High-level description of Churchland*, Cunningham*, et al (2012) Nature.

Human brains have developed remarkable faculties: memory, creativity, reason, and emotion. Though significant, these abilities merely elaborate on the true evolutionary goal of the brain: perceiving sensory information and driving movements that promote survival. Two key brain areas involved in these functions are the primary visual cortex and the primary motor cortex. The primary visual cortex is the first area of cortex to receive information from the eyes, and its basic computational properties have been understood for over half a century. Neurons in primary visual cortex respond in a faithful way to aspects of the external visual world: they represent parameters such as shape, color and brightness. However, the basic computational structure of primary motor cortex has not been as obvious. Primary motor cortex is the principal area that sends information down the spinal cord and influences the muscles. One might imagine then that neurons in primary motor cortex, like visual cortex, should relate in a faithful way to external parameters. For example, neural activity might relate to parameters such as the direction, distance and speed of a reach. Many experiments have sought such lawfulness, yet none have found it. Our findings indicate that motor cortex is quite unlike visual cortex, and that an alternative principle is at play.

To employ an automotive analogy, our results argue that motor cortex does not act like an odometer or speedometer (whose function is to represent information about motion) nor does it act like a steering wheel (the position of which represents the direction of turning). Rather, the motor cortex acts somewhat more like the engine. An internal combustion engine contains a variety of parts (pistons, cams, valves) whose activities appear complicated in isolation and do not explicitly represent external descriptors of the car such as its direction, distance, and speed. Yet these parts cooperate in a very lawful way to generate the necessary motor output.

Our findings indicate that motor cortex acts as a sort of 'neural engine' for generating movement. As with any engine, it contains many parts that behave lawfully, yet do not have simple relationships with the final, external output. The nature of this engine is not simple, yet it has some strikingly simple aspects. To a first approximation, neurons in motor cortex exhibit brief rhythmic responses. These rhythmic responses are not independent from neuron to neuron: the entire neural population oscillates in a beautiful, lawfully coordinated way.

There are at least two reasons why this rhythmic "neural engine" strategy might be used by motor cortex. First, nervous systems evolved to produce rhythmic patterns and movements. Second, it has long been known mathematically that oscillatory patterns can be added together to produce arbitrary non-oscillatory patterns. Suppose you wish to throw a ball— your nervous system must create a specific pattern of activity in your muscles (your shoulder muscle must contract, relax, contract, and then relax completely, all in short order). If the motor cortex could simultaneously generate a few brief rhythmic patterns, perhaps they could be summed to generate the desired pattern of muscle activity. Remarkably, our experiments show that this 'underlying rhythm' strategy works very well. We studied a broad variety of reaching movements and found that the pattern of shoulder-muscle activity was always well-described by a sum of two underlying rhythms. Thus, the rhythmic activity seen at the neural level is in fact a good strategy for generating complex motor patterns.

In summary, our results argue that the motor cortex generates a broad range of movements by employing underlying 'hidden' rhythms. This occurs not only for overtly rhythmic movements (e.g., walking) but also for movements with no overtly rhythmic aspect (e.g., reaching from point A to point B). Finding these lawful and useful rhythmic patterns in motor cortex helps resolve an old paradox. It had historically appeared that neural responses in motor cortex were strange or lawless, having little consistent relationship with external parameters of movement. Yet motor cortex is in fact producing simple and lawful activity: a combination of a few rhythms. It is simply that the movement itself does not always appear rhythmic from the outside.