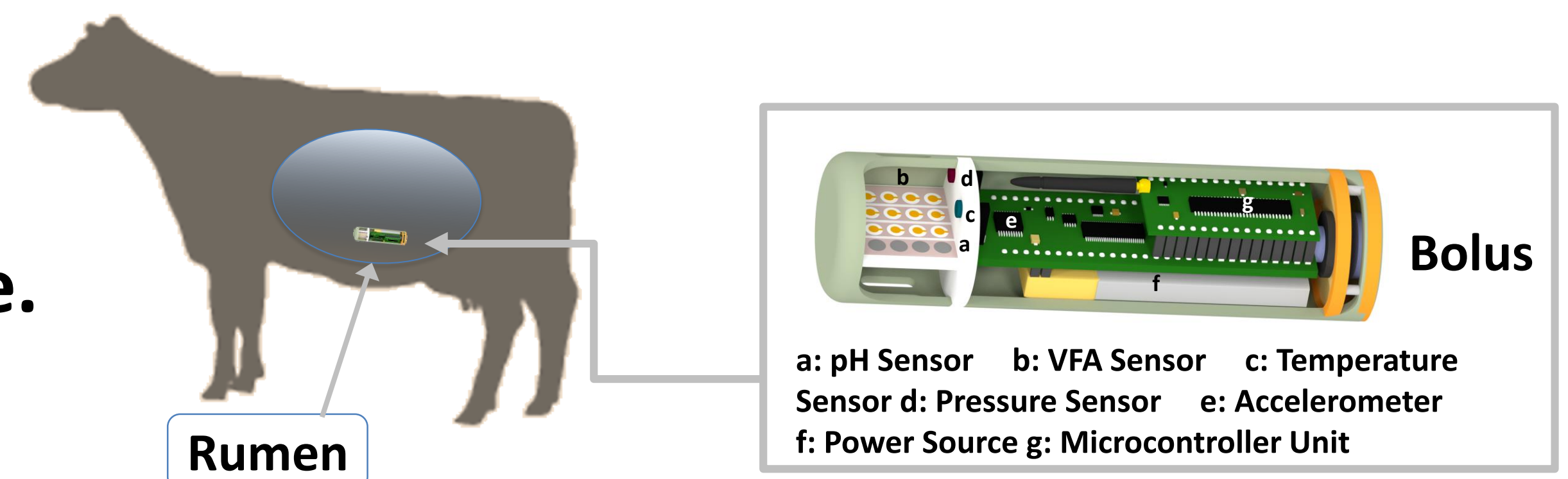# Rumen Understanding through Millipede-Engineered Navigation and Sensing (RUMENS)

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## Rumen fluid pH and Volatile Fatty Acids (VFAs) are good indicators of cow's health and productivity.

Conventional method of monitoring uses a Bolus.

Bolus measures pH, VFAs, motility and temperature.

Transmits the data wirelessly for analysis.



Rumen

Bolus

a: pH Sensor    b: VFA Sensor    c: Temperature Sensor d: Pressure Sensor    e: Accelerometer    f: Power Source g: Microcontroller Unit

## Challenges:

- Locomotion capability for RUMENS ROV.
- Controlled measurements from specific locations within the rumen.
- Ability to collect samples for in-situ analysis.
- Wireless transmission of the data at prescribed intervals
- Survival in the Rumen for long durations.

## Scientific impacts:

- Predictive health monitoring
- Animal welfare
- Environment Influence
- Stress factors
- Machine learning
- Data Analytics



Fermentation

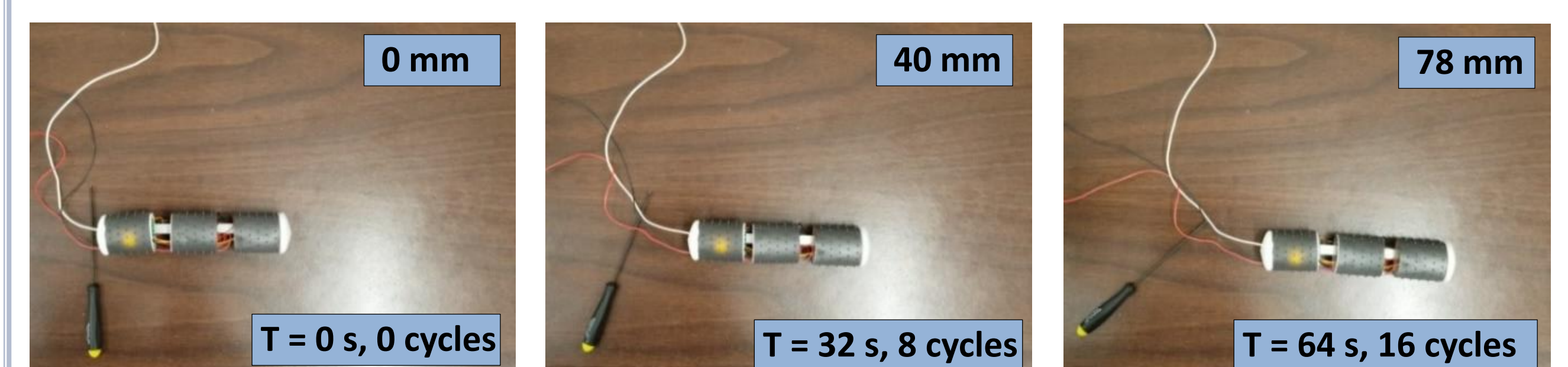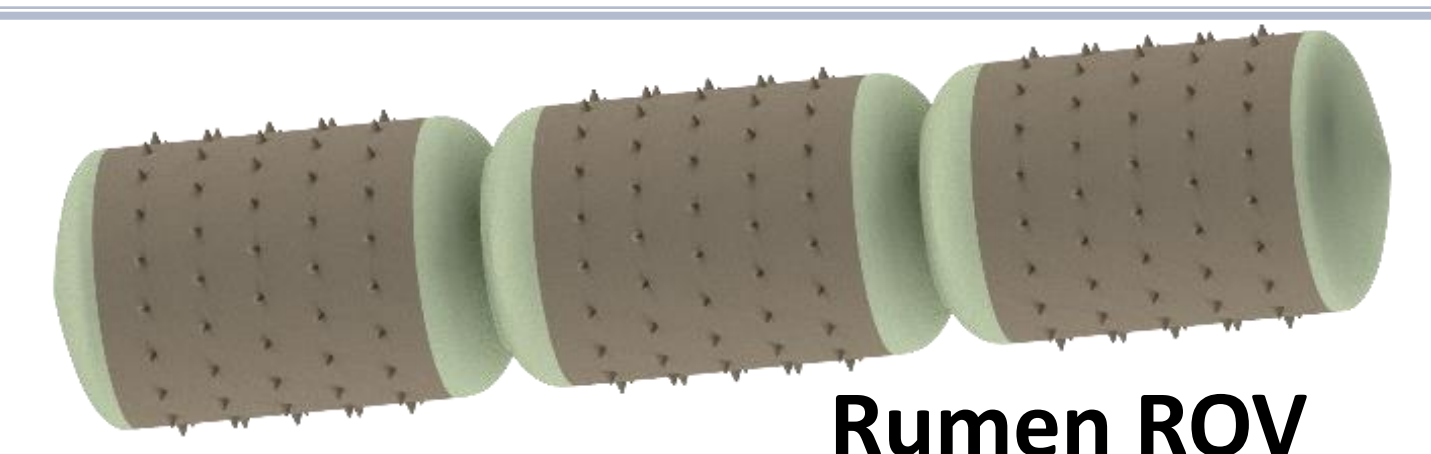Food Production

Energy Generation
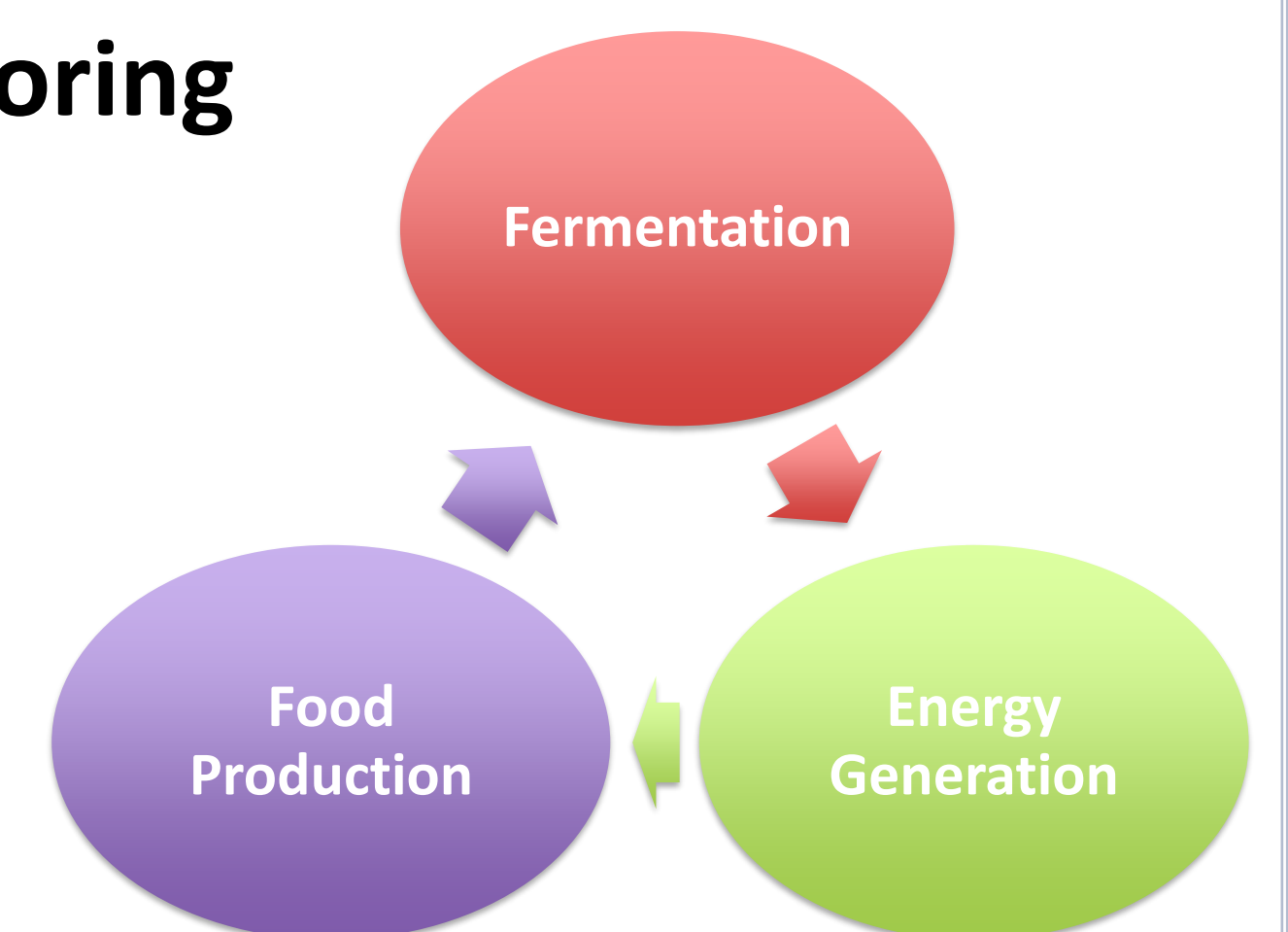
## Research Approach:

- A biomimetic remotely operated vehicle (ROV) inspired by an earthworm is being designed, fabricated and tested.
- pH sensor based upon extended-gate field-effect transistor and enzymatic electrochemical sensors for VFA are being developed.

## Impact on society / potential impact:

- Improved understanding of rumen
- Collaboration with farmers on improving food production efficiency, safety and quality.
- Student / postdoc / research faculty training

## Education and outreach:

- Develop interdisciplinary courses on emerging technologies covering biomedical robotics, bio-inspired locomotion and mechatronics.
- Organize summer camps and lab tours for high-school students to engage them in STEM activities.

## Research Progress:



Inchworm locomotion

Rumen ROV

0 mm        40 mm        78 mm

T = 0 s, 0 cycles    T = 32 s, 8 cycles    T = 64 s, 16 cycles



Drain    Gate    Source

Passivation

Signal line

Sensitive layer

Si substrate

Sensing unit

Epoxy

Wire

pH Sensor

$V_{ref}$ = 2 V

Drain current, $I_{DS}$ ($\mu A$)

pH6
pH7
pH8

Drain voltage, $V_{DS}$ (V)



Immobilized enzyme mixture

Working electrode

VFA Sensor

Acetate

Current ($\mu A$)

Concentration (mM)