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## EARTH-SYSTEM STABILITY THROUGH GEOLOGIC TIME

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The five great mass extinctions of the last 500 million years are each associated with significant perturbations of Earth's carbon cycle. But there are also many such environmental events not associated with mass extinction. What makes them different? We show that natural perturbations of the carbon cycle exhibit a critical rate of change resulting from a transient balance between the photosynthetic uptake and respiratory return of CO<sub>2</sub>. The critical rate is also the fastest rate at which the resulting excess CO<sub>2</sub> can be produced in a sustained steady state. We identify the critical rate with marginal stability, and find that four of the five great mass extinctions occur on the fast, unstable side of the stability boundary. Moreover, many severe yet relatively benign events occur close to the boundary. These results suggest that major environmental change is characterized by common mechanisms of Earth-system instability. The most rapid instabilities result in mass extinction.