Edible Soft Robotics:

An Exploration of Candy as an Engineered Material

Kari Love
of Super-Releaser and NYC Resistor

Identify Project/Value Proposition

- What do you want to make?
- Why is this worth doing?
    - Quad Chart
    - Heilmeier Questions
    - ?

Candy Soft Robot

Kari Love, Super-Releaser

Innovation

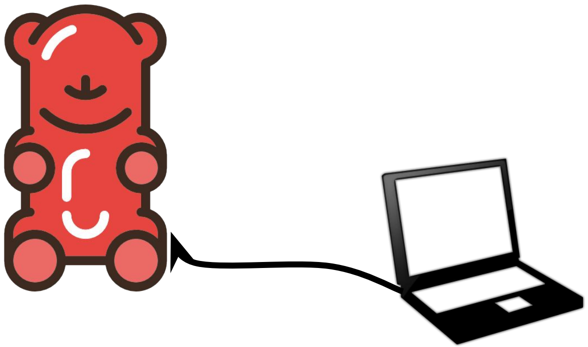
- Entirely edible soft robot
- Control system doesn't impede eating
- Candy sweetness novelty for maximum enjoyment

Technical Approach

- Evaluate engineering potential of various homemade and store bought candies
- Identify design patterns for candy actuators
- Document design exploration process as well as final how-to

Potential Benefits

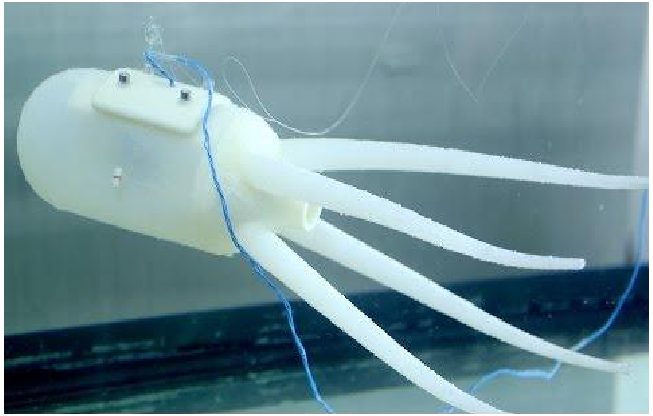
- Can be Soft Robotics book content
- Highest form of interactivity
  - Engages all 5 senses
  - Becomes part of the user
- Attractive entry point for experimenting on emerging technology
- Interdisciplinary
- Blurs the line between work and play

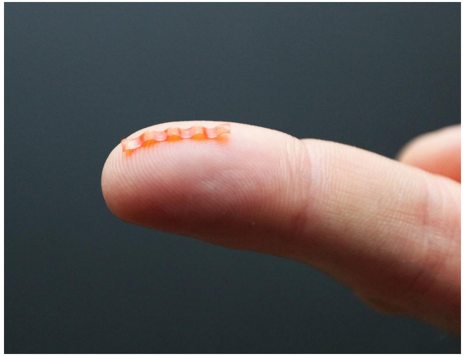


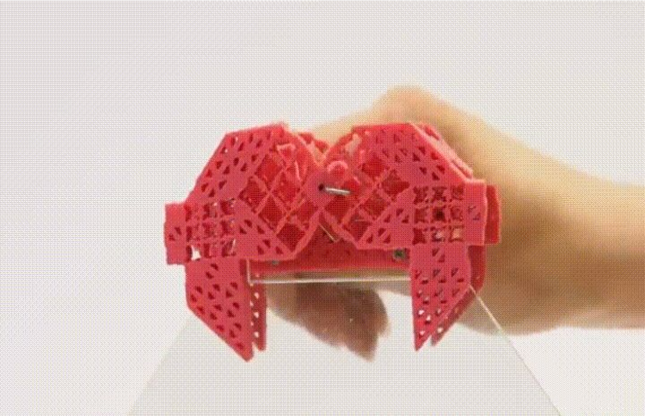
History and State-of-the-Art

- Is someone already doing this work?
- What is the historical context?
- What are related fields?
- Don’t reinvent the wheel!

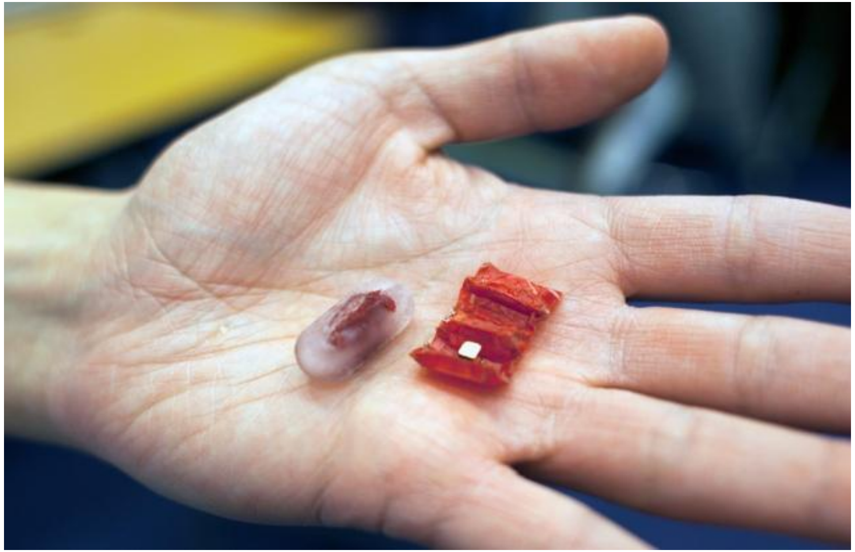
Soft Robotics:

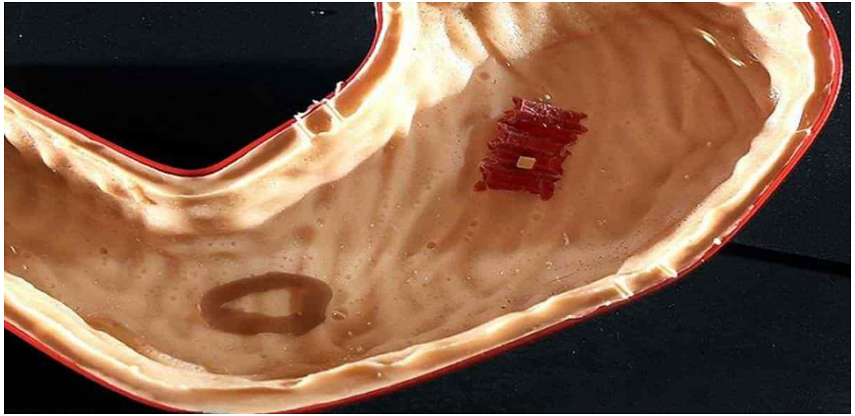






Molecular Gastronomy:





MIT CSAIL, Sheffield University, & Tokyo Institute of Technology:
Ingestible Origami Robot

“We spent a lot of time at Asian markets and the Chinatown market looking for materials.”

The researchers tested about a dozen different possibilities for the structural material before settling on the type of dried pig intestine used in sausage casings.

Carnegie Mellon Bettinger Group: Edible Battery

"I have eaten one of my batteries and I'm still fine — I'd be fine eating my battery every single day of my life!”

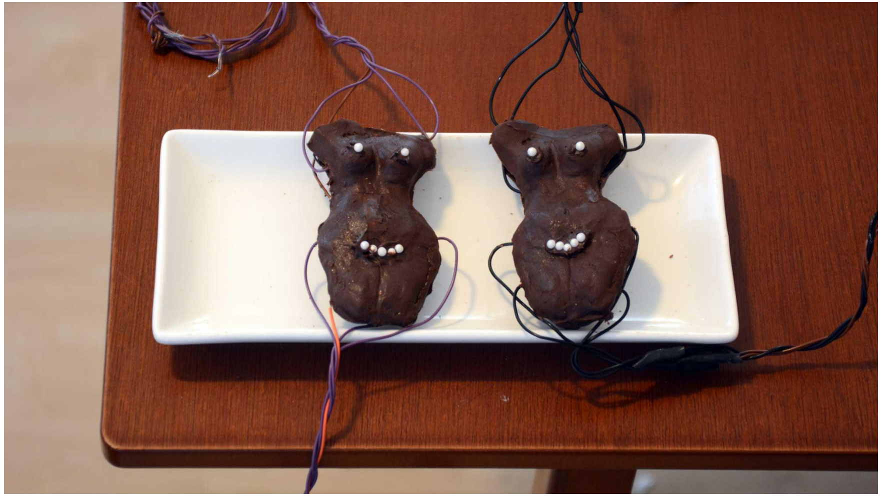
The battery is made from cuttlefish ink extracts and could be used to power pacemakers, neurostimulators, devices to deliver drugs at a specific time, ingestible cameras and glucose monitors.

Minsu Kim: Living Food

"In this respect I propose a future dining experience where food takes a life-form for aesthetic gastronomy. In a material way, I experimented which kinds of impressions could be designed into life-like food and how it would shape our dining experience."

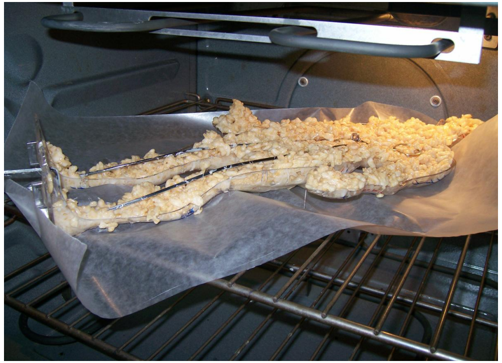
Ariel Cotton: Lady Godiva

“Upon learning that silver leaf is both edible and conductive, I decided to experiment with it. I created molds of nude women out of chocolate, and sandwiched the silver leaf in between the two halves of each female figure. I adhered wires to the silver leaf in a circuit configuration such that when the chocolates are bitten into, the circuit is broken.”



Robo250, Carnegie Mellon, Maya & The Mattress Factory:

“Cucumbers turned out to be a very promising and entirely organic robotic substrate. We attribute the success of cucumber-based robotics to the strong exosurface and self-lubricating properties of the garden variety seedless cucumber.”



Consult With Experts

- If no one has done this before, who counts as an “expert?”
- Broader is better than narrower
- The synthesis of ideas across fields is key

Matthew Borgatti - *Soft Roboticist*

“Part of our soft robotics agenda is to be awesome.”

Tim Rodriguez - *Polymath Trained in Food Science*

"To move from candy to vegetables is to move from the molecular-level to the cellular-level."

Liz Hara - *Pro Puppet Builder and Candy Enthusiast*

"I can tell you that stabbing licorice into a hot dog does not make for a durable puppet."

Definite Project Specifications

- How will you evaluate your materials and iterations?
- How will you know when you're done?

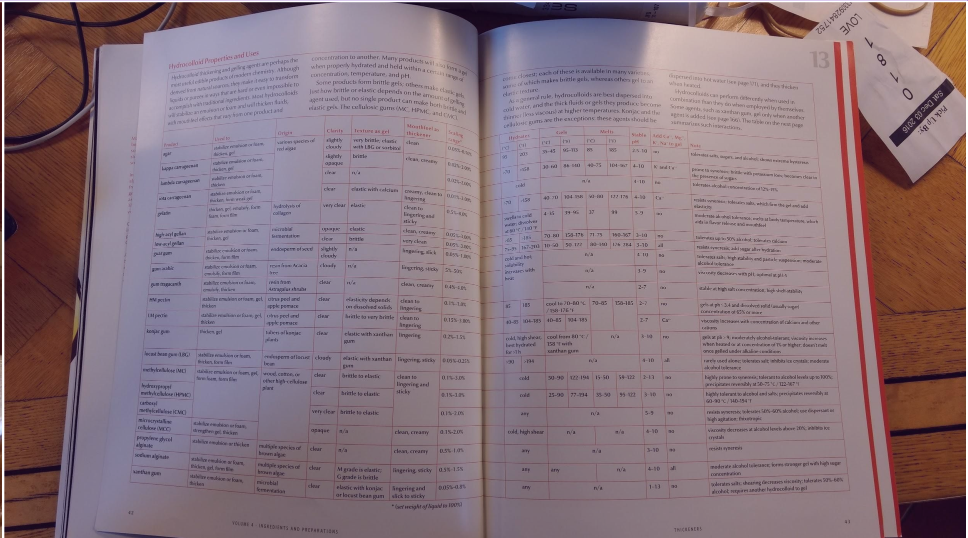
Edible Soft Robot Specs

- Eat the whole robot (up to computer control)
- Easy to reproduce
- Elicit an emotional response (joy or disgust)
- Baseline flavor standard (not just technically edible)
- Durable enough to make the day before
- No need for long-term stability

Materials Exploration

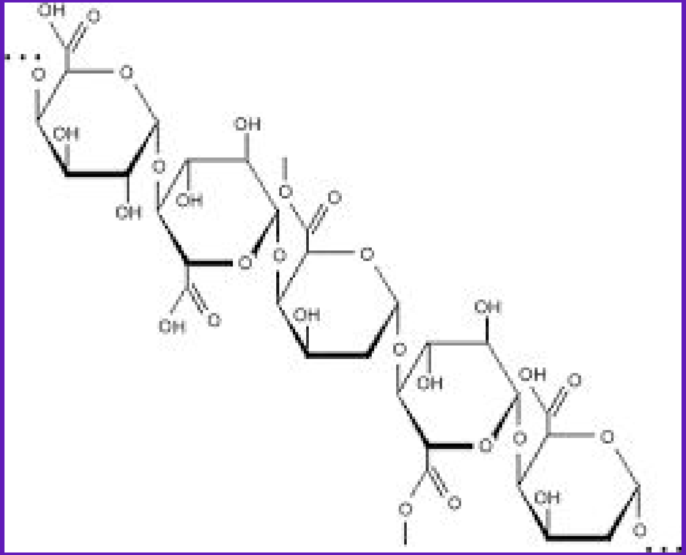
- Survey possible materials
- Touch & Compare
- Analyze material properties
- Begin generating unedited list of potential applications
- Play!

Gelling, particularly of hydrocolloids, is a foundational problem of molecular gastronomy!



Hydrocolloid materials: Pectin, Gelatin, Gellan, Carageenan

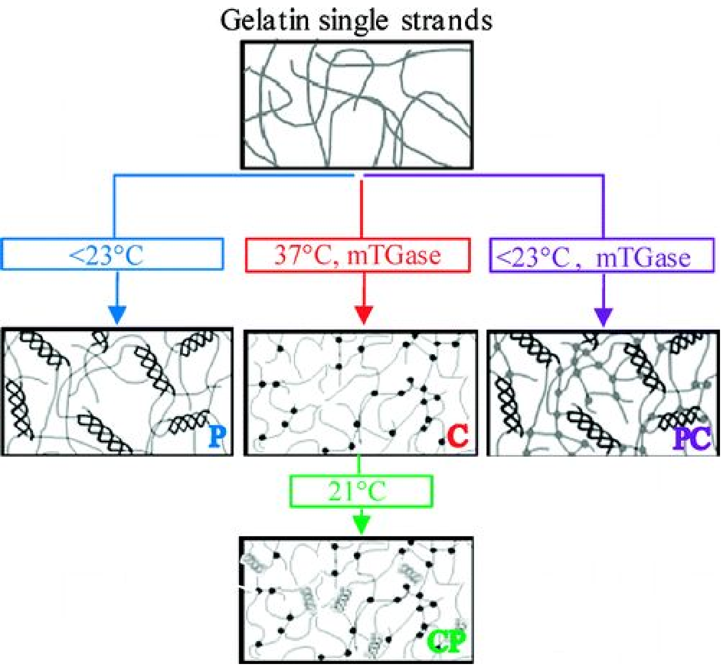
#1 Pectin:
Can form a stiff, but brittle gel



#2 Burned Gelatin
Makes horror smells... it is made of skin and hooves after all.

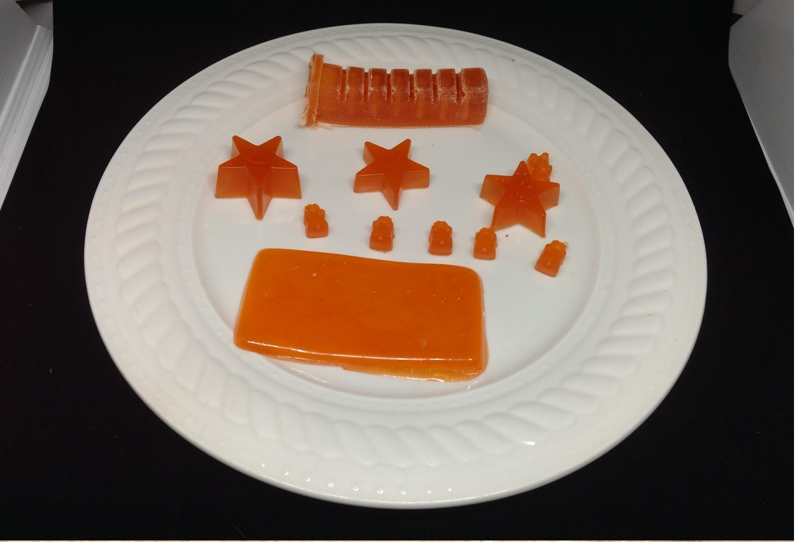
3 Gelatin:

Too much gelatin in the recipe produces durable/tough elastic material that tastes like skin.



#4 Jello brand Gelatin: Good compromise between flavor, ease of handling, and flavor.

#5 Gellan (high acyl): Extremely elastic, also very tender and soft



#6 Jello brand Gelatin (reduced gelatin recipe): Very similar in texture/elasticity to Smooth-On silcone

#7 “Haribo” Recipe (sheet gelatin, subbed sugars, added acid): Delicious! Most promising in terms of flavor, and seems possible to adjust amounts to alter physical properties.

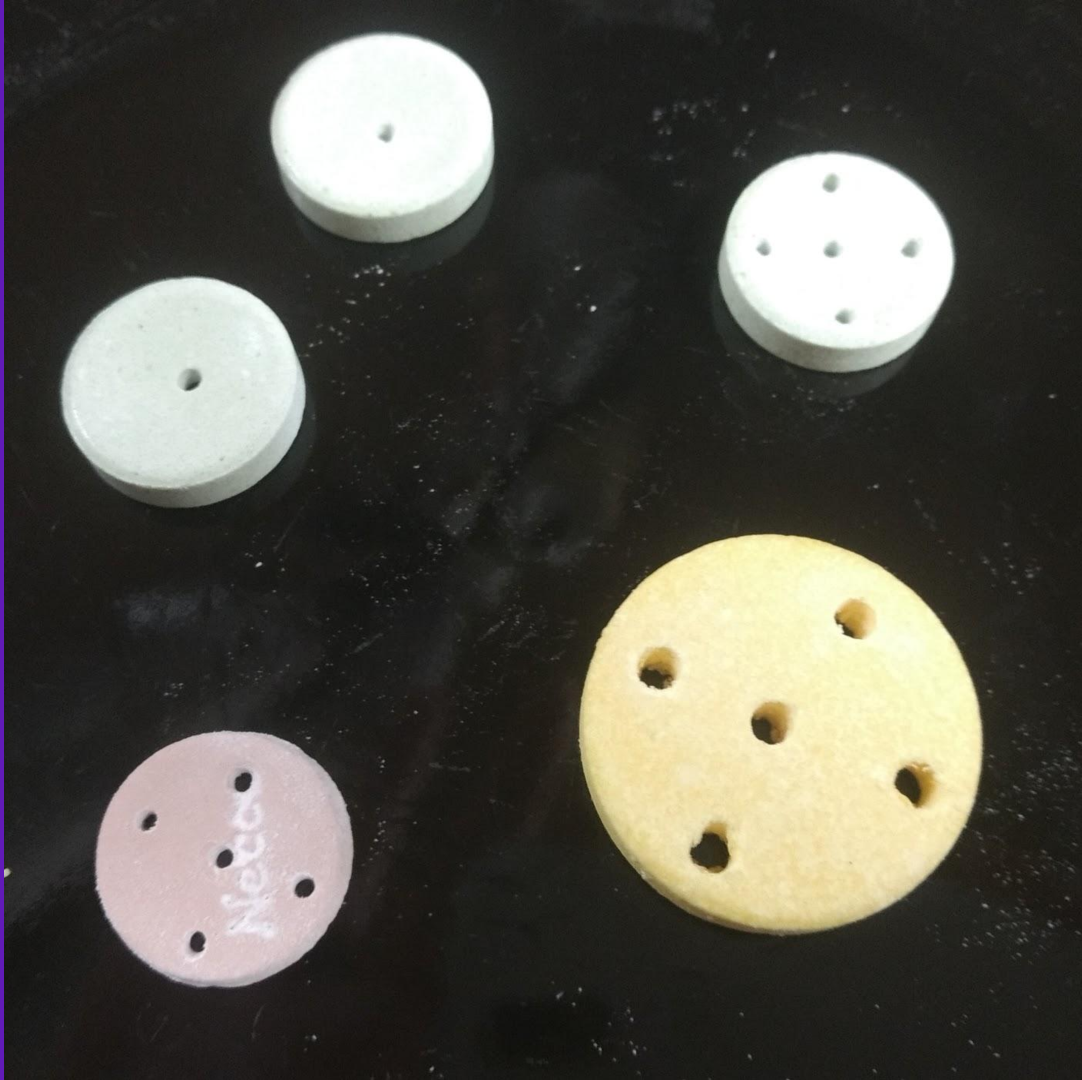
Planned testing for assessment of homemade edible gels

- Durometer
- Elasticity
- Flexibility
- Durability

Store-bought Materials

American Smarties (XL), Necco wafer, Chewy Sweet Tart: Electric drill for hybrid robotics (soft/hard together)

American Smarties (XL), Necco wafer, Chewy Sweet Tart: Clean and durable holes in a variety of sizes.



Pop Rocks: Does not provide significant chemical reaction (aka a negative result is also a result)

Gummi Cola (Haribo): Microwavable or other heating methods

Fruit Leather: Air tight and provides moderately effective self-seal

Dried Mango and Red Vines (licorice): Great performance for pulling strength, retaining knots, and flexibility.

Red Vines (licorice): Excellent source of airtight tubing, also has good flex properties

1st Iteration: Wide Field

- One rapid iteration each of ALL promising materials
- Quantify and Assess across the field

Planned approaches to actuation for 1st round iteration:

- Cable controlled
- Pneumatic
- Hydraulic
- Chemical Reaction

Cable: (Kind of) Working Candy Actuator!

Cable controlled: Assessments/Conclusions

Lubricants:

- Oil creates a sticky gummy surface
  - Oops! Sugar dissolves in moisture
  - Water and juice would face similar problems
- Corn Starch
  - Creates paste with cycling
- Confectioner's Sugar
  - Most promising, need further tests

2nd Iteration: Narrowed Field

- One rapid iteration each of most promising materials
- Quantify and Assess across the field

2nd Iteration Narrowed Field

TBD

- On rapid iteration each of most promising materials
- Quantify and Assess across the field

Repeat Iterations Until Specifications Met

- Specs met?
  - No - Assess and Iterate!
  - Yes - Finished!

Repeat Iterations Unt[illegible] Specificat[illegible]ons[illegible] Met

TBD

Spe[illegible] met?

- [illegible]o - Assess and Iterate!
- [illegible]es - Finished!

Process for Working on Emerging Technology

Identify Project & Value Proposition

- What is it?
- Why is it worth your time?

History & State-of-the-Art

- Who is already doing the work?
- Related Fields
- Don't Reinvent the Wheel

Consult Experts

- Who counts as an expert?
- Go Broad and Deep
- Interdisciplinary is the most fruitful

Define Specs

- Testing & Evaluation Criteria
- How will you know when you're done?

Materials Exploration

- Survey possible materials
- Touch & Analyze
- Generate unedited list of possible solutions
- Play!

Narrowing Pathways Through Iteration

- 1st: Broad Field
- 2nd: Narrowed Field
- 3rd: Iterate Single Design Until Specs Met

Final thoughts...

- Design thinking or other known processes yield effective pathways through the unknown
- Focus on emerging fields wherever you find them!
  - exciting problems and interesting opportunities
- Reach out if you want to share or collaborate on edible robotics
  - Chemistry
  - Control systems for soft actuators
  - You tell me?!

Contact

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My other hats:
Soft Robotics
Space Suits
Costumes
Puppets