From the files of Doctor Bright Spark.

Earle Steele MacPherson and the MacPherson Strut.

It's one of the most common suspension designs used on modern cars, found on everything from the lowliest Proton Savvy to the fearsome Porsche 911 Turbo. It's also frequently misspelled, with a lot of misconceptions about how it came about, and about the career of the man for whom it was named. Therefore, this month, we will try to set the record straight about the origins of the workings of the MacPherson strut.

ORIGINS - Ordinarily, we wouldn't consider the early life of Earle MacPherson to be terribly relevant to this article, but the amount of misinformation we've found about him, even in semi-reputable published sources, is so immense that it's worth laying out the facts.

First, his full name was Earle (not Earl) Steele MacPherson (not McPherson). He was not born in England; he was born on July 6, 1891 in Highland Park, Illinois, a suburb of Chicago. After graduating from the University of Illinois in 1915, he moved to the Detroit area and went to work for the Chalmers Motor Company. MacPherson did spent time in Europe during the first world war, working as an engine mechanic for the Aviation Section of the U.S. Army Signal Corps (the ancestor of the U.S. Army Air Corps) -- not a fighter pilot, as has sometimes been reported.

Earl MacPherson in the mid-1950s. (Ford Motor Company)

When the war ended, however, he returned to Detroit, and took a job with the Liberty Motor Car Company. After Liberty was bought out by Columbia Motors in 1923, MacPherson left for Hupmobile, where he remained for more than a decade. In 1934, he became the assistant to GM's corporate vice president of engineering. The following year, he was promoted to chief design engineer of Chevrolet division, reporting to Chevy chief engineer James Crawford.

After Pearl Harbor and the American declaration of war, Chevrolet, like the rest of the domestic auto industry, was rapidly converted to military production. Chevy's last civilian cars and trucks were built on January 30, 1942. Even during the war, work on post-war cars and trucks never entirely stopped, and by early 1945, GM was looking ahead to the resumption of civilian production.

Chevrolet's general manager, M.E. Coyle, was very concerned about the potential state of the post-war economy. The end of World War One had led to a bitter recession, which had had a chilling effect on auto sales. By the 1942 model year, Chevrolet's cars had become relatively large (over 3,000 pounds) and fairly expensive, topping the $1,000 mark for the first time. Coyle was concerned that Chevy's standard cars might be too big and too expensive to sell in a post-war recession. Although GM's senior leadership had less gloomy expectations, they authorized the development of a compact "Light Car" as a companion for the standard-size Chevrolet. Its target price would be just under $1,000, about 10% less than the cheapest big Chevy.

In the spring of 1945, Coyle named Earle MacPherson chief engineer of the Light Car project, which subsequently became known as the **Chevrolet Cadet**. Although the Cadet was hardly a one-man operation, MacPherson was its guiding force, directing every aspect of its engineering. As a result, the Cadet emerged as a very sophisticated design, with novel features like unitary construction, an overhead-valve six-cylinder engine, and fully independent suspension. Although its top speed was about 70 mph, 10 mph slower than a full-size Chevrolet, it offered 50% better fuel economy. Better yet, despite its modest, 2,200-pound curb weight, the Cadet had significantly better ride and handling than its larger brother, thanks to its independent suspension.

At the time, independent suspensions -- that is, suspension designs allowing independent movement of each wheel -- were still a relatively new development in the United States. Independent front suspension had only become standard on big Chevrolets in 1941, and Ford wouldn't offer it until 1949. Independent rear suspension was little known, outside of a handful of exotic European cars. GM and Chevrolet management protested its inclusion on the Cadet, claiming that it would be too expensive. MacPherson insisted vehemently that its benefits outweighed its costs, and set about designing the most cost-effective independent suspension he could concoct: the ancestor of what we now call the "MacPherson strut" suspension.

As with many automotive inventions, MacPherson's concept was not a wholly new idea. "The engineers who worked with MacPherson [on the Cadet] thought he might have been inspired by some foreign designs he had seen," Karl Ludvigsen noted in **Special Interest Auto** in 1974, "though nothing then existed of a comparable logic and clarity." Guido Fornaca, former managing director of Italy's FIAT, had applied for a patent on several conceptually similar suspension designs back in 1927, although none was directly comparable to MacPherson's design. Indeed, MacPherson filed for a patent on his initial version of the design in March 1947; it was granted in 1953. MacPherson intended the Cadet to have his strut-type suspension at all four wheels, but by 1946, GM management was pushing hard for a cheaper beam-axle rear suspension. Had the Cadet made it to production, it likely would have had a live axle, rather than independent rear suspension, and other cost-cutting measures. Cost was becoming a serious problem for the Cadet project. When civilian production resumed in late 1945, it quickly became clear that there would be no post-war malaise; buyers had money to spend, and four years of pent-up demand. To make money on the Cadet, Chevrolet would have needed to sell at least 300,000 units a year for three years. The sales force, which had not been part of the development of the concept, balked at that prospect. Their attitude was that every Cadet they sold would cost them a sale of a bigger, more expensive, more profitable full-size Chevy. Had the economy been in worse shape, it might have been another matter, but buyers were lining up to pay full sticker price and more for every car they could get their hands on. Sales insisted Chevrolet didn't need the Cadet.

In September 1946, GM announced that production plans for the Cadet would be suspended, citing concerns about the availability of raw materials -- a big problem in the immediate post-war years. Development work continued for a time, but in May 1947, the project was cancelled entirely. According to Karl Ludvigsen, higher-placed men in GM wanted to keep MacPherson 'on ice'...until they could find an opening for him at one of the more progressive GM divisions, such as Oldsmobile." By then, though, MacPherson had been soured by his repeated clashes with his former boss, James Crawford, who had been promoted to corporate VP of engineering in 1945. It was clear that he and Crawford would not be able to coexist happily.

Around that time, Ford Motor Company executive vice president Ernest R. Breech -- formerly the head of GM's Bendix division -- was scouting for current and former GM executives to help revitalize Ford. Apparently at Breech's suggestion, Ford chief engineer Harold Youngren called MacPherson and made him an attractive job offer. MacPherson left Chevrolet for Ford in September 1947. Contrary to some accounts, MacPherson did not move to Europe; he remained in the Detroit area.

In the mid-forties, Ford had been working on its own Light Car project. Their design was even smaller than the Cadet, and featured both unibody construction and front-wheel drive. Although the U.S. version was cancelled in September 1946 -- immediately after GM announced that it was suspending production plans for the Cadet -- the design became the 1949 Ford Vedette, sold by Ford's French subsidiary. MacPherson hastily adapted his suspension concepts for the Vedette, which debuted less than 15 months after he joined Ford. The Vedette's front suspension was not identical to that of the Cadet, but it was a clear evolution of MacPherson's earlier design. (MacPherson filed for a patent on the refined suspension design in January 1949; it was granted in 1953.) Although the "MacPherson strut" suspension was not well suited to Ford's body-on-frame domestic cars, it subsequently found its way onto Ford's other small European cars, including the Consul and Zephyr (from Ford of Britain) and the Taunus (from Ford's German subsidiary). Other manufacturers were relatively slow to adopt the design, probably in large part due to MacPherson's patents. The first outside adopter was technically Simca, which acquired Ford's French operations in 1954, and continued to manufacture the Vedette under license until the early 1960s. Porsche adopted strut-type suspension for the 911 in 1963 (albeit with torsion bars, rather than coil springs), while Volkswagen began using MacPherson struts in the late 1960s. After the patents expired in 1973, it quickly proliferated throughout the industry, particularly for compact, front-wheel-drive cars like the Volkswagen Golf.

MacPherson had originally intended his strut suspension design to be used on all four wheels. For cost reasons, many of the production models that use it have MacPherson struts only on the front wheels, with a beam axle in back. In 1957, Colin Chapman utilized a very similar strut-type layout for the rear suspension of his Lotus 12 Formula Two racers, as well as the subsequent Lotus Elite production cars. As a result, rear strut suspensions are often (somewhat unfairly) called *Chapman struts*, rather than MacPherson struts, although the designs are basically identical. Curiously, the MacPherson strut wasn't used on any American Ford products until the 1970s.

Another of MacPherson's achievements, however -- the use of ball joints in the front suspension, replacing the traditional kingpin -- was adopted in the mid-fifties, and became universal on American cars by the end of the following decade. (MacPherson didn't invent the ball joint suspension, which was largely the work of Ford supplier Thompson Products, but he was responsible for the design making it to production, which many contemporary engineers had thought impractical.) Thanks to these successes, MacPherson was promoted to corporate vice president of engineering in May 1952, succeeding Harold Youngren. He remained in the VP slot for six years, finally retiring in May 1958, at the age of 66. He died in 1960.

To understand how the MacPherson strut works, we need to consider why you would want independent suspension in the first place. Beam axles are simple, cheap, and sturdy, which is why they serve perfectly well for horse-drawn carriages and heavy-duty vehicles. However, an independent suspension has several major advantages over a beam axle. First and most obviously, it allows each wheel to move separately, so that a bump that affects one wheel doesn't necessarily affect the other. Second, it avoids the uncontrolled oscillations a beam axle between the wheels, which would otherwise cause wheel tramp and shimmy, hurting both handling and directional stability. Third, it reduces the vehicle's un-sprung weight.

A car's *sprung weight* is the mass supported by the suspension: the body, engine, passengers, and cargo. The car's *un-sprung weight* is the mass of the suspension components, wheels, tires, and anything that moves with them (such as the brakes, if they are mounted in the wheels or the beam connecting the wheels of a beam-axle suspension). Every time the car hits a bump, its suspension transmits the force to the body; the greater the un-sprung weight, the more severe the shock. High un-sprung weight also increases the inertia of the suspension components, making it harder to convince them to change direction, or to stop moving once they've started.

Because of all of these factors, a car with independent suspension -- particularly independent front suspension -- tends to have better handling and ride quality than one with a beam axle, which is why IFS became standard on most cars by the late forties. (Of course, as with all things, the theory and the practice are often different things. Ford's first independent front suspension, introduced in 1949, had very poor geometry, and its early IFS cars handled notably worse than their beam-axle predecessors.)

Outside of a brief flirtation with Dubonnet cylinders, the most common form of independent front suspension on American cars of the forties (and for about thirty years thereafter) was the *unequal-length control-arm* or *double-wishbone* layout, also known as a *short/long-arm* (SLA) suspension.

LEFT: A typical U.S.-style unequal-length control arm suspension; this is the front suspension layout of the late-sixties Chevrolet Camaro and Pontiac Firebird.

As you can see from the illustration, an SLA suspension connects the wheel spindle (red) to the frame with two transverse control arms, each shaped like a wishbone or a capital A. The upper control arm (green) is shorter than the lower arm (orange), usually by between 20% and 50%. A tubular shock absorber (purple) is mounted between the arms. The actual suspension is usually by coil springs (yellow), which are sometimes mounted over the shock absorbers ("coil-over") to save space; some cars mount the spring on the inboard side of the lower arm or on top of the upper arm, while others substitute torsion bars or semi-elliptical leaf springs. On many cars, there is also an anti-roll bar (blue), a torsion bar spring that connects the lower control arm to its counterpart on the other side of the car.

A properly designed SLA suspension offers a number of benefits, compared to either a beam axle or other types of independent suspension, like swing arms or trailing arms:

Low un-sprung weight: The control arms themselves are relatively light, and only a portion of their mass is actually part of the unsprung weight, which keeps the total un-sprung mass quite low.

Strength: The triangular, wishbone shape of the control arms makes them stiffer without making them heavier, helping them resist bending and distortion -- important to avoid shimmy and wheel tramp.

Long swing-arm length: *Swing-arm length* is the radius of the arc through which the wheel moves as it goes up and down on the springs. If this radius is relatively short, as on a swing-arm or swing-axle suspension, the wheel traces a long arc between the extremes of its travel. This often results in major changes in wheel alignment, which produces erratic handling. Making the effective swing-arm length as long as possible keeps the geometry of the wheel closer to constant, giving more predictable handling.

Camber gain: Tires have the best traction when they are vertical -- that is, when their *camber* angle is zero. With a beam axle or trailing arms, as the body leans toward the outside of the turn, the top of the outside wheel tilts outward, reducing its grip on the pavement; this is called *camber loss*, and it reduces the car's maximum cornering power. With an SLA suspension, the longer lower control arm causes the lower half of the wheel to tilt faster than the upper half, which keeps the wheel's camber closer to zero, even as the body leans; this is called *camber gain*, and it greatly improves handling ability. - An SLA suspension has two major drawbacks:

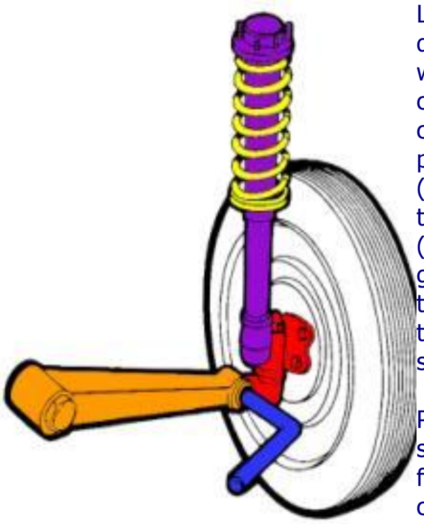
Cost: An unequal-length control arm suspension is fairly complicated (particularly compared to a beam axle), which costs more to build and install.

Width: The control arms need to be relatively long to provide good suspension geometry, which takes up more space in the body.

THE MacPHERSON STRUT

Earle MacPherson confronted both of these limitations when designing the Cadet in the mid-forties. The Cadet's track width was only about 48 inches -- fully a foot narrower than the track width of a contemporary full-size Chevrolet -- which didn't leave a lot of space for suspension components. Furthermore, the ambitious price target meant that the cost had to be reduced as much as possible. Beam axles would have been easier, but they would not have provided acceptable ride or handling, particularly considering the Cadet's low sprung mass.

MacPherson's strategy was essentially to simplify the unequal-length control arm layout. The Cadet's suspension retained the lower control arm, which was actually formed by a relatively narrow transverse arm and a skinny, diagonal radius rod. Instead of an upper control arm, however, the wheel spindle was mounted on a vertical strut, mounted rigidly to the body. The strut incorporated a tubular shock absorber, and it served both as the upper control arm and as the axis around which the front wheels were steered. The coil spring was mounted over the upper part of the strut, near where it attached to the body; this saved space, and allowed the lower control arm to be thinner, since it didn't have to handle the loads generated by the springs. The refined version of this design, first used in the Vedette and found on many modern cars, dispenses with the radius rods. Instead, it uses a torsion bar spring, connected to the outer end of each lower control arm. The torsion bar acts as an anti-roll bar, and it also triangulates the control arms, acting as the front half of each lower "wishbone."



LEFT: Compare this colour-coded diagram of the MacPherson strut system with the SLA diagram above. The upper control arm has been omitted completely, with its locating function provided by the shock absorber strut (purple), which is mounted directly to the spindle (red). The lower control arm (orange) is narrower and simpler, but it gains strength by the triangulation of the anti-roll bar (blue), which connects to the lower control arm of the opposite side of the car.

Photo RIGHT: MacPherson strut front suspension. Note how the anti-roll bar forms a wishbone shape with the lower control arm, providing both roll stiffness and suspension stability.

Also note the location of the engine driveshaft (identifiable by the rubber CV boots on each end) -- with a MacPherson strut, there are no suspension components to block the driveshaft. By eliminating several components and making others do double duty, the MacPherson strut design is both cheaper and lighter than an SLA suspension. It's also narrower, which is helpful in smaller cars. Although MacPherson didn't have front-wheel drive in mind when he designed this suspension, it has an additional advantage for FWD cars in that there are no suspension components to interfere with the driveshaft's which is not the case for many SLA designs.

Most MacPherson strut suspensions use coil springs mounted high on the struts, like MacPherson's original designs, but that isn't universally true. Porsche has frequently used MacPherson strut suspensions with torsion bars, rather than coil springs, while both Ford's Fox platform and GM's 1982-1992 Camaro and Firebird used "modified MacPherson struts" with the coil springs mounted on the lower control arms, rather than on the shock towers. By the same token, there are many suspensions with coil-over shocks that are not MacPherson struts. What defines a strut suspension is not the location or integration of the spring, but the use of the shock tower as the upper control arm. MacPherson struts offer many of the benefits of a SLA suspension, including strength, long swing-arm length, and low un-sprung weight, but without the cost and space penalties. However, they also have several significant drawbacks, including:

Unsuitability for body-on-frame vehicles: The vertical strut must be firmly attached to the body, which in turn must be strong enough to absorb the loads created by the suspension. That generally requires a unitized or semi-unitized body; with a body-on-frame car, the body is generally not rigid enough to handle those loads. (This is why MacPherson struts were not common on American cars until the 1980s.)

Excessive height: Although a MacPherson strut suspension isn't very wide, it is taller than an SLA layout, which means it doesn't fit well in cars with a low hood line. Some MacPherson-strut cars (like Mitsubishi's 1990-2001 GTO/3000GT and the related Dodge Stealth) have noticeable bulges in the hood or front fenders to provide clearance for the shock towers.

High replacement cost: Because the vertical struts are also the shock absorbers -- and sometimes incorporate the springs, as well -- replacing the shocks on a car with MacPherson strut suspension is usually more expensive than changing the shocks on a comparable vehicle with double-wishbone suspension.

No camber gain: Because the top of the vertical strut is mounted rigidly to the body structure, MacPherson struts do not provide camber gain -- the wheels lose camber as the body leans. You can compensate to some degree by designing the suspension with a few degrees of static negative camber (that is, aligning the wheels so that the upper halves are tilted slightly inward when the car is level), but too much negative camber causes uneven tire wear. The only way to prevent camber loss is to use stiffer springs and/or anti-roll bars to reduce body lean, which results in a stiffer ride. It's possible to make a MacPherson strut car handle very well, as Porsche, Volkswagen, and BMW have repeatedly demonstrated, but it compromises ride quality more than would be the case with a double-wishbone suspension.

Despite these drawbacks, the MacPherson strut suspension remains very popular for both economy cars and for any vehicle where space is at a premium. Even automakers like Honda, which has traditionally preferred double-wishbone suspensions, have gone to MacPherson struts for their smaller cars. That's not a bad legacy for an engineer -- even if nobody can spell his name right.

Written by Aaron Severson.