A Tale of Invention: *the birth of the modern bicycle*

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Introduction

This is a sequel to my piece on the Physics of Cycling, though perhaps it should be a prequel since in concerns the evolution of the bicycle itself in the 19th century. As I write this it's near mid-winter, too cold or too wet or too windy for my fair-weather cycling habits. However with the poor weather has come the opportunity to browse the *Scientific American* pages over some 30 years leading up to the end of the 19th century. One of the subjects that has caught my attention is how the bicycle developed from its primitive mid-century form to something recognizably modern. The *Scientific American* was then quite parochial, concentrating on American inventions but reporting on events in Europe too. It was in fact a magazine more for technophiles than a prime source of science but 19th century America was a hot-bed of technical invention and the *Scientific American* survived by being up-with-the-times. The bicycle became very popular in Britain, France and other European countries as the century progressed but it did so in America too and by the end of the century American bikes were as good as any in the world. They would have said 'better'. Sticking with the American based perspective gives a good flavour of the changes that were happening in other countries too.

One of the fascinating aspects of my browsing was to see the variations on the bicycle theme that have failed the test of time or given rise to other devices we now don't particularly associate with bicycles. Nowadays most bikes have a similar overall appearance: divided diamond frame made of tubing, two similarly sized wheels with pneumatic tyres, sprung saddle, handlebar operated brakes and so on. There are important differences between bikes, with mountain bikes made from thicker tubing, having wider tyres, suspension on the forks, etc.; racing bikes with drop-handlebars, thin high-pressure tyres, light-weight frames; we sometimes see recumbent bikes and tandems on the roads but on the whole the range of bicycles is small compared with the diversity of 19th century inventions. Our predecessors explored a wide range of possibilities that have now been forgotten. They got some things wrong, such as brakes applied to the tyres, chainless transmission, iron-rimmed wheels, wheels of different sizes on the same machine and more besides. They did though develop many of the bicycle features that one associates with a 20th century machine, such as the modern crank running on ball bearings driving a chain to the rear wheel, pedals turning on ball bearings and the idea, if not the optimal solution, of gears; wheels with a modern spoke arrangement, adjustable handlebars and ball-race steering, sprung seat, electric cycle lamps, and more besides.

My plan is to illustrate the invention trail that made the modern bike, or at least the fairly modern bike, with numerous examples quoted from the *Scientific American*. What also comes through is the process of invention at work, an aspect that one often doesn't get from formal textbooks on a subject.

In the beginning

Anecdote gives some in France the priority of seeing the first device that one might call the predecessor of the bicycle, possibly in the late 18th century but if not then, certainly early in the 19th century. However credit for a commercial beginning is given to Baron Karl von Drais who patented a largely wooden design in 1818. His pattern was soon improved by Simon Johnson in London and was briefly popular among Regency dandies. "*the swiftness*

with which a person, well practised, can travel is almost beyond belief; eight, nine and even ten miles may be passed over within the hour, on good and level ground." The 'dandy horse', amongst its several slang names, quickly wore out quite a lot of boot leather. It was the product of cartwrights, with a wooden frame, iron shod wheels, a dip in the centre to allow larger wheels. 'Good level ground' was in short supply two centuries ago and in spite of some variants over the next decades the early velocipedes languished like discarded toys.

My beginning is really as far on as the late 1860s, a time that saw 'velocipede mania' ignite in both Western Europe and the United States. The Engineer magazine wrote in early 1869 "*Little did our ancestors imagine, fifty years ago, when the first rude velocipede was made an object of their ridicule, that the victim of caricaturists would one day become the centre of attraction among their grave and matter of fact descendants. Yet so it is."*

Here is the *Scientific American* in 1869: "*Many have expressed doubts as to the real utility of velocipede and the permanency of their use. Most of these croakers have based their opinions upon the disuse into which the rude machines of former times have fallen and the want of adaptability to the roughly paved roadways of our cities. The first of these objections is answered by the fact that the seemingly slight differences in the construction of modern velocipedes have entirely changed the character of the vehicle"*. The illustration here is of Michaux's 'boneshaker' of 1866. You can see one of the originals in the Royal Museum of Scotland in Edinburgh. The quotation implies that the modern machine of 1869 was seen as superior to its predecessors. Quite frankly, the only big change over the half century since von Drais had introduced his velocipede was the addition of pedals to the front wheel.

In the version illustrated above, the tiller (i.e. the handlebars) is brought back so the rider can sit almost upright. "*By a simple pressure forward against the tiller, and a backward pressure against the tail of the saddle, the saddle-spring is compressed, and the brake attached to it brought firmly down upon the wheel"*. 'Velocipede' was the name of choice; 'velocipedestrian' the rider; 'velocipedagogue' someone who taught riding. *The Brooklyn Morning Union of Jan. 20th, says: "The first school for instruction in the art of riding velocipedes had not opened its doors a month before it had to be enlarged, for though commencing with twenty-five pupils, it closed the first month's book with a list of two hundred and twenty-five"*. 'Velodrome' is still the English word for a cycle racing-track; *un vélo* a French synonym for *une bicyclette*. Over the 1870s 'bicycle' replaced velocipede as the more popular choice of word but all velocipedes weren't bicycles. Velocipedes were generally used only in cities and social habits were not yet well developed: *"If a fellow goes with his velocipede to call upon a lady, whose house has no front yard, and no back yard,*

and there is a lot of boys in front of it ready to pounce upon his machine, and the lady is smiling through the window, what is he to do with it?" Indeed.

LEWIS' IMPROVED VELOCIPEDE.

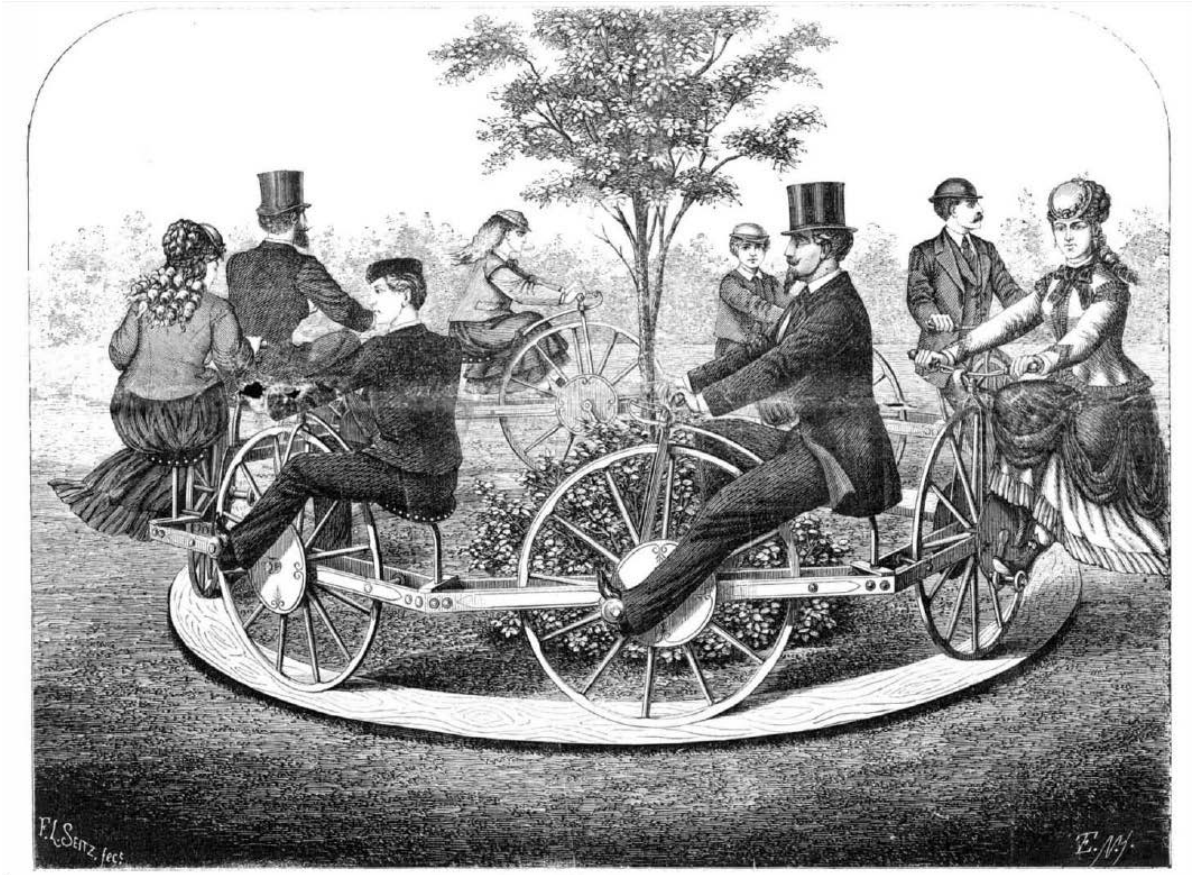
The New York Herald wrote, in jest or otherwise, "*A wheeled vehicle without a horse is a thing so preposterous to the eyes of aldermen that it must be forbidden altogether. Such is the experience of several cities, and our city promises to follow suit. Now, though the horse is favored by popular prejudice. a man may move his wagon with a mule, or a jackass, or a goat, or a dog; but he is not permitted to move it without one of these in front, or he will be fined twenty-five dollars.*" It seems that in every generation there are people who think that if something is new it should be forbidden, or failing that should be circumscribed by laws and taxes.

HEMMINGS' UNICYCLE OR FLYING YANKEE VELOCIPEDE.

Some city parks allowed velocipedes; others did not for want of wide paths and for a fear of frightening horses, though the practice was well established in Paris, London and other European cities. The accompanying few illustrations from 1869 show that velocipedes came in a variety of forms. Front wheel drive was the norm. Ladies

sat ‘side-saddle’, making it impossible for them to contribute power. They were also hindered by clothes and corsets. Hemmings’ Unicycle is an example of an epicyclic machine. *Mr. Hemmings' son, but thirteen years old, propels one of these machines of 5ft. diameter at a pace that enables him to keep up with good roadsters without allowing them to pass him.* It worked.

Of the designs here, the nearest survivor has been the ‘pedalo’, now seen in park lakes and on beaches warmer than Aberdeen’s. As these woodcuts hint, the velocipede gained popularity as a recreational item and soon as a sport. The final 1869 woodcut below emphasises the entertainment value of the velocipede.



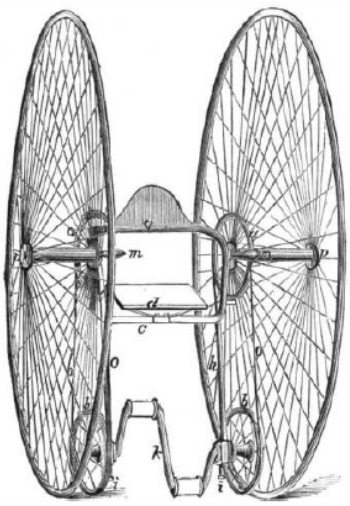
“*The arrangement of the apparatus in a pleasure ground or courtyard may be made very ornamental, and it will afford inexhaustible and healthful merriment to persons of all ages. It would seem impossible for the most worn-out man of business to mount one of these seats with a party of spirited young people and not forget for the time that he was other than a rollicking lad in his" teens." It does one's heart good says our enthusiastic informant, to hear children fairly shriek with glee as the maximum speed is attained.*” As with all the devices illustrated, this one was patented. American patents lasted 17 years (British patents only 14 years, traditionally twice the length of time a man was apprenticed to a master craftsman).

The patent system was the means for many inventors to get rich, or at least make a living from their inventions, for the patent prevented others from copying the design. However, patents that looked as if they would make a lot of money for their owners because of the popularity of the devices were highly likely to be challenged in court by others probing for loopholes or simply claiming priority, so a successful inventor had to be prepared to keep his lawyers in the lifestyle they enjoyed.

THE COLUMBIA BICYCLE.

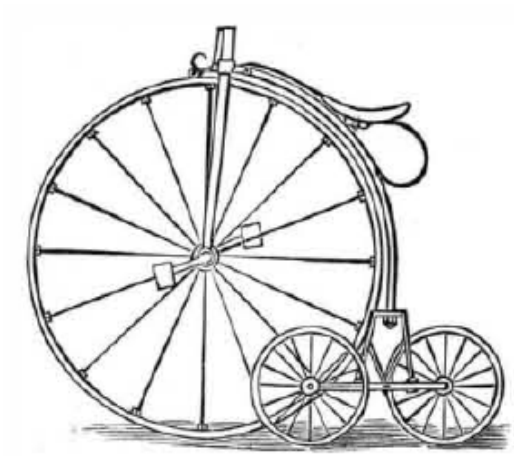
As the 1870s progressed, the 'penny farthing" (named after two pre-decimal British copper coins of different sizes; not the name used in America) became popular, typically with a driving wheel about 4 feet (1.2 m) in diameter and the whole weighing some 50 lbs (23 kg). Three grades of machine, 'special', 'standard' and 'ordinary', were generally advertised, having decreasing sophistication. The velocipede mania died out but bicycles proper came back towards the end of the decade, sooner in Europe than in America. Designs in which the rider sat over the wheel were easier to use, for "*every rider who sits much behind his driving wheel knows that in driving up hill his arms have to counteract the push of his feet, whereas push downwards on the treadle requires very little pull on the handles to keep the wheel right*". Brakes were an added extra. "*The best brake is your feet on the pedals, holding back; and if the hill is so steep that it overcomes you, then you may depend it is not safe to ride down, but get off and walk. Always lean well back when descending a hill, and incline forward when ascending, or when riding against a head wind*". Others thought a brake desirable. "*I consider it highly dangerous to attempt a run down some hills unless you have a brake you can depend on, and then the run down will be splendid and swift; yet with a good brake, you can keep the machine well in hand*".

The bicycle "*has arrived at great perfection, and is constructed more scientifically than formerly. It is of great practical utility as well as a rational means of amusement. It is, in fact, an ever-saddled horse that eats nothing and requires no care. Undoubtedly the most perfect bicycle now made is the 'Columbia'*" (shown above). Riding a mile in 3 minutes would likely win you the local cycle race; over longer distances averaging 10 miles per hour (16 km h^{-1}) was good going.

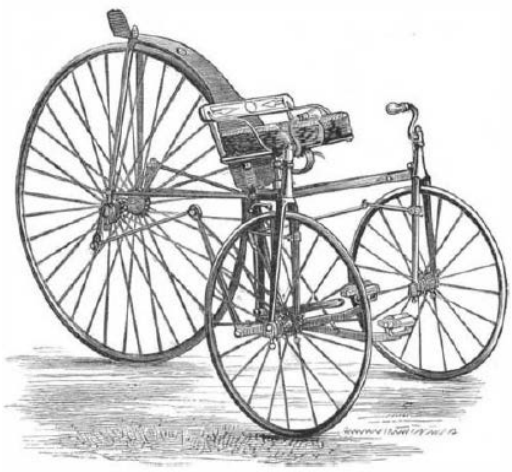


The illustration on the right shows "*a new style of bicycle lately brought out in London. Its lightness and simplicity of construction are said to make it one of the safest and easiest going bicycles. The steering is effected by a very simple contrivance, which does not cause any effort to the rider*". This is the 'Otto cycle', praised by no less a physicist than CV Boys. The large wheels (~1.4 m diameter) easily overcome most obstacles in a rough road. The treadles drive the wheels via bands. Slackening one band allows that wheel to go slower and the device corners.

Back on a penny farthing in 1876: *"A ten mile race, between a fast horse named Happy Jack and a velocipede rider named Stanton, recently took place at Little Bridge, England, for $250. For the first three miles the horse kept level with the bicyclist. The ground was rather sticky-owing to late rains for both, and Stanton seemed laboring, but this is his peculiar way of riding. Stanton was the favorite at as much as 3 to 1, for the start allowed him was generally considered too much. For three miles the horse went easily; where he lost at the corners he made up in the straight. This style he kept up until the sixth mile, when his stride began to falter, not being ridden so well as on the last occasion, combined with the effect of the extra weight he was carrying. Stanton from this point gradually went ahead, and in the next mile he had gained fifty yards. The horse was now beaten, and after going another lap was pulled up at eight miles. Stanton went on and finished the distance, ten miles less 764 yards, in 34 minutes 34 seconds, being at an average velocity of nearly eighteen miles an hour. He rode a 58 inch machine made by Keen, weighing 40 lbs. He seemed to have a good deal more in him had it been required"*. In terms of personal transport, the bicycle was filling a niche, but it was a niche bounded on one side by the horse and on the other by Shank's pony (namely, on foot). By the end of the century the average workman who could never have owned a horse would own a bicycle that would transport him faster, further and cheaper.



The tricycle was a serious contender in popularity for the bicycle, though it, too hadn't settled in form. The 'Dreadnought Tricycle' (left) of 1878 was just a more stable version of the by then standard bicycle. The illustration below it (also from 1878) had two forward wheels. The central position of the rider effectively between a triangle of supports gave good stability; the riding position offered central steering; the cranks gave good mechanical advantage; the cushioned seat was ideal for ladies as well as gentlemen and the good footbrake acted on the larger rear wheel. The illustration right was offered in the Columbia range in 1885. With ball-race bearings the frame without treadle and chain is a clear predecessor of the racing machines used today by para-Olympians. The seat (right) is quite modern in appearance.



IMPROVED TRICYCLE.

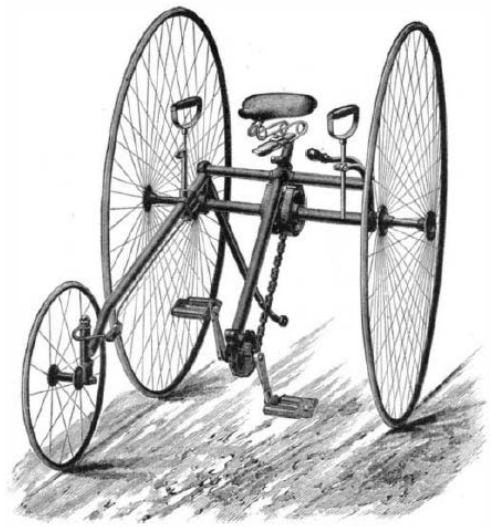


Fig. 1.—COLUMBIA TWO-TRACK TRICYCLE.

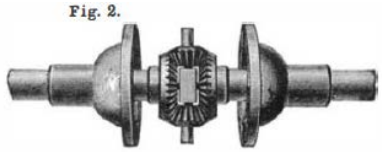
Tricycles were also the

way to get more ladies interested in cycling. The Perkins tricycle of 1880 was one offering. It is hard these days to credit what the objections were to ladies riding bicycles but *"the chief objections brought against these machines are the position of the rider, the unnatural action of the muscles in propelling them, and the difficulties connected with guiding the apparatus"*. With women habitually floating around in voluminous, floor-length dresses, men had clearly forgotten women had legs very similar to their own. It's doubtful if the Perkins tricycle proved to be what women were looking for though Ruggles' variant of 1879 could take a youngster as well. In this version the hand levers were for steering and the power provided via treadles.

PERKINS' VELOCIPEDE.

RUGGLES' VELOCIPEDE.

Fig. 2.



Tricycles continued to be popular in the 1880s. The Columbia tricycle had a true differential gear in the rear axle that allowed both wheels to be driven and the outer wheel to go faster when rounding a bend, the very same system that would be used in cars.

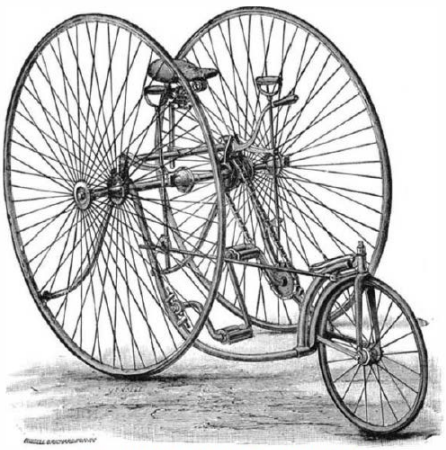


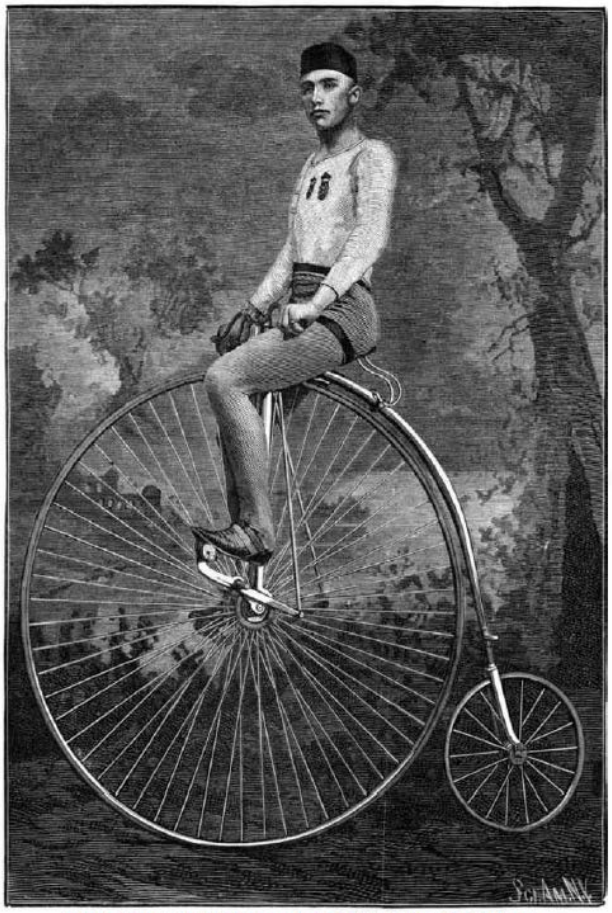
Fig. 1.—THE COLUMBIA TRICYCLE.

In answer to a query about how it is possible to travel further and faster on a velocipede than on foot the *Scientific American* opened a discussion of the science of cycling that in many ways is still going on. They pointed out that in walking a mile *"taking military regulation steps of 28 inches each"* it will take 2263 steps and if at each step one raises one's centre of gravity by 1 inch (25.4 mm) then the work done is equivalent to climbing 188 feet (57.5 m). Much less work is done on a bicycle since all that is being lifted is a leg. Moreover, walking is a more complicated physical operation than pedalling, involving more physiological energy expenditure per step than per pedal turn. Into the bargain, one step covered 28 inches (0.71 m) but one pedal turn on a velocipede took one a complete turn of the large wheel, say 150 inches (3.8 m), a gain of more than a factor of 5.

"A STEP," IN WALKING AND ON THE WHEEL.

The magazine had broached the physics of cycling before when it reported on Glasgow's engineering professor

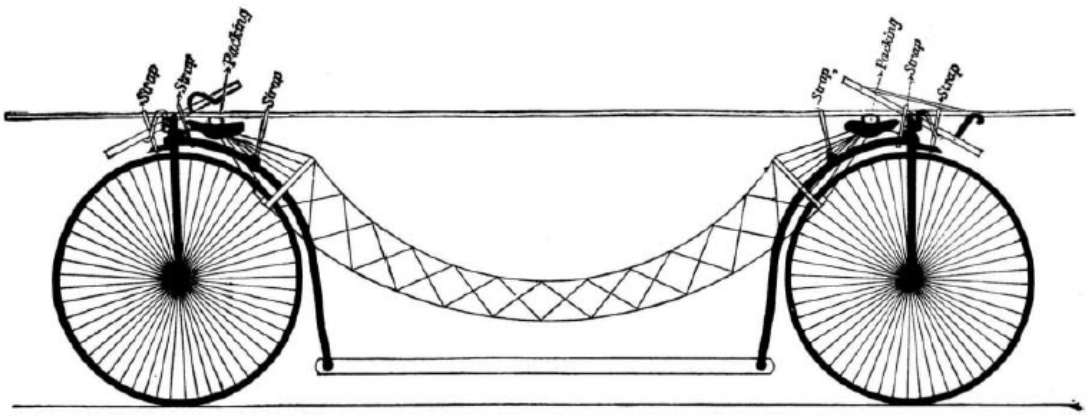
Macquorn Rankine's series of articles in the *Engineer* in 1869. The articles were clearly beyond the capacity of the Scientific American writer. *"We may correct our 'horizontal oscillations' by the application of the formula:* $\frac{gy}{v^2 p}$ *which Professor Rankine has so kindly bestowed upon mankind, and which once stored up in the head of a velocipede rider will forever effectually prevent a loss of balance in his body, whatever may be the effect upon his brain"*. The *Scientific American* took up the 'science' theme again later in the century: *"When a wheelman is moving forward on a bicycle, what keeps him up? That is the question asked by inquisitive minds, as the rider passes swiftly along on a wheel base practically without width"*. This was just the question that Rankine was answering had the writer looked back more than 20 years earlier but apart from likening the stability of the bicycle to that of a flywheel, the journal did not go into the underlying physics but digressed into the issue of the force of collisions. However, they illustrated the moderate speed easily obtained on a bicycle by comparing the cyclist with a pedestrian tall enough to keep up with a 'wheel man'. The height they used was 18 feet (5.5 m). *"While the bicycle has the advantage over the extremely tall pedestrian, it is obvious that the tall wheel man has no advantage over the short one"*.



TAYLOR'S IMPROVED TREADLE FOR BICYCLES.

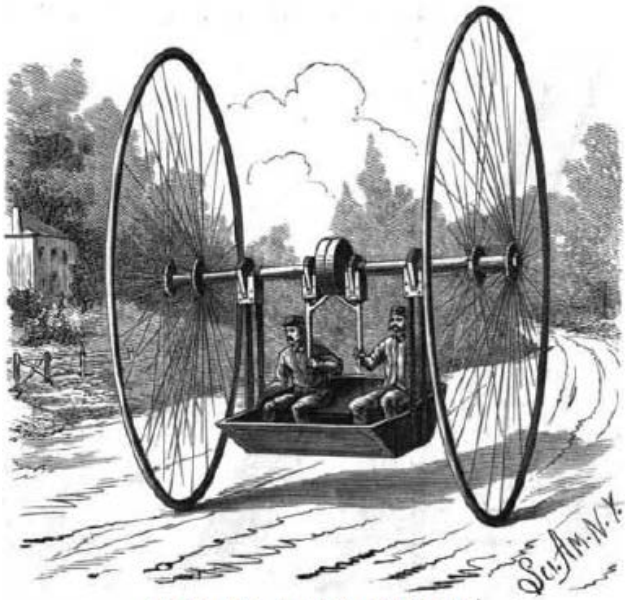
There was one big breakthrough in the second half of the 1880s that we shall come to. There was also a variety of improvements to individual parts of a bicycle, for example the addition of a cyclometer to record mileage and the attachment of a small luggage rack. Means of changing the leverage of the leg were investigated, first by having an adjustable crank, as shown in 'Taylor's improved treadle' and secondly by the introduction of hub gearing. Neither of these systems were adjustable while running but the germ of the idea was clearly present. Nowadays you will not see an adjustable crank anywhere – there is less room for it above the road – but the provision of two or three chainwheels on a touring bike has a similar effect.

CREDLEBAUGH'S LUGGAGE CARRIER FOR BICYCLES.



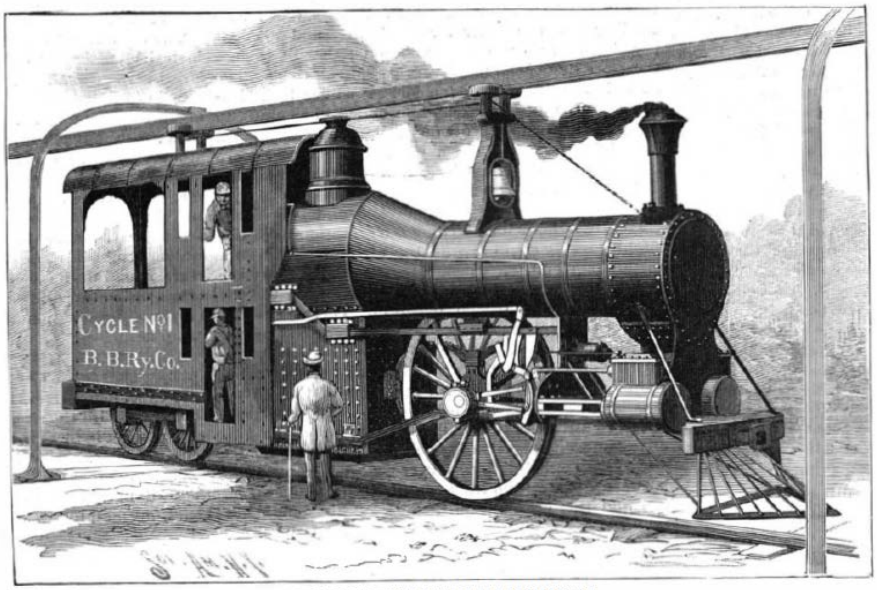
BICYCLE AMBULANCE.

With good sense also came developments that in their own way were bizarre but quite logical. The ambulance bike shown above was developed in India. It looks as if the only 'rider' was the ill or injured party who was pushed along. The swing bike of 1887 was just for fun. A system of ratchets engaged when the swing was put in motion and drove the wheels forward (I guess as the swing went backwards) and disengaged for the rest of the swing. The levers hanging from the axle were an integral part of the system for activating the swing and controlling the ratchets so that one wheel could be made to run faster for going around a bend. The circular objects seen near the centre of the rear axle are disk brakes, so this fun item was in fact quite innovative.

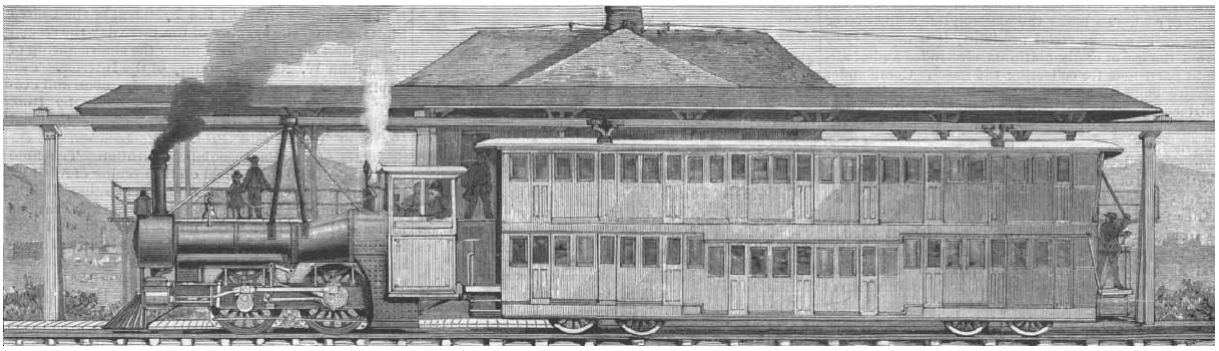


BROWN'S SWING BICYCLE.

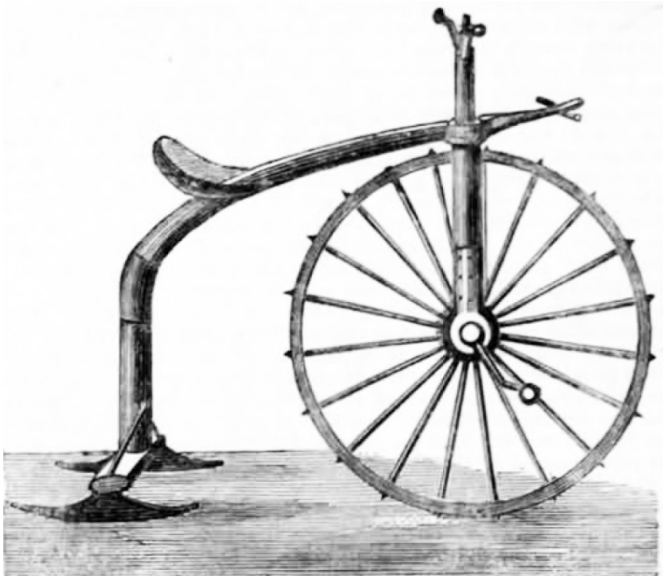
The Boynton locomotive cycle looks truly 'loco' but it was designed to pull double-height, narrow carriages only 4 feet wide, all on a single rail. The top rail was simply a guide, taking no weight. A lighter variant of the Boynton railway with twin driving wheels on the engine did run from 1891 at least and is shown in the following cut. It was said to be able to go at 100 mph, an impressive speed for the times. Far from being a bonkers idea, the



THE BOYNTON BICYCLE LOCOMOTIVE.



Boynton railway morphed into an electric monorail operating in Long Island in 1894.



To return to bicycles, it would seem that the big wheel could cope quite well with rutted roads, cobbles and mud, though I personally would not relish taking a header from a perch little short of 5 feet (1.5 m) high when the bike hit a pot-hole. Many places in America get worse winter weather than us, in spite of being below the 49th parallel. As a writer in The Engineer noted in the late 1860s, in winter s*now fell in quantities and froze on the ground. The velocipedes turned out as usual, but, with a prudence characteristic of intelligent beings, refused to progress. It is true their wheels rotated rapidly on the slippery surface but not a yard would they move on.* Inventors were not slow to think of adaptations.

HOLTKAMP'S ATTACHMENT FOR BICYCLES.

Adapting the bicycle for ice and snow didn't escape the inventors. The illustration above is from pre-1869. The Holtkamps' device pictured here is in the form of attachments to an ordinary bicycle that will allow it to be ridden on hard-pack snow or ice. Bray's velocipede (overleaf) would in due course have the spiked wheel replaced by a track and with the aid of motorcycle technology the snowmobile would be the 20th century result.

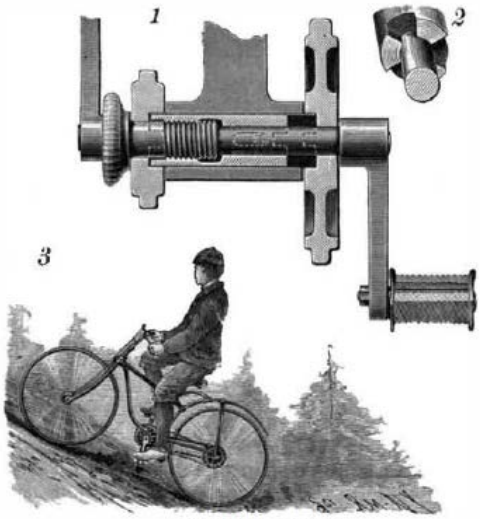
The biggest revolution would come in the mid 1880s with the advent of the 'safety cycle'. *"Of the various forms of outdoor exercise, it is now generally admitted that 'cycle riding is one of the most healthful and delightful. The movement of the lower limbs in driving the pedals, the*

gentle force given by the arms in steering, and the constant undulations of the body with the motions of the vehicle, result in a rapid and general strengthening of the system; while the mere act of riding in the fresh, open air, amid constant changes of scene and prospect, brings on a peculiar cheerfulness and exhilaration of spirits that compensate a thousand-fold for all the bodily exertion involved. Those who have been deterred from the pleasures of 'cycle riding by fear of accident on the high wheel will dismiss all their fears if they use the Rudge bicyclette, of which we here give an illustration" (in 1887). The writing was on the wall for the 'penny farthing'. *"Among other advantages claimed for this vehicle are the following: perfect immunity from headers, very great brake power, easy mounting and dismounting, great power up hill, ease of working against head winds, little vibration and bumping, ability to ride where ordinary 'cycle or tricycle could not venture, no skidding when driving up hill; maximum of speed with minimum of exertion, comfortable foot rests, little splashing from mud and wet, saddle and handles raised at will"*. The velocipede of the late 1860s had two similar sized wheels. The penny farthing design was a blind alley of development, an example of how habit and fashion can keep alive a fundamentally flawed product for over a decade. Notice in passing that almost all bicycles before the safety cycle had front wheel, direct drive. The chain and rear wheel drive took a long time coming and seems to have developed from the tricycle.

BRAY'S VELOCIPEDE SLEIGH.

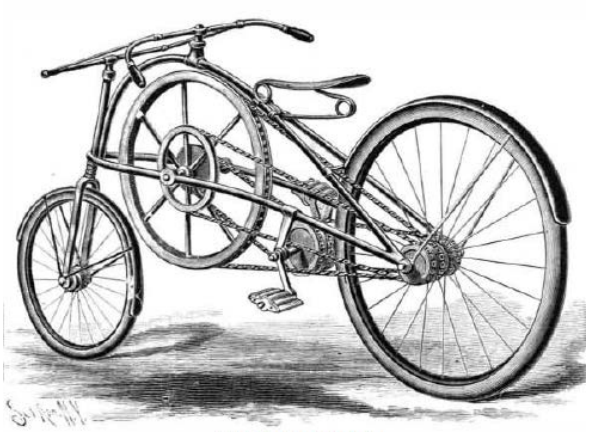
THE RUDGE BICYCLETTE.

By the 1890s, the bicycles illustrated in the *Scientific American* were almost exclusively 'safety cycles' and presumably those selling in the shops were similarly styled. There followed a series of gradually developments from the peripheral, such as a steering lock to discourage theft, improved seats (quite important) including the tilting seat, novel cranks, bicycle stands to support the bike, bicycle bells, improved cyclometers to measure distance travelled, a handlebar clip for pocket-watch or stop-watch, a child seat and more, to the fundamental innovations. Gearing was clearly an issue. Biglow's solution of 1891 was to provide twin chain drives on either side



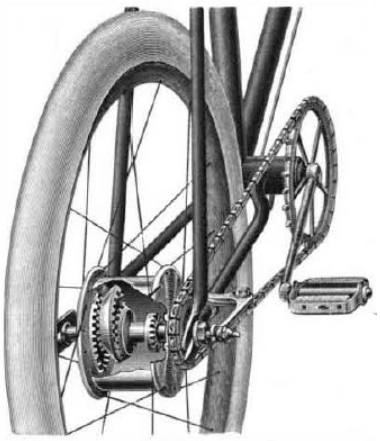
BIGELOW'S BICYCLE.

of the bike with different sprocket sizes and a clutch mechanism on the crank spindle that could engage one or the other. At a time when a typical bike with 30 inch (0.76 m) wheels weighed 40 lbs (18 kg), adding a second chain and sprocket wheels and some extra mechanics was not a big deal but such a solution (for only two gears) wouldn't be accepted today. The illustration of a rider effortlessly ascending a hill that is almost 30° with such a device is a fantasy. A 1 in 5 hill (20%) is a serious incline even for today's cyclist.



JENKINS' BICYCLE.

Gearing was proving a difficult problem to crack. Jenkins' cycle of 1893 shows a cumbersome attempt at providing 3 gears. Two larger intermediate wheels were involved placed near the front of the bike with 4 chains altogether. It's not clear how the different drive chains were swapped in and out of action. The large additional wheel was said to act as a flywheel, but it could not store enough mechanical energy to be useful in this rôle.



20th century bikes usually had either *Sturmey-Archer* gears, offering 2 or 3 choices selected via a cable operated mechanism in the rear hub, or *derailleur* gears in which the chain is moved over a selection of rear-wheel sprockets and perhaps across a selection of 2 or 3 chain wheels. A spring activated chain tensioning device adjusts to compensate for the varying size of the wheels involved. The Sturmey-Archer company was founded in Nottingham in 1902 but their 3-speed epicyclic hub gear was introduced as late as 1936. This was about the same time as the modern derailleur gear appeared, though earlier versions go back to the beginning of the 20th century. The precursors of both systems can be found in the 1890s. The neighbouring picture shows Balloch's hub gear of 1898.

Braking was also an issue. Many bikes had no brakes. There was no ratchet in the rear hub (the so-called 'fixed wheel' configuration) so back pedalling slowed the bike and the side of one's shoe applied to the front tyre was also quite effective. Astor's bike of 1890 had handlebar operated brakes superficially similar to 20th century brakes in which the handlebar levers operated a rod, except that the brake still operated on the tyre. The brake shoe (shown separately in the diagram) was of metal with cuts that allowed it to be shaped to the tyre. In a sense this was the 'obvious' solution, especially with solid tyres and with the wooden wheels that the majority of bikes had, for the rubber provided the large quantity of high friction material. Aluminium and steel wheels were made for the higher end of the market. What the bike needed, though, was the application of the now well-known design principle 'look at the issue the other way around'. In this case, make the lever operated part out of a high friction material and apply it to the wheel rim, preferably a metal rim. A worn brake-shoe can be

ASTOR'S BICYCLE BRAKE.

replaced much more easily and cheaply than a worn tyre and, besides, the tyre has another very important job to do, which is done less well if it is also used as a brake pad. The New Mail bike of 1891 (shown right) went part of the way towards the modern braking solution by having a brake that was a band of steel lined with leather operating on the rear hub. As well as rear wheel braking, the New Mail had ball races in the steering head as well as the hubs, sloping handlebars, basic diamond frame and a spoke pattern that looks modern.

Almost all the earlier diagrams show bicycles with radial spoke, a pattern that carried on the practice of cartwheels. In a bicycle there is a big premium on reducing weight and hence searching for the very best solution to each problem. One problem with wheels is that the force driving the bicycle forward is provided tangentially by the road and must be transmitted by the spokes to the hub attached to the frame. This results in a torque on the spokes that twists them. Likewise there is a twist when braking. The spokes also have to support the weight of rider and bicycle frame. A 'tangential' spoke pattern (tangential to the hub) will better resist this twist than a purely radial pattern, as seen in the New Mail bike already illustrated. However, as the *Scientific American* explained in

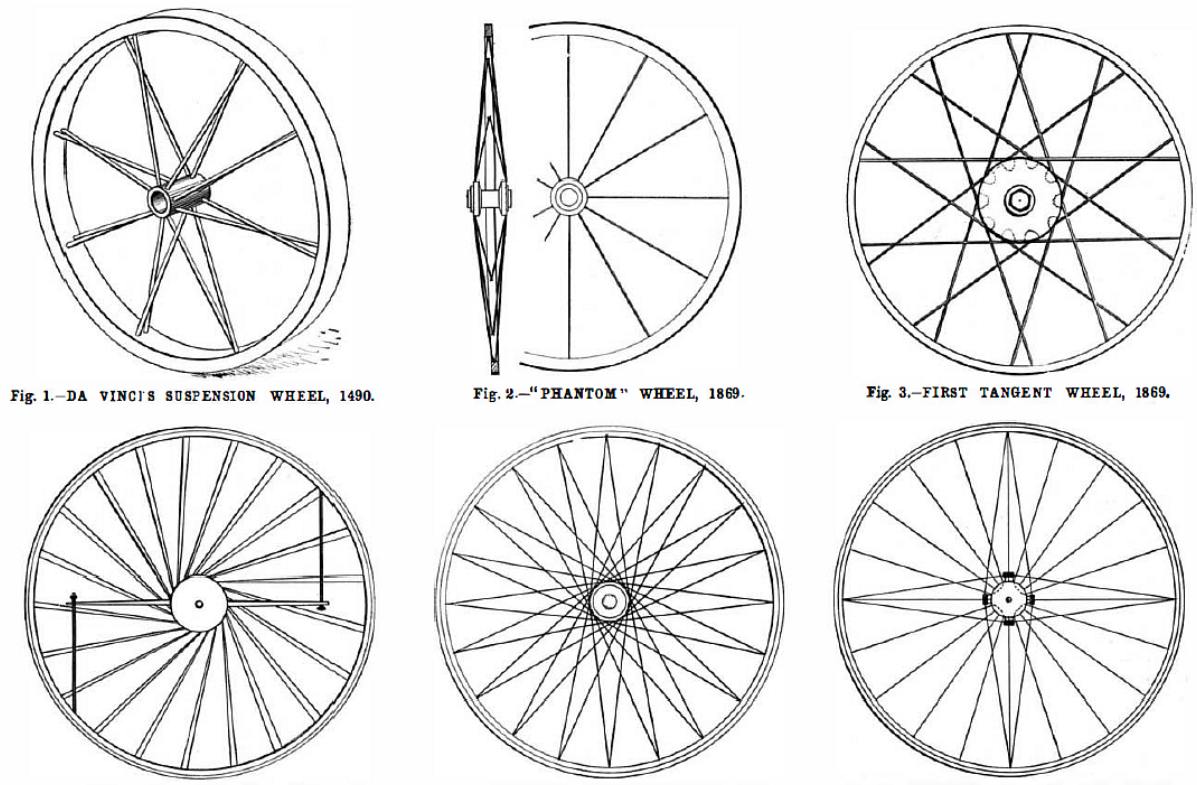


Fig. 1.—DA VINCI'S SUSPENSION WHEEL, 1490.
Fig. 2.—"PHANTOM" WHEEL, 1869.
Fig. 3.—FIRST TANGENT WHEEL, 1869.
Fig. 4.—CROSS LEVER TENSION WHEEL, 1870.
Fig. 5.—STARLEY'S TANGENT WHEEL, 1874.
Fig. 6.—COMBINED TANGENT AND RADIAL SPOKES, 1875.

EVOLUTION OF THE BICYCLE WHEEL.

1896 with the following diagram, the invention of such a spoke arrangement really went back to a British patent of James Starley of 1874. However, patents can hold up the widespread use of an idea.

Spokes are not mere connectors of the hub to the rim. They give the rim stiffness in three dimensions. If you try to squash a circular hoop, part of it goes in and part goes out. The

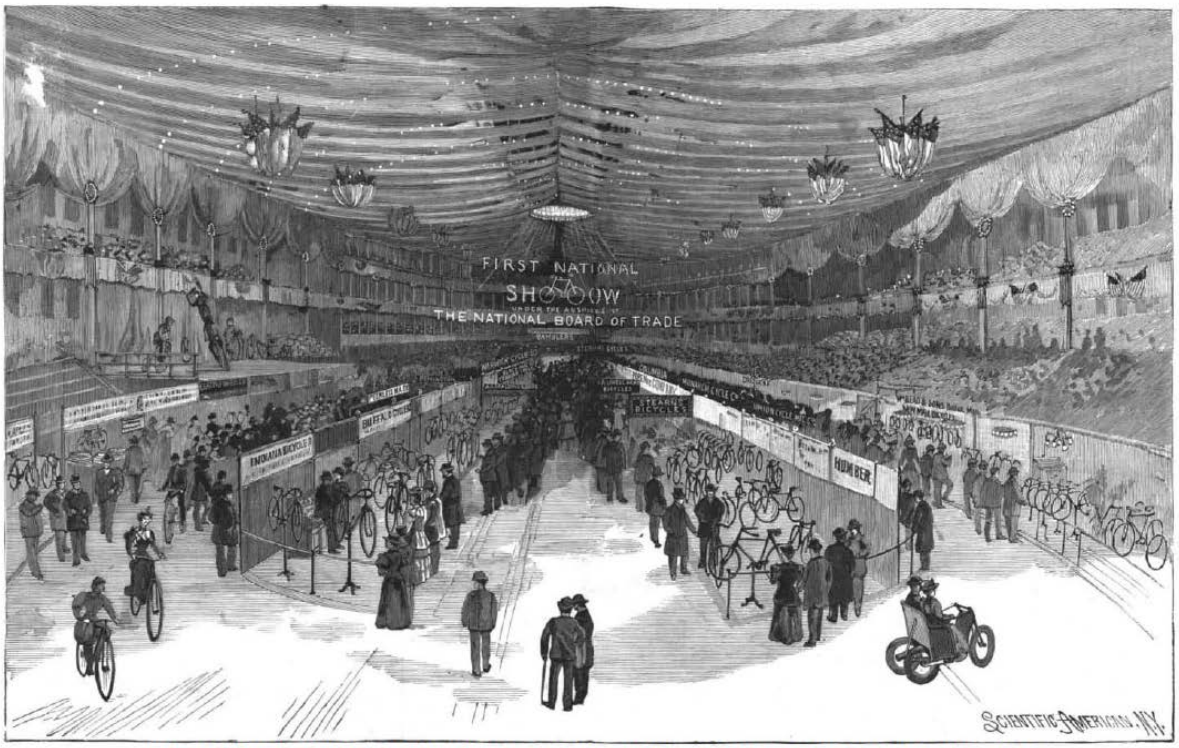
spokes prevent the part trying to go out from doing so and hence give the rim a stiffness against compressive deformation. If the spokes are all in one plane, though, a sideways jolt will cause the rim to buckle. This is counteracted by taking spokes to either extremity of the hub so that there is a sideways tension to counteract the buckling twist of a sideways jolt. The hub needs to be wide enough give enough sideways slant to the spokes for lateral stiffness.

THE VICTOR "FLYER" OF 1893.

Every age thinks that they have finally got all the answers. Choosing the 'Victor flier' as an example of a modern bike (illustrated on the next page), the *Scientific American* wrote: *"The highest grade bicycles of 1893, such as the world-famed Victor bicycles, have probably reached that stage of development where many more improvements are improbable, if not impossible. The maximum and minimum in weight have been reached, and it is now assured that from 28 to 35 pounds is the proper standard, varying from the former for a racing wheel to the latter for rough usage and very heavy riders. Above or below these weights is undesirable"*. For comparison, my Dawes touring bike weighs about 13.6 kg (30 pounds), a mountain bike more but a modern sports bike less than 10 kg (22 lb).

The mid 90s brought some reflective comments to the *Scientific American*. *"The lessons of construction taught by the bicycle are valuable as much in their exclusion of the unsuccessful as in their lessons of achievement. It has been found that a machine with some twelve finely adjusted, apparently delicate ball bearings can, without repeated oiling or attention, be driven for hundreds of miles through dusty roads. It has been found that lightness of structure is made possible by the pneumatic tires, which prevent destructive jarring every time a bicycle noiselessly glides past a rattling carriage, whose wheels rotate on thickly greased axles, and where every stone and inequality in the road opposes progress, seems to tell the story of the superior construction of the bicycle. Yet we are content to rest with the development of the man-propelled vehicle. It certainly is time something was done for the other"*. The requirement to make the bicycle light, strong and efficient because of the personal limitations of its power source had pushed the bicycle into the forefront of mechanical technology. Lessons learnt could be applied in other fields.

In 1895 the first annual National Cycle Exhibition was opened at Madison Square Garden in New York. The bicycle had gone from toy to prime source of locomotion. *"Wherever one travels in the country, whether near or far from the center of population, the omnipresent bicycle is found. On country roads the woman school teacher is met riding home from the district school; in manufacturing places the artisan is seen, perhaps dressed in his overalls and carrying his dinner can, going on his wheel on his way to and from his work. In road houses and in some stores special provision is made for the care of bicycles. Men go to their business on them, and it is at last proved that a new mode of everyday, practical locomotion has been developed"*. This was by way of an introduction to the bicycle being seriously considered in the design of city streets. *"It is not saying too much to assert that the time has now come for a change. On the roads and streets it is no longer the two thousand pound truck, the lighter carriage and the slow moving pedestrian that are to be considered; the bicyclist is a new element, which has created a new condition of things which must be*



THE NATIONAL BICYCLE EXHIBITION IN MADISON SQUARE GARDEN, NEW YORK—GENERAL VIEW.

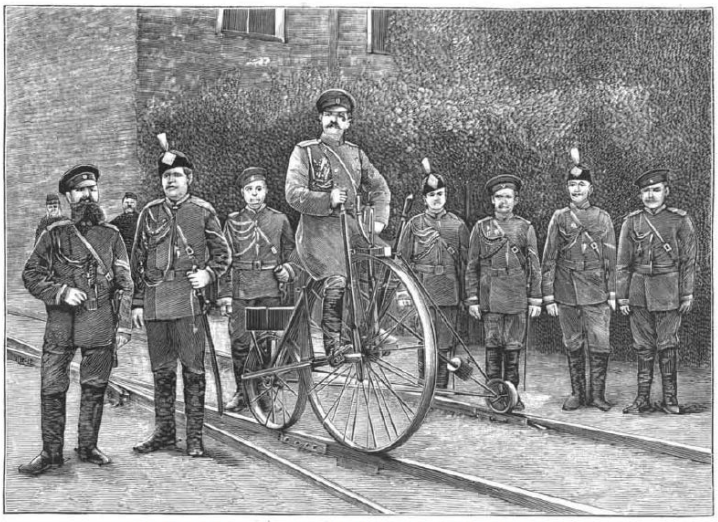
recognized and provided for, and is destined sooner or later to have its interest conserved. The day for inimical legislation passed long ago; the time has come for special consideration. The streets of our large cities, as a rule, are ill adapted in the business districts especially for the bicycle. In cities where the business streets are ridable, the bicycle has come into the most extensive use for business men and tradesmen of all classes. But the stone paved street, adapted to heavy traffic, is but ill adapted to the bicycle, and what seems to be wanted is a compromise pavement, which will suit all classes of traffic". The call in 1895 for city streets to be laid to cater for bicycles was in effect steam-rollered by the appearance of the automobile. The automobile did bring macadamised road surfaces, good

A NAUTICAL BICYCLE.

NEW WATER VELOCIPEDE RECENTLY TRIED AT MARSEILLES.

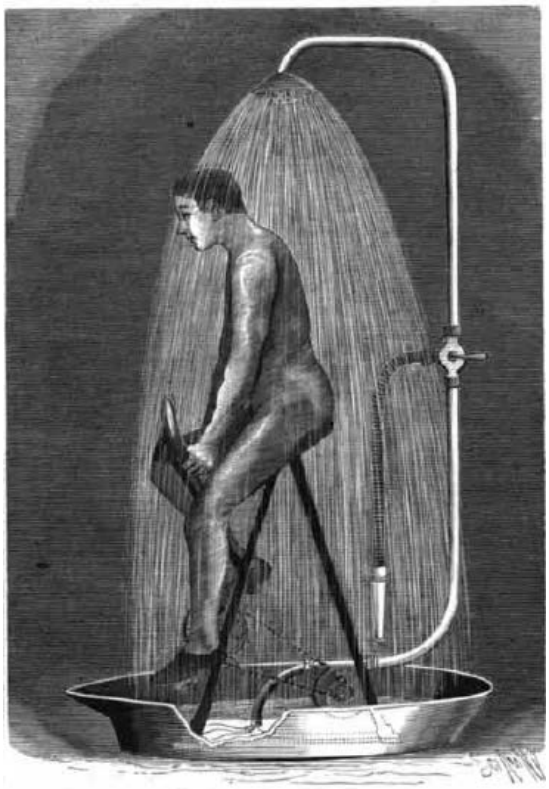
cycling, but filled the streets with fast moving objects potentially lethal to the cyclist. It seems likely to me that most city streets will not become cycle friendly until well into the 21st century.

Looking at a few more odd but logical variants of the bicycle, throws up the French water tricycle (above right) that looks as if it would be blown away by a reasonable wind but it was amphibious (perhaps explaining the attire of the cyclist). It was difficult to capsize and could pull two people who were in difficulties from the sea. Something similar to the nautical bicycle of 1895 (above left) can still be seen at resorts. The duplex side-by-side (below) was a more sophisticated bicycle than it looks, with the two wheels not in alignment and it had a facility that allowed it to be ridden by one person if necessary. It was, of course, aimed at the now substantial recreation market. Several railway bicycles were illustrated in the early



BICYCLE FOR THE INSPECTION OF RAILWAY TRACKS.

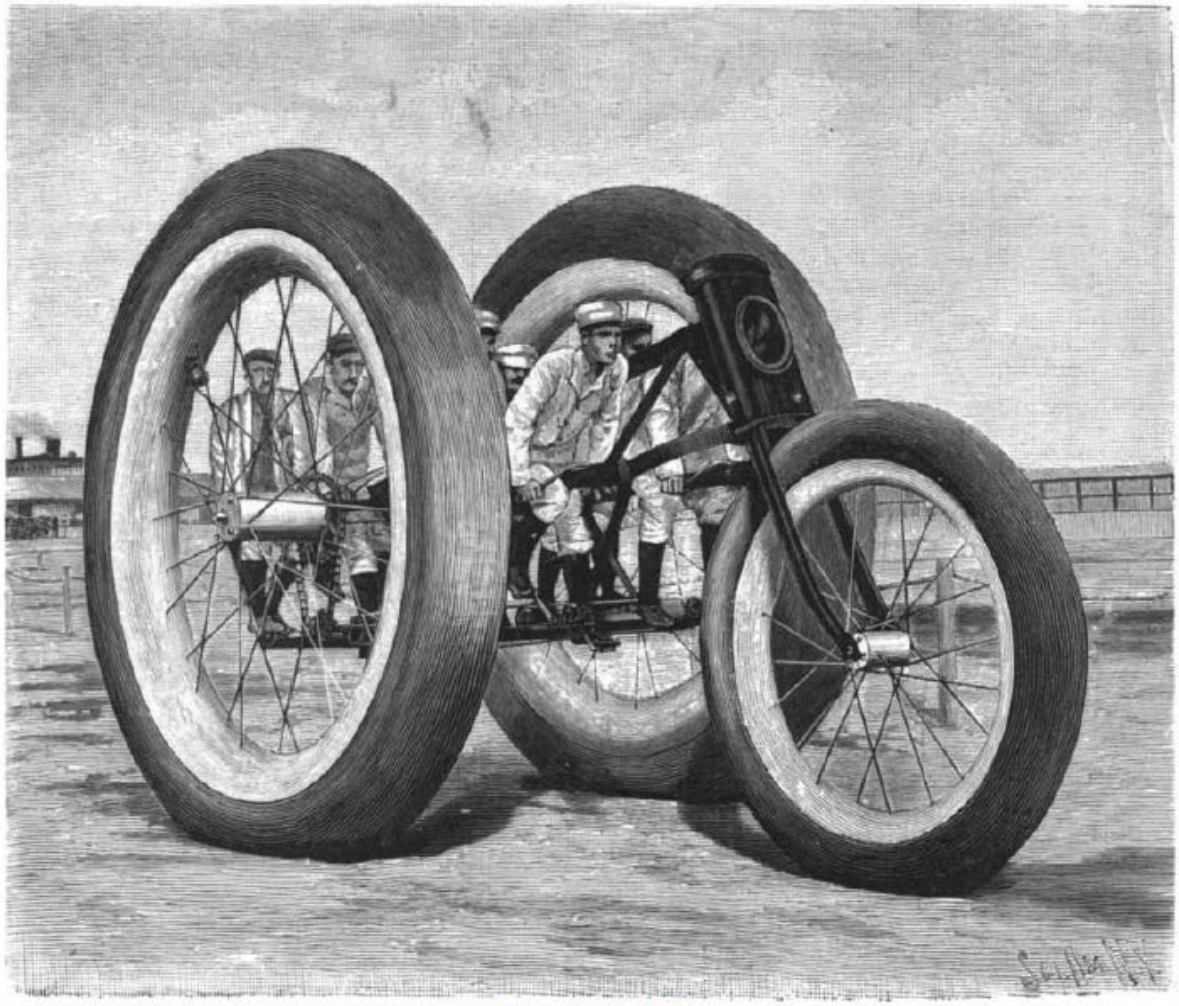
1880s. The Russian railway cycle of 1894 (above) was used by the security forces to check that the line was safe from sabotage by 'nihilists' prior to the Czar travelling. Since steering was not an issue you can see levers at the front that are operated by the arms to assist the propulsion of the treadle. If you think I've shown illustrations of all possible variations of the bicycle theme, believe me I have not, even if I add the *vélo-douche*, exhibited in Paris in 1897 and touted to have *a future for use in cycle clubs, riding academies, sanitariums and in the army.* Useful if the power fails.



A VELOCIPEDE SHOWER BATH.

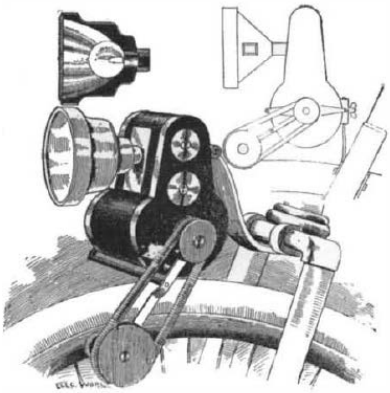
Men wanting "boys' toys" is nothing new and we are talking about America here. The colossal tricycle of 1896 (next page) had rear wheels 11 feet (just over 3 m) in diameter. 4 men operated the treadles for each wheel and one steered. The trike was ridden from Boston to Concord in New Hampshire, a

distance of 150 miles, but was more usually seen in parades.



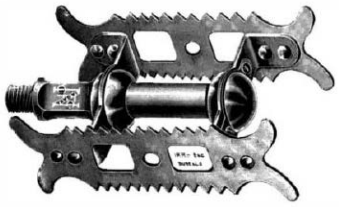
A GIANT TRICYCLE.

These illustrations by no means exhaust the 'odd but logical' theme. Among other devices shown in the mid 1890s were the training cycle, now familiar to every professional cyclist, that was fixed indoors, a folding bicycle and a Swiss variant that was close to a recumbent bike.



AN ELECTRIC BICYCLE LAMP.

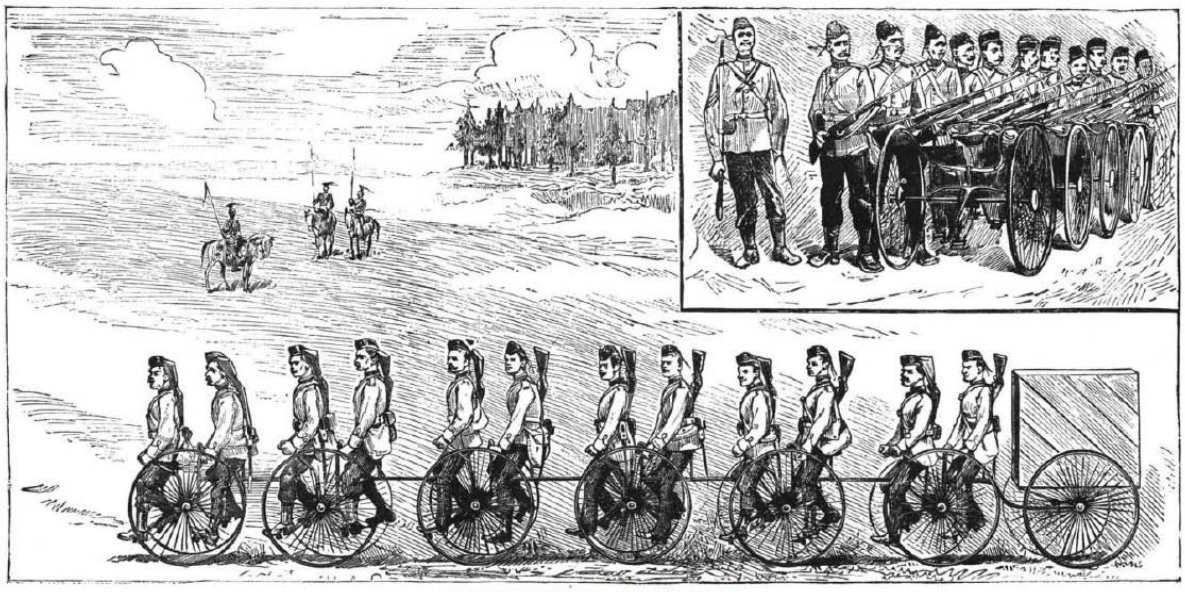
The columns of the *Scientific American* were filled with reports of 'new improved' aspects of the bicycle. Two modest items illustrated here are a pedal, which looks very close to the modern pedal and electric lights for the bicycle. The lights were either driven off a dynamo that pressed onto the wheel (a system very common for more than half of the 20th century) or off a battery. That said, 'carbide' lamps were the more common until well into the 20th century. These were invented in the 1890s and enclosed a flame of acetylene gas that was generated in the lamp itself by trickling water onto calcium carbide lumps. My mother recalled these on bicycles in her childhood.



THE "NIAGARA" BICYCLE PEDALS.

The bicycle was seen as having military potential too, notably in a communications rôle when the telegraph wasn't available. The military took note in 1894 of a relay race (against the clock) conveying a stout leather dispatch bag containing a message from San Francisco to New York, a distance of 3340 miles. The cyclists were mainly amateurs. They took 13 days, a pretty impressive time really, especially considering the conditions: *"for many hundreds of miles the riders had to wheel along the old emigrant trails which, fifty years ago, carried the ox team of the pioneers into the far West. Moreover, some hundreds of miles of the steepest hill climbing were encountered in the Sierra Nevada and Rocky Mountains, where the passes lie some seven thousand and eight thousand feet above the sea, and the surface of the mountain grade is roughened and rendered perilous by "washouts", loose rock, and gravel. To the difficulties arising from poor roads must be added those due to the weather, which on several days and nights was marked by rain storms, which turned the poor roads into mud, and rendered fast travel on the good roads impossible"*. There were a good many stories of the race. On one occasion a rider and his companion *"were riding by night and in a blinding rainstorm by a road which crossed a swollen torrent, whose bridge, a corduroy affair, had been washed out two or three hours before they reached the crossing. The riders, speeding on through the darkness, plunged into the river, first courier, then trailer. Climbing out, they used a fence rail with a spike driven through to fish out their wheels, and then rode 36 miles to the nearest telegraph station"*. In fact 80% of the journey was carried out on dirt roads, bringing to national noticed the need for tarred roads outside the cities. Just as this was going on Marconi was making his first experiments in radio and it would be radio that squashed the military need for long-distance communication using bicycle relays. The motor cycle would take over the dispatch rôle of the 'push bike'.

While mentioning the military, I must include the following sketch of a military field multicycle under test in 1887. Regardless of the practicality of the transport, the prospect of establishing a firing position behind a set of bicycle wheels was not likely to create much confidence in the soldiers.

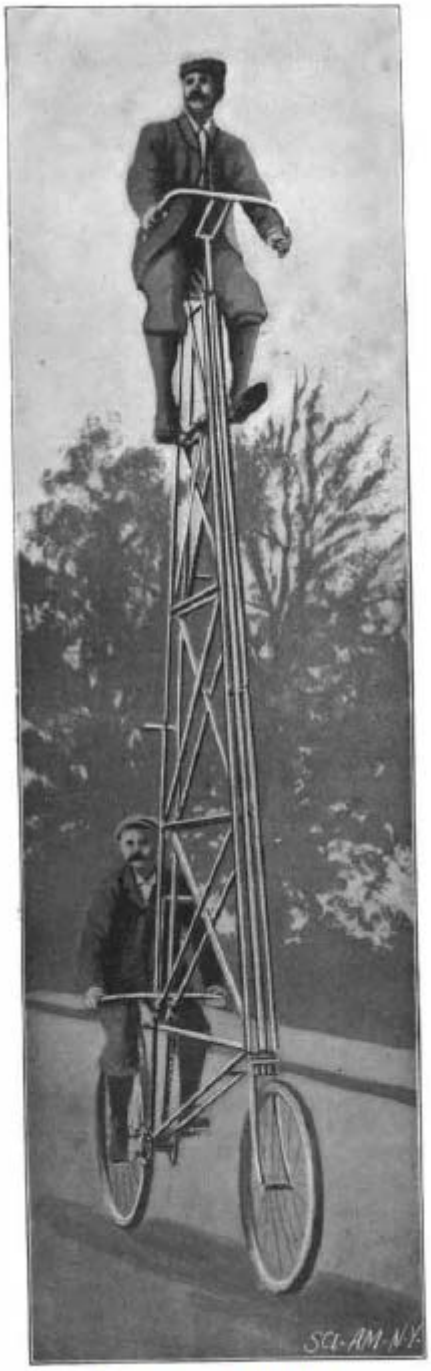


INFANTRY SOLDIERS ON THE ROAD.

THE NEW MILITARY MULTICYCLE NOW BEING TESTED AT ALDERSHOT.

The bicycle as entertainment continued to be a theme throughout the 1890s. The manufacture of American bicycles (or 'wheels' as they often put it) was big industry by the mid 1890s. In earlier years cycles were assembled from assorted parts in small numbers by a

BICYCLE EXERCISES AT LEIPZIG.

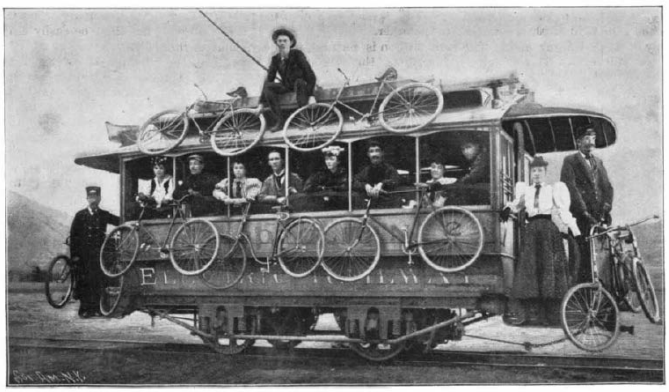


THE EIFFEL TANDEM.

wide range of makers but the largest firms now had dedicated facilities to make all the parts themselves, test production themselves in their own 'laboratories' and innovate. *"The bicycle makes the slow fast, and now telegraph messengers, postmen, lamplighters, building and street inspectors, "walking delegates", policemen, firemen, coast patrollers, express messengers, doctors, and others are all using the bicycle in their respective avocations … .*

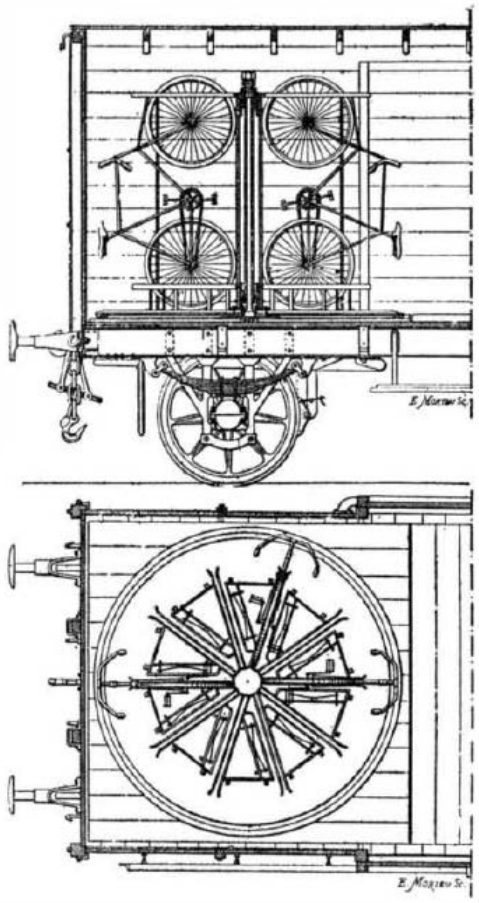
In England and on the Continent riders are perfectly satisfied with wheels weighing from 30 to 50 lb; here bicycles must weigh from 18 to 26 lb. The consequence is that American wheels must be of the highest standard, or they will be accounted low grade by the rider….. America has made the most wonderful progress in the development of the wheel, and her manufacturers have been so alert and enterprising, competition so keen, and the public so critical, that the American wheel is today the most beautiful mechanism and the lightest and easiest running of any wheel manufactured in any country". Self promotion, perhaps, but the magazine was independent of the industry and its job was to report the technological news. It did report that a 24 hour distance race in Putney (England) was won by a Mr Fountaine, who

cycled 474.7 miles, a feat that not many could emulate today on a modern bicycle. It doesn't say if his machine was American.



STREET CAR WITH HOOKS FOR BICYCLES.

The picture I get from the *Scientific American* is that in the years that saw the development of the first cars, cities were in a phase of rapidly accommodating more and more bicycles. Horses still pulled carts and wagons in the cities, and trams full of people (try that with a bike), but for personal transport bicycles were everywhere. The previous two pictures show a tram (in 1895, in Montana) with external hooks to take bicycles and a system for carrying bikes on trains that is better than today's facilities.

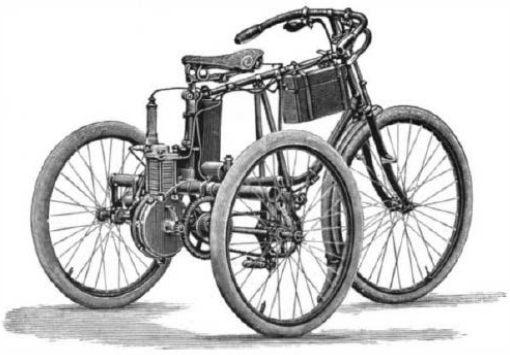


APPARATUS FOR THE CARRIAGE OF BICYCLES ON RAILWAYS—ELEVATION AND PLAN.

THE NEW BICYCLE PATH, OCEAN PARKWAY, BROOKLYN, N. Y.

The city of Brooklyn opened a 5 mile long cycle path along its Ocean Parkway in 1895 extending from the park to the beach. The track went past a new, banked velodrome under the direction of the National Cycle and Athletic Club of Coney Island constructed at a cost of $60,000 and with seating capacity for 8,000 in the stands. By the end of the 1890s, cycling was an integral part of society.

As we know, the idea of the cycle-friendly city crumbled before becoming fact. Cars and motorbikes came along. The tricycle was the obvious variant to motorise first and the accompanying illustration shows the motor tricycle of De Dion and Bouton in 1895. It's not that different from today's quad bike, popular with farmers and others in the countryside.

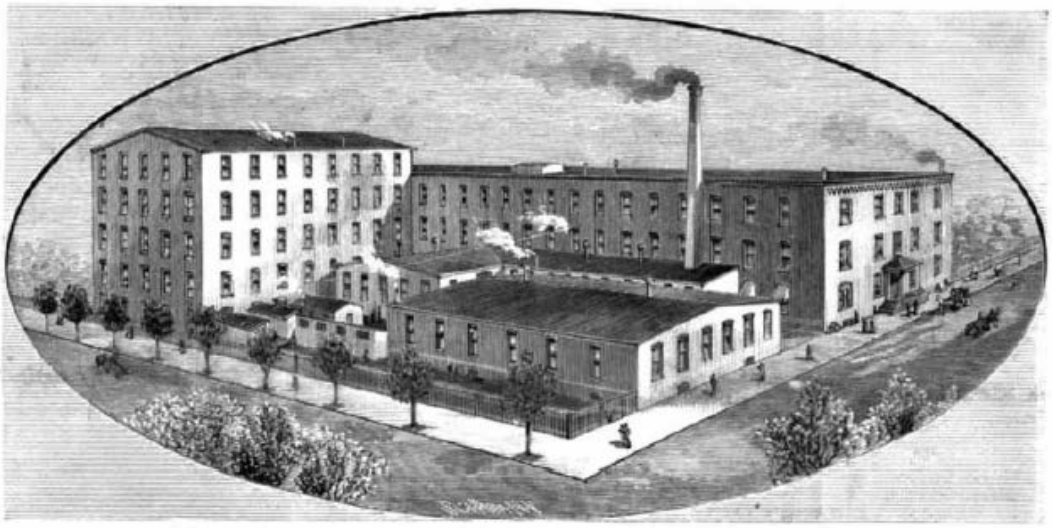


A PETROLEUM TRICYCLE.

Come the 20th century, the *Scientific American* was filled with news about the development of the automobile. There are a strong of reasons why the automobile was going to win any battle for the hearts and minds of those planning a city and of society at large. Some of these reasons echo my opening remarks about it being 'too cold or too wet or too windy' for comfortable cycling. It's history that the automobile won out but times change and priorities change. If I were a gambling man I'd put some money on their being a renewed rise of bicycle variants in the next half century.

The 19th century bicycle was better than it is often given credit for. This piece hasn't been a definitive history of bicycle evolution, just a look at developments that were presented to the *Scientific American* reader. Indeed it's not even complete on that score since the *Scientific American* in every issue had short notices of "*Recent Inventions*", "*Miscellaneous Inventions*", "*Patents and Claims*" and like pieces. Approaching 2000 notes and articles over the years I have covered had some relevance to bicycles and related inventions. For example, the *Bowden cable*, which pretty well every bike today uses to connect the handlebar controls for gear changing and braking, was patented in Britain and America in 1896 by the Irishman Ernest Bowden, along with a brake acting on the rim, not the tyre. This is just the basis of the modern system but it wasn't illustrated in the *Scientific American* so I haven't described it above.

THE BICYCLE OF 1896.



VIEW OF EXTERIOR BUILDINGS—BLACK BICYCLE MFG. CO.

What aspects of a modern cycle were not invented in the 19th century? Not a lot. I can think of the use of carbon fibre or titanium in bicycles more expensive than mine; today's gears are a lot better but aren't new concepts; today's pneumatic tyres are a lot better (I haven't had a puncture for several years and a good few thousand miles, though the roads I've ridden have been better than those of the 19th century); I'm sure the construction materials used today are generally better, from the paint through the metals to the synthetic oil but I'm struggling to think of any radical concept that wasn't present in the 19th century. Perhaps forks with suspension is one such concept. It can truly be said, though, that the modern bike had been born by 1899. *JSR*