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How Differentials Work

by [Karim Nice](#)



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If you've read [How Car Engines Work](#), you understand how a car's power is generated; and if you've read [How Manual Transmissions Work](#), you understand where the power goes next. This article will explain **differentials** -- where the power, in most cars, makes its last stop before spinning the wheels.

The differential has three jobs:

- 1 To aim the engine power at the wheels
- 1 To act as the final gear reduction in the vehicle, slowing the rotational speed of the transmission one final time before it hits the wheels
- 1 To transmit the power to the wheels while allowing them to rotate at different speeds (This is the one that earned the differential its name.)

In this article, you'll learn why your car needs a differential, how it works and what its shortcomings are. We'll also look at several types of positraction, also known as **limited slip differentials**.



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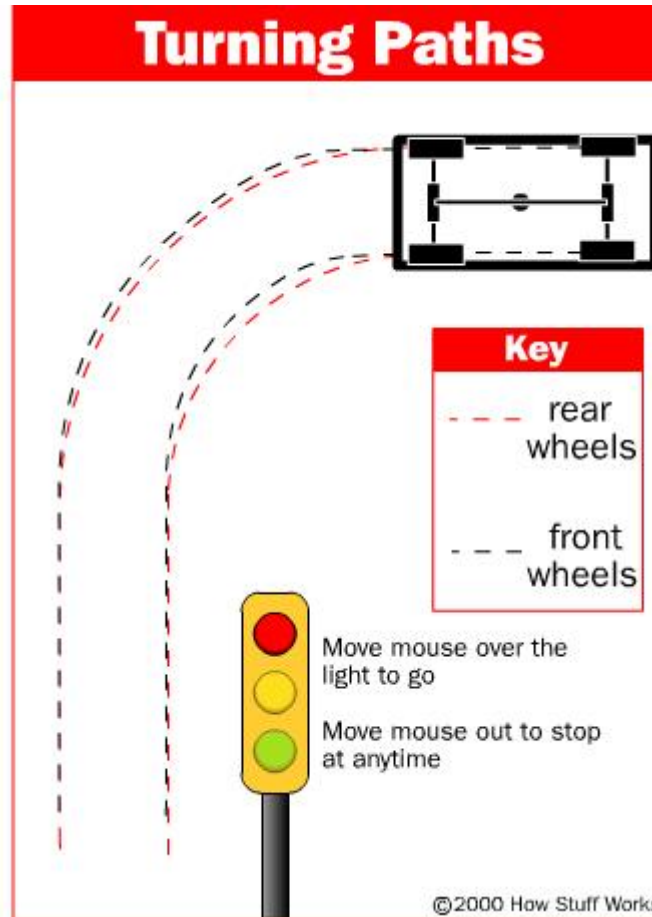
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Why You Need a Differential

Car wheels spin at different speeds, especially when turning. You can see from the animation below that each wheel travels a different distance through the turn, and that the inside wheels travel a shorter distance than the outside wheels. Since speed is equal to the distance traveled divided by the time it takes to go that distance, the wheels that travel a shorter distance travel at a lower speed. Also note that the front wheels travel a different distance than the rear wheels.



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For the **non-driven wheels** on your car -- the front wheels on a rear-wheel drive car, the back wheels on a front-wheel drive car -- this is not an issue. There is no connection between them, so they spin independently. But the driven wheels are linked together so that a single engine and transmission can turn both wheels. If your car did not have a

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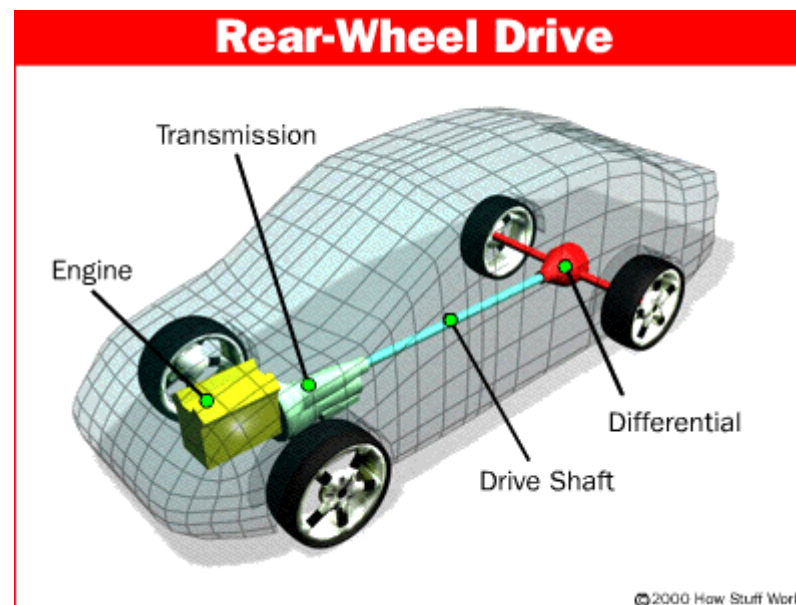
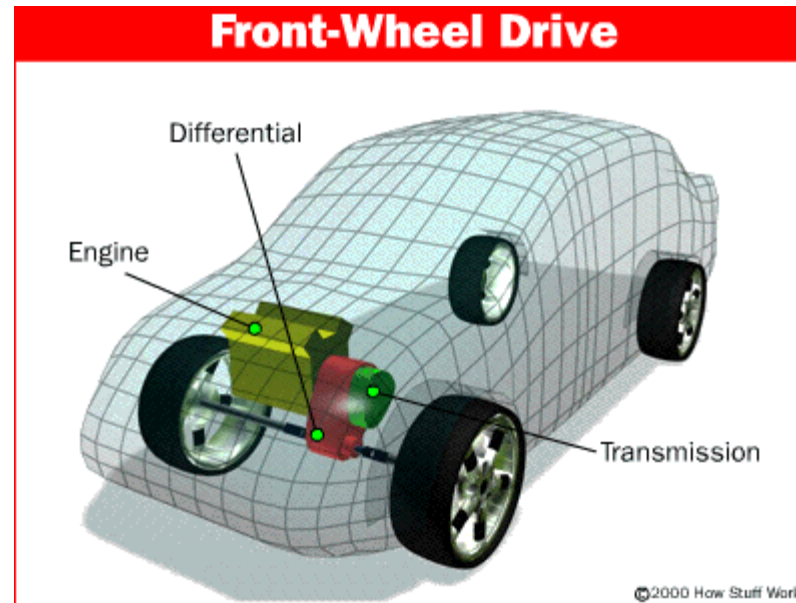
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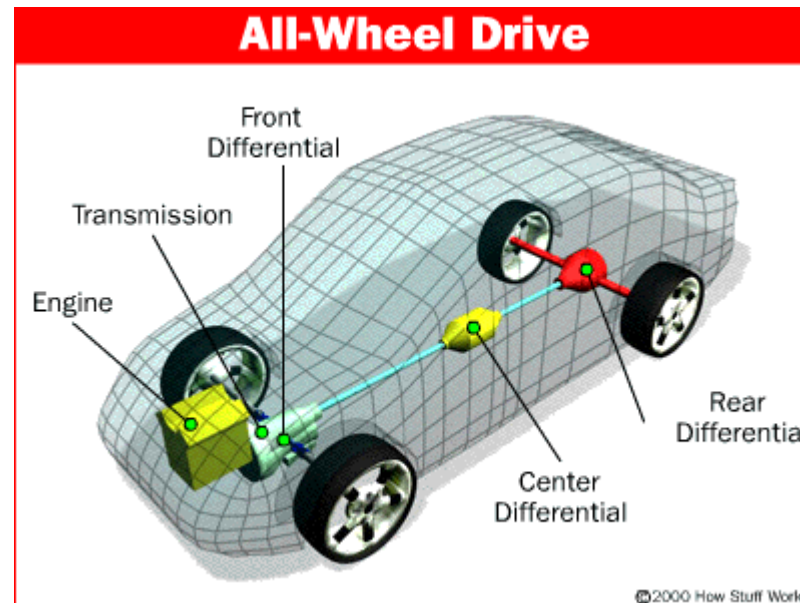
differential, the wheels would have to be locked together, forced to spin at the same speed. This would make turning difficult and hard on your car: For the car to be able to turn, one [tire](#) would have to slip. With modern tires and concrete roads, a great deal of force is required to make a tire slip. That force would have to be transmitted through the axle from one wheel to another, putting a heavy strain on the axle components.

What is a Differential?

The differential is a device that splits the engine [torque](#) two ways, allowing each output to spin at a different speed.



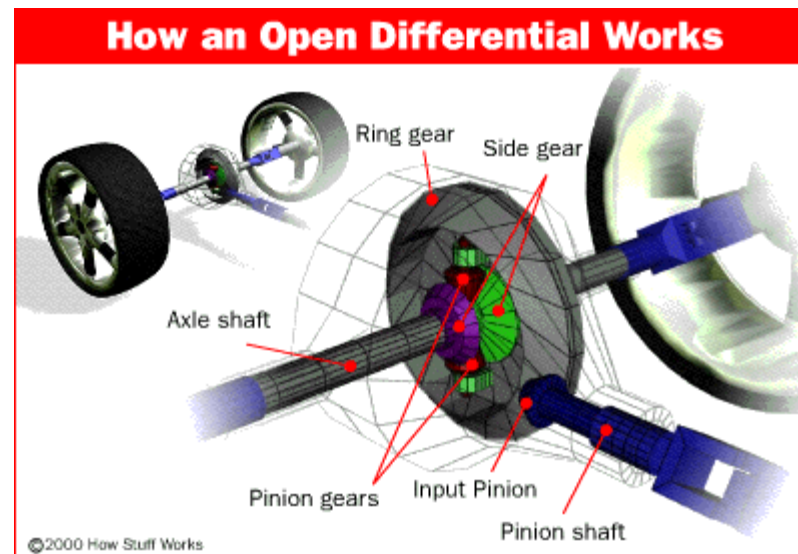
The differential is found on all modern cars and trucks, and also in many all-wheel-drive (full-time [four-wheel-drive](#)) vehicles. These all-wheel-drive vehicles need a differential between each set of drive wheels, and they need one between the front and the back wheels as well, because the front wheels travel a different distance through a turn than the rear wheels.



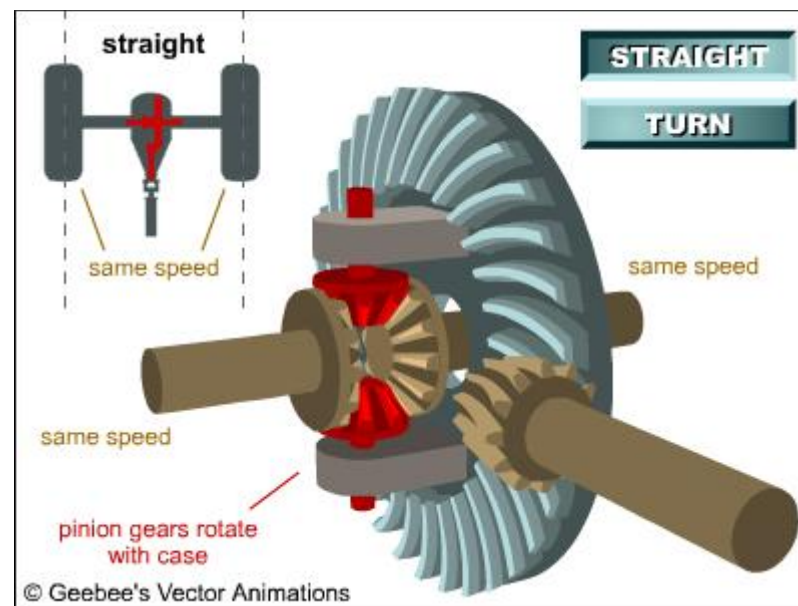
Part-time four-wheel-drive systems don't have a differential between the front and rear wheels; instead, they are locked together so that the front and rear wheels have to turn at the same average speed. This is why these vehicles are hard to turn on concrete when the four-wheel-drive system is engaged.

Spinning at Different Speeds

We will start with the simplest type of differential, called an **open differential**. First we'll need to explore some terminology: The image below labels the components of an open differential.



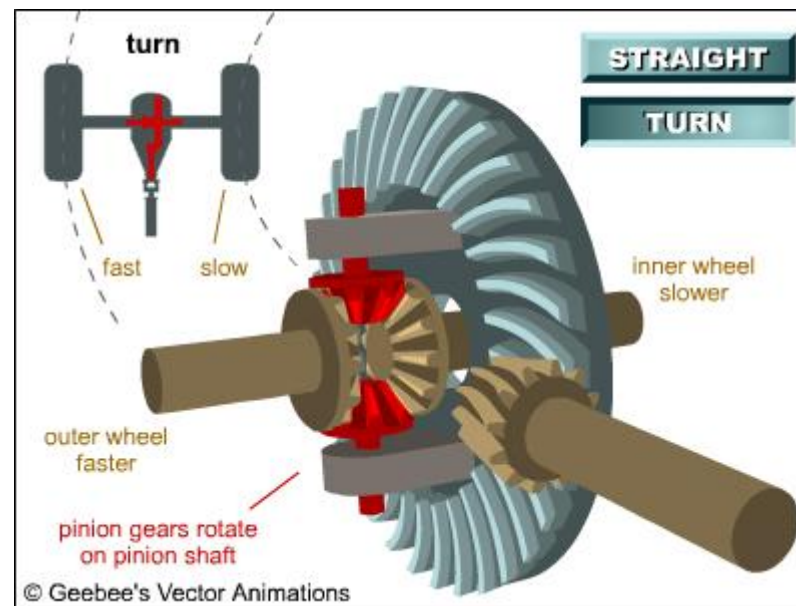
When a car is driving straight down the road, both drive wheels are spinning at the same speed. The **input pinion** is turning the ring gear and cage, and none of the pinions within the cage are rotating -- both side gears are effectively locked to the cage.



Animation courtesy Geebee's Vector Animations

Note that the input pinion is a smaller gear than the ring gear; this is the last gear reduction in the car. You may have heard terms like **rear axle ratio** or **final drive ratio**. These refer to the gear ratio in the differential. If the final drive ratio is 4.10, then the ring gear has 4.10 times as many teeth as the input pinion gear. See [How Gears Work](#) for more information on gear ratios.

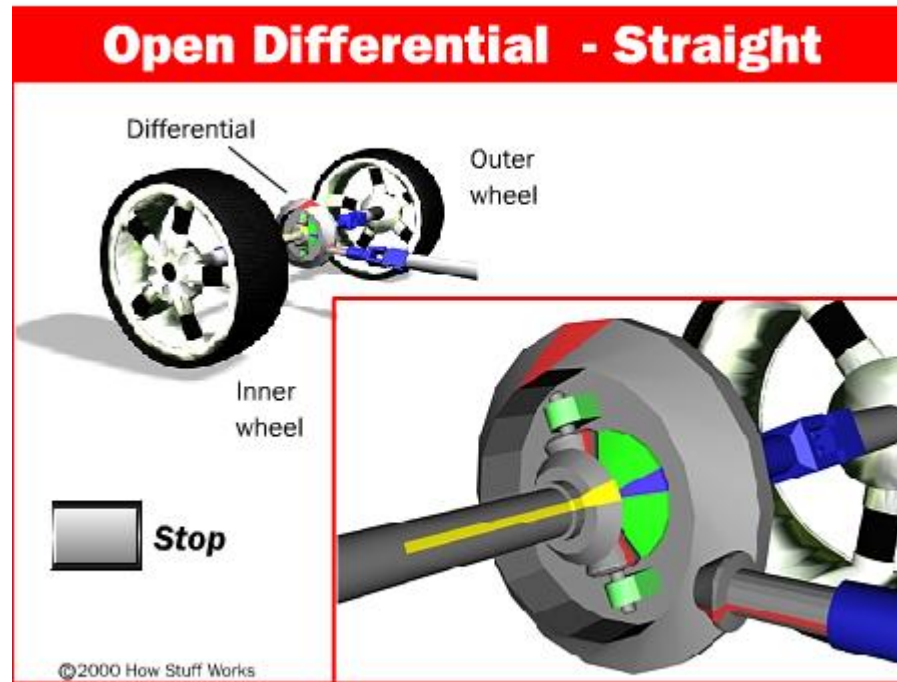
When a car makes a turn, the wheels must spin at different speeds.



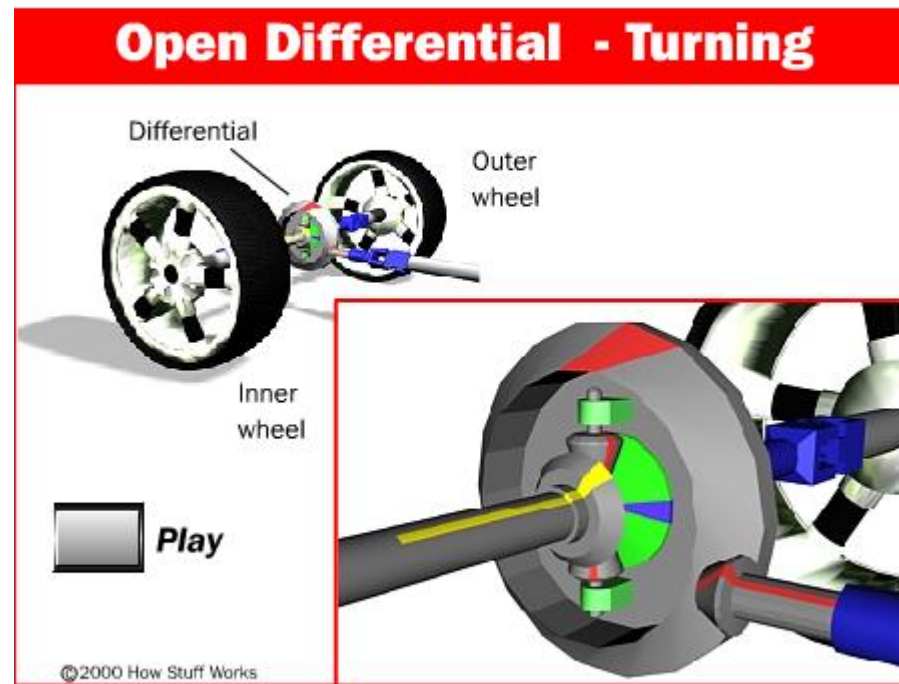
Animation courtesy Geebee's Vector Animations

In the figure above, you can see that the pinions in the cage start to spin as the car begins to turn, allowing the wheels to move at different speeds. The inside wheel spins slower than the cage, while the outside wheel spins faster.

Open Differential - Straight (600KB)



Open Differential - Turning (1.1MB)



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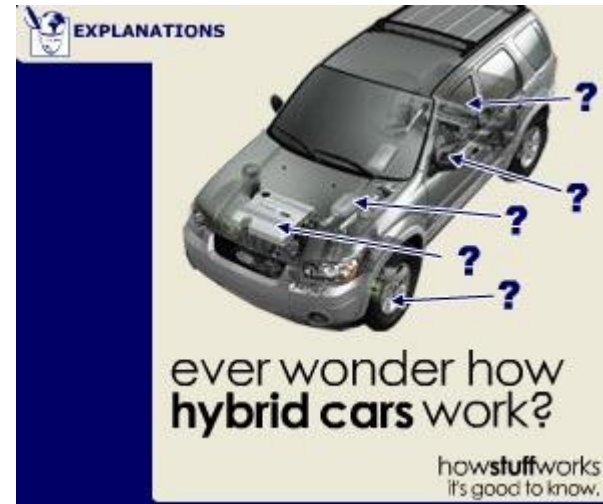
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