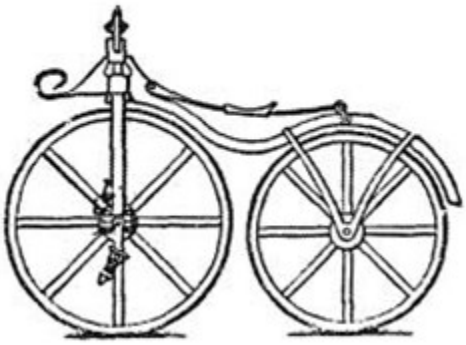
Generation 4 Bicycle Legacy

The "Generation 4 Bicycle" (G4 Bike) name is a reference to the development history of bicycles. Each generation can be categorized by its power transmission system and associated rider position. The following summarizes this development, explains the basis for the G4 name and the benefits of this new configuration.

- **Generation 1** - Baron Karl von Draise developed the first commercially successful bicycle in 1817. The two wheeled "Hobby Horse" or "Draisine" had a steerable front wheel, which is what actually allowed the machine to be balanced, a seat and a connecting frame. The upright rider propelled it by pushing their feet directly against the ground.

- **Generation 2** - "Velocipedes" or "Bone Shakers" were developed about 1863. The key improvement over the first generation was the use of pedals and crank fixed to the front wheel for propulsion. As this generation evolved and lighter bicycles were developed, a larger diameter front wheel was used for increased speed. These "High Wheel" bikes were called the "Penny Farthing", "The Wheel" or the "Ordinary".



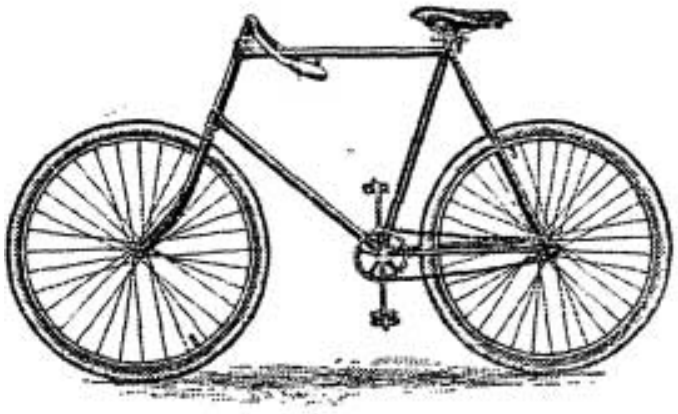
Since these were single speed fixed gear bikes, the front wheel had to be sized to allow both reasonable speed on the flats as well as the ability to accelerate and climb hills. Although standing

to pedal a high wheeler was unsafe, the rider could take advantage of a limited "Pedal-Steering-Interaction" (PSI) to increase force on the pedals by using upper body strength to pull alternately against the handlebar in opposition to the pedal stroke.

Generation 3 - Circa 1885 the "Safety Bike" emerged. The change to Rear Wheel Drive (RWD) separated the bicycle steering and propulsion functions. It used a roller chain and fixed sprockets for power transmission to the rear of two smaller wheels. Here the sprocket ratio provided the same speeds as the Ordinary but allowed the rider to be in a much safer position, lower and between the wheels.

Since multispeed power transmissions were not yet available, the ability to engage the upper body for increased pedal torque was important. The new seating position allowed the rider to safely stand on the pedals, pull against the handlebars and roll the bike back and forth into the pedal stroke. Although pedal-steering-interaction was no longer possible, the rider could now "stand and deliver" to accelerate and climb.

The added complexity of the chain drive was certainly justified by the resulting G3 capability. The riding position allowed widespread use of bicycles by both men and women in what soon became a "Golden Age of Bicycles".



As with the preceding generations, many different variations have been developed over the G3 bike history, both to implement improved technology (e.g. changeable gears/derailleurs, materials, components) and for different applications (Cruiser, Mountain, Hybrid, Touring, Race, Folding, Tandem and more). However, they all share the same basic rear wheel drive configuration with the rider over the pedals.

It is important to note that evolution of the upright G3 bicycle configuration was dramatically impeded by a 1930's Union Cycliste International (UCI) ruling that prohibited use of anything else in sanctioned bicycle races. This ruling, which is still in effect, was apparently to emphasize the human performance aspect in the sport of competitive cycling. It has also impeded cycling technology development.

In spite of the UCI ban, a special "Recumbent" subclass of the G3 bike developed. These bicycles take advantage of wide range gearing to mitigate the need to stand and pedal. This capability is traded for a comfortable, semi-reclined position with the rider supported over their seat and back. Aerodynamic advantage resulting from the reduced frontal area of this position can also make recumbents faster. However, not being able to add upper body strength to the pedals may be one of the reasons recumbents are reputed to not be good climbers.

Although there are variations, recumbent bicycles can generally be organized into three classes based on wheel base and pedal location relative to the front wheel.

- The Long Wheel Base (LWB) puts the pedals behind the front wheel. The front wheel is usually small to clear the pedals when steering. This bike provides a comfortably reclined seating position with the riders feet close to the ground. It is generally easiest of the three to learn to ride. The LWB is stable at speed but handling can suffer as a result of the long wheelbase and small, lightly loaded front wheel. The length also makes the bike harder to transport and store.

- The Short Wheel Base (SWB) puts the pedals over the front wheel. Again, a small front wheel is used for clearance. The short wheel base makes the bike more agile but the elevated pedal position makes it harder to quickly get a foot on the ground when needed.

- The Compact Long Wheel Base (CLWB) uses two large diameter wheels with pedals mounted high to clear the front wheel. The aerodynamic advantage of the pedals in line with the steeply reclined seat, along with the low rolling resistance of the large diameter wheels, makes this the fastest of the three configurations. It is also the hardest to ride.

In summary, a wide range of G3 bicycles have been developed. Of both an upright and a recumbent position.

Upright G3 bicycles have been heavily optimized for a variety of applications. They enjoy widespread popularity across the world. They all share a configuration employing RWD with the rider seated over the pedals.

A wide range of recumbent G3 bicycles are also available. They have taken advantage of standard multispeed drive trains to provide the rider with a comfortable and aerodynamic seating position. Along with these improvements, recumbent configurations have shortcomings. One critical problem is integrating the pedals/power transmission system in a safe and efficient package. A second is that the rider cannot effectively use their upper body to help pedal - they can't, "stand and deliver". These issues have prevented recumbents from enjoying the widespread acceptance of the upright G3 bicycle configuration.

After 130 years, the Generation 4 Bicycle innovation provides the best capabilities of both the upright and recumbent G3 bicycles.

- **Generation 4 -** An integrated system engineering approach was used to develop a new high performance fourth generation bicycle. The G4 bike is defined by a unique Front Wheel Drive (FWD) power transmission system with concentric front wheel and pedals. This is a critical enabling characteristic that seats the rider in a safe, comfortable and aerodynamic position; and importantly, provides pedal-steering-interaction so that the seated rider can effectively use the upper body to add power. With the G4, there is no need to "stand and deliver" for fast acceleration and climbing.

The G4 experimental prototype currently being tested is shown below. The photo is followed by a more complete summary of the G4 configuration capabilities.

1. Power Transmission

    - A unique, multispeed, Front Wheel Drive (FWD) system is used.
    - The pedal cranks and front wheel share a common axle.
    - The coaxial FWD uses many common parts and keeps the power train compact, light and efficient.
    - FWD eliminates the power lost to chain line induced frame flex typical of RWD recumbents.
    - Dual 700c wheels and mid length wheelbase provide excellent handling, a smooth ride and low rolling resistance.

2. Rider Position

    - Seating is more "in" than "on" the bike, balanced between the wheels, comfortable and aerodynamic. The rider feels like an integrated part of the bike.
    - Feet are reassuringly low and forward, making the G4 easy to start, stop and learn to ride.
    - Vision is forward, up and at car eye level. This enables seeing and being seen in traffic. It also makes it much easier to enjoy the scenery.
    - Seat pedal distance and tilt are easily adjusted for rider size.

3. Enhanced Power Application

    - The FWD G4 rider interface allows increased power development through Pedal-Steering-Interaction (PSI).

    - The handlebar and pedals are both part of the rigid front fork structure that allows the seated G4 rider to use PSI to effectively add upper body strength to help pedal.

    - For most riding, a normal cadence and pedal stroke makes it easy to hold the bike on a steady path. PSI is easily managed.

    - To increase power, pedal cadence can increase or the legs can push against the seat back for more torque.

    - PSI allows additional power increase by using the handlebar to force the pedal crank into the leg stroke. Arm and leg effort is additive. Maximum power is generated by actually rotating the fork assembly into the pedal stroke. This is the same result obtained by standing on an upright bike and rolling it back and forth against the pedal rotation.

    - The G4 rider can quickly increase power without having to stand. PSI is both faster and more efficient than standing on an upright bike.

    - The exceptional power development enabled by PSI is great for rapid acceleration and climbing.

    - A cyclist can learn to ride the G4 almost immediately. Learning to ride faster by spinning at higher cadence is next. Followed by effective use of PSI to add upper body power.

4. Fairing Integration

    - A fairing can readily be mounted to the front fork assembly.

    - Importantly, another advantage of pedal-steering-interaction is that fork mounted fairing aerodynamic forces are easily controlled through the handlebars and pedals. Pedaling the G4 configuration actually helps stabilize the bike when riding through strong and gusty wind conditions.

    - Crank rotation concentric with the front wheel minimizes the necessary fairing size.

    - There is no rear wheel drive system to be accommodated.

    - A first, simple front fairing installation is shown below. This work is just beginning but results are encouraging. This partial fairing increased maximum average speed about 2 mph (from 17 to 19 mph) over a 20 mile ride that included about 1200 total feet of climbing.

5. Integrated Cargo Capacity

    - Adding weight to the front fork assembly can improve handling.

    - The FWD clears volume both below and behind the rider which can be used to carry cargo.

6. Follow on Capability Development Enabled by the Concentric FWD

    - Supplemental rear wheel electric drive (resulting in "all wheel drive") is a simple installation.

    - A single, center mounted frame and brake cable coupling would allows the bike to quickly be disassembled for transport or storage.

    - The rear wheel and frame can be replaced by a narrow track leaning delta tricycle assembly. Unlike other trikes which must be low and wide for stability, the G4 will be a high performance trike suitable for use on public roads with traffic.

- **Conclusion**

The concentric front wheel drive of the G4 bicycle enables a configuration synergy. The result is an integrated road cycling package that is safe, comfortable, fast, easy to learn and fun to ride. The pedal-steering-interaction provides the benefits of standing on a conventional bike while being seated. PSI also facilitates effective use of a front fairing.

After 200 years, there is a new generation of bike for the next century of cycling!