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# Chaotic dynamics of a fractional order glucose-insulin regulatory system

**Key words:** Diabetes mellitus; Chaos; Bifurcation; Multistability; Antimonotonicity

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# Motivation

- The total estimated 2017 cost of diagnosed diabetes of \$327 billion includes \$237 billion in direct medical costs and \$90 billion in reduced productivity. So, this cost motivates research about this disease.
- The number of people with diabetes has risen from 108 million in 1980 to 422 million in 2014. So, this prevalence motivates research about this disease.

# Main idea

- Proposing mathematical models for biological phenomena can help scientists better understand and even control diseases.
- We want to propose a model considering different parameters, leading to different types of these diseases.
- Fractional systems can be used in modeling of biological phenomena which have shown some complex dynamics in experimental data.

# Method

We consider nonlinear methods like stability of equilibria, Lyapunov exponents, bifurcation diagrams, and the basin of attraction of the system.

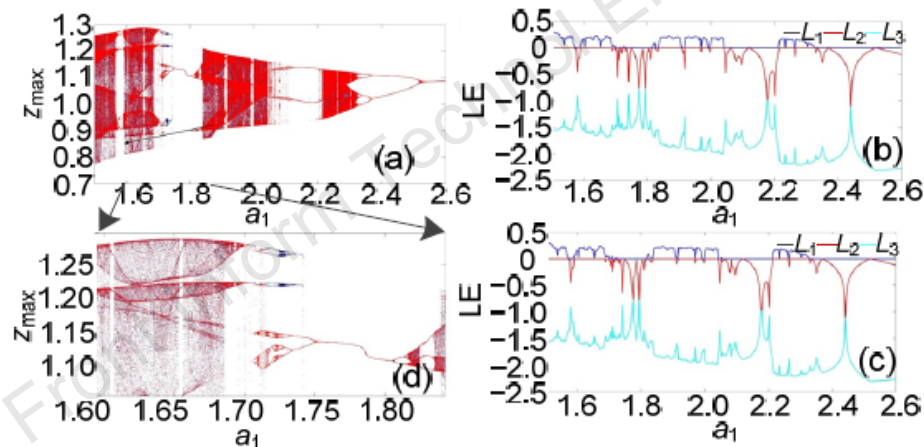
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# Major results

- A novel fractional order glucose-insulin regulatory system is derived.
- Various biological disorders caused by an unregulated glucose-insulin system are studied in detail.
- We have revealed that the glucose-insulin regulatory system shows multistability and antimonotonicity in its fractional order form.

# Conclusions

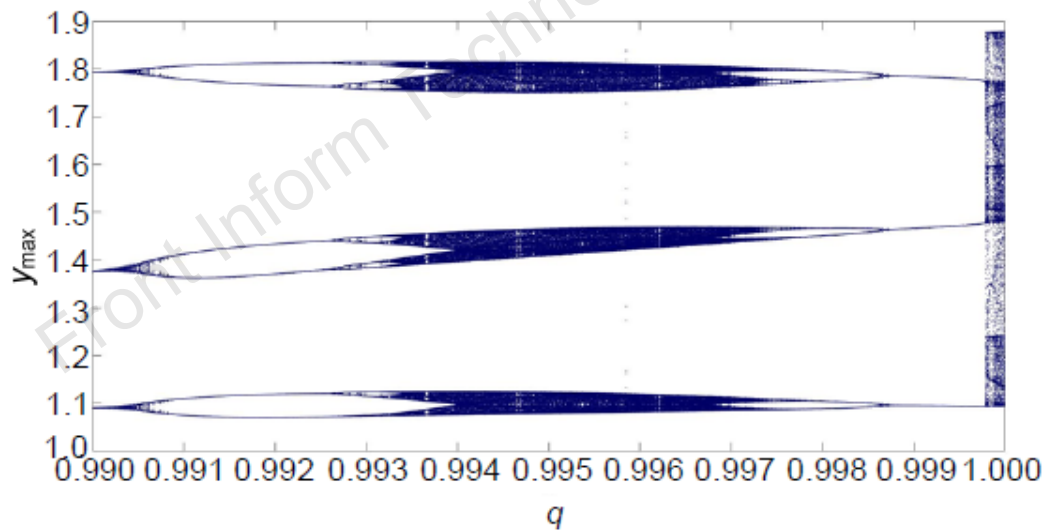
- Nonlinear methods like stability of equilibria, Lyapunov exponents, bifurcation diagrams, and the basin of attraction of the system are powerful methods to analyze the biological systems.



**Fig. 5 Bifurcation diagram and Lyapunov exponents of FOGIRS as parameter  $a_1$  changes: (a) forward and backward bifurcation diagrams of FOGIRS; (b) LEs of FOGIRS changing the parameter in forward continuation; (c) LEs of FOGIRS changing the parameter in backward continuation; (d) specified portion with multistability**

# Conclusions (Cont'd)

- The fractional order model exhibited the properties of coexisting attractors and antimonotonicity which have not been reported in the literature.



**Fig. 9 Bifurcation diagram of FOGIRS for different values of the fractional order of the system**