.
Martini-Henry, with 1350 ft.-sec muzzle velocity	0·04in.	0·34in.	2·6in.	22in.
24-bore spherical ball, with 1500 ft.-sec. muzzle velocity	0·17in.	1·61in.	15·7in.	...

DIFFERENCE IN DROP WITH 10IN. DIFFERENCE IN BAROMETER (20″ AND 30″).

	At 100yds	At 200yds	At 400yds.	At 800yds.
Martini-Henry, with 1350 ft.-sec. muzzle velocity	0·43in.	3·6in. ...	2ft. 2in. ...	$17\frac{1}{2}$ft.
24-bore spherical ball, with 1500 ft.-sec. muzzle velocity	1·70in.	15·4in. ...	13ft. 0in. ...	

It will be observed that, with every doubling of distance, the difference with the Martini-Henry bullet increases in about an eightfold degree, whereas with the spherical ball it is even greater, the increase being tenfold or thereabouts; and although, when the barometer falls from 30″ to 29″ (which might happen in the course of a few hours in these islands), the 24-bore bullet would show only about $\frac{1}{8}$in. greater variation than the Martini in 100 yards, yet the augmentation is so rapid that the difference in the height of the spherical ball at 400 yards would exceed 15in., although in the case of the long bullet it would be less than 3in. With the great reduction in barometrical pressure that occurs in high mountain regions the differences increase accordingly. Thus, at the height of about 11,000ft. (where the barometer marks only 20″ instead of 30″) the bullet loses no more velocity in traversing 300 yards of this attenuated air than it would in passing through 200 yards of the heavier atmosphere near the sea level. Consequently, about ten times as much effect is produced by the 10in. reduction on the barometer as by the 1in. fall previously alluded to; and in 400 yards the difference with the 24-bore spherical ball would amount to about 13ft., so that the bullet which would strike less than $1\frac{1}{2}$in. high at 100 yards would increase the difference in height more than ten times for every doubling of distance. Obviously, it would be useless to give the difference with the spherical ball in ranges beyond 400 yards.

It may probably be said that nobody would think of firing at game 400 yards off with a 24-bore spherical ball. These particular remarks, however, are not intended to demonstrate what would be done nowadays, but to illustrate principles that are still in force by striking examples of what was done in days gone by; and the writer quoted said, in one part of his narrative, after alluding to game found at elevations up to 11,000ft.: "I amused myself with three long shots at a gooral, who was feeding about 400 yards off, down a khud, but missed him. . . . . He could not see me, and, on the first two shots being fired, seemed *not to understand it at* all. . . . . The third bullet, hitting the ground close to his feet, roused him from his fancied security, and away he bounded out of sight. This animal was probably much farther off than I have stated; for distance is so deceptive in mountainous ground, and I should not have seen him at all if I had not discovered him with the aid of my binoculars."

Elongated projectiles, more especially heavy ones, are affected much less than spherical ball; but the following figures will show the regularity of increase in velocity and diminution in drop of a Martini-Henry bullet in a 1000-yards range, with each successive reduction of an inch in the barometric scale. The last column shows the consequent rise of the bullet above the mark aimed at, supposing the elevation of the rifle to be equal throughout. The initial velocity of the bullet is taken at 1350 feet per second, and the third column shows the remaining velocity at the end of the 1000 yards range. A text-book issued by Government for officers at the School of Musketry gives the muzzle velocity of the Martini-Henry as 1365 ft.-sec.; but various chronograph records have not greatly exceeded 1300, so that 1350 is taken as an intermediate round number.

Barometer.	Height above sea-level.	Velocity of bullet at 1000 yards	Drop of bullet in 1000 yards.	Height of bullet above mark.
30in. ...	0 ...	672 ft.-sec. ...	186·0 feet ...	0
29 ...	841 feet ...	684 „ ...	182·1 „ ..	3·9 feet
28 ...	1832 „ ...	696 „ ..	178·3 „ ..	7·7 „
27 ...	2859 „ ...	708 „ ...	174·6 „ ...	11·4 „
26 ...	3926 „ ...	720 „ ...	171·0 „ ...	15·0 „
25 ...	5033 „ ...	733 „ ...	167·3 „ ..	18·7 „
24 ...	6186 „ ...	746 „ ...	163·6 „ ...	22·4 „
23 ...	7389 „ ...	759 „ ...	160·1 „ ..	25·9 „
22 ...	8644 „ ...	773 „ ...	156·7 „ ..	29·3 „
21 ...	9958 „ ...	787 „ ...	153·3 „ ...	32·7 „
20 ...	11336 „ ...	801 „ ..	150·0 „ .	36·0 „

Express rifles vary so much in the velocity and weight of their projectiles, and the atmospheric resistance alters so greatly in ranges of different length, that a very extensive series of tables would be required to set forth the relative effect of changes in barometrical pressure with Express bullets differing in size, weight, and speed; but sufficient has been said to show that, at ordinary sporting ranges, with our modern weapons, the reduction of weight in the atmosphere affects the drop of the bullet only to the extent of inches, where formerly the difference amounted to feet.

It may be as well, however, to give the following two as typical examples; but the inch-by-inch variation differs so little from the mean of 10in. that it is not thought necessary to give the figures throughout:

DROP OF EXPRESS BULLETS AT DIFFERENT BAROMETRICAL PRESSURES.

·450 BORE; 260GR. BULLET; 1900 FT.-SEC. MUZZLE VELOCITY.

Height of Barometer.	Drop of Bullet in 100yds	150yds	200yds	300yds	400yds.
30″	6·09in. ..	15·50in. ..	31·25in.	88·96in. ..	191·51in.
29″	6·03 ...	15·31 ...	30·71	86·90 ...	187·06
..	..		...	.	......
20″	5·62 ...	13·69 .	26·43 ...	70·26 ..	146·89
Total reduction in 10″......	0·47in. ...	1·81in. ...	4·82in. ..	18·70in. ...	44·62in.
Mean reduction per 1″.........	0·05 ...	0·18 ...	0·48 ...	1·87 ...	4·46

·450 BORE; 360GR. BULLET; 1600 FT.-SEC. MUZZLE VELOCITY.

Height of Barometer.	Drop of Bullet in 100yds	150yds	200yds.	300yds.	400yds
30″	8·09in.	19·89in.	38·58in.	101·94in.	207·01in
29″	8·04	19·72	38·12	100·44	203·60
......	......	......	......	......	......
20″	7·63	18·25	34·35	86·74	172·24
Total reduction in 10″. . .	0·46in.	1·64in.	4·23in.	15·20in.	34·77in.
Mean reduction per 1″	0·05	0·16	0·42	1·52	3·48

It will be seen that at 100 yards the reduction of drop is almost exactly the same with both bullets; but on comparing 100 with 200 yards, 150 with 300, and so on, it will be found that the rate of reduction proceeds more rapidly with the lighter projectile, there being in double the distance more than a ninefold difference with the 260gr. bullet, and little over eightfold with the 360grs.; and at 400 yards the latter is about seventy times greater than at 100 yards, while the former is about ninety times greater. The light bullet suffers most from air-resistance at high barometrical pressures, and consequently receives most advantage from their diminution, and the result is shown in its flying higher than the heavier bullet of the same bore.

There is another way, too, in which atmospheric resistance affects bullets, though not in a great degree such as are used for sporting purposes. As stated in page 61, bullets are retarded by the air when falling towards the earth; and this especially affects the drop of those fired at very long ranges. The time of the Martini-Henry for 1000 yards is nearly 3½ seconds; in that time the velocity of descent would exceed 100 feet per second, but the more rapid the drop becomes, the greater is the resistance encountered, so that the projectile is to some extent, buoyed up by the air during its descent. This would operate on light bullets to a greater extent than on heavy ones if the range were equal, and would tell most on those that have great length in proportion to diameter. Sporting weapons, however, are seldom fired at distances that take more than a second for the bullet to traverse; and the air-resistance in a drop of one second would not be a tenth part of that which occurs in a drop that lasts for 3½ seconds.

Temperature and moisture are other causes of variation in the weight of the air, and consequently alter the amount of resistance it offers to the passage of the bullet. Fortunately, however, in many cases the alteration due to temperature tends to counteract the alteration due to elevation. In high mountain ranges the barometrical pressure diminishes, and so does the temperature; but the weight of the air is increased by the latter and decreased by the former. This subject, however, will be further alluded to in the chapter relative to the estimation of trajectories, as likewise will that of moisture in the atmosphere.

The force of the wind also has an influence on the drop of the bullet. It is commonly said that a head wind "beats the bullet down," whereas a wind from the rear "drives the bullet up." These expressions, however correct they may be in the sense of the bullet being placed higher or lower on the target, are apt to mislead as to the cause of the difference of position. The "beating down" is not to be taken in its strictly literal acceptation, but as representing the effect produced by a lessening of the speed of the bullet—in consequence of which it takes a longer time to traverse a given distance; and the longer the time the greater is the amount of drop, as already explained. The wind from the front or rear produces, indeed, a somewhat similar effect to a rise or fall in the barometer: it increases or diminishes the amount of resistance encountered by the bullet, and thus, by affecting its speed, indirectly lessens or increases the drop. Let us suppose, for example, that a bullet has a mean velocity of 1200ft. in a

400-yards range: it would thus take just one second to traverse the distance, if there were no wind. If, however, there were a head wind, the bullet would be delayed in proportion to the wind's velocity. One mile an hour is equal to rather more than 17½in. a second; and, taking half a yard per second as a round number, a wind of twenty miles an hour would be equal to 10 yards a second. A bullet meeting with such a head wind would be retarded to the extent of about 10 yards in the 400-yards range above mentioned, and consequently would take rather more than a second to traverse the distance; whereas, if it had a rear wind of the same velocity, it would do the like distance in rather under a second. The effect would be similar to increasing the range to 410 yards in the one case, and reducing it to 390 in the other, if there were no wind. The difference may seem small, but the drop, as already stated, is in proportion to the "square" of the time, and the difference between the two positions of the bullet would be about 19in.; the one being about 9½in. above and the other about 9¾in. below what it would have been had there been no wind. In a range taking double the time, the difference would be increased fourfold; in one of half the time there would be only a fourth of the difference, and so on. Hence (if we assume the mean velocity to be equal in each case) there would be in 100 yards a variation above or below of little more than half an inch; but in 1000 yards the variation would be about 5ft. each way. This is on the supposition that the wind has a velocity of twenty miles an hour. If the velocity were but ten miles an hour, the difference of drop would be but half as much; and so with other wind velocities. Moreover, the supposition here is that the mean velocity of the bullet is uniformly 1200ft. per second; but every bullet having a different velocity would require a different estimation, and as all bullets lose speed during their flight, there would be some amount of variation with every change of distance.