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# Demonstration of Follicle Waves Using Delay Differential Equations

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## Demonstration of Follicle Waves Using Delay Differential Equations

### Abstract:

This study presents a mathematical model of hormonal control of the menstrual cycle. In addition to the normal cycle, modified equations can exhibit follicle waves leading to more than one follicle of ovulatory size. Follicles develop sequentially and present the possibility of two ovulations during the same menstrual cycle, and therefore possibility of dizygotic twins through a process called superfecundation. Concentrations of five key hormones are predicted using a nonlinear system of delay differential equations containing 13 state variables, 51 parameters, and 3 auxiliary equations. Sensitivities were calculated and parameters optimized to data for blood concentrations of five hormones. A unique stable periodic cycle exists representing normal hormone levels for both ovarian and pituitary hormones. Modifications to model equations result in follicle wave behavior from multiple rises in a pituitary hormone follicular stimulating hormone during a single menstrual cycle. Using the added mechanism for follicle waves, the existence of a period doubling bifurcation followed by a period doubling cascade, window of chaos, and window of a stable 6-cycle are also shown. Studying of this behavior may have implications in understanding of female fertility and female reproductive aging.