D in the section, Fig. 2, is the drum, mounted on a spindle revolving freely on centres, and driven by a V wheel, which in its turn is driven from the double V wheel L, in centre pipe. The object of this arrangement will be obvious. The wheel L is driven from the fly-wheel below by a long gut passed over

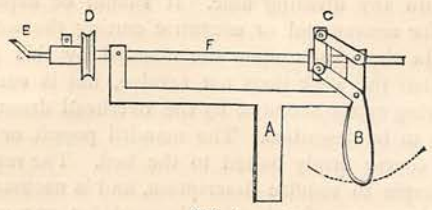


FIG. 4.

pulleys, as shown by the dotted line, and transmits its motion by another gut to the drum D. The drum is kept up to its place by counter-weights, W, and the wires M, but is free to move forwards and downwards without interference with its revolution.

Fig. 4 is the eccentric cutter, which is fitted in the slide-rest perfectly square to the surface to be ornamented, by the socket. It consists of a frame, A, carrying a spindle, F, which, by means of the handle B and bar C, working in a boss on the spindle, may be advanced or withdrawn a given distance at each cut. A gut from the overhead drum D (Fig. 3) drives this spindle with great rapidity by means of the pulley-wheel D (Fig. 4). It follows, then, that any drill or cranked cutting-point placed on the socket, as E, will describe a circle on the face to be ornamented; and by rotating the work given distances by means of the dividing plate before described, these circles can be arranged geometrically, overlapping each other, and resulting in very lovely patterns. The greater the ingenuity displayed in arranging and varying the patterns, the more beautiful the results. I am aware that the Fig. 4 cutter is not a usual form, as I contrived it myself; but as I have found it most effective, I venture to make a drawing of it.

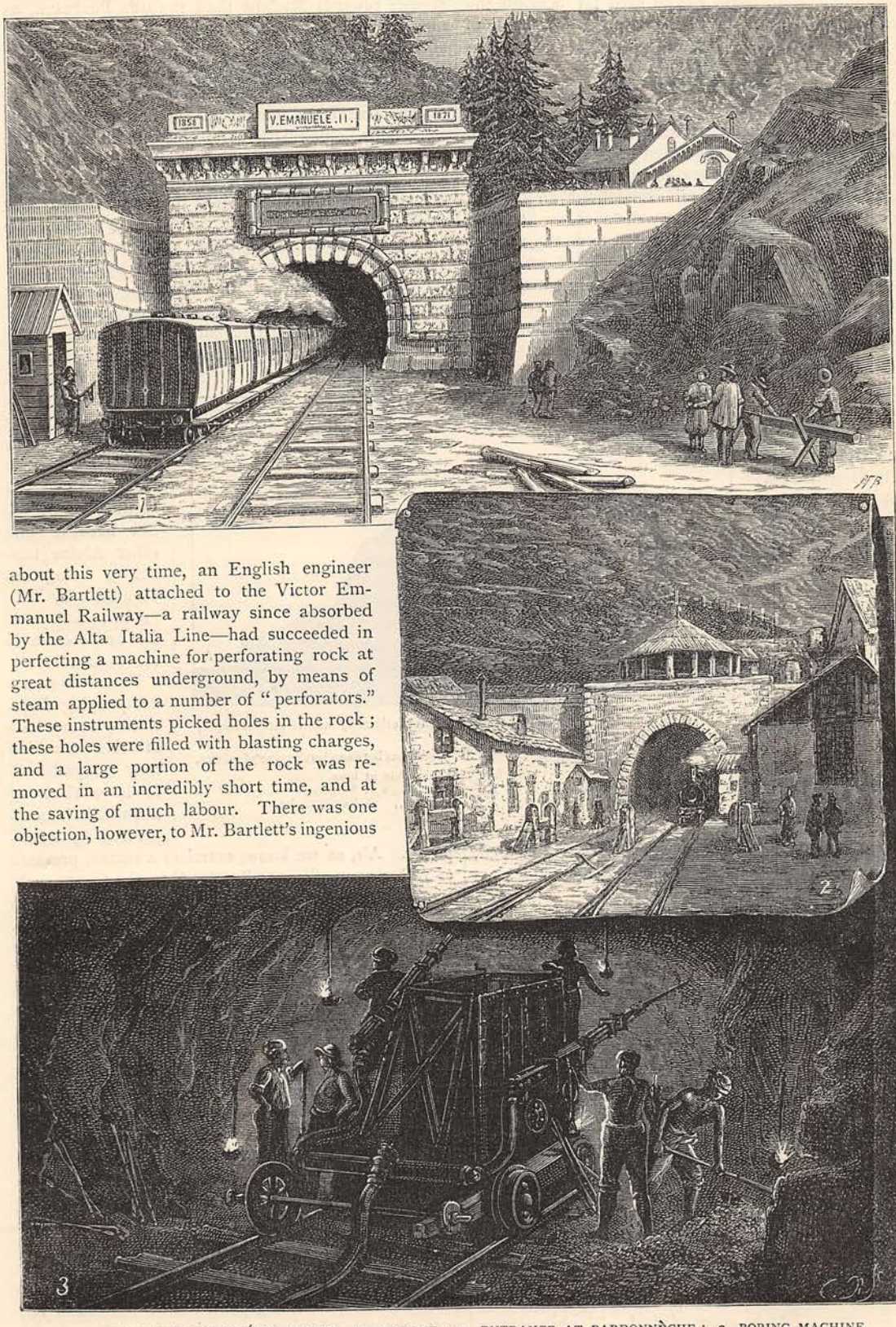
A word or two about the necessary chucks, and I have done. A chuck may be defined as a means of holding work in the lathe, and only a few of the many varieties need be mentioned here. First, the driver-chuck screws on the mandril-nose, as all chucks do, and has a centre-point and a projecting bar catching a driver which screws on the rod to be turned. This rod is centred and a hole drilled at each end, so that the two centres (chuck centre and back poppit centre) may catch and hold it tight. Wedge-chucks are cups of iron or metal of various sizes, into which blocks are driven after being roughly turned to fit very tightly. They have the advantage of holding a block without the aid of the back centre, and are indispensable for work to be hollowed out. A face-plate is a true flat plate to which any surface may be attached by bolts. A very useful but somewhat expensive addition is a self-centring chuck for drills, and a similar but larger one for circular work; but it will be better to leave these more elaborate developments to the amateur's own investigation.

THE THREE ALPINE TUNNELS.

I.—THE MONT CÉNIS.

IT may not be generally known that the great Mont Cénis tunnel is not cut through Mont Cénis itself. It actually passes through Mont Vallon, a smaller mountain, and extends from Modane, Savoy, to Bardonnèche in the valley of the Dora, Piedmont. Of the hundreds of English travellers who annually pass through this wonderful tunnel, very few care to inquire how it was made. But let it be our task to set before our readers—pleasantly, we hope—the almost romantic and altogether wonderful history of this mighty work; the pioneer of the St. Gotthard and the Simplon, the father of the Alpine tunnels of Europe.

More than twenty-five years ago, the first suggestion respecting the construction of such a tunnel was made to Count Cavour; but even then the idea was no new one in the minds of the sturdy Piedmontese. Yet it is very doubtful whether the enterprise would have finally succeeded, had not a curious combination of circumstances tended to bring it about. Just previously to the suggestion being made to the Government, three young Piedmontese had come over to England to learn engineering and mechanics. They had been taken through the various workshops, and finally had been enabled to inspect our atmospheric railways, which naturally riveted their attention. For did they not hope to carry a railroad across their mountain boundaries, and what method more fit for the purpose than the traction of a train by atmospheric air? They returned home to apply the invention, if it were possible, to Mont Cénis. Curiously enough,



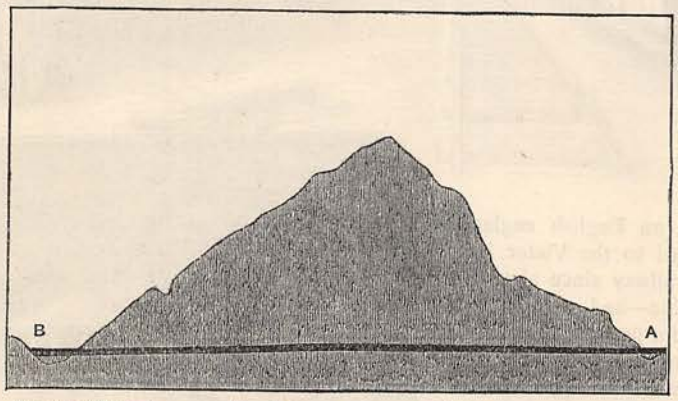
about this very time, an English engineer (Mr. Bartlett) attached to the Victor Emmanuel Railway—a railway since absorbed by the Alta Italia Line—had succeeded in perfecting a machine for perforating rock at great distances underground, by means of steam applied to a number of "perforators." These instruments picked holes in the rock; these holes were filled with blasting charges, and a large portion of the rock was removed in an incredibly short time, and at the saving of much labour. There was one objection, however, to Mr. Bartlett's ingenious

1. ENTRANCE TO MONT CÉNIS TUNNEL AT MODANE; 2. ENTRANCE AT BARDONNÈCHE; 3. BORING MACHINE.

invention : steam could not be used far beneath the surface of the earth, for there was no steady supply of oxygen to create it, and fires were of course impossible.

But the "atmospheric" idea had taken possession of Germain Sommelier and his two student companions. What steam could not do, air might. Steam could not be generated such a distance beneath the surface as they proposed to drive their tunnel, but atmospheric air—condensed air—might be carried through tubes for any distance, far from the busy hum of furnaces, and released to do the duty of steam. A Commission was appointed after the Italian Chamber had been made acquainted with the proposal. The Government consented to construct a portion of the line, and the three Piedmontese gentlemen—Sommelier, Grandis, and Grattoni—were appointed as joint directors of the works.

But even now the trouble was only beginning. The boring machine having been fixed upon, it was necessary to decide in which direction the boring should commence. The first cuttings would be executed in the normal manner, as air and light were sufficiently available. But the shortest and most convenient route must be ascertained, the levels and gradients had to be calculated, and the distances between the opposite openings arranged.



Length of Tunnel, 12,220 mètres, between entrances originally made. Actual length, 13,440 yards.
Entrance at Bardonnèche (A), 1,335·38 mètres } Difference between levels=132·56 mètres.
,, Modane (B), 1,202·82 ,, }
Dimensions of Tunnel { 25 feet 3½ inches wide at base. / 24 ,, 7 ,, high at Modane. / 35 ,, 7¾ ,, ,, at Bardonnèche.

The months of August and September, 1857, were occupied in endeavouring to hit the proposed opening at Modane, from the opposite side of the mountain at Bardonnèche. This was at last managed, notwithstanding the storms and avalanches, and the wild tempests of wind, which swept the instruments away, or the mists that shrouded the observations of the hard-working engineers. The 11,000 feet of mountain had to be bored; the decision arrived at long before by Maus and Sismonda was found to be correct, and the seven miles and three-quarters of tunnel must be cut before the cherished plan could be accomplished.

The first suggestion had been to carry the tunnel through at a uniform gradient, for the difference in the level at Modane and at Bardonnèche is nearly 400 feet; but on reflection it was considered advisable to commence the excavations at both ends simultaneously, and work up to a central point, so that the drainage might be accomplished. The gradient is steeper towards Modane than towards Piedmont, as may be observed from the accompanying outline sketch. The gradient from the French side is 22.2 in 1,000, that from the Italian side is 6 in. in 1,000.

Very soon two good-sized villages sprang into existence near the mouths of the tunnel. Lodgings, workshops, repairing-houses, and storehouses were built in rapid succession. Gas was provided, and subsequently, as the work advanced, was carried in tubes farther and farther into the tunnel. But four weary years were expended, between 1857 and 1861, before the excavations made very great progress. The wonderful "perforators" worked by compressed air were set to work at the beginning of the latter year, and the advance was comparatively rapid.

This really wonderful invention, by which alone the termination of this gigantic enterprise was rendered possible in a reasonable time, deserves description here, because not only is it necessary to understand the method employed, but because one other Alpine tunnel is being excavated by its means, and one description will suffice for all.

From the accompanying illustration some idea of this machine may be gathered. It is worked by air, which is compressed by water-power. Air, as we know, exercises a certain pressure of rather more than 14 lbs. (14.6) to the square inch. If a quantity of the atmospheric air be compressed to four, five, or six times less than its natural bulk, the force it acquires will be in proportion to the compressing power exercised. The air is compressed by water-power, the water being forced into vertical cylinders, and the air is then pushed into a reservoir through a valve. The water then sinks; more air is admitted from outside; the water is again forced up, and so the air is "compressed" and stored in huge tanks ready for use; the expansive force of the imprisoned atmosphere being very great—viz., five or six times its normally accepted force, or say 80 lbs. to the square inch. When required, this air is admitted to the boring machine through tubes which can be elongated at will by "lengths" being added as required. The boring machine looks very complicated, and is furnished with machinery, a description of which may be perused in any scientific journal of the early part of 1869. It would encroach too much upon our space to enter into details. The perforating point can be directed in any way; the point darting out against the rock, and with

a boring, twisting motion, soon cutting a hole. There were at one time nine "perforators" at work in the Cénis Tunnel, each working a boring rod, each rod smiting the rock at the rate of 1,800 strokes a minute, and with an estimated force of 200 lbs. at each stroke.

This boring was begun in January, 1861, and by August, when the workmen had become more skilful, the progress was about thirty inches a day. Thirty inches out of all those miles! But the blasting, carrying, and boring was not relaxed day or night, and in 1869 no less than 4,000 men were employed on the tunnel. In 1866 half the work had been accomplished, after nearly nine years' hard labour. Two years later great progress had been made, and in December, 1870, the workmen could hear each other blasting, as they advanced from Italy and France respectively.

That was a nervous time, as we can imagine. The success of the undertaking then depended upon the result of the calculations as to direction and elevation. As a matter of fact, a slight error of about forty yards occurred in the length estimated, but the direction was correct, and on Boxing Day, 1870, the navigators cut through the last rocky partition, and the engineers shook hands through the breach.

The Mont Cénis Tunnel was then an accomplished fact; but unfortunately two of the three bold Piedmontese to whom the enterprise is due did not live to see the result of their labours. MM. Grandis and Sommelier passed away before the great work was accomplished: they were not permitted to witness the triumph of their genius. *Dieu dispose!*

That it is a triumph no one can doubt. The high mountain road is forty-nine miles long, and necessarily winding. The very ingenious railway carried over Mont Cénis by Mr. Fell ran upon, and alongside, the diligence road, and shortened the time previously occupied to about four and a half hours, or nearly one half. But the completion of the Mont Cénis Tunnel carries an uninterrupted railroad for the distance of about 1,300 miles, from Calais to Brindisi. The Mont Cénis is the longest existing tunnel in Europe, its exact measurement being seven miles and a half and 242 yards. It was opened on the 17th of September, 1871, with great pomp and ceremony.

For the information of our inquiring readers we will add the statement of the composition of the mountain through which the tunnel is pierced. It consists, from the French side, of schist, then quartz, then limestone, then schist again, all the way into Piedmont. The cost was three millions sterling, certainly not an extravagant sum for such a completed work. The transit is comfortably managed, and no inconvenience is felt, as the ventilation is well attended to. Such is a brief account of the great highway through the Alps; and the example thus set has been quickly followed. Tunnels are now in progress through the St. Gotthard and Simplon ranges, and another is actually hinted at which is to traverse Mont Blanc, from Chamouni to Courmayeur. Whether this last will ever be accomplished, it is of course impossible to say.

OUR FOUNDATION SCHOOLS.

II.—MARLBOROUGH AND WELLINGTON.

ONE feature of the educational movement during the present century has been the establishment of new public schools, in which peculiar privileges are reserved for the sons of divers classes in our social community, and the idea underlying the formation of such foundations is that, though there are some professional men among us who are well and handsomely paid for their services, there are others whose income falls very far short of their position and its claims. The pupils of private schools, and the small proportion of boys who are trained under the paternal wing, either by parents or private tutors, are often at a disadvantage when they go to the Universities, not one in a thousand of them being able to win any honour for himself, or even to take his place on an equality with those of his fellows who aim at nothing higher than getting their degrees with the least possible amount of trouble. One memorable exception to this rule, however, was that of the late Rev. J. Keble, who was entirely educated at home by his father in the seclusion of a rural vicarage, and yet before he was fifteen obtained by competition a junior studentship at Christ Church, Oxford, and at eighteen took a double first-class—the only instance on record, it is believed, of any one gaining that distinction at so early an age.

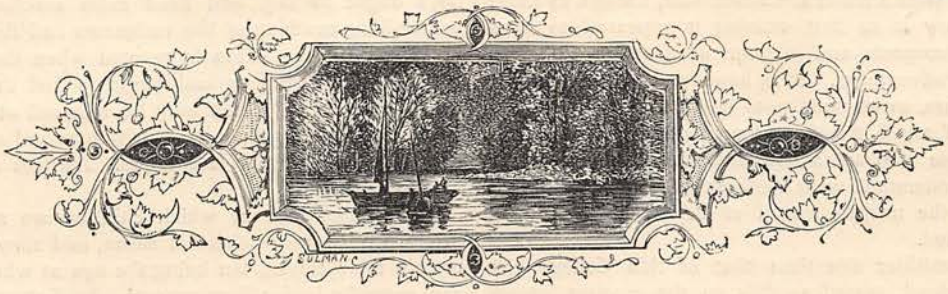
But some of the older (we can hardly say greater) public schools are far beyond the means of such professional men as have not been fortunate enough to make large sums of money out of their work, or have little or no private income to supplement the stipend or emolument attached to their post, or earned by their efforts, though many of them have received a liberal education in their time, and are the parents of promising sons whom they would fain see enjoying the advantages of a University career with a fair chance of carrying off some of its prizes. And the consciousness of this state of things has led to the founding of a new order of schools or colleges, with a view to the needs of clever boys not favoured by Dame Fortune at their birth with the traditional silver spoon, and foremost among them, both from the position it has achieved, and from the consideration usually awarded to the class for whose benefit it was originally designed, is Marlborough College, Wiltshire, the favours of which are dispensed especially to the sons of the clergy, who are also received at much lower

ships for Mathematics are worth £25 per annum, and are tenable for two years. The Council may at any time take away a scholarship on a report from the Head Master that the holder does not satisfy him in regard to either conduct or industry.

To the English Universities there will be this year, and also in every succeeding one, three exhibitions of the value of £25 per annum, which may under certain circumstances be increased to £50. Candidates must have been pupils of the College for two years immediately previous to the election, and the examination will form part of the one which is always held in July. It is worthy of notice that Physical Science forms part of the regular work in most classes, Drawing of various kinds is also a prominent feature, Vocal Music is taught free of charge in the Preparatory and Junior divisions, and the choir, which is about 100 strong. The College also possesses two splendid organs, which are available for practice and lessons to those who are able to take up the study of the "king of instruments."

Boys are not permitted without written leave to go beyond College bounds, which are sufficiently wide, and defined by a map hanging in the cloisters; and with this last wise regulation we must take our leave of Clifton College on its breezy upland, almost within sound of the sea on one side, and hardly out of reach of the hum of a great city on the other.

E. CLARKE.



THE THREE ALPINE TUNNELS.

BY HENRY FRITH.

THE ST. GOTTHARD AND THE SIMPLON.

MOST visitors to the Paris Exhibition in 1878 doubtless observed a panorama of the St. Gotthard, showing the proposed great tunnel; and we, in common with many hundreds of our countrymen *en route* to Switzerland, studied the map displayed in the Swiss section. We had always enjoyed the grand scenery of the St. Gotthard, and can recall one or two narrow escapes in early summer, when snow was treacherous and we were rash.

The St. Gotthard range is in reality very extensive, but the name is more generally understood to apply to the portion comprised between Fluelen, on Lake Lucerne, and Airolo; but more correctly between Hospenthal and Airolo. The main tunnel commences at Göschenen, on the Swiss side of the pass, about three hours distant from Amsteg, and 2,200 feet above Lake Lucerne. The path across St. Gotthard was for hundreds of years the only one over the Helvetic Alps, and about a hundred years ago vehicles began to traverse the road. It is the most dangerous pass in Switzerland, and readers will remember that last year many fatal accidents occurred on that splendid post-road during the early part of the summer.

It must not be imagined that the Gotthard line embraces only one tunnel, such as the Mont Cénis. The line is really about twenty miles long, and is a series of tunnels, the longest of which is in round numbers 49,000 feet long (48,936), or over nine miles. The other tunnels are three and four miles long, and there are numerous shorter ones, as well as galleries, besides. Of course the enormous sum necessary to complete this immense undertaking could not be found easily. The question was an international one. The first estimate was 187,000,000 francs, but even this stupendous amount was 102,000,000 francs short of that actually required. Italy, Germany, and Switzerland increased their subscriptions; and M. Favre, of Geneva, accepted the contract.

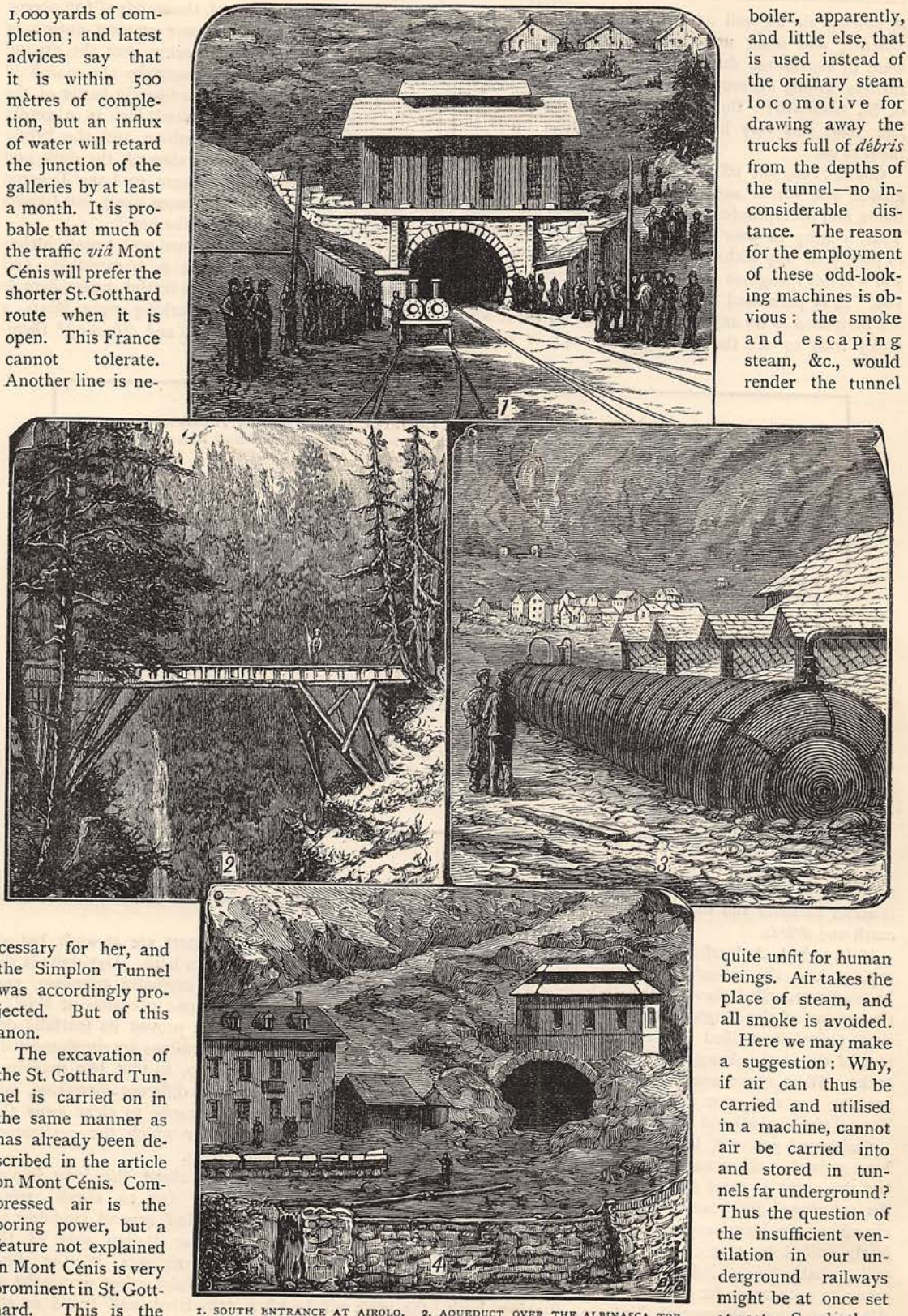
By his agreement the tunnel should be completed and ready for traffic early this year. A large sum was to be forfeited for delay; and should the year expire and the tunnel remain incomplete, the contract will be void. The St. Gotthard main tunnel is about the same dimensions as (but longer than) the Mont Cénis, already described. It enters the mountain at a height of 3,600 feet above the sea, and comes out at Airolo at 3,700 feet elevation. The gradient on the Swiss side is 1 in 172 for about half the distance; at the summit is a short level run, and then the descent into Italy begins at the gradient of 1 in 1,000. It will thus be perceived that the level point is on the north side 142 feet above the entrance, and 24 feet on the south side.

This line, in direct opposition to the French Mont Cénis Railway, naturally gave rise to a further opposition in the Simplon line, which we will refer to later on. Last autumn the St. Gotthard Tunnel was within

1,000 yards of completion; and latest advices say that it is within 500 mètres of completion, but an influx of water will retard the junction of the galleries by at least a month. It is probable that much of the traffic *viâ* Mont Cénis will prefer the shorter St. Gotthard route when it is open. This France cannot tolerate. Another line is necessary for her, and the Simplon Tunnel was accordingly projected. But of this anon.

The excavation of the St. Gotthard Tunnel is carried on in the same manner as has already been described in the article on Mont Cénis. Compressed air is the boring power, but a feature not explained in Mont Cénis is very prominent in St. Gotthard. This is the "air locomotive"—a boiler, apparently, and little else, that is used instead of the ordinary steam locomotive for drawing away the trucks full of *débris* from the depths of the tunnel—no inconsiderable distance. The reason for the employment of these odd-looking machines is obvious: the smoke and escaping steam, &c., would render the tunnel quite unfit for human beings. Air takes the place of steam, and all smoke is avoided.

Here we may make a suggestion: Why, if air can thus be carried and utilised in a machine, cannot air be carried into and stored in tunnels far underground? Thus the question of the insufficient ventilation in our underground railways might be at once set at rest. Surely there can be no difficulty



1. SOUTH ENTRANCE AT AIROLO. 2. AQUEDUCT OVER THE ALBINASCA TORRENT. 3. GREAT RESERVOIR OF COMPRESSED AIR. 4. NORTH ENTRANCE AT GÖSCHENEN.

in storing air as well as gas, and the Metropolitan, District, and other underground lines are sadly in want of ventilation during the day. Now, will my readers kindly accompany me into the main tunnel of St. Gotthard? But few English people ventured last year, and very likely the trip will be novel to most of us.

Come, then, put off all *table-d'hôte* array, and be guided and thrust and shoved into old hats, muddy boots, and waterproofed and petroleum-lined garments. Take a lamp in your hand, and a staff or alpenstock to prod your way withal; and when you are equipped, you will not recognise yourself—if your eyes could see you. It is permitted to walk into the tunnel—if you are permitted to do anything at all; but for those who really wish to see the machines at work, it will be necessary to cling to the eccentric locomotive, which is about to enter the tunnel in search of trucks full of earth and *débris*.

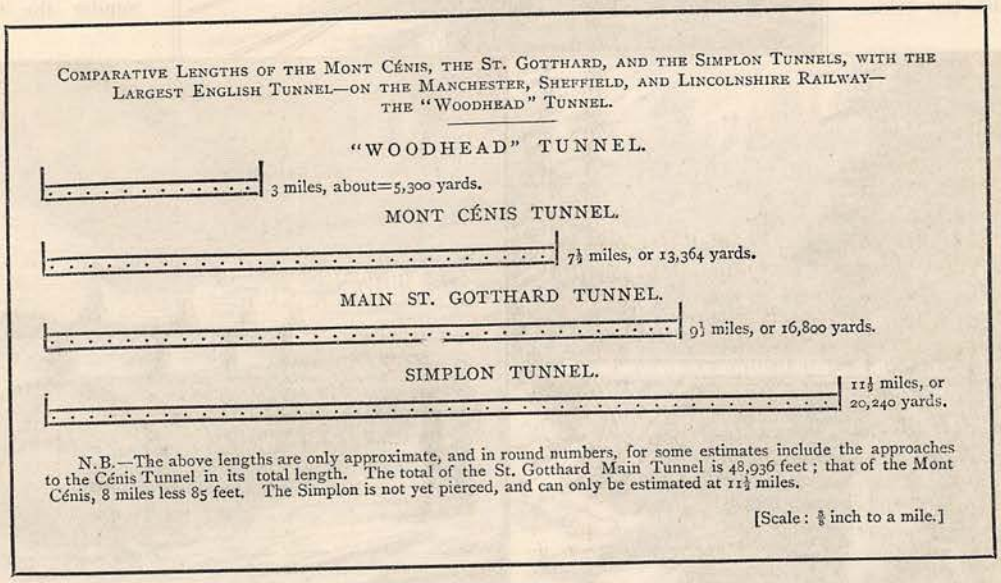
Hold tight! A fearful shriek, and we are moving rapidly into the mine's darkness. If those who have ever travelled through the Balcombe Tunnel on the engine of the Brighton express will imagine that noisy tunnel intensified four times, they will have an idea of the clatter, bang, and roar of the St. Gotthard rocks. Were space available, it could be described; but any one can open the window in the Balcombe Tunnel (for choice) and try the effect.

Cui bono? you will be tempted to ask when you have arrived in the granite chambers of St. Gotthard; but the scene is most interesting, not to say exciting. An occasional dull roar in front tells the visitor the chambers are being exploded—those little chambers lately drilled by that cunning "perforator." There will probably be an influx of water, for it is no uncommon occurrence for a hidden spring to break out. All around are glimmering lanterns, flashing back from the rocks; far overhead, thousands of feet above are melting snows; tourists—your greatest enemy, or your dearest friend, mayhap gazing over the ground rendered famous in history's pages by the march of the grim Suwarrow and the hard-fought battle of the Devil's Bridge. A few hundred feet in a gently sloping line in front, are sunshine and the bright Italian landscape. Behind us, through the dark and murky atmosphere, is the descent to Lake Lucerne and the Righi, where just then, most likely, our friends are being rudely repulsed from the hotel.

The roof of the tunnel is lined with twenty inches of solid masonry. The heat is tremendous, and how these men can live in this fearful atmosphere is almost incomprehensible. Working eight hours a day for scarcely five shillings, and "finding" themselves, is apparently bliss to the Italians, and from this amount they save and send sometimes half their wages home.

A great number of perforators are at work, but we need not describe their action here. Dynamite is the substance chiefly used for explosive purposes, and occasional accidents or, on one occasion at least, a premeditated explosion have proved its fearfully destructive qualities. The excavations are simultaneously conducted at different points, so that two machines may actually be working in different directions, one forwards and another backwards, to clear away the upper portion of rock under which the perforators have succeeded in penetrating.

There is one peculiarity about the long line of St. Gotthard—namely, the (so to speak) spiral ascents. The trains will wind around gradients as the diligence winds up the Italian side of the road, or as the railway zig-zags in the Blue Mountains of New South Wales. But wonderful as the work will be when completed, and grand as the



enterprise must always appear—to the traveller who seeks scenery the St. Gotthard route will seem almost useless. True, at the Lucerne side the ascent is grand. Altdorf, sacred to the memory of Tell; Wasen; and, on the Italian side, Airolo and Bellinzona are very fine, and we have often traversed the classic ground. But no tunnel, however useful, can compensate us for the view or the delicious air upon the old post-road of the St. Gotthard. In January, 1871, the "headings" were pushed in. In September, 1872, the work was begun at Airolo, and at Göschenen in November. In March, 1880, we may expect to hear that the great tunnels are completed, and the line will probably be open for traffic before the summer has closed. There are about 4,000 people employed at the St. Gotthard: Italians, Germans, Swiss, but no English, French, or Americans, as far as we could learn. These will not work so cheaply as Italians, who do all the boring, Most of the superiors are Swiss. The exact centre, nearly five miles from the entrance, was reached from Göschenen on the 31st of October last.

Before closing this article, we may make a few remarks upon the Simplon scheme, which the French Government are so anxious to carry out, in order to secure the Anglo-Indian traffic.

Any one who visited Switzerland in 1879, knows that in July of that year the line of railway through the Rhone Valley was open to Brigue, at the foot of the Simplon. On the opposite side the Italians are busy with a line which will extend to Arona (Lago Maggiore). When the Simplon Tunnel and its approaches are completed we shall have an uninterrupted line from Paris to Brindisi, through Pontarlier, Lausanne, Brigue and Arona (*viâ* Simplon), and Milan.

This history of the Simplon scheme can be stated very briefly. The proposal was made to the French Government in 1873, but the scheme fell through for several reasons, the chief of which were the failure of the Ligne d'Italie, and the apparently hopeless opposition of the St. Gotthard route. But when, in 1874, a new company took up the line, and the St. Gotthard was being actually tunnelled, things looked gloomy for French traffic, which can be retained by the construction of the Simplon Tunnel.

The different lengths of the three Alpine tunnels are as follows:—Simplon, 18½ kilomètres; St. Gotthard, 15; Mont Cénis, 12. But the first-named will possess many advantages in construction. The respective heights of the entrances to the Cénis and the St. Gotthard are far above the sea-level. The entrance to the Simplon is on a level plain, and the line, as most of us know, is perfectly even, and almost straight from Bouveret or Villeneuve on the Lake Leman to Brigue. The gradient never exceeds 1 in 100 in the Simplon, though on the Italian side it is a little more. It is a curious fact that the highest point is not in the mountains at all, but on the road between Lausanne and Dijon. Snow will offer but inconsiderable opposition, the rock is less hard, water-power exists in abundance, and the climate in the Valais is less cold than in the localities already pierced.

The cost of the Simplon Tunnel is estimated at 80,000,000 francs—or 4,000,000 per kilomètre for the actual tunnel, and 6,000,000 for stations and permanent way. This estimate does not compare favourably with the 2,500,000 francs per kilomètre expended on the St. Gotthard Tunnels.

More than half this sum is found by France, the remainder by Switzerland and the railways interested, but even now the suggestion of one alternative scheme for tunnelling the Mont Blanc comes to our ears, and another to construct a line through the Tarentaise and the Col du Mont. Both of these schemes are unpractical, because the lines would be longer than either the Cénis or the St. Gotthard routes, and therefore useless as competitors.

The Swiss are naturally averse to the Mont Blanc project, because it would leave their country out in the cold. The Simplon route is already half accomplished, and would greatly favour French traffic, which otherwise would be carried *viâ* Basle by German subsidised railways through the St. Gotthard; and though the Savoy route would be advantageous to the French, the distance is too long.

We have now rapidly reviewed the three great Alpine tunnels, wonderful examples of human skill and perseverance. There have been long tunnels constructed before these, but none to equal these giants, as will be seen by a glance at the accompanying table.

Even as we write, a slip has been put before us representing the determination of the French Government to lay down a line of railway from Annemasse, on the route to Mont Blanc, to Chamouni. The Administration has already sanctioned the construction of the line from Annemasse to Sallenches. This line will join at St. Gingolph the almost completed railway from St. Gingolph to Callonges and Annecy. This extension will bring Paris and all the southern districts in direct communication with Savoy, and in such a case the tunnel through Mont Blanc may not be unworthy of consideration; but for our own part we do not think that such a line would ever successfully compete with the already projected and completed lines. The survey will, however, be made, and we may yet travel in a Pullman car through the Monarch of Mountains.