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Faculty of Design; Industrial Design

department.

The development of the bicycle as a machine and as a mode of transport.

by Mark Walsh.

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Also many thanks to the enthusiasts working in the WUK (Work and culture centre, Wahringer Strasse, Vienna.) for their input and for inviting me to work with them in the first place.

Lastly thanks to Dr. Frances Ruane for her advice throughout the compilation of this thesis.

Table of contents:

List of plates:

Introduction:

This thesis will deal with the evolution of the bicycle from its earliest inception up until the present day.

I will be looking at the way in which various developments have been adopted or rejected due to a combination of factors and considering each stage of the development in light of these factors. These areas are technical, economic, social and environmental in nature. Obviously some factors do not apply to some of the areas. For instance in the 1800s there were no concerns about the environment per se or in the design of a top racers bike economic concerns would be negligible.

I shall be analyzing the reasons why the bicycle has enjoyed periods of immense popularity and then has sunk to such a level that its image was one to which only the poor or those too young to drive were attracted.In the historical development of the bicycle in chapters 1 & 2 the factual information comes mainly from four books on the subject. They are all generally in agreement and their contents are interchangeable. Most of the evaluation of various designs in this section and the later chapters is my own or that which I have hammered out in debate with friends and acquaintances who are also active in the field of bike design. In many cases my analysis concurs with that given by various authors in the articles listed in the bibliography and much of this especially in the earlier simpler designs is held as common opinion. Where I do not agree I have stated some general opinions and then argued against them.

I approach this thesis from a design and engineering background having qualified as a Mechanical Engineering Technician prior to entering Industrial design as a student. I am therefore qualified to make this analysis. I have also worked For 4 months in Vienna on the design and construction of experimental bikes.

I am primarily concerned in my study of bicycles not with technical ingenuity and engineering skill although these are the means through which my real interest may be reached. I am concerned with the development of cycling not simply as stopgap measure or a sporting activity but as a mode of transport that can offer viable and acceptable alternatives to cars and even public transport.These are my criteria for judging bicycles and other self propelled machines unless they were designed for a particular purpose where I evaluate them on how well they meet the requirements of that application.

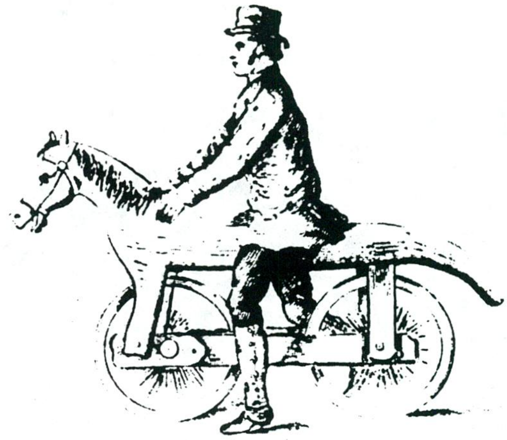
Chapter 1:

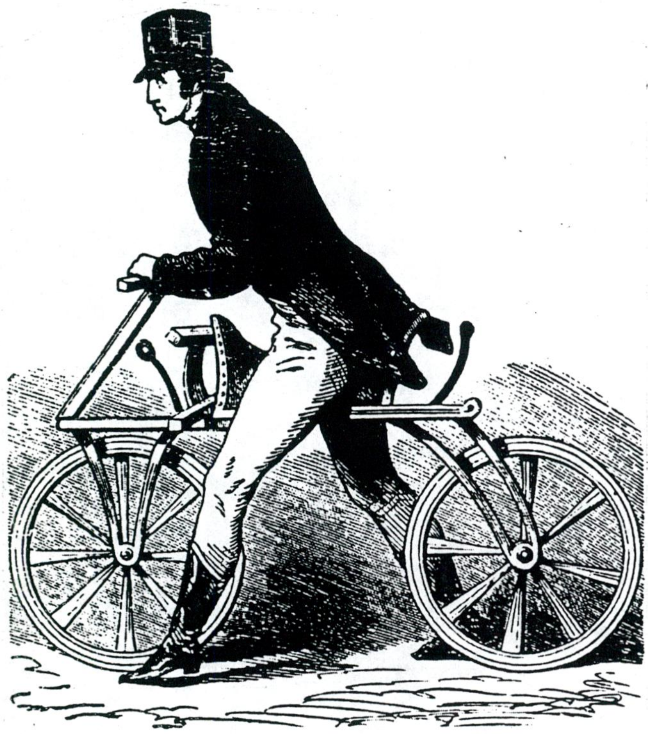
This chapter will deal with the earliest development of the bicycle from its earliest incarnation up until the advent of the "penny farthing" or "ordinary".

The first record available of any two wheeled device, or any device for that matter, for the transportation of people under their own power,is that of a "velocifere".This strange device first appeared in Paris in 1791, being ridden in a public park by a young gentleman known for his eccentricities, the Compte de Sivrac.It is unclear whether he was the inventor or merely the owner.I feel it is pertinent to point out at this juncture that the first velociferes were in the shape of a horse with wheels attached.I believe, and I am by no means alone in speculating that this initial shape and the fact that at the time the only other mode of transport was the horse or at least horse powered was in a large part responsible for the general layout of the bicycle that we are left with today.Of course many factors which shall be discussed later also hindered further development.

These devices became immensely fashionable in Paris for a short time following their introduction but their popularity soon waned as there was no steering and many people caused themselves injury dragging the front wheel sideways to change direction, not to mention those who suffered from rupture of the groin due to the ungainly method of propulsion.This craze was not to last.

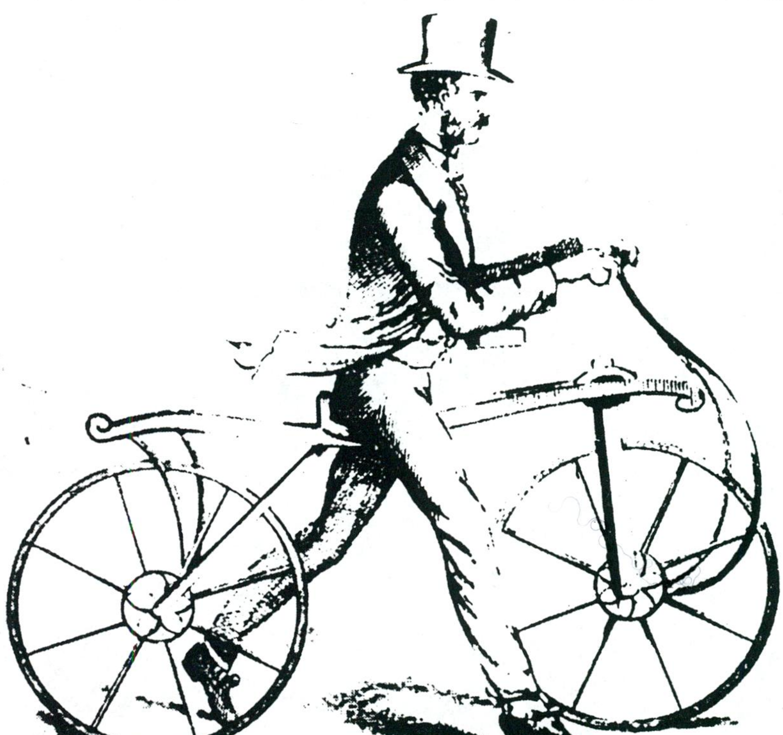
1.1 Celerifere 1793.





1.2 Velocifere 1818.

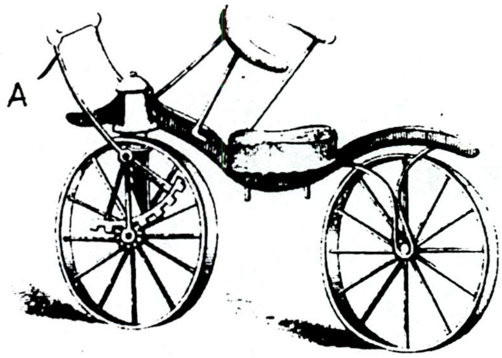
1.3 Draisienne 1819 by Baron
Von Drais de Sauerbrun.
The first with steering.



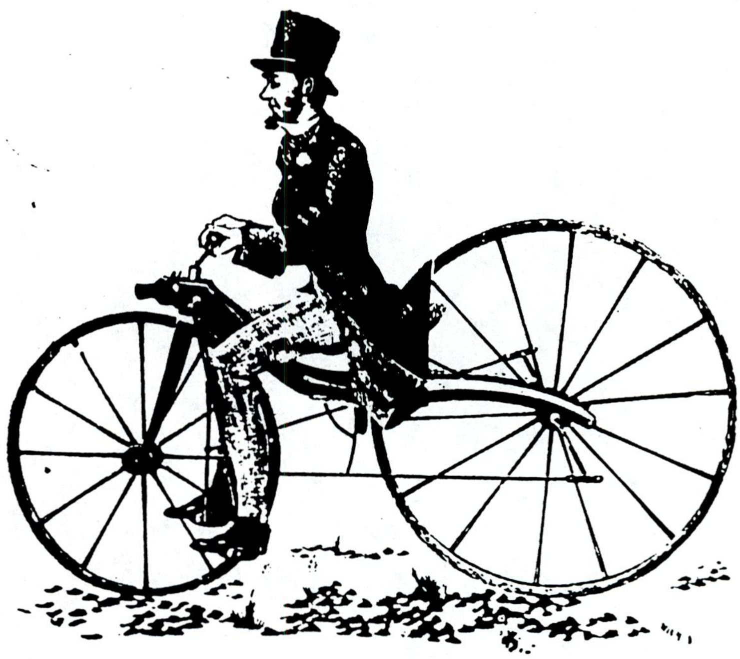
It was not until 1817 that a German, Baron Von Drais de Sauerbrun, added steering to the velocifere.While still clumsy and heavy Von Drais found it of great help to him in his employment in forestry for speed along the roads he had to patrol.

This time, in 1819, the fashion caught on in Britain and here is where the appellation "hobby horse" or "dandy horse" caught on.Again I must point out the association of the horse here, as the riding position of a horse and a bicycle are strikingly similar. Once again, however, the phase was doomed. While the steering problem had been solved the English, ever sensitive to the idea of ridicule or a whiff of impropriety, were being subjected to ridicule by the wits and cartoonists of the day.This combined with the incidence of hernia due to the awkward riding position and the jarring of iron rimmed wheels, from which came the name "boneshaker", put paid to interest in the device.

1821 saw the invention of the first indirectly propelled machine, where the rider had extra propulsion other than at pushing the ground with his feet. This was by a Lewis Gompertz Surrey.His invention was basically a velocipede, as they were being called by now, with a toothed quadrant levered through the front fork which acted on the geared axle. This appears to me as if it would be extremely difficult to control and not surprisingly had very little impact.



1.4 Gompertz velocipede 1821. The first machine not powered solely by pushing off the ground with ones feet. The rider pulled back on the front lever (A) which delivered power to the front wheel.



1.5 MacMillans' velocipede which was the first rear wheel drive machine. It was strikingly similar to later machines still in use to day.

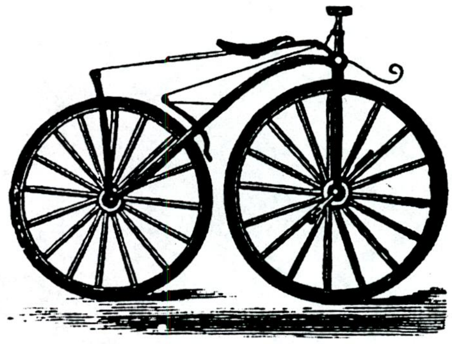
In fact, by this stage, due to their uncomfortable ride, impracticality and the annoyance they caused to pedestrians and to those whose livelihoods concerned horses(some such as blacksmiths were given to acts of retribution against riders)meant that there were only small groups of enthusiasts left.As a result little was undertaken in the way of two wheeled transport for the next forty five years.

While most others were turning their attention to the possibilities of three or four wheeled self-propelled vehicles the first true bicycle came into being in Scotland in 1839. It was the invention of Kirkpatrick MacMillan and was the first two wheeler that could be ridden without the feet coming into contact with the ground at all.It was strikingly similar to bicycles of today and in retrospect I find it hard to understand why efforts were not later made to improve upon this machine. I and can only attribute it to the lack of public communication and that the general public were not aware of his machine. Many elements solved in later devices such as resistance to tipping forward while stopping or when in collision with a minor obstruction and the rider remaining in the same axis as the drive wheel while turning had already been solved. Mac Millan of course may not have even anticipated these future difficulties with other designs but the fact remains they did not exist in his. The power was also transmitted to the back wheel which would have helped in hill climbing and skid prevention though this is debatable as MacMillan was using iron rims.Even so he propelled his device at fourteen miles per hour, unheard of at the time!

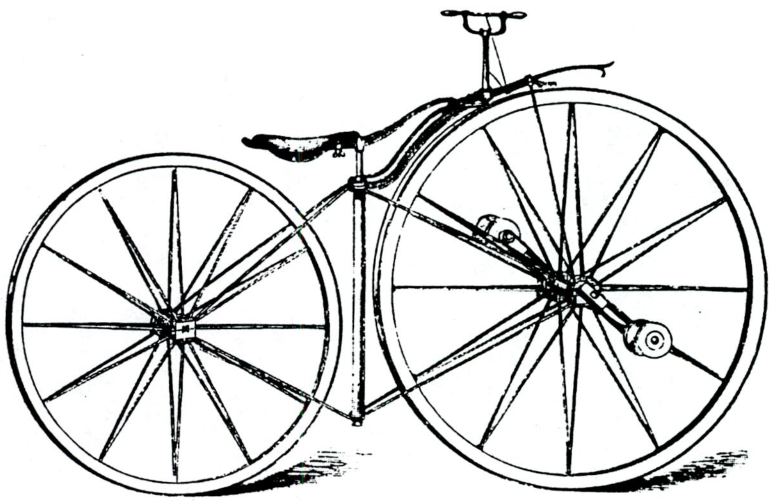
While I feel that Mac Millans' concept was superior to many that followed, the later rotary motion of pedals as opposed to the back and forward action of MacMillans' rod-connected treadles,was undoubtedly an improvement. The introduction of pedals attached to the front wheel was a rather rushed and arbitrary decision and gave rise to the problems I referred to earlier. Again perhaps Mac Millans design was not widely known and indeed there is no evidence that he ever sold any.

The first machine with direct acting pedals was conceived in 1861 by Pierre and Ernest Michaux.Pierre's son Henry leaves an account which states that an old hobby horse was left into their workshop for repair and after a road test and some discussion on what to do with it, Pierre suggested attaching a cranked axle to the front wheel as with a grindstone of the time to permit the wheel to be turned by the rider's feet. By 1865 they were turning out over 400 machines annually.While their machines very much resembled the unpopular hobby horse, the pedalling motion was far smoother and less strenuous and pedalling itself had its own added novelty.

While Michaux began to make trials on weight reduction by making the front wheel bigger and the rear smaller, a certain Rowley Turner ,the Paris representative of the Coventry sewing machine company,was taking a great interest in these new velocipedes and in fact secured one to bring back to England.He seemed to have quite a head for business, and more to the



1.6 Michaux velocipede 1865. This was the first to incorporate rotary action pedals.



1.7 Phantom 1865. Introduced by Reynolds and May it attempted to overcome problems of drive wheel and ride moving with respect to each other.

point publicity. The first thing he did on his arrival in England was to give a public demonstration at "Spencers Gymnasium in Old Street" whereupon he thoroughly amazed all present by cycling around the room and the coming to a halt without falling over, which completed the effect.He rode the machine from Coventry station to the sewing machine factory where he demonstrated it to his uncle, Josiah Turner who was at that time the manager of the company.This in effect started the Coventry cycle industry, as he persuaded his uncle to manufacture 400 units for the French market.By February 1869 they had changed the name to the Coventry Machinists Company and were supplying the domestic velocipede market.

At this time James Starley, who later became known as the father of the cycle trade, was the foreman at the factory. He also had under him G.Singer and W .Hillman.These later went on to become car manufactures as did, ironically to green cycle enthusiasts today, many of those who started off in bicycle production.These men were responsible for many developments in bicycle design, some of which for better or worse are still with us today.

The main link between the velocipedes and the later "penny farthings" was the "Phantom" introduced by Reynolds and May, an English firm, in 1868.They were attempting to solve the problem of steering through the drive wheel by hinging the frame in the middle. This eliminated the side to side thrust on the handlebars caused by the action of direct action pedals on the front wheel.It also meant that the rider stayed in line with the drive wheel(all problems not present in MacMillan's machine).It was also the first to experiment with wire spokes instead of wooden to reduce weight.The Phantom's steering, however, proved extremely difficult to master and the design failed. It is however interesting to note that this centre hinging principal was used again in the 1980s in a modern front wheel drive recumbent, the Flevo bike, to good effect.

While the Phantom was a failure it did pave the way for the "penny farthing" or "ordinary".

Chapter 2:

This chapter will cover the development of the bicycle from the advent of the "ordinary" or "Penny farthing" up until the early 1900s. By this time the interest of wealthy "patrons" previously supportive of cycle development had begun to transfer to the automobile. This was to signal a halt to bicycle development for the purpose of transportation for many years to come.

The ordinary proceeded to ignore problem the phantom sought to overcome.In their sales pamphlet Reynolds and May refer with gusto to the dangers of attempting to turn the wheel you are driving between your legs and the discomfort and loss of power which the rider encounters just when it is needed to complete the turn and also of the grazing action of the outside of the wheel against one's inner thigh while attempting to turn.I can personally testify to the truth of these claims, if they were not already obvious enough, as I spent several months in Vienna one Summer working on experimental bikes at the invitation of some friends. I had the dubious pleasure of riding a modern reconstruction of an ordinary which they had built for a display previously. It is worth noting that the ordinary had less of the problems listed above than the velocipedes which they sought to replace. This had several modern components and was no doubt easier to handle than the originals but still I feel it was a strange breed of lunatic who would voluntarily gather any serious speed, i.e.more than 5m.p.h., on these most unstable of machines.

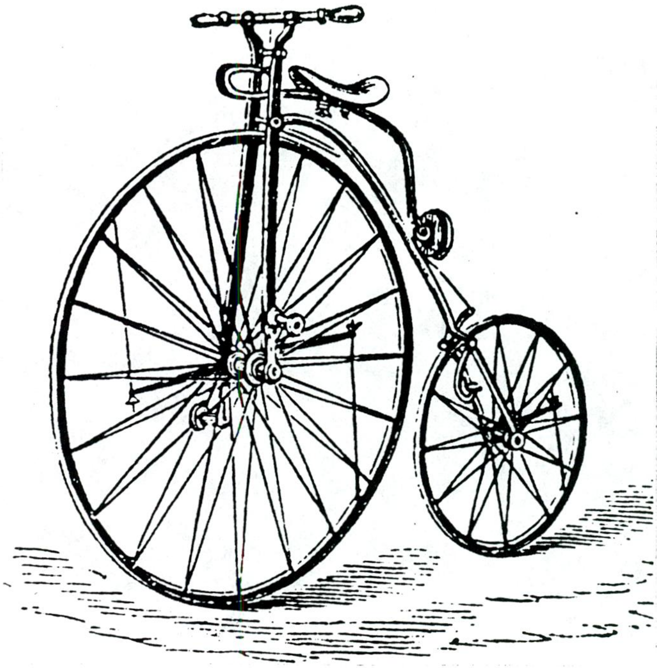
Only two years later, in 1870, James Starley and William Hillman patented the "Ariel" perhaps the most celebrated of the ordinaries. This was quite a leap forward in several respects. Firstly, it was the first all metal bicycle that could be called light.Calling a machine light or heavy depends on its rivals the power source, being the human leg, and what is required of it. It weighed in at 40-45 lbs depending on the size of the wheel and hence the length of the forks and rear spine.The front wheel was so enlarged for the very good reason that the larger the front wheel the farther and faster one could travel for a single revolution of the wheels. The tiny rear wheel was thus in order to save weight, it being really nothing more than a stabiliser. The large front wheel would probably have ridden quite well over the rough and rutted roads of the day. Of course the size of the wheel depended totally on the length of the rider's legs and thus the most successful racers of the days, when the most successful racing machines were the ordinaries, in general, would have been the tallest.The "Ariel" also used Solid rubber tyres and wire spokes that could be tensioned if they got out of true(buckled). These were truly superior refinements and within two years velocipedes and boneshakers were only in use by beginners and the nervous or older riders.

In 1874 Starley introduced tangentially arranged spokes which were stronger and gave a more positive ,less spongy ride. With these modifications introduced the bicycle was to remain virtually unchanged for the next twenty years. The main disadvantage of this type of bicycle is the athleticism it took to mount and ride it in the first place limiting its use solely to young men. This was not unusual at the time but previously it was due to social factors rather than physical limitations. There were a few daring young women riders but this was generally frowned upon by society at the time.

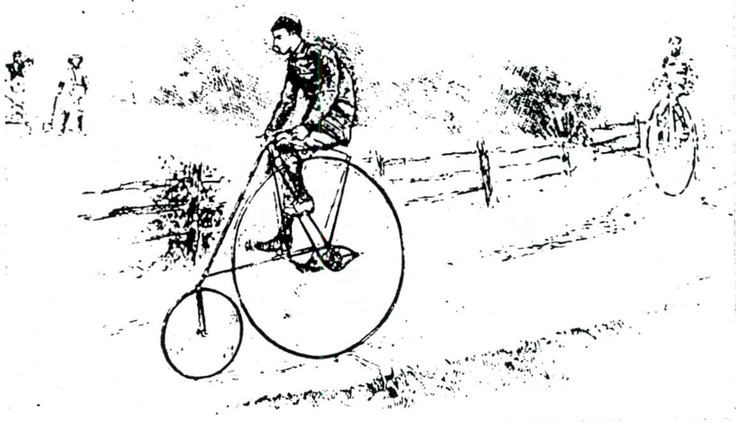
These new machines with their greatly improved speed met with resistance and in many cases sabotage or prosecution. The favoured charge of the police in certain areas (regulations were left to local authorities) was "cycling furiously".One police officer apparently deposed in December 1881 that he had been on duty the previous evening and had observed a group of cyclists doing 40 m.p.h..He then walked after them,overtook them and brought them to the station in handcuffs!..clearly there was a need for some form of standardisation as regards regulations. The ordinaries which were capable of 20 m.p.h. on the flat and with a decent road were also subject to attack by horse drawn coach workers and blacksmiths who feared for their livelihoods.

As in later days, racing affected the design of the bicycle and by the early 1880s Thomas Humber of Nottingham (the current home of Raleigh, The largest bike factory in the world) had begun to produce machines that weighed less than 20 lbs.

Interest in America that had died off when velocipedes had been banned



2.1 Ariel 1870. Starleys most famous ordinary.

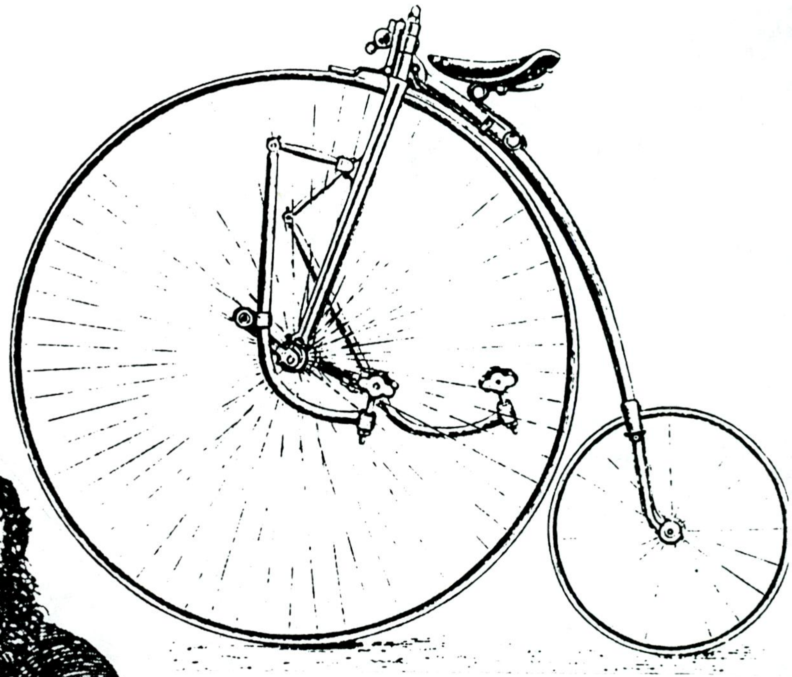


2.2 American Star 1881. An attempt to address the safety problems which beset the ordinarys.

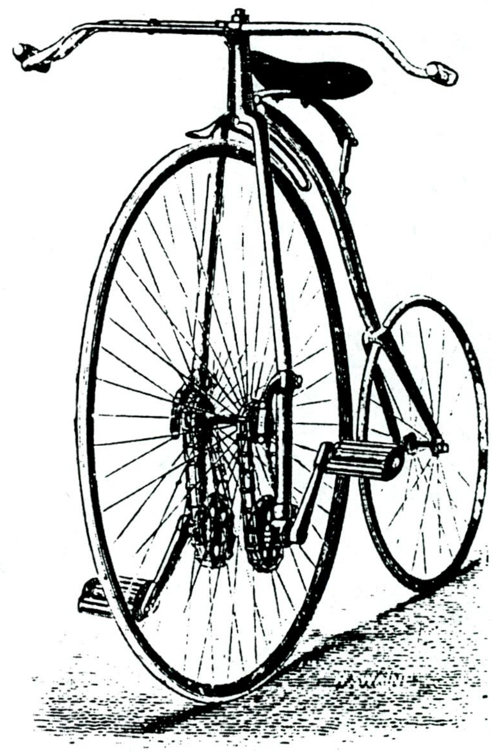
from city pavements was reawakened by the arrival of the ordinary.This really started off the next phase of development.People in America who had not been exposed to the development of the bicycle were naturally considerably more nervous on viewing the ordinary.Immediately there was consternation about its propensity for tipping violently forward and dumping its riders on their heads. This concern gave rise to the American "Star". This looked very much like an about face version of the ordinary and with the small wheel at the front doing the steering and the fixed drive wheel at the rear all the problems seemed solved. The "Star" however due to its Geometry proved quite difficult to master and did not catch on especially in England where people had become accustomed to the ordinary.

These worries about safety had also,however, prompted concern in England and behind the scenes considerable effort was being expended to find a cycle as fast as the ordinary but without the instability problems.This quest resulted in some odd machines from a technical standpoint.The manufacturers had found through tests that simply moving the saddle on the ordinary backwards along the spine was not enough to solve the problem of tipping forward as it diminished power to the pedals and increased the vibration from the rear wheel to the rider. They quickly discovered that indirect drive was the only answer. Of the resulting machines, (three most popular) the "Xtraordinary", the"Facile" and the "Kangaroo",two were driven by treadles and one by a geared chain.These were methods of power

2.3 Xtraordinary 1878. First European attempt to address safety.



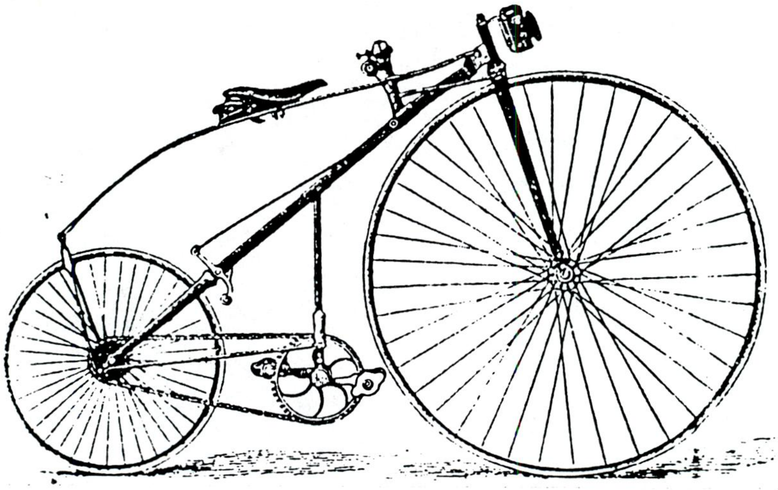
2.4 Facile 1883 with rider. Very similar to the Xtraordinary but less prone to running in reverse if the wrong treadle was pushed first.



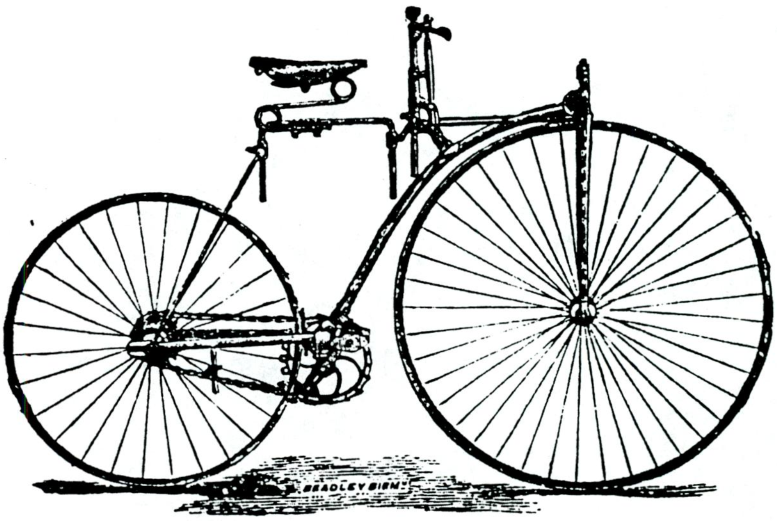
2.5 Kangaroo 1885. Similar to the two above but using a chain drive similar to that still used today.

transmission, especially the chain drive, far superior to anything MacMillan had access to and were perfectly suited for power transmission to the rear wheel. However still no one made the required leap and thought of using rear wheel drive and equal sized wheels.The "Kangaroo" in particular had the type of chain drive which we still use today and this could easily have dealt with the gearing up effect as it did later. The only explanation I can offer is lack of awareness of MacMillan's machine and perhaps a lack of confidence in the strength of their materials; even still, the lack of trial and experimentation is scarcely forgivable. These machines were, however, very successful at the time and several time records were set on them, especially the Kangaroo.

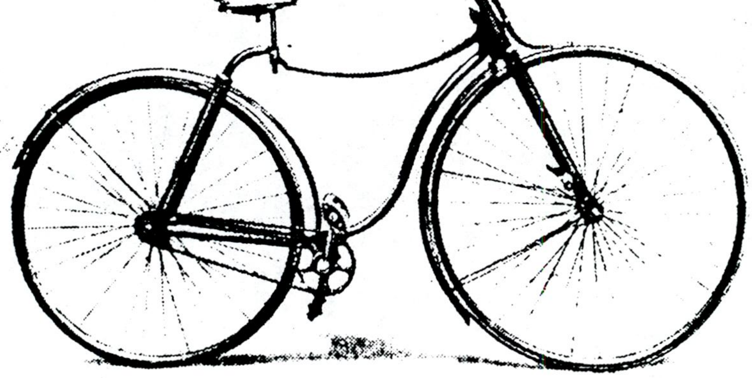
Within a year, in 1884, the connection between indirect and rear wheel drive was finally made and the first of the early "safeties" began to appear. The first bicycle with a chain drive to the rear wheel was H.J Lawsons Bicyclette even though inexplicably it still had a larger front wheel. These had a chain driven rear wheel with which we are now so familiar and strain free front wheel steering.At first people refused to believe that these short ugly machines would ever seriously challenge the high wheeled ordinaries but their increased safety was undeniable.It was thought that the chain drive wasted power when in fact the amount of "give" in the ordinary's large wheel would waste just as much(still about 2-3%).The safeties did vibrate more due to their smaller more rigid wheels and because of these prejudices it was to be another six years before the safety would challenge



2.6 H.J.Lawsons 1879 Bicyclette.It was the first to use a rear wheel chain drive.



2.7 Starleys first Rover safety 1883.

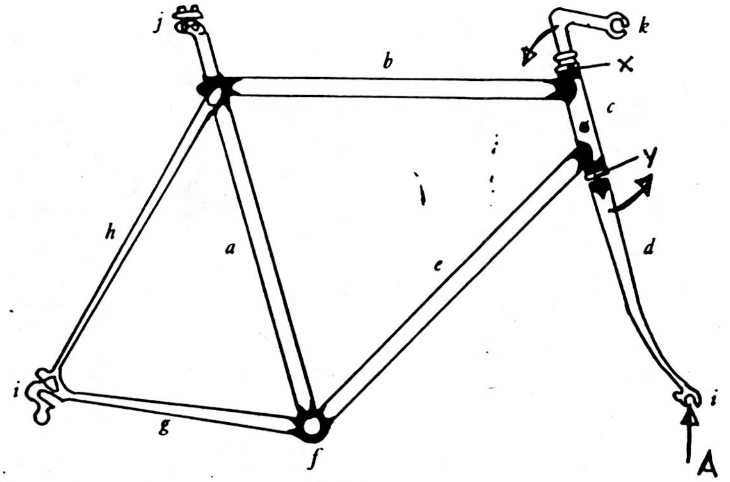


2.8 1885 Rover safety already has diamond frame riding position.

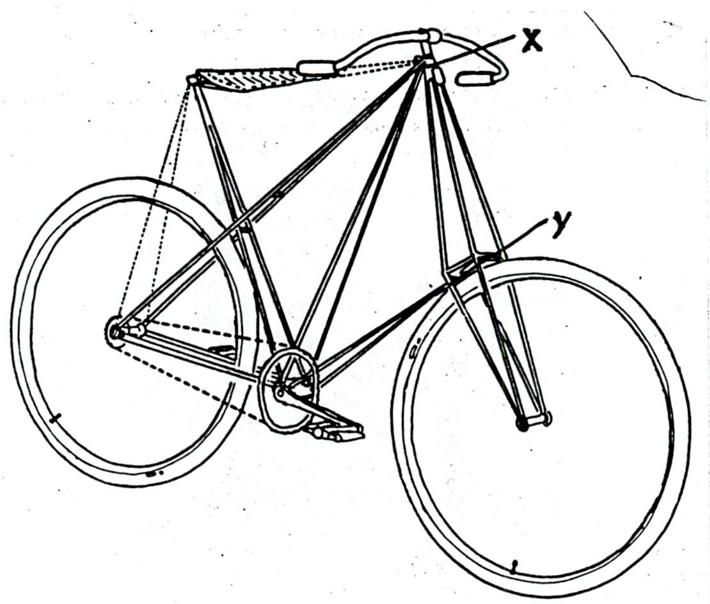
the ordinary. The advent of the pneumatic tyre as developed, and initially thought invented, by John Dunlop began to tip the balance in favour of the new safety bicycles.

When in 1889 W.Hume rode a pneumatic tyred safety on a Belfast race track he was greeted with derisive laughter which was quickly silenced as he left all others behind. After some successful racing in England in 1890 the superiority of the safeties was clearly established and the ordinaries days were numbered, despite the efforts of some manufacturers and "die-hard" enthusiasts to belay this progression. Superior safety and ride characteristics in addition to the removal of many of the physical barriers (i.e.length of leg) brought many non-riders into the cycling fold. In 1885 J.K.Starley, nephew of James Starley, introduced the Rover safeties and these were the blueprint for the diamond framed bicycles still with us today. Cycling boomed again with this new accessibility but in design terms very little was to happen from this point on for a long period of time.

This was the real time for further development because of the huge interest by the rich who were willing to pay for new and advanced machines.It is in some ways disappointing that, even at this stage the way in which the diamond frame riding position had ceased to be questioned.It must of course be remembered that very little was known of aerodynamics at the time and this would have been, and still is, the main reason to



2.9 Frame schematic. As gravity applies force in direction "A" the fork will tend to rotate around point C. This must be prevented by material strength and bearing resistance. This problem is addressed in Pedersens design below. By increasing the distance between points X and Y the leverage at contact points is reduced.



2.10 Pedersens bicycle was very light and strong due to well spread forces and placing of the frame members.

change it.

One notable reworking of the bicycle in 1893 was by a Danish engineer Mikael Pedersen.He rethought the idea of using bent tubes to fit the shape of a rider and used one of the ultimate engineering shapes for strength, the triangle, to produce an exceptionally light frame which was respectively rigid and flexible in the proper orientation. The relevance of the rigidity/flexibility balance will be explained later. In fact, the result he came up with is in some ways superior to the machines familiar to us today. The clearest superiority Pedersen's machine had was in the head tube, which is that part of the frame connecting the handlebars and the forks. His did not have one. Considering the excellent balance of forces in a tubular bike frame the one real botch job is the head tube and headset where misaligned forces have to be kept in check by strength of materials and sturdy bearings. In Pedersen's design the forces are well resolved into compressive and tensile forces; an ideal situation as any engineer will tell you.This design still has its enthusiasts today and some frames are even commercially available on a small scale in Holland and Denmark.

For the most part very little was done in the line of design thinking from the early 1900s. In fact, one model brought out in 1902 by John Marston & Co. called the Golden Sunbeam remained unchanged for the next 34 years because nobody could think of any reason to change it.

Some development was going on concerning parts quality and the addition of gears on distance racing tourers.Many clubmen, however, were unconvinced of the resilience of hub and derailleur, the type familiar to us today, type gears and scorned them. Many riders in fact had a fixed gear on either side of their rear wheel. They would stop and turn the rear wheel around depending on the length and inclination of the stage to be covered.

The popularity and popular development of the bicycle was soon to grind to a halt at the advent of a new invention, the motor car. The rich began to take an interest in the new horseless carriages which were beginning to appear and the rich who had previously enabled the continuing development of the bicycle began to lose interest and turned towards the new novelty.The less wealthy cyclists saw the bicycle as a new cheap and personal mode of travel. The only previous alternative being horses which were expensive to buy and even more expensive to keep. They could not however afford the newest and most up to date models.Because of this lack of financial support the development of the bicycle ground to a halt and for a long time after this there were only minor modifications to give an appearance of being superior to the competitors while still keeping the all important costs low.Indeed many of those responsible for the design and production of bicycles changed over to production of cars.

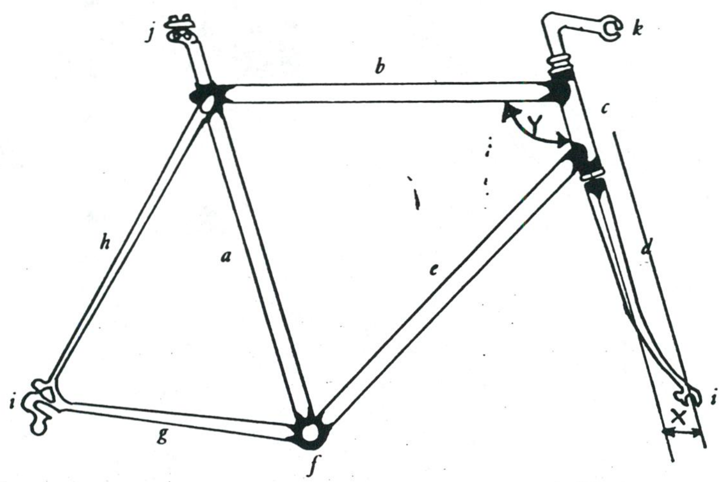
Chapter 3:

This chapter will bring us through cyclings ignominious days where cycling was considered the option of the proletariat and derived an image which thoroughly militated against its re-adoption as a popular mode of transport.It covers the period when the only real innovations were in the field of racing bikes which of course had to adhere to strict rules. This era only gradually faded out when environmental aspect began to weigh on peoples minds and cycling became acceptable again to a small extent.

As with the motor car, the most innovation in bicycles was in those designed for racing. Here was a group of individuals who did not look on cycling as a cheap form of transport but, as in any sport, as a struggle towards the ultimate. Here were a group of individuals who were willing to pay for small improvements such as reduction of weight and better quality and reliability in the different components.

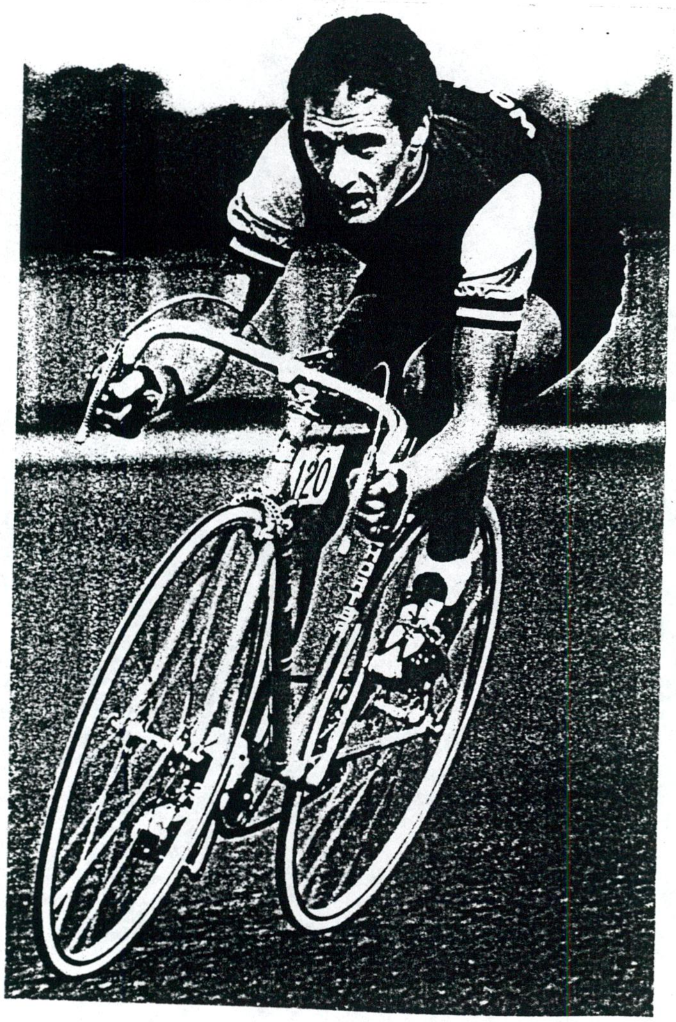
During this period the image of the common bicycle had increasingly disimproved. It was only those who could not afford to own a car or were too young to drive who rode bicycles. In certain areas of society the spectacle of an adult man on a bicycle was seen as a badge of failure and a lack of status was associated with it. Had it not been for the racers and cycling clubs the bicycle may well have stayed just as it had been in the 1900s.

In England particularly a "cottage" industry, sometimes literally, grew around clubmen who wanted special frames built to their exact specifications.There was lively argument between cyclists concerning the optimum geometry of a bicycle frame,such as height of certain points from the ground,length of wheelbase, the angle of the head tube and the rake or sweep, being the angle which the fork is out of line with the head tube, of the forks.All of these made a very great difference to the handling and ride of a bike.In truth however this grail-like search for the perfect frame is in vain as a lot depends on the preference, riding style and physique of the rider. Even assuming the rider knows exactly what he, or since the mid 1890s often she, wanted there were still inherent compromises. For instance a short wheel base, which is the distance between the centres of the wheels, makes a bike more responsive to sharp turns as does a steep fork angle.However sharp turning in racing generally means that the bottom bracket, where the pedals are connected, must be high enough to allow a racer to pedal around a corner without snagging the ground. However this short wheel base and high riding position make for instability and "twitchy" handling. This may be difficult enough with a small wiry rider but with many of the taller, larger and more powerful riders (a good modern example would be Miguel Indurain or "Big Mig") the weight of the rider is perched too high. The power of each thrust will affect the relatively "twitchy" handling and the tubes making up this short wheel base will not be long enough to accommodate him. Clearly a compromise must be made.



Frame schematic names the various parts of the frame.(a) seat tube, (b)top tube, c)head tube, (d)front forks,(e) down tube, (f)bottom bracket, (g)chainstays, (h)seat stays, (i)front and rear dropouts, (j)seat pillar, (k)stem.

3.1 Frame schematic. The distance between "i" & "i" is the measurement referred to as the wheel base. The measurement "x" is the rake or sweep of the front fork. Measurement "x" in conjunction with angle "y" affect the responsiveness of the steering and are the cause of "twitchy" or "spongy" handling depending on their orientations.



3.2 This shot of a '70s racer shows extensive drilling out of brakes levers and handlebars.

This was where hand builders came in who assessed the rider and their own preferences and then gave the rider the choice. During this period up until the 1970s riders went to extraordinary lengths to try and improve the performance of their bikes. This often involved extensive drilling out of components and even frame members and handlebars. These measures definitely saved on weight but it is debatable whether the honeycombed remnants of these drilled parts actually required more effort to overcome the added drag than carrying the original weight or for that matter if the missing material allowed for greater flex thus wasting energy input by the rider.

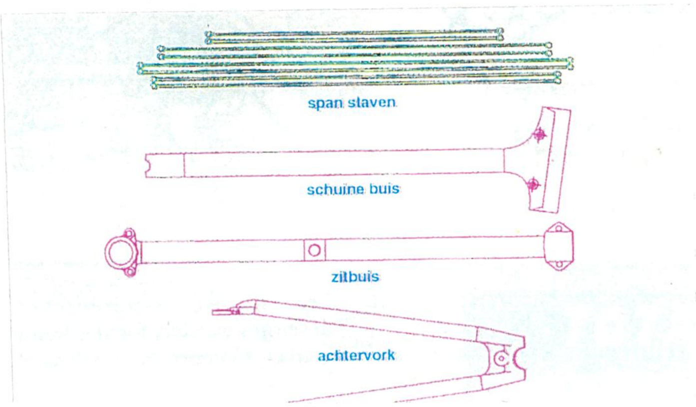
Considering this fevered fetish for weight reduction and higher performance it is surprising that no one took up two innovative bicycle designs of the time. The first of these was the small wheeled bike designed by Sir Alex Moulton. He collaborated on the design of the Mini car and inventor of rubber cone suspension first used on it. This bike was designed in 1956. Then came the later design for the span bike by Frans de la Haye, first drawn in 1967.

Moulton turned back to cycling as a mode of transport as a response to the petrol rationing brought about by the Suez crisis.When he returned to cycling he found himself dissatisfied with what was available and thus set about improving the workings of the bicycle from a strictly engineering point of view.He decided that there were two main problems with the bicycle one being its high centre of gravity the other being the size of the wheels.It was a questionable practice, in my opinion, to put any great effort into lowering the centre of gravity of the machine considering that the rider,by several times the more weighty of the man/machine symbiosis, remained at the same height. People who rode it, however, declared that it had a lively response and attributed it to the low centre of gravity of the machine. As I have not ridden a small wheeled bike (which wasn't a Moulton) since I was a child, I cannot really offer an accurate appraisal. However the reason that makes more sense to me, as a qualified mechanical engineering technician, for this extra responsiveness lies in the size of the wheels, including the chain rings.

If you can imagine the radius of a wheel being the length of a lever,and the weight of the rim, tyre etc. working along this lever to act upon the hub then it may easily be seen that there are two ways to reduce this leverage which resists the action of pedalling. One is simply to reduce the mass, which for these purposes the same as the weight, at the rim. The other is to reduce the effective length of the lever by making the wheel smaller and decreasing the radius. There are other reasons for fitting thin high pressure tyres as they have less road contact and hence less friction and, obviously, they offer less wind resistance. If narrow tyres are also applied to the smaller wheel then you gain in two departments. Of course,as was mentioned earlier while evaluating the "ordinary's" in relation to the size reduction of wheels, the smaller the wheel the greater the vibration. If you can envisage a rollerskate and a bicycle wheel (even with a solid tyre!) on a rough surface. What would jar and snag a roller skate the bike will roll easily over. However, considering this point, Moulton added his patented rubber cone suspension system to compensate. This proved lightweight and extremely effective. The bike was launched after the design was turned down by Raleigh in 1959, by Moulton under his own name and surprised Raleigh by being very successful. It even became popular with those who had come to regard the bike as the workhorse of the proletariat, probably due to the current trend of the mini car and skirt which all had the same type of image. In 1962 John Woodburn broke the Cardiff to London record on a Moulton which helped its ambiguous image enormously. By 1965 sales had reached 70,000 and Raleigh launched a small wheeler of their own, only the first of many imitators, and proceeded to buy out Moulton whose services they retained as a consultant. However Raleigh didn't use Moulton's suspension and lacking Moulton's expertise fitted large, fat, low pressure tyres which again increased the counter leverage and increased road friction. Apparently to anyone accustomed to a light sporty wheel this felt "like pedalling through glue"(Penguin).So much for the time being to Moultons' small wheeler.

The other design which, surprisingly, racers of the period ignored was the Span bike by de la Haye. This, in a far more sophisticated fashion than drilling out holes was the ultimate in weight saving and still is. Also conceived on an engineering basis he set out with the expressed intention

3.3 Moultons original 1967 small wheeler with suspension and unprecedented cargo carrying capability.



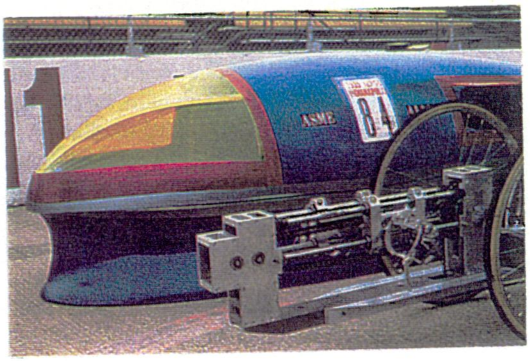
3.4 Frans de la Hayes incredibly light Span-Bike.The tubes take compressive forces and rods take tensile ones. The Frame comes in a kit ready to be assembled as shown below left.

of designing the lightest bike ever.De la Haye worked out the stress in a bike and decided which areas were subject to compression and which to tension.He then proceeded to use rods in opposing pairs to prevent longitudinal flexure in the tubular cross-frame in the middle. The rods took all the tension and the tubes took the compression. Despite a false start where a manufacturer built a prototype for a publicity exhibition in the late 70s' he had to wait until 1992 to get his bike in production. This was brought about when 300 municipal workers in the Hague chose the span bike in a move to support the local municipality's policy against cars. With this production order guaranteed, the bike finally went into production. The goal of lightness was clearly satisfied in the three models brought out. The heaviest stainless steel tourer weighed only 2.225Kg (roughly the same as the Lotus Superbike which took Chris Boardman to Olympic gold in 1992) ,dropping to 1337g for the Aluminium and titanium model and again to a mere 833g for the all titanium model (1lb=454g).

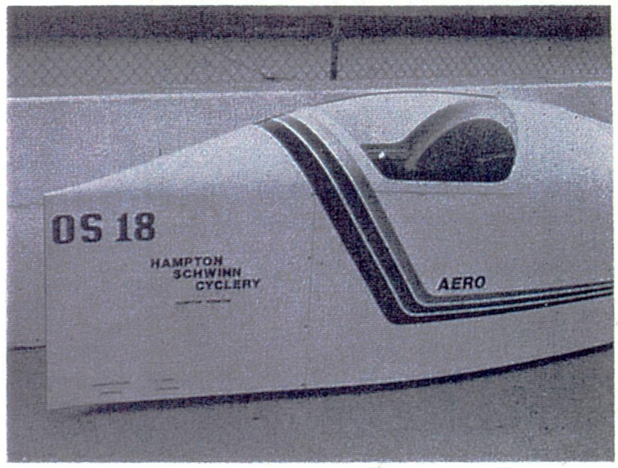
Chapter 4:

This chapter covers the period From the early 1970s up to the present day and looks at the new interest in self propulsion by human powered vehicle enthusiasts. These designers were motivated mainly by environmental concerns and the desire to break through the parameters on bike performance which were indirectly imposed by cycle racing regulations.It also looks at the recent boom in sport cycling being led by the craze in mountain bikes.

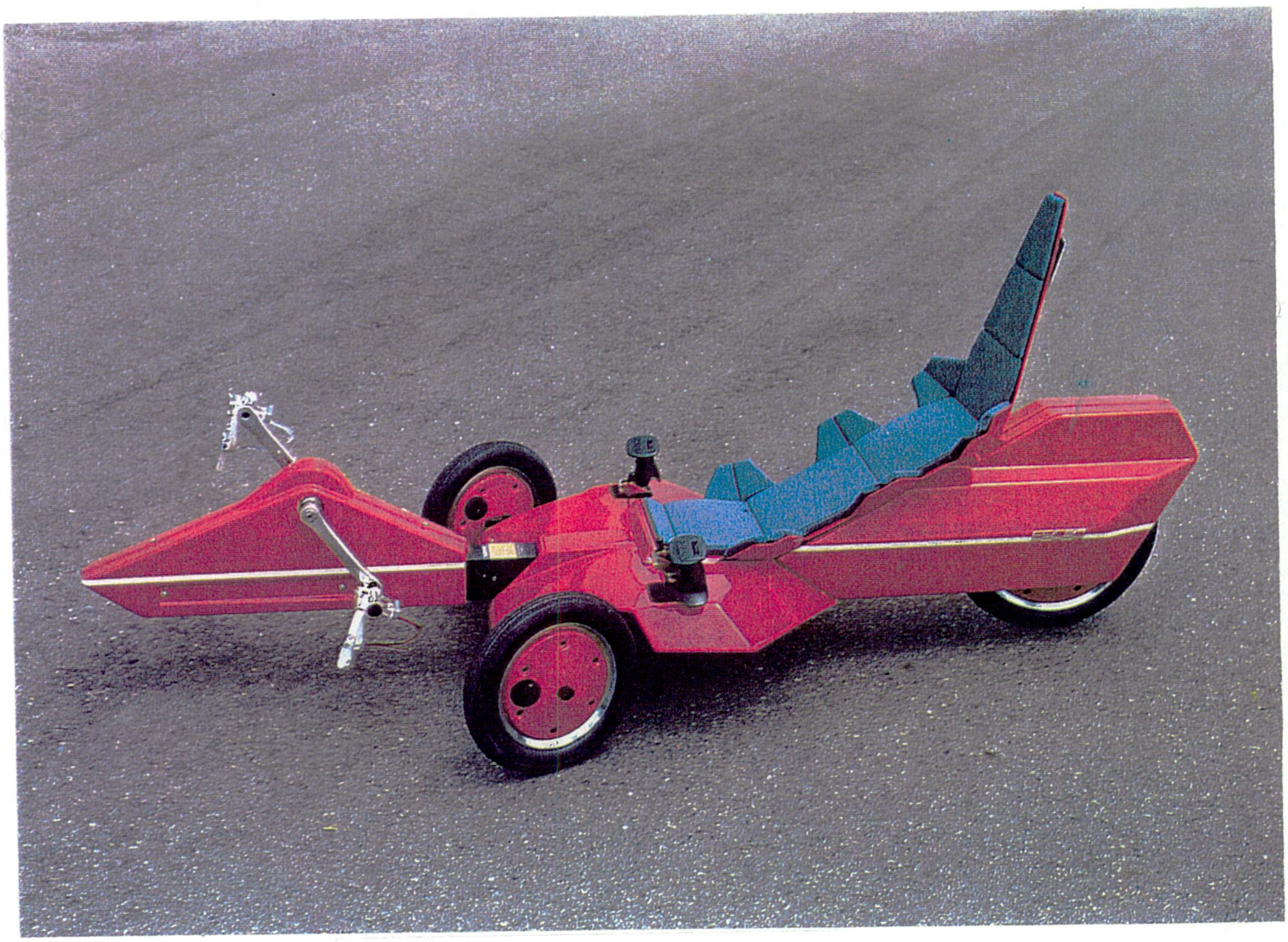
The oil crisis of 1973 was the next major influence on the development of cycling as a form of transport. This is the first stage when a large number of people began to realise that the resources of the world were finite and that once they were gone that was it. A lot of people from all walks of life began to cycle again, there now being a "legitimate" reason to cycle as opposed to the "status" of driving. Also bicycle designers, who had been frustrated by the regulations imposed by the Union Cycliste Internationale as regards the design of bicycles began to hold their own time trials and races. In 1976 Dr.Chester Kyle formed the IHPVA (International Human Powered Vehicle Association) to encourage the development of streamlined machines with or without farings(I am only discussing the ground travelling vehicles although there are successful sections for air and water i.e.by 1985 a human powered vehicle had flown across the English channel!) .It must be pointed out that a human powered vehicle is any form of transport which is solely human powered. This includes current bicycles but these



4.1 Fared recumbent HPV. The shell is sitting beside the internal mechanism.



4.2 Fared recumbent "Aero" has clocked at 59.1 mph.



4.3 This unfared recumbent, the "Corsa" is capable of over 40 mph. It relies on the riders aerodynamic position, its closeness to the ground and its low rolling resistance for its speed.

are inefficient relatives of their more advanced counterparts. The intention of racing regulations which effectively eliminated HPVs (human powered vehicles) except of course bicycles from competition was in order to make contests as fair as possible between athletes, as opposed to a competition between designers, and as such are completely valid. Unfortunately they tend to keep the development of HPVs,many of which are designed as viable forms of transport (which can still outpace racing bikes) out of the public eye and hence the subject out of mind.

The major point in favour of advanced HPVs is that they have eventually taken into consideration the single most important factors in the development of truly practical human powered transport that would be acceptable to a wide range of people. These factors are comfort, fear of traffic and wind resistance.

Comfort refers to both the riding position and the rider's exposure to the elements.Some would have us believe that the modification of the drop handlebar was a good idea but I feel it was a reactive measure to the problems posed by wind resistance and back strain as it allows a little variety in level of crouch. If bicycles had been designed with less wind resisting positions and with a riding position that did not induce back strain the problems would not have arisen. There are also few things as off-putting as the prospect of cycling somewhere in wind and rain. Many of the recumbent HPVs whether intentionally or not address this problem more than adequately with the their surrounding aerodynamic farings. Farings are the aerodynamic shell which surrounds the rider.

In my opinion the most important factor (technically at least) is the area of wind resistance. This is the main reason why throughout this thesis I complain about the continued usage of the conventional riding position. This position presents practically the full length of the body flat on to the air through which the rider must try to pass. Experimentation has shown that at speeds of 20-25mph on a bicycle 90-95% of the rider's energy input is required to overcome wind resistance! This was on the flat with virtually still air conditions; imagine cycling into a 20mph headwind up an incline. This may sound excessive but for a year I worked in a place where I was presented with approximately 16 miles of this every morning and a 20 mph wind was only a medium scale of wind speed at certain times of the year! It becomes patently obvious that a change in design is necessary. I had a friend along on this trip who is young, fit and fairly athletic riding a 10 speed bike in good working order. He was obliged to stop and rest twice on the way and had to recover for approximately half an hour on arrival. Imagine someone completely unfit and trying to persuade them to adopt cycling in its current form as a mode of transport?One journey of any distance would put them off immensely, especially if the weather was excessive either in heat or rain. There has been an argument made by many writers on bike design who worship the diamond framed bicycle as a marvel of engineering. I view it more as an excellent first attempt which has not been evolved to meet other criteria as they were established. Before the invention of the car the speeds attainable by bicycles could outpace the horses of the day and exposure to the elements was unavoidable except for the wealthy. It seems virtually everything else has evolved to meet new demand except the bicycle whose market was not deemed safe for investment. Those in favour of the diamond frame assert that the wind rushing against the rider is entirely necessary in order to cool them off otherwise they would overheat. In the present circumstance I must agree. However bear in mind 90-95% of the exertion expended is to overcome this "cooling breeze" and is what causes the overheating in the first place. If cooling were required While using an advanced HPV the greater speed of travel will pass air over the body at a higher speed if not perpendicular to the rider as at present.I think it would take detailed experimentation to resolve this point and with the 90-95% statistic in my favour I would be surprised if I am not correct.

My point here being that unless a viable form of bicycle is produced which will be fairly easily usable the future of human powered transport looks bleak. Purists would hang me for this but maybe even a power assisted pack should be used to help novices "put miles in their legs" until they reach a reasonable level of fitness or even for those who may face a difficult uphill or headwind on a regular journey and are off-put by not being fit enough to cope;perhaps even for those who have to be somewhere in a hurry! All of this would make the idea more acceptable to the average person who may be thinking about cycling.

The other main problem that puts people off cycling is peoples fear of having to compete with other road users. It does not take long until a cyclist develops a healthy paranoia about anything that someone is not physically pushing, outweighs them severely and has lots of hard and painful bits. Either this or they become a regular at their local casualty clinic. People have also become accustomed to the idea of effortless transport thanks to the lag in development and undesirable image the bike garnered for itself.The view HPV designers take is that while the conventional bike is usually nimbler and better at getting through traffic and avoiding trouble ,the only reason that the fearful traffic congestion exists is that there is no real alternative to cars that has that level of freedom, flexibility, safety (because of the traffic!) and will allow a reasonable level of comfort to the user. I can't believe that all of these people want to sit around in traffic jams, swearing in frustration, if a viable alternative was available. Minus private traffic I think there would be more than enough room for cyclists, commercial traffic(lets be reasonable! I am not suggesting cyclist utopia)and public transport for those who cannot propel themselves due to illness, age, the need to carry objects or to bring babies or small children not to mention injury or pregnancy. As has happened in other countries those with particular needs receive a special permit to allow access to cities with private vehicles. This appears to be the general trend as cities become more and more clogged with traffic and hence more polluted. Increasingly authorities are taking the view that environmental and health considerations outweigh peoples convenience. The gap is generally filled by public transport which tends to improve dramatically with its guaranteed users.

There are many who find this tiresome and for whatever reasons will refuse to relinquish their cars unless forced to by legislation and unfortunately that's not my job! For those who are willing a valid form of human powered transport in conjunction with safety provisions such as cycle lanes would be welcome.

I believe that in the seventies bike manufacturers adopted a new strategy (there is no evidence for this apart from my speculation and hence is really more hypothesis than thesis... but I digress!) and the infamous Raleigh were the chief conspirators.I feel it was a bank-type strategy of "get 'em while their young and hang onto them".I also feel it may not be any coincidence that the first mountain bikes were cobbled together as early as 1974 by one Gary Fischer in California.First Raleigh introduced the functionally dubious, and in fact down-right dangerous in my opinion, Chopper with its small front wheel and large rear wheel.It was based heavily on the choppers (even pilfering the name) of biker gangs which were flourishing at the time. Next came a series of bikes which strongly resemble the mountain bikes although they were intended for children.

These were called the Boxer(4-6yr olds) and scaled up to the Strika followed by the Grifter which had three gears and then the Bomber which also had three gears and wheels the same size as a modern mountain bike.Then in the early '80s Raleigh introduced the Burner range which sparked off the BMX craze in Europe and America.This was all on a suspicious timescale, as when the children and adolescents who were originally targeted with the Boxer etc. range were in mid to late teens the early mountain bikes began to appear to a market already accustomed to the idea of off road cycling.Even though the majority of customers were unlikely to go off road and if they had I would not have bet on the safety or survival of rider or machine considering the engineering of some of the earlier models; the point, however; was moot. The cycle industry had eventually realised the importance of image in selling bicycles and having people,especially young people, ride them in public.This lead to the massive boom in bicycle purchases as no one wanted to be seen on an old style"banger". This was a serious problem for the cycle industry because there was no change of style and no progressive image attached to the designs people tended to recycle their bikes and hand them on to others ad infinitum. This was natural enough as no one is going to pay for a new copy of something old they had that still works.

I have many doubts about the design of some of the newer mountain bikes.Have they gone over the top in an effort merely to keep fashionable and have something new to sell? The same may be asked of Raleighs strategy. If so are some of the cycling advocators who condemn this tactic shooting themselves in the foot considering the enthusiasm it has generated. True it has not brought that many people around to using cycling as their primary form of transport but at least there is an interest there and the overall image of cycling has been changed. There is now a basis to work from in future drives towards cycling promotion.

I do, however have some reservations about the design of many new mountain bikes. Some of the designs seem to be partly thought through perhaps on their way to somewhere else. Perhaps this is deliberate to defray the costs of development by selling models at various stages of development? For instance the two Cannondale machines shown have several discrepancies. The mountain bike for instance is made partially from aluminium and partially from carbon fibre. I can scarcely think of a worse (practical) material to make a mountain bike from. True it has excellent strength to weight ratios but is also prone to fatigue and sudden failure under the repeated application of even modest loads; if a pedalling action is not repeated application of stress, what is? The rear chainstay is made of carbon fibre composite, no problem there even allowing for the expense and disregarding the fact that it cannot be recycled. This is, after all a top of the range/pro bike. Carbon fibre is tough, light, incredibly strong and has excellent impact resistance. Fine until you see the aluminium lug where the wheel attaches. This is a highly stressed point because if a rider is landing on the rear wheel all the weight plus

4.4 Cannondale mountainbike. The aluminium lug is pointed out in the photo. Even with this unusual frame geometry the same rider position is maintained.

4.5 This shows Shimanos Twist grip gear shifter incorporated into the hand grip.

momentum will go through this point. Apart from strength, the metal of the axle (no one I hope is insane enough to make an aluminium axle at standard size) will react with the lug then undergo galvanic corrosion, start to act like a battery and will eventually fall to bits. The reason for this lug was apparently that if the lug broke it is detachable and easily replaced. Cart before the horse? I think so. Besides, I want to see what happens to the rest of the bike and the rider if they do something capable of breaking off a carbon fibre lug! It also comes equipped with hydraulic disc brakes a la motorbike.These are,I feel,and I have tried them, an overly powerful hazard especially without the weight of a motorbike to hold you down or added ABS.(anti-lock braking system)

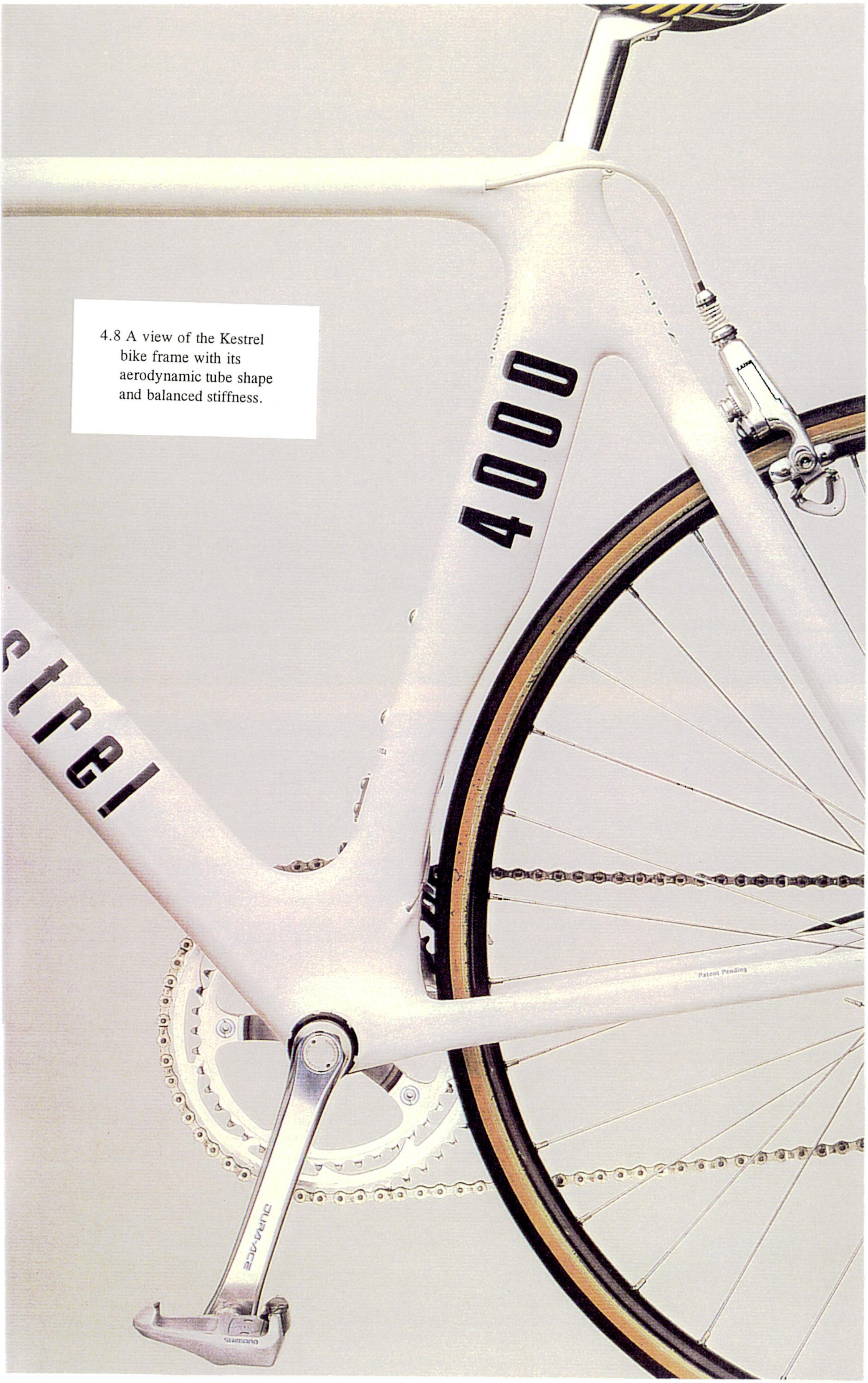
The triathlon bike presented is an extremely light machine for fast, steady long distance stages at a pace designed to conserve energy. It does this admirably but why the enlarged aluminium tubing on this where aerodynamics are important to conserve energy, the machine is not even designed for sprinting forces as anyone attempting sprints in a triathlon is insane because the swimming stage is still to come. Hence why the need for extra resilience? I think they would have been far better off following the lead of their fellow U.S company, Cycle Composites, who designed the Kestrel bicycle frame. They aimed to design a truly superior bicycle in order to convert people and take as much of the top end market as possible with a vested interest in later converting these customers to future HPV users. They set criteria for the bike to have a 10% more aerodynamic

4.6 This shows the oversized aluminium tubing used in Cannondales Triathlon machine.

4.7 This shows elbow leaner which must be used to reduce riders wind resistance. This also uses the twist shift and is certain to cause back pain.

frame and for the critical bottom bracket to be 20% stiffer than a good steel frame.The weight must also be kept below 3.5lbs which is the weight of a top notch steel frame. I mentioned the flexure element earlier and now I shall explain.Ideally a frame should be totally rigid as far as vertical flex in line with the frame is concerned but allow flex sideways in balance with the riders power. Why? I will use the analogy of the tennis racket to explain. It used to be believed that the tighter the racket was strung the better.However, if you take a top of the range properly strung racket and place it on a concrete floor. Now imagine the floor as the infinitely tight set of strings. Drop a tennis ball on each alternately from the same height and it will bounce higher from the racket. Again why? Some energy is absorbed by the racket (in proper use the handle assists here too) but before the ball leaves the strings the strings spring back giving back some of the lost energy; the concrete merely dissipates the energy far too quickly instead of storing it and returning it and it is gone before the ball leaves the floor. Likewise the sideways flex is transmitted back to the rider's effort (compare running on a wooden floor and a concrete floor,the principal is the same.)

The Kestrel had this balance very finely tuned.They also achieved the 10% superior drag they sought by making the vertical main tubes aerofoil shaped to cause minimum air turbulence fore or aft of themselves.And in a properly thought out use of materials no lugs were necessary to complete the job. Unfortunately amidst all this development of the bicycle there does



4.8 A view of the Kestrel bike frame with its aerodynamic tube shape and balanced stiffness.

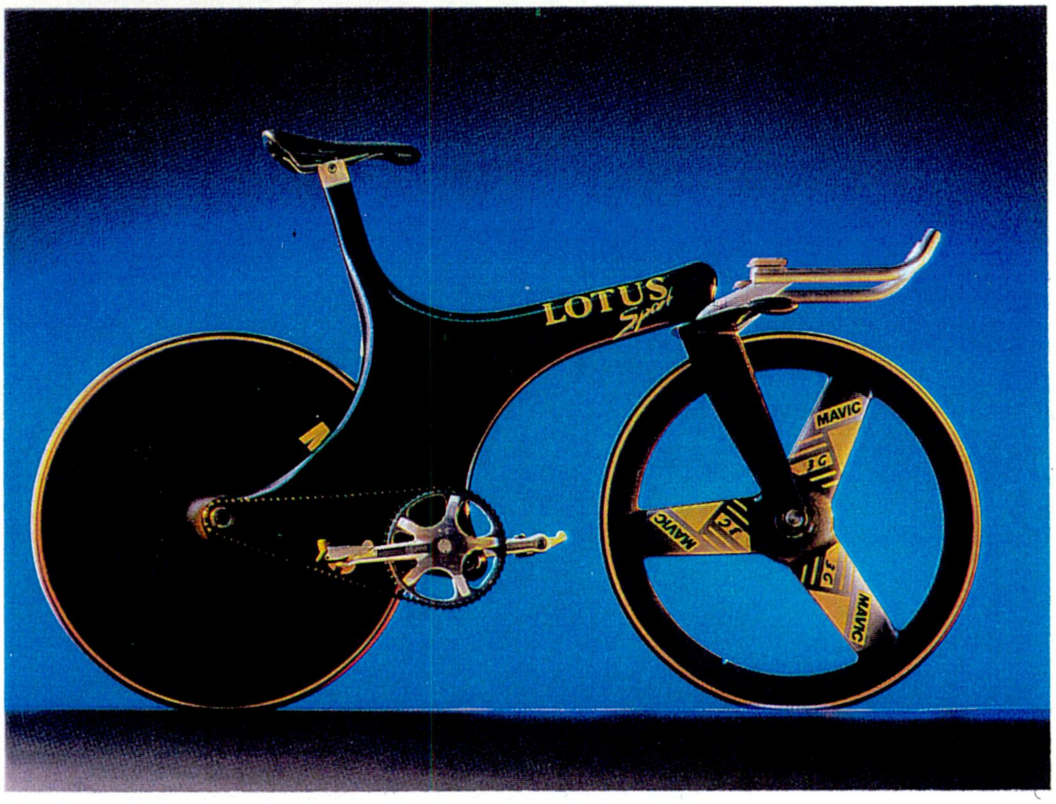
not seem to be much effort towards phasing it in as a mainstream mode of transport. The emphasis appears to be on cycling as a sport and a hobby. The really worrying part is that a lot of this staid thinking seems to be coming from independent bike designers who are leading the field and one large cycle component company, Shimano. The reasons for these strange routes in innovation are many and varied. Most of them are valid according to the design criteria that the designers set themselves. It is these criteria and the objectives of the design that I would question. These designers and "inventors" tend to set themselves a particular problem, be it greater speed, luggage or child carrying capability, lightness, aerodynamics, foldability or a host of others. The problem here is that people will never be persuaded to relinquish their cars until there is another mode of transport that offers most if not all of the flexibility of a car or offers different advantages to trade off against its' shortcomings (i.e.cargo handling capacity etc.) The designers need to take an overall look at the human powered vehicle including bikes and synthesise a complete overall approach to act as a viable mainstream alternative to cars.

An example of this unyielding approach came in 1994 when Shimano a Japanese company decided to hold a design competition in Europe. This gave Shimano the image of being the leading edge in bicycle development. Shimano however have a lot to answer for themselves and were duly berated for it in the course of the design forum which accompanied the competition. 80% of bicycles in Europe now come with Shimano gear.

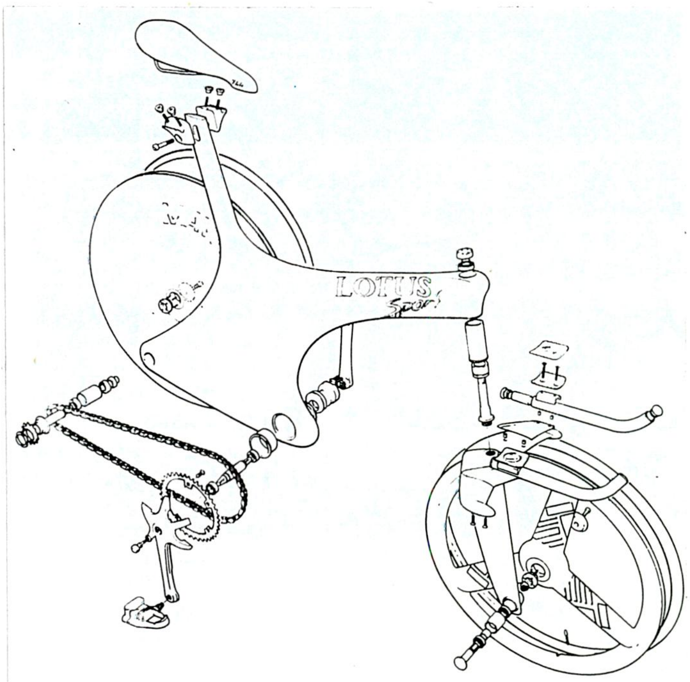
This includes gears, gear shifting, braking and almost all of a bikes added components (i.e. not the frame). They achieved this by taking the best available, Campagnolo, an Italian firm, and copying then improving (though not necessarily in terms of quality) upon them. This is all business and precious little to do with bicycle design. But their attitude begs the question, why does a firm with the dominance of Shimano try to exert such a stranglehold on design? For instance, why in their publicity competition did they feel the need to restrict entries to those using Shimano gear? They were also duly set upon for their practice of introducing new equipment annually, often not compatible with their previous ranges which is a problem you will not find with Campagnolo gear unless it is intended for a different style or level of riding. Through their introduction of a fashion element in componentry they also introduced a tendency to kill new innovation by bike manufacturers because any new format of cycle they try may not be compatible with Shimano gear or not conform to the image Shimano is creating. Surely with this kind of dominance in the market it would be in their favour to encourage true innovation; after all, the more people converted to cycling the more bicycles will be sold and hence all the more new customers for Shimano. While Shimano has made some useful design contributions such as indexed gear shifting which gives positive feedback to indicate correct change (I bought it myself immediately) one often gets the impression that Shimano leaves slight faults and shortcomings in some of their designs on purpose so that when they redesign them next year as an improved product. An example of this is the fairly newly introduced grip-shift gear changer which works by twisting the handgrip.This idea was available in 3 speed form on the Raleigh Grifter of the '70s(mentioned earlier) and before that on the Triumph 20 small wheeler Moulton copy. Myself and several friends with a similar interest had initially assumed, stupidly now that I think about it!, that this system previously used on 3 speed hub-contained gearing, had some kind of functional problems when attached to a derailleur system. We assumed this because it was such an old idea and so simple to use we thought they must have tested it initially and rejected it for some reason. Imagine our incredulity when it was introduced as a top of the range system!.(The offending item is shown fitted to the Cannondale machines.)

Apart from these industry related constraints the Shimano forum all showed the linear, constrained thinking of many of those currently regarded as bicycle design gurus. The forum was reported on by Richard Seymour of Seymour Powell Design in the September 94 edition of Blueprint magazine. Some of the attitudes are perhaps best displayed his description of some of the forum debate as follows:

> ..things started to heat up at the Design Forum when Mike Burrows, eccentric designer of the Lotus Olympic Superbike, decided to cross-examine Socha Lakik, the respected young French designer, about his much-vaunted future concept machines.
> "How does the drive get to the back wheel?"demanded the bristling maestro.
> "By electro magnetic drive," Lakik replied.
> Burrows drew his filleting knife and went for Lakik head on:"So what's that then?"
> "It is in the future and has not been invented yet..." responded Lakik, seeing too late the trap open up beneath him.



4.9 Mike Burrows Lotus Superbike on which Chris Boardman won Olympic gold for Britain in 1996.



4.10 An exploded view of the bike above shows its construction more clearly.

"Bollocks," opined Burrows heartily and went to work on Lakik until the moderator prised him off.(Seymour 1994,p.22)

Burrows later argued that at 98.62% efficiency in a chain drive it was futile to attempt to improve on it. Technically I think Burrows is correct in this view as there are other facets of bike design altogether more wide open to improvement. It must be remembered that when Burrows originally designed the Lotus Superbike he was not trying to race it officially but simply to go faster. His latest design has come around to designing an aerodynamic recumbent but considering how the number of years Burrows has spent on his work he certainly took his time! It is the unwillingness of the designers at the edge of the industry to open their minds to new avenues of thought that is so depressing considering the increasing buoyancy in the bicycle market.If designers will not even consider alternative approaches to what they themselves are working on how can any real progress be made any a uniform strategy be established? It should be born in mind they are mostly independent conceptualists and not subject to the influences of industry.

Seymour informs us that later, when a young student asked if the bicycle were invented today would it look considerably different there were howls of outrage from the assembled fanatics. They used the example of the Rover safety and Pedersen bicycles which had not been significantly improved upon in 100 years to argue their point. The student responded that today market research would have told the designer that the bike must carry a briefcase or luggage as standard and protect the user from the elements. The gurus were outraged but the student was right. The "top minds" in the field have become so wrapped up in their obsession that they have failed to step back and take a look at what a modern bicycle for use as transport should be. I must admit Shimano and their associated mountain bike designers have, realise that there is more to the acceptance of the bike as normal transport than technical excellence alone .The product presented must present a desirable image to the user and give some level of emotional benefit, i.e. the "x" or "feel good" factors. This is what I mean by an overall approach. Without it the idea of human powered transport is dead before it begins. All of peoples concerns and desires must at least be considered even if rejected later rather than point blank indignant refusal to compromise.

I have recently heard, indirectly via the T.V programme Equinox, that an inventor has managed to produce a hydrogen operated machine based on the Hydrolysis principle (splitting water into Hydrogen and oxygen) which operates at well over 100% efficiency. This has apparently been independently measured, verified and patented. This meaning it gives out more energy (power) then is actually put in. This was previously thought impossible and was the domain of the mythical perpetual motion machine. If this proves practicable then most of my environmental reasons for change are sunk! (the by product of using Hydrogen in combustion applications is water).This is of course assuming there are no unforeseen side effects to this process; that however falls within the range of a physics PhD and not within the scope of this thesis.

In addition to environmental reasons the only reasons for cycling are reduction of congestion, improved personal fitness, a massive reduction in the cost to taxpayers of medical costs for "lifestyle" related ailments and the greatly reduced likelihood of death due to heart failure. For most people these are not good enough reasons for a bit of good healthy exercise. But at least the option would be available for those willing to take it up. Also if the situation requires legislation to prevent urban traffic there would be another mode of transport available.

Conclusion:

As with all goods especially mass produced ones the design of the bicycle and any innovations it may undergo are market driven. Therefore as we can see throughout the history of the bicycle most of the development has been during periods and in areas where there were a sufficient number of people interested in new development and more importantly were willing to pay for it.

This was most obvious in the pre-automobile era, the area of bikes developed for racers and club riders and currently in the mountain bike boom. In these cases there were people willing to pay for the newest and the best along with a firm base of those less well-off or less enthusiastic to buy goods with the new developments as they filtered down to lower priced models after recouping the development investment at the higher end of the scale.

During the lull in development between 1900s and the 1970s the only improvements were in the area of racing bikes. These were governed by rules on bike design for official competition. Other users were the poor and children who used bicycles as transport. They did not have the purchasing power or the necessary enthusiasm to warrant significant development.Hence every little happened in the way of design for transport purposes.

Further progress was made in this area after the arousal of concern surrounding environmental issues and the organisation of the IHPVA. However the majority of those who changed their mode of transport would have gone to public transport. This was due to a variety of reasons such as exposure to the elements, lack of fitness, lack of carrying facilities and others which I can hardly believe but I suspect are set in a thorough ignorance of, or an unwillingness to acknowledge, the wastefulness of cars and the damage they do.

There has been a recent boom in the sale of mountain bikes which are mainly designed for sport. These are also popular with the young for transport. This however seems to die off as soon as the user reaches an age when they finish school and where their journeys are no longer predominantly suburban. There is some crossover to transport cycling but in order to encourage this there is a need for designs which cater for urban transport. Mountain bikes are not really suited to this as they are heavy especially in the wheels and are even worse than older designs in terms of aerodynamics. For the purpose for which they are designed the riding position is good allowing good balance at low speed and the required agility. They are just not built as a commuter machine. This interest has recreated interest in cycling and at prepared a lot of youngsters mentally and physically to use pedal powered transport but if an upgrade is not available for urban travel most will inevitably turn away.

In the end, however, all personal optimism aside, I cannot see a large scale shift to human powered vehicles without the introduction of legislation to enforce it as has been the case in other cities. This is because this change would require a change in attitude and lifestyle that is both mental and physical which few people are willing to undertake. Perhaps if the situation continues as its going people will realise they must change but as in many other cases where change was in everyone's best interest people will probably leave it until the last minute if given the choice. I just hope people can be convinced to change in time.

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