

# Project Notes:

## Project Title:

Name: Gandhi, Rishi

**Note Well:** There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

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## Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
Limited understanding of origami-inspired actuation mechanisms	Reading Onal, Wood & Rus (2013): An Origami-Inspired Approach to Worm Robots	PDF from IEEE Xplore	Aug 22, 2025
Unsure how foldable structures translate to continuous locomotion	Studied Tolley et al. (2014) soft-bodied crawling robot paper	IEEE Xplore, cited by Rus Lab publications	Sept 9, 2025
Lack of clarity on pneumatic actuation systems for soft robots	Analyzed Rus & Tolley (2015) overview paper on soft robotics design principles	ScienceDirect	Sept 26, 2025
Difficulty connecting foldability rules (Maekawa/Kawasaki) to 3D folding	Consulted Demaine & Hull (2021) work on higher-dimensional origami	Google Scholar and OrigamiUSA conference papers	Oct 4, 2025
Unclear how origami-inspired geometry can enable adaptive terrain response	Reviewed Felton et al. (2014) on foldable robots with terrain adaptability	IEEE Xplore	Nov 3, 2025

Limited understanding of how crease geometry affects stiffness and load bearing	Studied mechanical metamaterials literature on origami stiffness tuning	ASME Digital Collection and Nature Communications	Nov 18, 2025
Uncertainty in modeling fold kinematics for simulation purposes	Reviewed computational origami and folding kinematics papers	arXiv and ScienceDirect	Dec 2, 2025
Difficulty integrating actuation models (pneumatic/SMA) with origami geometry	Analyzed magneto-origami and SMA-origami hybrid papers	Nature Communications and Google Scholar	Dec 16, 2025



## Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.

List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Google Scholar	“origami-inspired soft robotics”, “Cagdas Onal worm robot”, “folding mechanisms in robotics”	Found important foundational papers, including <i>An Origami-Inspired Approach to Worm Robots</i> (Onal, Wood, Rus, 2013). Provided an overview of origami-based actuation mechanisms and flexible body locomotion.
<b>IEEE Xplore</b>	“soft robotics actuation”, “pneumatic origami robots”, “continuum robot modeling”	Identified technical discussions on actuation methods and control systems for compliant robots. Found related works by Daniela Rus and R. J. Wood expanding on soft actuation principles.
ScienceDirect	“folding kinematics”, “origami engineering”, “adaptive structures robotics”	Gathered papers linking origami mathematics and mechanical design, useful for developing geometric models and simulation frameworks.
Academia.edu	“Daniela Rus origami robots”, “Cagdas Onal soft robotics thesis”, “Robert Wood flexible actuation”	Found related publications and lab reports detailing experimental setups and control architectures used in early soft robot prototypes.
USPTO / Google Patents	“origami robot patent”, “foldable soft actuator”, “origami-based robotic structure”	Identified patents covering origami-inspired soft actuators, foldable robotic structures, and inverse origami design methods. These sources helped establish prior art and practical implementation strategies beyond academic prototypes.

arXiv	“computational origami”, “origami robot modeling”, “foldable metamaterials”	Found preprints on mathematical modeling, simulation, and algorithmic generation of crease patterns. Useful for exploring theoretical extensions and computational approaches not yet formalized in journals.
Nature / Nature Communications	“magneto-origami”, “origami soft machines”, “foldable robotic materials”	Located high-impact experimental papers demonstrating magnetically actuated origami robots and scalable fabrication methods. These sources emphasized material design, actuation integration, and real-world demonstrations.
ASME Digital Collection	“origami mechanisms”, “deployable structures robotics”, “mechanical metamaterials”	Found mechanical engineering–focused papers on deployable origami mechanisms, bistability, and stiffness tuning, relevant for understanding load-bearing and structural behavior in foldable robots.

## Tags:

Tag Name	




## Article #1 Notes: Title

Article notes should be on separate sheets

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<b>Source Title</b>	
<b>Source citation (APA Format)</b>	
<b>Original URL</b>	
<b>Source type</b>	
<b>Keywords</b>	
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	
<b>Research Question/Problem/ Need</b>	
<b>Important Figures</b>	
<b>VOCAB: (w/definition)</b>	
<b>Cited references to follow up on</b>	
<b>Follow up Questions</b>	

<b>Source Title</b>	4D Multiscale Soft Robotics: A Review
<b>Source citation (APA Format)</b>	Son, H., Park, Y., Na, Y., & Yoon, C. (2022). 4D Multiscale Origami Soft Robots: A Review. <i>Polymers</i> , 14(19), 4235. <a href="https://doi.org/10.3390/polym14194235">https://doi.org/10.3390/polym14194235</a>
<b>Original URL</b>	<a href="https://www.mdpi.com/2073-4360/14/19/4235">https://www.mdpi.com/2073-4360/14/19/4235</a>
<b>Source type</b>	Journal Article
<b>Keywords</b>	Soft actuators, intelligent systems, self-folding, stimuli-responsive, soft robotics
<b>#Tags</b>	#soft robotics, #self-folding
<b>Summary of key points + notes (include methodology)</b>	This article surveys the use of both origami and 4D printing techniques in the development of soft robots that can change shape over time in response to environmental stimuli (heat, pH, light, magnetic or pneumatic signals). Several stimuli-responsive materials such as hydrogels and polymers are discussed alongside different fabrication strategies. The applications of this technology range from soft actuators and grippers to biomedical devices. Several challenges are also addressed; precise control of the material in vivo, and untethered microscale actuation.
<b>Research Question/Problem/ Need</b>	How have multiscale origami-inspired structures using stimuli-responsive 4D materials advanced the design, fabrication, and application of shape-transformable soft robots?
<b>Important Figures</b>	 <p>Hydrogel bilayer, shown to be responsive to both changes in temperature and pH.</p>
<b>VOCAB: (w/definition)</b>	<p>Actuator - a machine that moves or controls components in a system by converting energy into physical motion.</p> <p>Microscale - very small and detailed scale, usually under 1mm.</p> <p>Hydrogel - a gel in which the liquid component is water.</p>

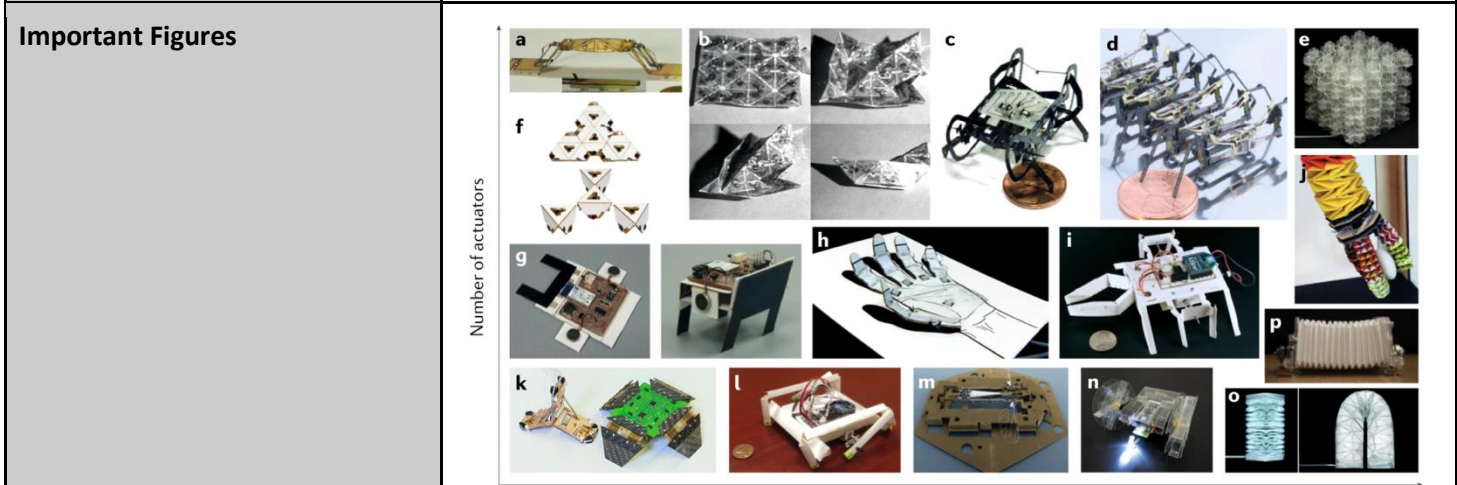
<b>Cited references to follow up on</b>	<p>Hines, L.; Petersen, K.H.; Lum, G.Z.; Sitti, M. Soft Actuators for Small-Scale Robotics. <i>Adv. Mater.</i> <b>2017</b>, <i>29</i>, 1603483.</p> <p>Rus, D.; Tolley, M.T. Design, fabrication and control of origami robots. <i>Nat. Rev. Mater.</i> <b>2018</b>, <i>3</i>, 101–112.</p> <p>Ding, M.; Jing, L.; Yang, H.; Machnicki, C.; Fu, X.; Li, K.; Wong, I.; Chen, P.-Y. Multifunctional soft machines based on stimuli-responsive hydrogels: From freestanding hydrogels to smart integrated systems. <i>Mater. Today Adv.</i> <b>2020</b>, <i>8</i>, 100088.</p>
<b>Follow up Questions</b>	<p>How can integrating sensors into origami soft robots enhance autonomous feedback control and adaptability in deployment?</p> <p>What combinations of stimuli-responsive materials optimize both actuation speed and mechanical strength?</p> <p>Can layering origami designs to form soft robotic systems that translate micro-scale movements to large-scale ones improve medical functionality?</p>

## Article #2 Notes: Design, fabrication and control of origami robots

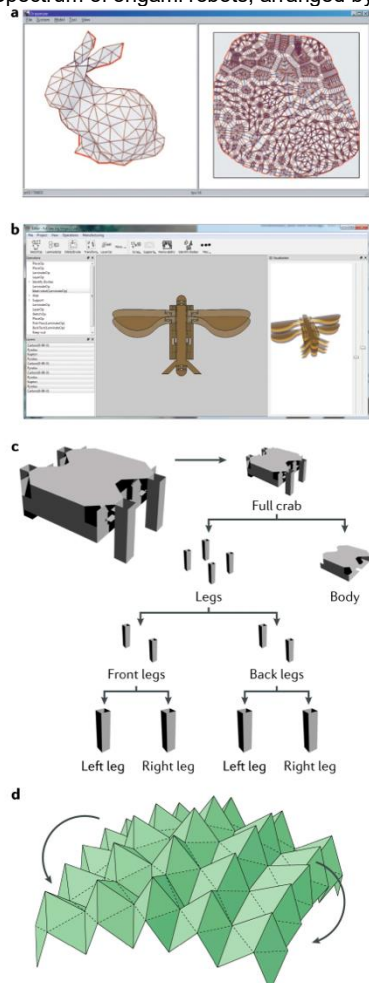
Article notes should be on separate sheets

<b>Source Title</b>	Design, fabrication and control of origami robots
<b>Source citation (APA Format)</b>	Rus, D., & Tolley, M. T. (2018). Design, fabrication and control of origami robots. <i>Nature Reviews Materials</i> , 3(6), 101–112. <a href="https://doi.org/10.1038/s41578-018-0010-8">https://doi.org/10.1038/s41578-018-0010-8</a>
<b>Original URL</b>	<a href="https://www.nature.com/articles/s41578-018-0010-8">https://www.nature.com/articles/s41578-018-0010-8</a>
<b>Source type</b>	Journal Article
<b>Keywords</b>	Origami robots, smart materials, actuation, design methods, folding mechanisms, control strategies
<b>#Tags</b>	#origami-robotics, #smart-materials, #design-frameworks
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>• This paper synthesizes developments in origami-inspired robotics, characterizing folding-based design as a “top-down” approach (starting from a flat sheet) compared to conventional “bottom-up” assembly.</li> <li>• The paper categorizes different approaches by actuation mechanism (thermal, pneumatic, magnetic, light) and by scale (macro to micro). For each, it discusses materials, control strategies, and trade-offs, such as speed, energy consumption, and precision.</li> <li>• It emphasizes integration. Combining mechanical, electrical, and computational elements so the crease pattern itself participates in the robot’s functionality (as a compliant joint or other function).</li> <li>• The authors highlight challenges in dealing with multi-layer fold interactions, precise control of fold angles under disturbances, and durability of folding structures in repeated deployment.</li> <li>• They also propose future directions, such as fully autonomous self-folding sheets, better simulation tools, and integration of sensors for feedback control.</li> </ul>

**Research Question/Problem/Need** How to systematically design foldable robots with integrated actuation and control such that folding is robust, repeatable, and functional in real-world settings?



Spectrum of origami robots, arranged by number of actuators and folds



Software design tools used to produce crease patterns from functional

	specifications.
<b>VOCAB: (w/definition)</b>	<ul style="list-style-type: none"> <li>• Compliant joint - a joint (hinge or flexure) that bends elastically rather than using rigid mechanical parts.</li> <li>• Multilayer folding - when parts of the sheet must fold over others, creating stacks; managing interference is nontrivial.</li> <li>• Actuation density - how many actuators per unit area or per fold; more density gives finer control but adds complexity/weight.</li> </ul>
<b>Cited references to follow up on</b>	<ul style="list-style-type: none"> <li>• Felton, S. M., Tolley, M. T., Demaine, E., Rus, D., &amp; Wood, R. J. (2014). Self-folding origami at any scale. <i>Science</i>, 345(6197), 644–646.</li> <li>• Onal, C. D., Tolley, M. T., Wood, R. J., &amp; Rus, D. (2015). Origami-Inspired Printed Robots. (PDF)</li> </ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"> <li>• Which actuation strategy provides the best trade-off of speed, energy efficiency, and precision in small-scale origami robots?</li> <li>• How can fold failure modes such as tearing, buckling, or fatigue be predicted via simulation in complex crease patterns?</li> <li>• Can an “origami design compiler” become mature enough for non-experts to design foldable robots systematically?</li> </ul>

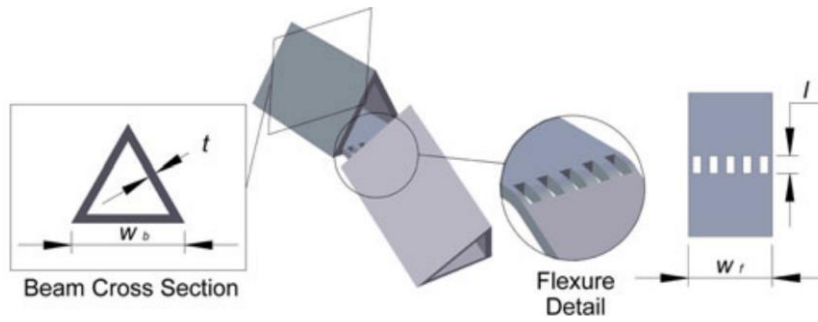
## Article #3 Notes: Origami-Inspired Printed Robots

Article notes should be on separate sheets

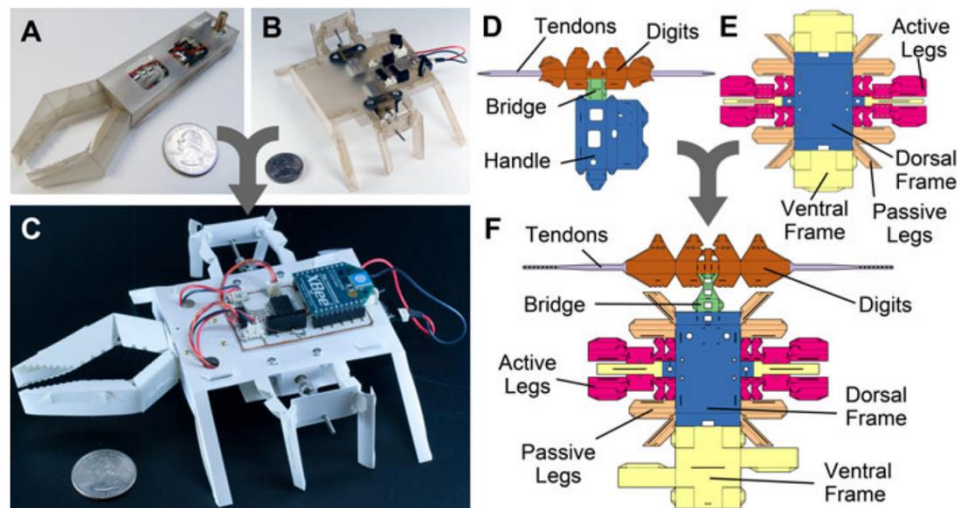
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<b>Source Title</b>	Origami-Inspired Printed Robots
<b>Source citation (APA Format)</b>	Onal, C. D., Tolley, M. T., Wood, R. J., & Rus, D. (2015). Origami-Inspired Printed Robots. <i>IEEE/ASME Transactions on Mechatronics</i> , 20(5).
<b>Original URL</b>	<a href="https://dspace.mit.edu/handle/1721.1/101026">https://dspace.mit.edu/handle/1721.1/101026</a>
<b>Source type</b>	Journal Article
<b>Keywords</b>	Printable robots, laminate fabrication, electromechanical integration, origami folding
<b>#Tags</b>	#printable-robotics, #laminate-fabrication, #integrated-design
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>• This paper proposes a printable robot; an integrated electromechanical laminate is fabricated in planar form, then fold-assembled into a 3D robot via origami techniques.</li> <li>• The authors present prototypes, such as a legged robot or a robotic manipulator, built from a single sheet combining mechanical substrate and printed circuits. After folding, embedded actuators (shape memory alloys, microlinear servos) and electronics drive locomotion or manipulation.</li> <li>• Methodology includes a tab-and-slot scheme to lock folds, bridging folds to route wiring, and integrated crease-hinge design to support mechanical strength.</li> <li>• Performance metrics: fabrication speed (&lt; 3 hours), cost (low), and functional demonstration (walking, grasping) are shown.</li> </ul>
<b>Research Question/Problem/ Need</b>	How to reduce fabrication complexity and increase integration so that foldable robots are accessible, modular, and functionally capable?

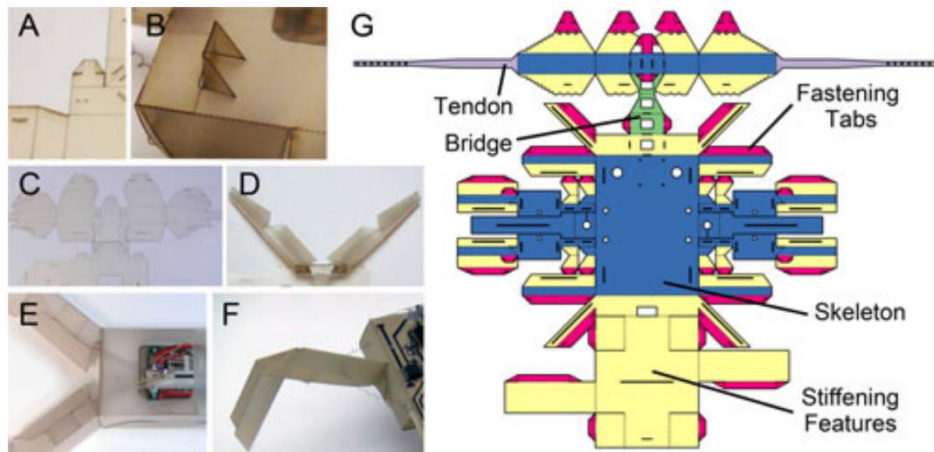
Important Figures



Cross-sections of hinge and fold locking features.



Fold pattern diagrams mapping 2D layout to 3D robot.



Crease pattern with methods of construction highlighted.

<b>VOCAB: (w/definition)</b>	<ul style="list-style-type: none"><li>• Laminate fabrication - building a layered structure combining structural, electrical, and actuation layers in planar form.</li><li>• Tab-and-slot locking - a mechanical fastener scheme where tabs on one part insert into slots on another, locking folds in place manually or by elastic tension.</li></ul>
<b>Cited references to follow up on</b>	<ul style="list-style-type: none"><li>• Felton et al., "Self-folding origami at any scale."</li><li>• Rus &amp; Tolley, "Design, fabrication and control of origami robots."</li><li>• Methods in shape-memory composite actuators in origami robotics.</li></ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"><li>• How to generalize the tab-and-slot scheme to more complex 3D topologies without collisions or material interference?</li><li>• Can fold patterns self-correct misalignment during folding?</li><li>• How to achieve actuation without external wiring (such as wireless power or integrated batteries) in such folded structures?</li></ul>

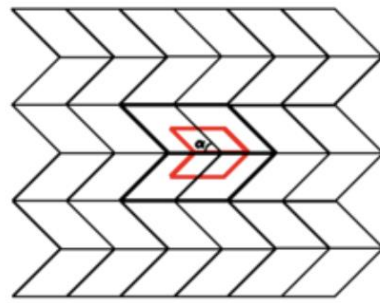
# Article #4 Notes: Elastic Theory of Origami-Based Metamaterials

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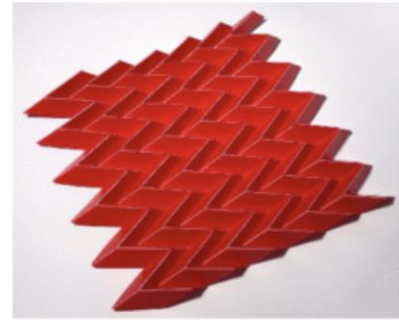
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<b>Source Title</b>	Elastic Theory of Origami-Based Metamaterials
<b>Source citation (APA Format)</b>	Brunck, V., Tancogne-Dejean, T., & Guest, S. D. (2016). Elastic theory of origami-based metamaterials. <i>Physical Review E</i> , 93(033005). <a href="https://doi.org/10.1103/PhysRevE.93.033005">https://doi.org/10.1103/PhysRevE.93.033005</a>
<b>Original URL</b>	<a href="https://link.aps.org/doi/10.1103/PhysRevE.93.033005">https://link.aps.org/doi/10.1103/PhysRevE.93.033005</a>
<b>Source type</b>	Journal Article
<b>Keywords</b>	Origami metamaterials, elasticity, crease stiffness, mechanical response
<b>#Tags</b>	#metamaterials, #mechanical-behavior, #elastic-modeling
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>• Authors develop an elastic continuum theory to describe how origami-based metamaterials respond under loading. They model creases as rotational springs and panels as rigid facets connected by the springs.</li> <li>• Using linear elasticity approximations, they derive effective stiffness of the macrostructure as a function of crease stiffness and geometry.</li> <li>• They simulate and compare behavior across different crease network topologies to show how geometry tunes global stiffness and Poisson's ratio.</li> <li>• The model helps explain why origami metamaterials can display negative Poisson's ratio (auxetic behavior) or anisotropic stiffness.</li> </ul>
<b>Research Question/Problem/ Need</b>	How can we predict the mechanical behavior of foldable structures under external loads, and use that to optimize crease designs for desired stiffness or deformation behavior?

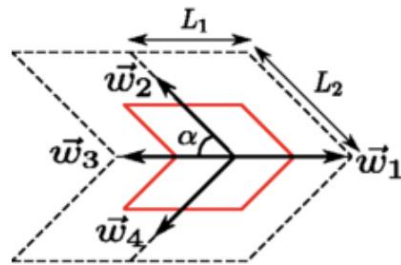
Important Figures



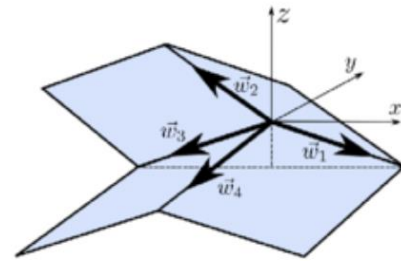
(a)



(b)

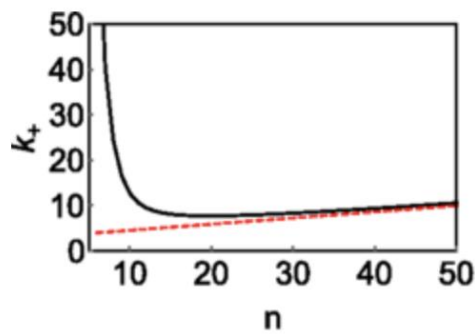


(c)

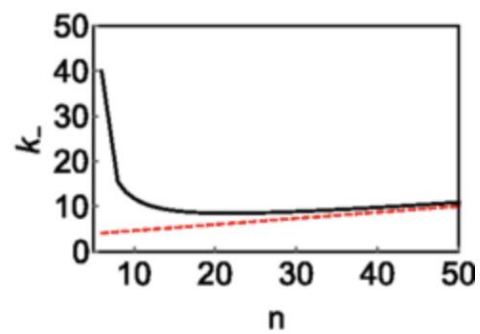


(d)

A model of a periodic origami tessellation under compression and shear.



(a) (+) solution



(b) (-) solution

Graphs showing stiffness vs. crease stiffness for various topologies.

VOCAB: (w/definition)

- Metamaterial - engineered structure whose mechanical (or electromagnetic, etc.) properties derive from geometry rather than just material composition.
- Auxetic behavior - when a material expands laterally (perpendicular direction) when stretched, i.e. negative Poisson's ratio.

	<ul style="list-style-type: none"><li>• Rotational spring model — modeling each crease as a torsional spring with stiffness coefficient.</li></ul>
<b>Cited references to follow up on</b>	<ul style="list-style-type: none"><li>• Guest, S. D. papers on origami metamaterials</li><li>• Tachi, T., work on rigid-foldable origami</li><li>• Rus &amp; Tolley, “Design, fabrication and control of origami robots.”</li></ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"><li>• Can this elastic model be extended to nonlinear regimes like large deformations or buckling?</li><li>• How does crease fatigue over repeated cycles affect global stiffness?</li><li>• How to integrate actuation like shape memory unfolding into this elastic framework to predict dynamic response?</li></ul>

## Article #5 Notes: A Review on Origami Simulations: From Kinematics to Dynamics

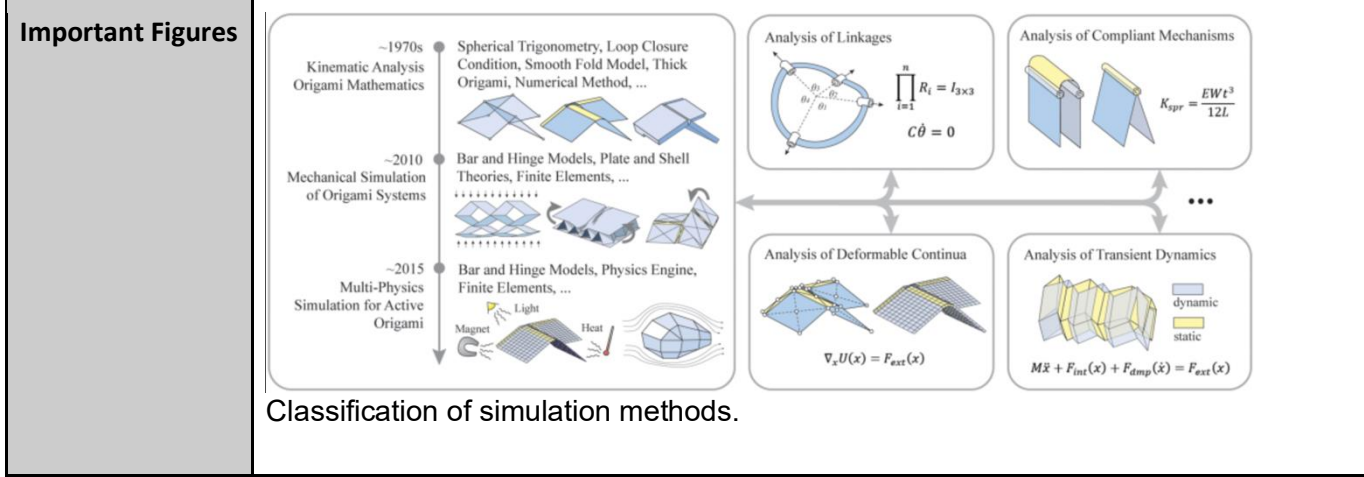
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<b>Source Title</b>	A Review on Origami Simulations: From Kinematics to Dynamics
<b>Source citation (APA Format)</b>	Zhu, Y., Schenk, M., and Filipov, E. T. (August 16, 2022). "A Review on Origami Simulations: From Kinematics, To Mechanics, Toward Multiphysics." ASME. <i>Appl. Mech. Rev.</i> May 2022; 74(3): 030801. <a href="https://doi.org/10.1115/1.4055031">https://doi.org/10.1115/1.4055031</a>
<b>Original URL</b>	<a href="https://asmedigitalcollection.asme.org/appliedmechanicsreviews/article/74/3/030801/1143221/A-Review-on-Origami-Simulations-From-Kinematics-To">https://asmedigitalcollection.asme.org/appliedmechanicsreviews/article/74/3/030801/1143221/A-Review-on-Origami-Simulations-From-Kinematics-To</a>
<b>Source type</b>	Review Article
<b>Keywords</b>	Origami simulation, kinematics, dynamics, finite element modeling, multi-physics
<b>#Tags</b>	#origami-sim, #computational-methods, #dynamics
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>• This review surveys computational techniques for simulating origami behavior, from rigid-body kinematic folding to continuum shell models and finite element/dynamic simulations.</li> <li>• It categorizes methods as: <ul style="list-style-type: none"> <li>○ geometric (paper-folding algorithms)</li> <li>○ mechanical (spring models / continuum mechanics)</li> <li>○ multi-physics coupling (thermal, electrostatic)</li> </ul> </li> <li>• Strengths and limitations of each are compared. Geometric methods are fast but ignore material stresses; mechanical models capture deformation but are computationally heavy; dynamic simulations allow time-dependent behaviors like folding under actuation.</li> </ul>

- The review documents benchmark problems used in the community and suggests standard datasets and tools.

**Research Question/Problem/ Need**  
 How can simulation tools be improved in fidelity, speed, and usability to guide origami robot design rather than post-facto verification?



**VOCAB: (w/definition)**

- Kinematics - study of motion without regard to forces.
- Dynamics - study of motion including forces and inertia.
- Continuum model - treating sheet as a continuous medium rather than discrete hinges and panels.

**Cited references to follow up on**

- Tachi, T. work on rigid origami simulation
- Rus & Tolley review
- Brunck et al., elastic origami models

**Follow up Questions**

- Can one build a hybrid simulation combining fast geometric folding plus local mechanical correction only where needed?
- How to validate simulation models with experimental measurement reliably?
- How to incorporate failure modes like crease fatigue or delamination into simulation pipelines?

## Article #6 Notes: Rigid-Foldability and Mountain-Valley Crease Assignments of Square-Twist Origami Pattern

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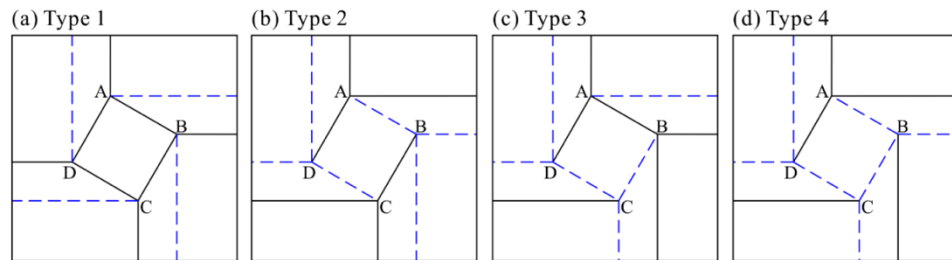
<b>Source Title</b>	Rigid-Foldability and Mountain-Valley Crease Assignments of Square-Twist Origami Pattern
<b>Source citation (APA Format)</b>	Feng, H., Peng, R., Zang, S., Ma, J., & Chen, Y. (2020). Rigid-Foldability and Mountain-Valley Crease Assignments of Square-Twist Origami Pattern. <i>arXiv preprint arXiv:2003.12921</i> .
<b>Original URL</b>	<a href="https://arxiv.org/abs/2003.12921">https://arxiv.org/abs/2003.12921</a>
<b>Source type</b>	Preprint / Technical paper
<b>Keywords</b>	Rigid origami, square-twist pattern, mountain/valley assignment, kinematic analysis
<b>#Tags</b>	#rigid-origami, #kinematic-analysis, #crease-assignment
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>• Authors explore rigid foldability in the square-twist, which is used often in origami design. They analyze different possible mountain-valley (M-V) assignments and test which ones yield consistent rigid folding.</li> <li>• They use kinematic equivalences to model the origami as a network of spherical 4R linkages, deriving equations for fold compatibility. Two of four examined assignments are shown to be rigidly foldable; the other two are not, unless creases are added or modified.</li> </ul>

- They propose a method of crease-addition to convert non-rigid versions into rigid ones. The paper also discusses bifurcations (how small changes in assignment cause sudden change in possible folding pathways).

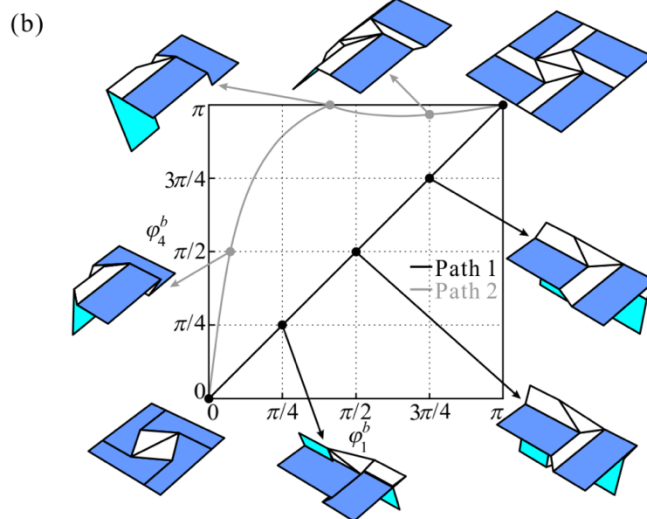
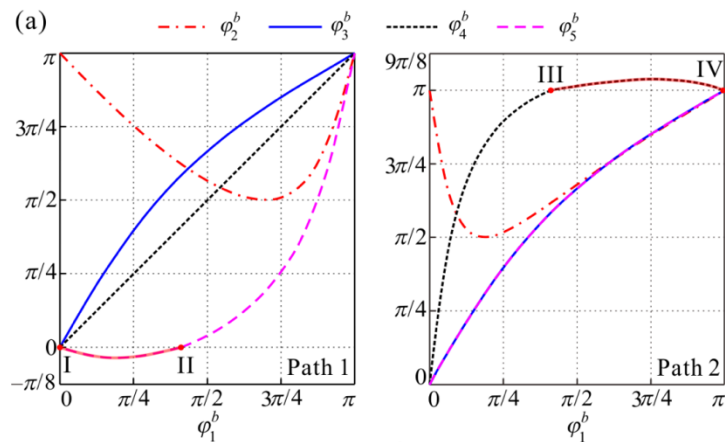
**Research Question/Problem/ Need**

Under what conditions does a given crease assignment yield rigid foldability? And how can one adjust assignments or add creases to force rigidity?

**Important Figures**



Diagrams of square-twist patterns with different M-V assignments.



Plots showing folding bifurcation thresholds.

<b>VOCAB: (w/definition)</b>	<ul style="list-style-type: none"><li>• Mountain fold - fold such that crease protrudes upward (like a mountain ridge).</li><li>• Valley fold - crease folds inward (like a valley).</li><li>• Rigid-foldability - the property that panels remain undeformed (pure rotation about crease lines) during folding motion.</li><li>• Bifurcation: a splitting of possible solutions or motion trajectories when parameters cross threshold.</li></ul>
<b>Cited references to follow up on</b>	<ul style="list-style-type: none"><li>• Tachi's work on rigid origami</li><li>• Rus &amp; Tolley review for general origami robotics integration</li><li>• Other studies on crease assignment algorithms</li></ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"><li>• Can similar analysis be done for more complex patterns like multi-vertex or higher-degree crease networks?</li><li>• How sensitive is rigid foldability to small perturbations?</li><li>• Can one systematically suggest crease additions to repair non-rigid designs?</li></ul>

## Article #7 Notes: Origami-based Integration of Robots that Sense, Decide, and Act

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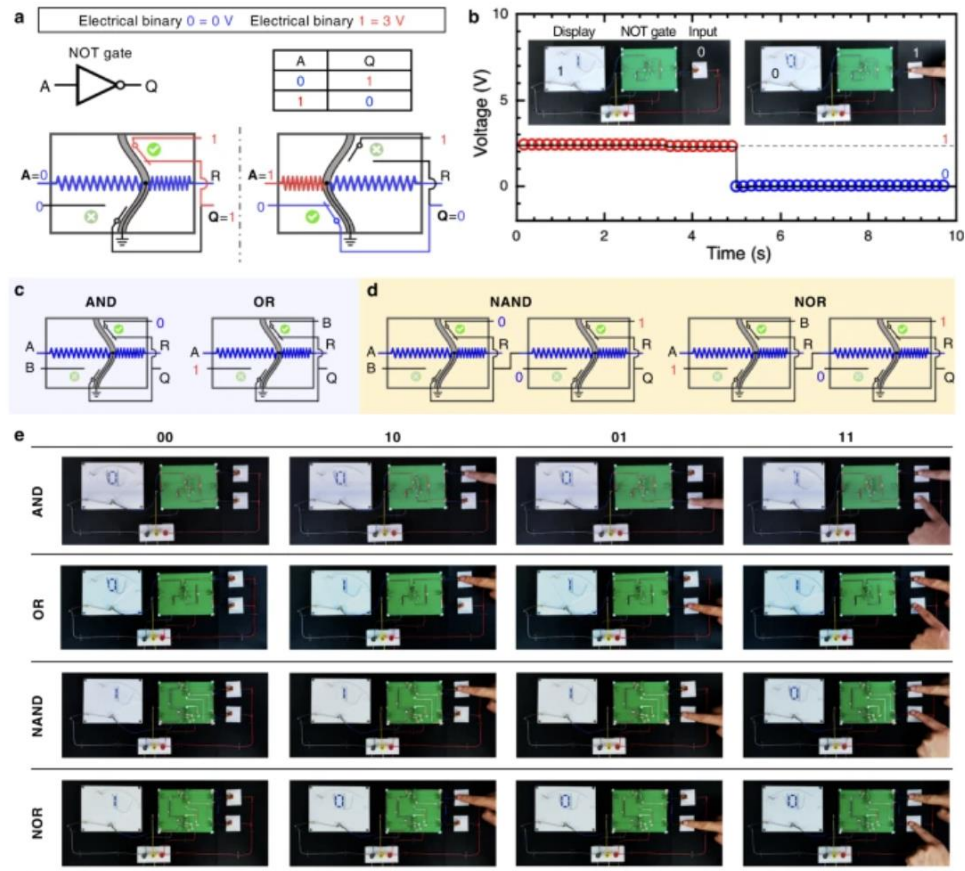
<b>Source Title</b>	Origami-based Integration of Robots that Sense, Decide, and Act
<b>Source citation (APA Format)</b>	Yan, W., Li, S., Deguchi, M., Zheng, Z., Rus, D., & Mehta, A. (2023). Origami-based integration of robots that sense, decide, and respond. <i>Nature communications</i> , 14(1), 1553. <a href="https://doi.org/10.1038/s41467-023-37158-9">https://doi.org/10.1038/s41467-023-37158-9</a>
<b>Original URL</b>	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC10070436/">https://pmc.ncbi.nlm.nih.gov/articles/PMC10070436/</a>
<b>Source type</b>	Journal Article
<b>Keywords</b>	Robotic integration, sensing, computing, actuation, origami substrates
<b>#Tags</b>	#origami-integration, #embedded-systems, #autonomous-folding
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>• Paper demonstrates a framework for embedding sensing, decision-making, and actuation into a single origami foldable substrate, moving beyond mechanical folding into functional autonomous robots.</li> <li>• Uses compliant conductive materials and foldable electronics so that folds become part of circuitry paths or sensor paths.</li> </ul>

- Prototypes include foldable robots where decision logic and sensors are built into the folds themselves.
- Emphasis on co-design, meaning mechanical, electrical, and computational aspects must be designed in tandem.

**Research Question/Problem/ Need**

How to build origami robots that are not just foldable, but smart, able to sense environment, compute responses, and actuate accordingly, all in one folded structure?

**Important Figures**



Structure of origami logic gates

**VOCAB: (w/definition)**

- Compliant conductive material - a material that is electrically conductive while able to flex or bend.
- Co-design - designing multiple subsystems (mechanical, electrical, computational) in an integrated fashion rather than sequentially.

<b>Cited references to follow up on</b>	<ul style="list-style-type: none"> <li>• Rus &amp; Tolley review</li> <li>• Onal et al. printable robots</li> <li>• Works on foldable electronics and soft circuits</li> </ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"> <li>• How to design fold patterns that preserve signal integrity across folds?</li> <li>• How to test durability of fold-embedded circuits over many cycles?</li> <li>• Can energy harvesting (piezoelectric, flexible photovoltaics) be integrated into origami robots to power embedded electronics?</li> </ul>

## Article #8 Notes: Reprogrammable Curved-Straight Origami

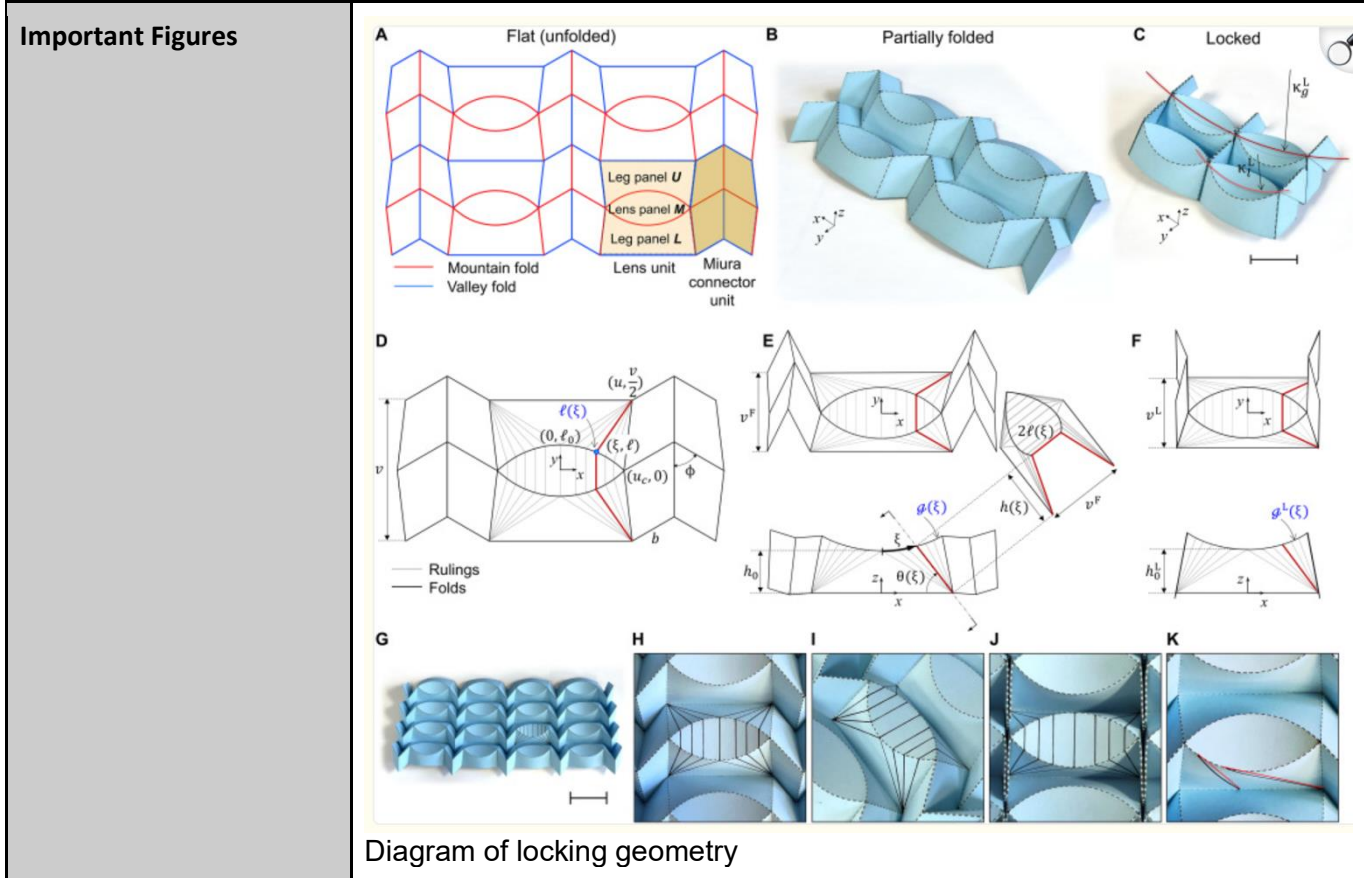
Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Reprogrammable Curved-Straight Origami
<b>Source citation (APA Format)</b>	Mirzajanzadeh, M., & Pasini, D. (2025). Reprogrammable curved-straight origami: Multimorphability and volumetric tunability. <i>Science advances</i> , <i>11</i> (17), eadu4678. <a href="https://doi.org/10.1126/sciadv.adu4678">https://doi.org/10.1126/sciadv.adu4678</a>
<b>Original URL</b>	<a href="https://pmc.ncbi.nlm.nih.gov/articles/PMC12017307/">https://pmc.ncbi.nlm.nih.gov/articles/PMC12017307/</a>
<b>Source type</b>	Journal / PMC (full text)
<b>Keywords</b>	Curved-crease origami, bistability, reconfigurable folding
<b>#Tags</b>	#curved-crease, #reprogrammable, #bistability
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Introduces a hybrid origami design combining curved creases and straight creases to yield reprogrammable folding behavior: the same sheet can switch between multiple folded forms.</li> </ul>

- The curved creases confer flexibility and allow smooth transition between states, while straight creases impose rigid constraints, giving controllability.
- The authors demonstrate bistability and reversible switching between them. This is relevant to deployable systems or shape-morphing structures.

**Research Question/Problem/ Need** How to design crease networks that allow not just a single deployment shape, but reprogrammable or multi-stable folding states?



**VOCAB: (w/definition)**

- Curved crease: a crease not along a straight line; allows continuous curvature in folding.
- Bistability: having two stable equilibria or configurations.
- Reprogrammable origami: foldable systems whose final shape can be “reassigned” or switched dynamically.

**Cited references to follow up on**

- Karami, A. et al., “Curved-Crease Origami for Morphing Metamaterials.”

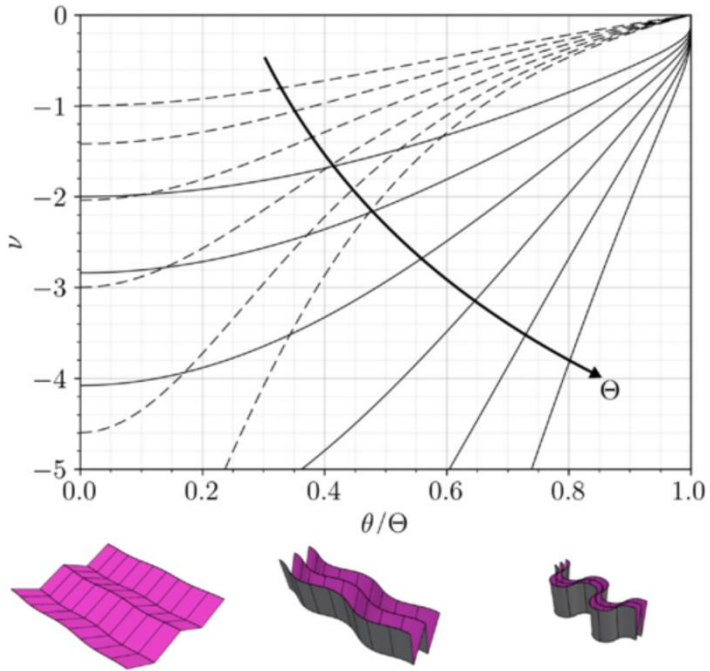
	<ul style="list-style-type: none"> <li>- Rus &amp; Tolley (origami robots)</li> <li>- Momeni et al. (4D printing reviews)</li> </ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"> <li>• Can curved-straight origami designs be integrated with actuation to switch states dynamically?</li> <li>• How to predict energy barriers and stability margins for switching?</li> <li>• Can these designs scale up for use in macro structures rather than small robots?</li> </ul>

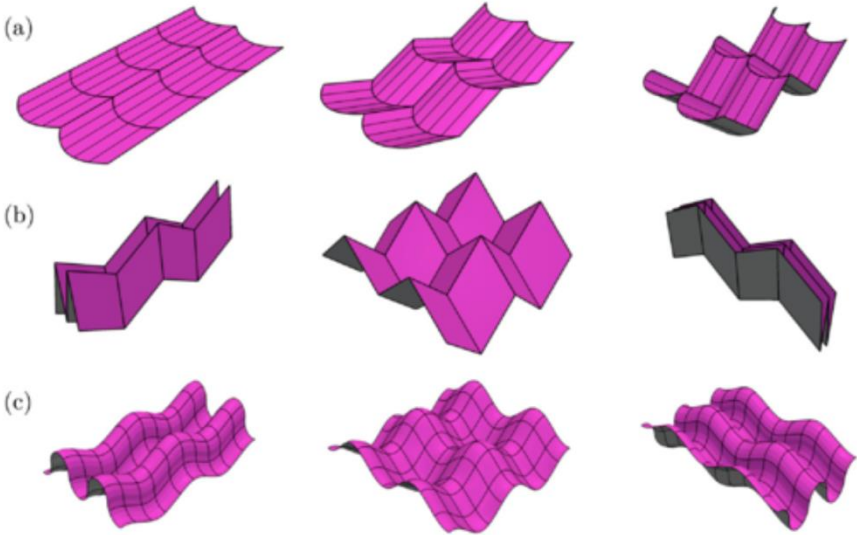
## Article #9 Notes: Curved-Crease Origami for Morphing Metamaterials

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Curved-Crease Origami for Morphing Metamaterials
<b>Source citation (APA Format)</b>	Karami, A., Lee, S.-W., & Overvelde, J. (2024). Curved-Crease Origami for Morphing Metamaterials. <i>Physical Review Letters</i> , 132(108201). <a href="https://doi.org/10.1103/PhysRevLett.132.108201">https://doi.org/10.1103/PhysRevLett.132.108201</a>
<b>Original URL</b>	<a href="https://link.aps.org/doi/10.1103/PhysRevLett.132.108201">https://link.aps.org/doi/10.1103/PhysRevLett.132.108201</a>
<b>Source type</b>	Journal Article
<b>Keywords</b>	Curved crease origami, morphing metamaterials, Poisson's ratio, mechanical tunability
<b>#Tags</b>	#curved-origami, #metamaterials, #morphing-structures
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- The authors propose curved-crease variants of the Miura-ori tessellation and derive closed-form expressions for mechanical properties such as Poisson's ratio in these systems.</li> </ul>

	<ul style="list-style-type: none"> <li>- Their models and experiments show that by adjusting the curvature parameters, one can tune mechanical response (expansion, contraction) and enable morphing of the structure under load.</li> <li>- They demonstrate prototype sheets that morph shape under external load, confirming theoretical predictions.</li> </ul>
<b>Research Question/Problem/ Need</b>	How to design crease curvature parameters to control mechanical behavior and shape-morphing in origami metamaterials?
<b>Important Figures</b>	 <p>Poisson's ratio, shown to correspond to relative folding angle of the Miura – ori tessellation.</p>

	 <p>Isometric deformation of various surfaces of translations.</p>
<b>VOCAB: (w/definition)</b>	<ul style="list-style-type: none"> <li>- Morphing metamaterial: a metamaterial that can change shape or mechanical response under stimulus.</li> <li>- Poisson's ratio: the negative ratio of transverse to axial strain.</li> <li>- Curvature parameter: a geometric parameter controlling how curved the crease is relative to straight.</li> </ul>
<b>Cited references to follow up on</b>	<ul style="list-style-type: none"> <li>• Mirzajanzadeh et al., reprogrammable curved-straight origami</li> <li>- Brunck et al., elastic origami models</li> </ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"> <li>- Can we embed actuation or control so the morphing is commanded?</li> <li>- How does the presence of multiple curved crease designs in the same network interact or interfere?</li> <li>- What is the fatigue behavior of curved creases under repeated morphing cycles?</li> </ul>

## Article #10 Notes: Exactly Solvable Flat-Foldable Quadrilateral Origami Tilings

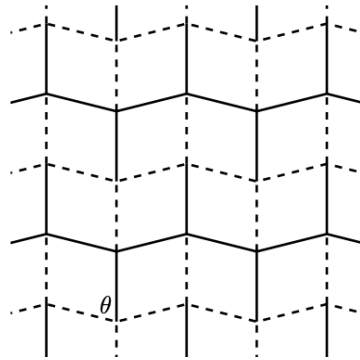
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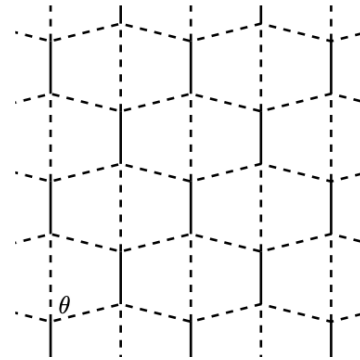
<b>Source Title</b>	Exactly Solvable Flat-Foldable Quadrilateral Origami Tilings
<b>Source citation (APA Format)</b>	Assis, M. (2017). Exactly solvable flat-foldable quadrilateral origami tilings. <i>arXiv preprint arXiv:1705.04710</i> .
<b>Original URL</b>	<a href="https://arxiv.org/abs/1705.04710">https://arxiv.org/abs/1705.04710</a>
<b>Source type</b>	Technical Paper

<b>Keywords</b>	Flat-foldable tilings, quadrilateral meshes, crease defects, statistical models
<b>#Tags</b>	#origami-tilings, #statistical-mechanics, #flat-foldability
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Author models certain quadrilateral origami tessellations, such as Miura-ori, as exactly solvable statistical models. The crease states (mountain/valley or crease reversal defects) are treated like spin variables in lattice models.</li> <li>- Using analogies to known solvable models like eight vertex, three coloring lattice models, the paper derives analytic expressions for defect densities and phase transitions in crease networks.</li> <li>- Mechanical properties of origami metamaterials can be tuned by controlling defect densities or crease ordering.</li> </ul>
<b>Research Question/Problem/ Need</b>	How do local crease defects or reversals propagate and influence global foldability and mechanical behavior in large origami tilings?

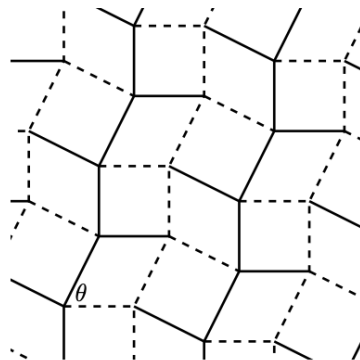
## Important Figures



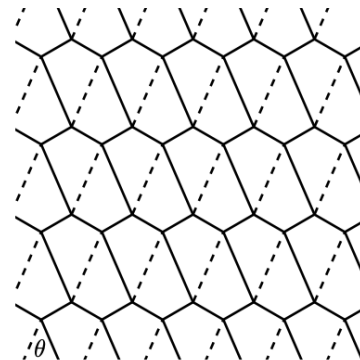
(a) The Miura-ori CP.



(b) The trapezoid CP.

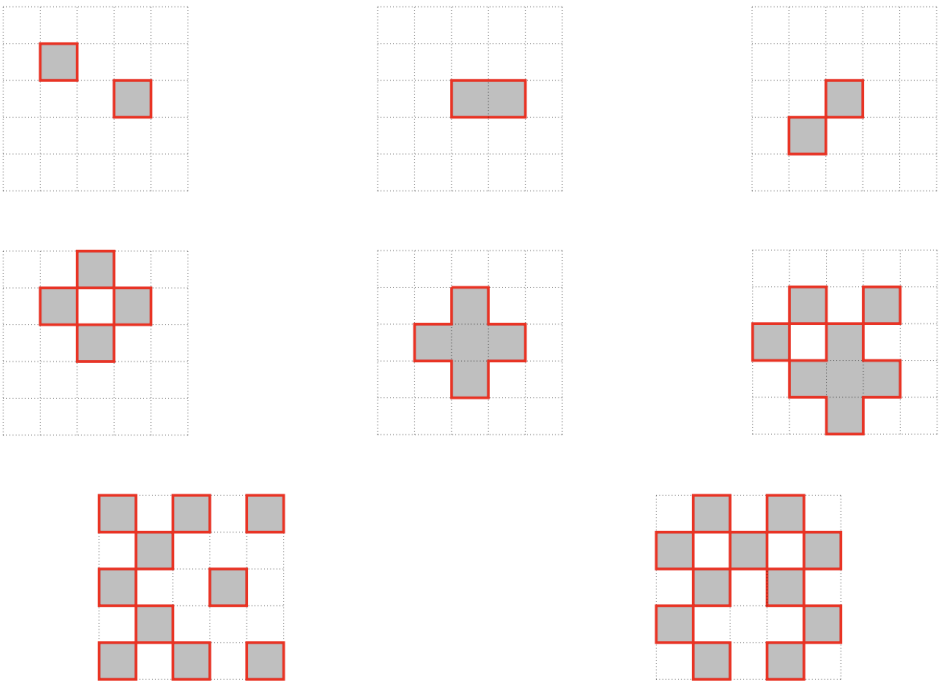


(c) Barreto's Mars CP.



(d) The kite CP.

Five replicable crease patterns with structural integrity (excludes simple square tiling)

	 <p>Diagram showing face-flip defect configurations, from high to low density. Solid red lines represent crease reversal for Miura-ori, Barreto's Mars (only diamond faces), and simple square (top middle is only configuration that can occur in simple square).</p>
<b>VOCAB: (w/definition)</b>	<ul style="list-style-type: none"> <li>- Defect: a crease that is “reversed” relative to the ground (intended) folding assignment, i.e. a mountain is a valley or vice versa.</li> <li>- Phase transition: a sudden change in global behavior (many creases flipping) when a parameter passes threshold.</li> <li>- Exactly solvable: models for which closed-form analytical expressions (not purely numerical) exist.</li> </ul>
<b>Cited references to follow up on</b>	<ul style="list-style-type: none"> <li>- Brunck et al. (elastic origami models)</li> <li>- Demaine &amp; Demaine works on computational origami</li> </ul>
<b>Follow up Questions</b>	<ul style="list-style-type: none"> <li>- How can these statistical/defect models assist in the robust design of crease layouts to minimize failure under variation?</li> <li>- Can one measure defect densities experimentally and relate them to folded mechanical behavior?</li> </ul>

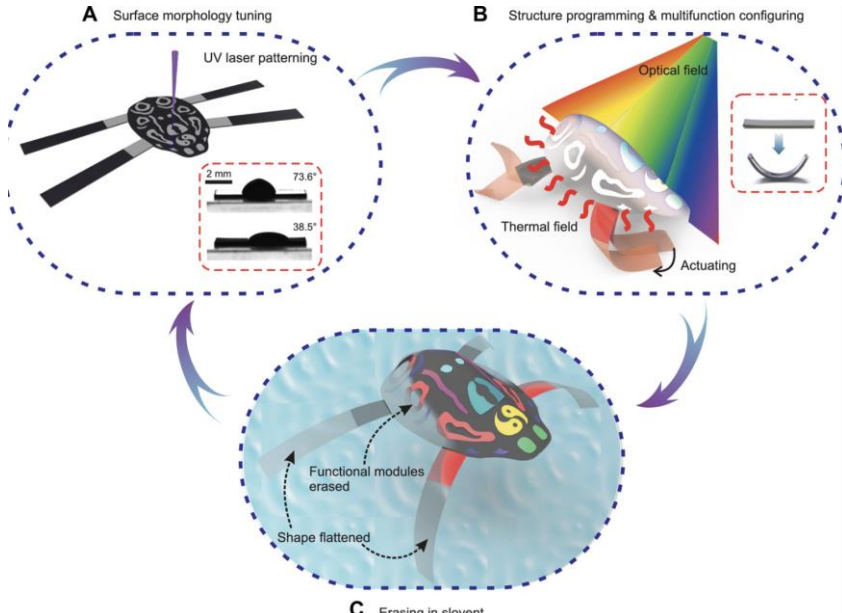
- |  |   |
|--|---|
|  | - How do boundary conditions (edges, added cuts) disrupt the ideal infinite-lattice models? |
|--|---|

## Article #11 Notes: **Programmable and reprocessable multifunctional elastomeric sheets for soft origami robots**

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Programmable and reprocessable multifunctional elastomeric sheets for soft origami robots
<b>Source citation (APA Format)</b>	Zhang, S., Ke, X., Jiang, Q., Wu, Z., & Shepherd, R. F. (2021). <i>Programmable and reprocessable multifunctional elastomeric sheets for soft origami robots</i> . Science Robotics, 6(56), eabd6107. <a href="https://doi.org/10.1126/scirobotics.abd6107">https://doi.org/10.1126/scirobotics.abd6107</a>
<b>Original URL</b>	<a href="https://www.science.org/doi/10.1126/scirobotics.abd6107">https://www.science.org/doi/10.1126/scirobotics.abd6107</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	Soft robotics, origami robots, elastomeric sheets, reconfigurable structures
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Paper presents multifunction sheets made from elastomers that can be programmed to deform into origami structures. The sheets can be reheated and reprocessed.</li> <li>- Researchers embed heat responsive pathways into the sheet and apply spatially localized heating for fold angles.</li> <li>- Robots can crawl, grasp, and shape change.</li> <li>- Robots are fabricated from sheets with heat paths, programmed thermally for activation via heating, mechanical testing for reconfigurability, and lastly a demonstration of both crawling and morphing prototypes.</li> </ul>
<b>Research Question/Problem/Need</b>	How can soft robots be made reconfigurable, recyclable, and programmable with no rigid joints?

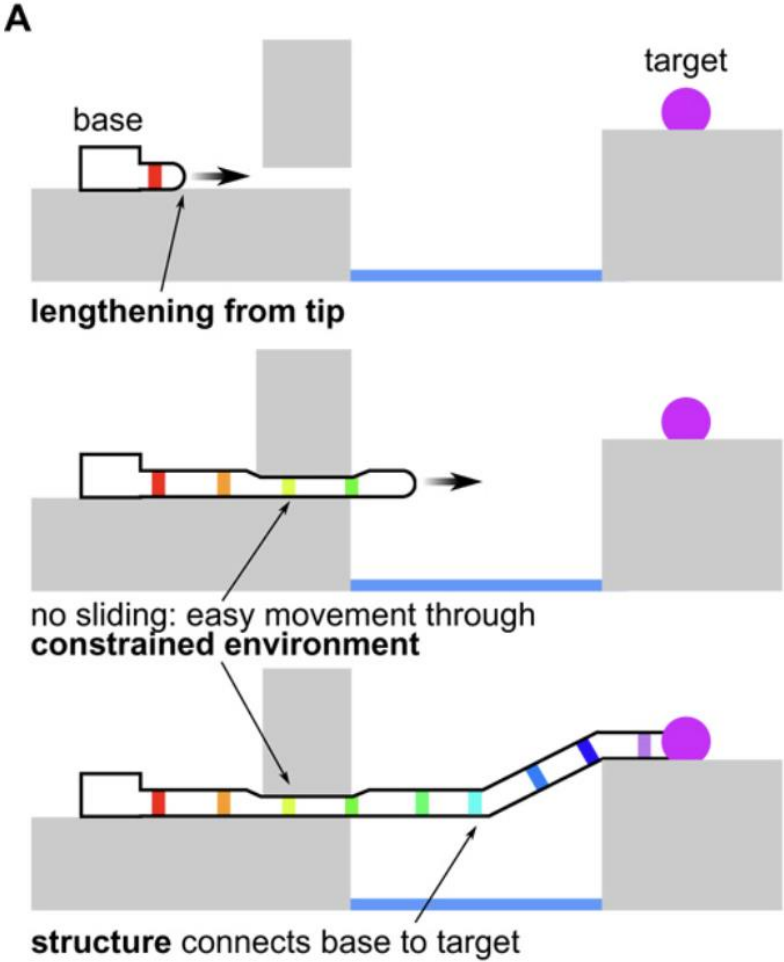
<p><b>Important Figures</b></p>	 <p><b>A</b> Surface morphology tuning UV laser patterning 2 mm 73.6° 38.5°</p> <p><b>B</b> Structure programming &amp; multifunction configuring Optical field Thermal field Actuating</p> <p><b>C</b> Erasing in solvent Functional modules erased Shape flattened</p> <p>Flowchart depicting thermal programming process – UV lasers are used to create heat pathways.</p>
<p><b>VOCAB: (w/definition)</b></p>	<p>Thermomechanical programming: Setting a desired shape by heating material and cooling it in position. Reprocessable elastomer: A polymer that can be reheated and reshaped.</p>
<p><b>Cited references to follow up on</b></p>	<p>E. W. Hawkes, L. H. Blumenschein, J. D. Greer, A. M. Okamura, A soft robot that navigates its environment through growth. <i>Sci. Robot.</i> 2, ean3028 (2017). Good example of a robot that uses a similar concept to move.</p>
<p><b>Follow up Questions</b></p>	<ul style="list-style-type: none"> <li>- Can SMA wires integrate into these elastomer sheets?</li> <li>- How might their fold-activation method compare with your SMA-driven origami crawler?</li> </ul>

## Article #12 Notes: A Soft Robot that Navigates Its Environment Through Growth

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	<i>A Soft Robot that Navigates Its Environment Through Growth</i>
<b>Source citation (APA Format)</b>	Hawkes, E. W., Blumenschein, L. H., Greer, J. D., & Okamura, A. M. (2017). <i>A soft robot that navigates its environment through growth</i> . <i>Science Robotics</i> , 2(8), eaan3028. <a href="https://doi.org/10.1126/scirobotics.aan3028">https://doi.org/10.1126/scirobotics.aan3028</a>
<b>Original URL</b>	<a href="https://www.science.org/doi/10.1126/scirobotics.aan3028">https://www.science.org/doi/10.1126/scirobotics.aan3028</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	Soft robotics, eversion, continuum robots
<b>#Tags</b>	#locomotion, #continuum-robotics
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Introduces a robot that moves by eversion, similar to plant growth</li> <li>- Instead of cyclic motion, pneumatic pressure is used to add extra length to robot and is steered via asymmetric pressure control</li> <li>- Robot is made of thin polymer tubes</li> <li>- Was tested in pressure-controlled environments for obstacle navigation</li> </ul>
<b>Research Question/Problem/Need</b>	How can a soft robot move through complex environments without relying on friction based crawling or articulated joints?

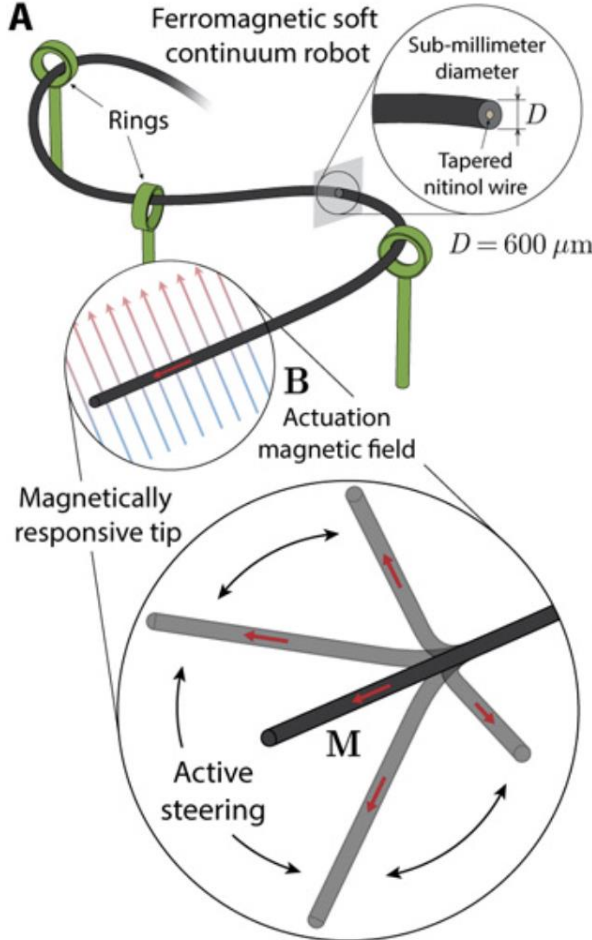
<p><b>Important Figures</b></p>	<p><b>A</b></p>  <p>base</p> <p>target</p> <p>lengthening from tip</p> <p>no sliding: easy movement through constrained environment</p> <p>structure connects base to target</p> <p>Figure 1. Depiction of robot locomotion. Only the end of the robot moves, so there is no relative movement of the body with respect to the environment.</p>
<p><b>VOCAB: (w/definition)</b></p>	<p>Eversion – turning material inside out as it extends forward          Continuum robot – a robot without discrete joints capable of smooth deformation</p>
<p><b>Cited references to follow up on</b></p>	<p>- Okamura lab work on continuum robots</p>
<p><b>Follow up Questions</b></p>	<p>0 Can origami crease patterns be embedded into growing robots?          How can growth based locomotion hybridize with fold based actuation?</p>

## Article #13 Notes: Ferromagnetic Soft Continuum Robots

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	<i>Ferromagnetic Soft Continuum Robots</i>
<b>Source citation (APA Format)</b>	Kim, Y., Parada, G. A., Liu, S., & Zhao, X. (2019). <i>Ferromagnetic soft continuum robots</i> . <i>Science Robotics</i> , 4(31), eaax7329. <a href="https://doi.org/10.1126/scirobotics.aax7329">https://doi.org/10.1126/scirobotics.aax7329</a>
<b>Original URL</b>	<a href="https://www.science.org/doi/10.1126/scirobotics.aax7329">https://www.science.org/doi/10.1126/scirobotics.aax7329</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	Magnetic actuation, ferromagnetism, control
<b>#Tags</b>	#soft-materials, #magnetic, #control
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Introduces soft robots embedded with hard magnetic particles that respond to external magnetic fields for motion and deformation, enabling wireless control</li> <li>- Magnetization profiles are programmed beforehand</li> <li>- Robot was tested in crawling, rolling, and bending states</li> </ul>
<b>Research Question/Problem/Need</b>	How can soft robots be actuated wirelessly without onboard power or tethered systems?

<p><b>Important Figures</b></p>	 <p><b>A</b> Ferromagnetic soft continuum robot Rings Sub-millimeter diameter Tapered nitinol wire <math>D = 600 \mu\text{m}</math></p> <p><b>B</b> Actuation magnetic field Magnetically responsive tip Active steering M</p>
<p><b>VOCAB: (w/definition)</b></p>	<p>Ferromagnetic – material that retains magnetization Untethered actuation – control without physical connection</p>
<p><b>Cited references to follow up on</b></p>	<ul style="list-style-type: none"> <li>- Origami robots using global actuation fields</li> </ul>
<p><b>Follow up Questions</b></p>	<p>How precise can magnetic folding control become? Can crease patterns encode magnetization logic?</p>

## Article #14 Notes: Magnetic Janus Origami Robot for Cross-Scale Droplet Omni-Manipulation

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Magnetic Janus Origami Robot for Cross-Scale Droplet Omni-Manipulation
<b>Source citation (APA Format)</b>	Jiang, S., Li, B., Zhao, J., Wu, D., Zhang, Y., Zhao, Z., et al. (2023). <i>Magnetic Janus origami robot for cross-scale droplet omni-manipulation</i> . <i>Nature Communications</i> , 14, 5455. <a href="https://doi.org/10.1038/s41467-023-41092-1">https://doi.org/10.1038/s41467-023-41092-1</a>
<b>Original URL</b>	<a href="https://www.nature.com/articles/s41467-023-41092-1">https://www.nature.com/articles/s41467-023-41092-1</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	Origami robots, Janus structures, magnetic actuation
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Introduces a magnetically actuated origami robot with a Janus (dual-property) surface, where folding dynamically changes surface functionality such as adhesion, enabling controlled manipulation of droplets across multiple length scales.</li> <li>- Methodology combines origami-inspired folding geometry, asymmetric material patterning, and external magnetic fields to achieve untethered actuation, with experimental demonstrations of droplet transport, release, and reconfiguration.</li> </ul>
<b>Research Question/Problem/ Need</b>	How can origami folding and magnetic actuation be combined to enable precise, reversible manipulation across micro- to macro-scales?

<p><b>Important Figures</b></p>	<p>Figure 1. Schematic of a Janus Origami robot with droplet carrying capabilities due to the double-sided nature of the robot.</p>
<p><b>VOCAB: (w/definition)</b></p>	<p>Janus structure - a structure with two sides exhibiting different physical or chemical properties</p> <p>Omni-manipulation - the ability to control motion and interaction in multiple directions and scales</p>
<p><b>Cited references to follow up on</b></p>	<p>Fabrication techniques for magnetic origami robots - Magnetic Soft Materials and Robots (Kim et al.)</p>
<p><b>Follow up Questions</b></p>	<p>Can Janus folding principles be adapted for terrain-adaptive gripping or locomotion? How scalable is this approach for larger, load-bearing origami robots?</p>

# Article #15 Notes: Magnetic Soft Materials and Robots

## KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Magnetic Soft Materials and Robots
<b>Source citation (APA Format)</b>	Kim, Y., & Zhao, X. (2022). Magnetic Soft Materials and Robots. <i>Chemical reviews</i> , 122(5), 5317–5364. <a href="https://doi.org/10.1021/acs.chemrev.1c00481">https://doi.org/10.1021/acs.chemrev.1c00481</a>
<b>Original URL</b>	<a href="https://pubmed.ncbi.nlm.nih.gov/35104403/">https://pubmed.ncbi.nlm.nih.gov/35104403/</a>
<b>Source type</b>	Review Article
<b>Keywords</b>	Magnetic elastomers, soft robotics, actuation
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Provides a comprehensive review of magnetic soft robotic systems, covering material synthesis, magnetisation programming, mechanical modelling, and control strategies, with comparisons to pneumatic, SMA, and dielectric actuation.</li> <li>- Synthesises experimental results across scales, identifying pros and cons between actuation strength, spatial resolution, response speed, and controllability, and outlining challenges for real-world deployment.</li> </ul>
<b>Research Question/Problem/ Need</b>	What material and design principles govern the performance, scalability, and controllability of magnetic soft robots?
<b>Important Figures</b>	<p><b>a</b> Magnetically Induced Recovery of Shape Memory Polymer based on Heating from Superparamagnetic Nanoparticles</p> <p><b>b</b> Magnetically Induced Thermal Actuation of Temperature Sensitive Hydrogel with Superparamagnetic Nanoparticles</p> <p>Figure 6. Magneto-thermal actuation of soft materials due to temperature change in responsive polymer matrices. The heating can lead to either a recovery of shape (a) or a deformation (b).</p>
<b>VOCAB: (w/definition)</b>	<p>Magneto-active elastomer - a polymer composite that deforms in response to magnetic fields</p> <p>Global field actuation - controlling a robot using an externally applied magnetic field rather than onboard actuators</p>
<b>Cited references to follow up on</b>	Yi et al. (2022), Magneto-origami machines

<b>Follow up Questions</b>	How does folding geometry influence magnetic torque and deformation? Can magnetic actuation be localised enough for complex origami crease control?
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## Article #16 Notes: High-Throughput Fabrication of Soft Magneto-Origami Machines

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	High-Throughput Fabrication of Soft Magneto-Origami Machines
<b>Source citation (APA Format)</b>	Yi, S., Wang, L., Chen, Z., et al. (2022). <i>High-throughput fabrication of soft magneto-origami machines</i> . <i>Nature Communications</i> , 13, 4177. <a href="https://doi.org/10.1038/s41467-022-31900-5">https://doi.org/10.1038/s41467-022-31900-5</a>
<b>Original URL</b>	<a href="https://www.nature.com/articles/s41467-022-31900-5">https://www.nature.com/articles/s41467-022-31900-5</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	Magneto-origami, scalable fabrication, soft machines, embedded actuation
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Demonstrates a scalable fabrication pipeline for soft magneto-origami robots, integrating patterned magnetic domains into foldable sheets that self-transform under magnetic fields.</li> <li>- Methodology emphasises high-throughput manufacturing with layered material deposition, programmed magnetisation, and fold based geometric design, experimental validation of repeatability, and functional motion.</li> </ul>
<b>Research Question/Problem/ Need</b>	How can origami-inspired soft robots be manufactured efficiently at scale while preserving precise, programmable actuation?
<b>Important Figures</b>	<p><b>a</b> <b>b</b></p> <p><b>c</b> <b>d</b></p> <p>Figure (a) shows the actuation of a square-based soft magneto-origami machine. It starts with a flat sheet (1) containing magnetic domains (blue circles). Upon applying a 200 mT magnetic field, the sheet folds into a 3D structure (2) and then into a more compact, flower-like shape (3). Time intervals of ~7.5 s and ~0.1 s are indicated between steps. A 5 mm scale bar is provided.</p> <p>Figure (b) is a graph of Diagonal length <math>\delta</math> (mm) versus Time (s) for the square machine. The diagonal length starts at approximately 34 mm (point 1) and remains constant until about 7.5 s (point 2), where it drops sharply to approximately 23 mm (point 3).</p> <p>Figure (c) shows the actuation of a circular soft magneto-origami machine. It starts with a flat sheet (1) containing magnetic domains (blue circles). Upon applying a 200 mT magnetic field, the sheet folds into a 3D structure (2) and then into a more compact, circular shape (3). Time intervals of ~7.5 s and ~0.1 s are indicated between steps. A 1 cm scale bar is provided.</p> <p>Figure (d) is a graph of Diagonal length <math>\delta</math> (mm) versus Time (s) for the circular machine. The diagonal length starts at approximately 48 mm (point 1) and increases steadily to approximately 68 mm (point 2) at 7.5 s, then drops sharply to approximately 48 mm (point 3) at 8 s.</p>

	Figure 3. The twisting and folding process of the origami magneto square twist in both folded and unfolded states. The blue faces represent faces with magnetization pointing outwards.
<b>VOCAB: (w/definition)</b>	High-throughput fabrication - manufacturing process optimised for speed and large-volume production Magneto-origami - origami structures whose folding or motion is driven by magnetic fields
<b>Cited references to follow up on</b>	Reference Onal et al. And Rus & Tolley for robot design frameworks
<b>Follow up Questions</b>	Can SMA or thermal actuation be integrated into this fabrication process? What are the limits of geometric complexity under high-throughput constraints?

## Article #17 Notes: Origami-Inspired Vacuum-Actuated Foldable Actuator Enabled Biomimetic Worm-Like Soft Crawling Robot

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Origami-Inspired Vacuum-Actuated Foldable Actuator Enabled Biomimetic Worm-Like Soft Crawling Robot
<b>Source citation (APA Format)</b>	Xu, Q., Zhang, K., Ying, C., Xie, H., Chen, J., & E, S. (2024). <i>Origami-inspired vacuum-actuated foldable actuator enabled biomimetic worm-like soft crawling robot</i> . <i>Biomimetics</i> , 9(9), 541. <a href="https://doi.org/10.3390/biomimetics9090541">https://doi.org/10.3390/biomimetics9090541</a>
<b>Original URL</b>	<a href="https://www.mdpi.com/2313-7673/9/9/541">https://www.mdpi.com/2313-7673/9/9/541</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	origami soft robot, vacuum actuation, worm-like crawling, Kresling
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Presents a fully soft origami crawling robot actuated by vacuum pressure, inspired by worm locomotion. The body comprises mirrored Kresling origami chambers that contract when vacuum is applied.</li> <li>- A friction bias between front and rear feet creates unidirectional motion during cyclic contraction–recovery sequences. The design allows crawling, turning, and even climbing slopes, demonstrating adaptability on varied terrains.</li> <li>- Methodology includes designing the origami structure, vacuum control sequencing, and validating the robot’s locomotion speed, slope performance, and payload capacity.</li> </ul>
<b>Research Question/Problem/ Need</b>	How can a simple, fully soft origami structure be actuated to achieve continuous, efficient crawling locomotion across different substrates?

<p><b>Important Figures</b></p>	<p>Figure 2. Locomotion schematic of robot. Vacuum actuation sequence enables crawling locomotion, although recovery is needed between different parts of actuation cycle.</p>
<p><b>VOCAB: (w/definition)</b></p>	<p>Vacuum actuation - Using negative pressure to induce contraction in a soft chamber</p>
<p><b>Cited references to follow up on</b></p>	<p>Work on Miura-ori pneumatic robots Biomimetic soft robots</p>
<p><b>Follow up Questions</b></p>	<p>Can vacuum actuators be miniaturised for micro scale applications? How to integrate untethered power and control into vacuum actuated origami robots?</p>

## Article #18 Notes: A Textile Origami Snake Robot for Rectilinear Locomotion

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	A Textile Origami Snake Robot for Rectilinear Locomotion
<b>Source citation (APA Format)</b>	Seyidođlu, B., Rafsanjani, A. (2024). <i>A textile origami snake robot for rectilinear locomotion. Device, 2(2)</i> , 100226. <a href="https://doi.org/10.1016/j.device.2023.100226">https://doi.org/10.1016/j.device.2023.100226</a>
<b>Original URL</b>	<a href="https://www.sciencedirect.com/science/article/pii/S2666998623003666">https://www.sciencedirect.com/science/article/pii/S2666998623003666</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	origami snake robot, rectilinear locomotion, textile robotics, pneumatic actuation
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Describes a soft snake like robot that achieves rectilinear crawling using a breathable textile with integrated origami pneumatic pouches, mimicking snake movement via alternating expansion and contraction.</li> <li>- The body uses origami inspired pneumatic chambers embedded in fabric, allowing it to travel across real terrains such as concrete or track surfaces. The design highlights how origami folding patterns and compliant textiles can create robust locomotion without rigid joints.</li> </ul>
<b>Research Question/Problem/ Need</b>	Can origami folding patterns integrated into soft textiles achieve efficient snake like locomotion across rough real-world terrains?

Important Figures



Figure 1. Depiction of snake inspired robot compared to a puff adder snake during rectilinear locomotion.

VOCAB: (w/definition)

Rectilinear locomotion – Straight line crawling movement typical of snakes  
 Origami pneumatic pouch - A foldable chamber acting as a soft actuator

Cited references to follow up on

Origami-based pneumatic crawling robots

Follow up Questions

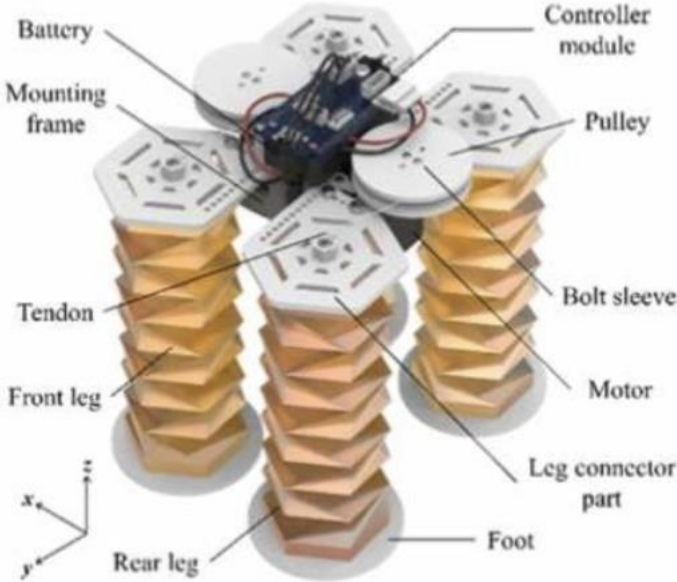
How does textile flexibility impact energy efficiency?  
 Can this be adapted for vertical climbing or obstacle negotiation?

## Article #19 Notes: Quadrupedal Robot with Tendon-Driven Origami Legs

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Quadrupedal Robot with Tendon-Driven Origami Legs
<b>Source citation (APA Format)</b>	Kim, J., Im, E., Cha, Y. (2024). <i>Quadrupedal robot with tendon-driven origami legs</i> . <i>Sensors and Actuators A: Physical</i> , 378, 115769. <a href="https://doi.org/10.1016/j.sna.2024.115769">https://doi.org/10.1016/j.sna.2024.115769</a>
<b>Original URL</b>	<a href="https://www.sciencedirect.com/science/article/pii/S0924424724007635">https://www.sciencedirect.com/science/article/pii/S0924424724007635</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	origami legs, tendon drive, Kresling pattern, legged locomotion
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Introduces a quadrupedal robot that uses tendon driven origami cylinders (Kresling pattern) as legs, translating folding deformations into leg motion.</li> <li>- Tendons driven by motors control fold/extension of each origami leg. The design demonstrates improved stiffness and force transmission while keeping a compliant, simple structure. Gait analysis decouples phases to study locomotion effectiveness and velocity.</li> </ul>
<b>Research Question/Problem/ Need</b>	How can origami structures serve as compliant yet controllable limbs for legged soft robots?

<b>Important Figures</b>	 <p>Figure 1. Schematic of quadrupedal robot. Each leg is contracted via a pulley-controlled tendon, with the controller alternating which leg is contracting during a locomotion cycle.</p>
<b>VOCAB: (w/definition)</b>	<p>Tendon drive - Actuation method using tendons pulled by motors to induce folding</p> <p>Gait cycle - The sequence of leg movements enabling locomotion</p>
<b>Cited references to follow up on</b>	<p>Soft legged locomotion design papers</p>
<b>Follow up Questions</b>	<p>Can the tendon-driven approach combine with embedded soft actuators for fully untethered motion?</p> <p>What are the limits of speed and load for origami-legged robots?</p>

## Article #20 Notes: Title

Article notes should be on separate sheets

**KEEP THIS BLANK AND USE AS A TEMPLATE**

<b>Source Title</b>	
<b>Source citation (APA Format)</b>	Sun, Y., Li, D., Wu, M., Yang, Y., Su, J., Wong, T., Xu, K., Li, Y., Yu, X., Yu, J. (2022). <i>Origami-inspired folding assembly of dielectric elastomers for programmable soft robots</i> . <i>Microsystems &amp; Nanoengineering</i> . <a href="https://doi.org/10.1038/s41378-022-00363-5">https://doi.org/10.1038/s41378-022-00363-5</a>
<b>Original URL</b>	<a href="https://www.nature.com/articles/s41378-022-00363-5">https://www.nature.com/articles/s41378-022-00363-5</a>
<b>Source type</b>	Peer reviewed journal article
<b>Keywords</b>	origami folding, dielectric elastomers, soft robot assembly, programmable actuation
<b>#Tags</b>	
<b>Summary of key points +</b>	- Presents a method for assembling dielectric elastomer actuators into origami

**notes (include methodology)**

folding structures, enabling programmable motion for soft robots, including walking and manipulators.

- Uses laser-cut PET supports and dielectric elastomer films to build multilayer actuators. These can fold into complex shapes and exhibit stable crawling while carrying payloads, showing how electrical control can integrate with origami geometry for soft robot function.

**Research Question/Problem/ Need**

Can electrically controlled dielectric elastomer actuators be combined with origami folding design to achieve programmable soft robotic behaviors?

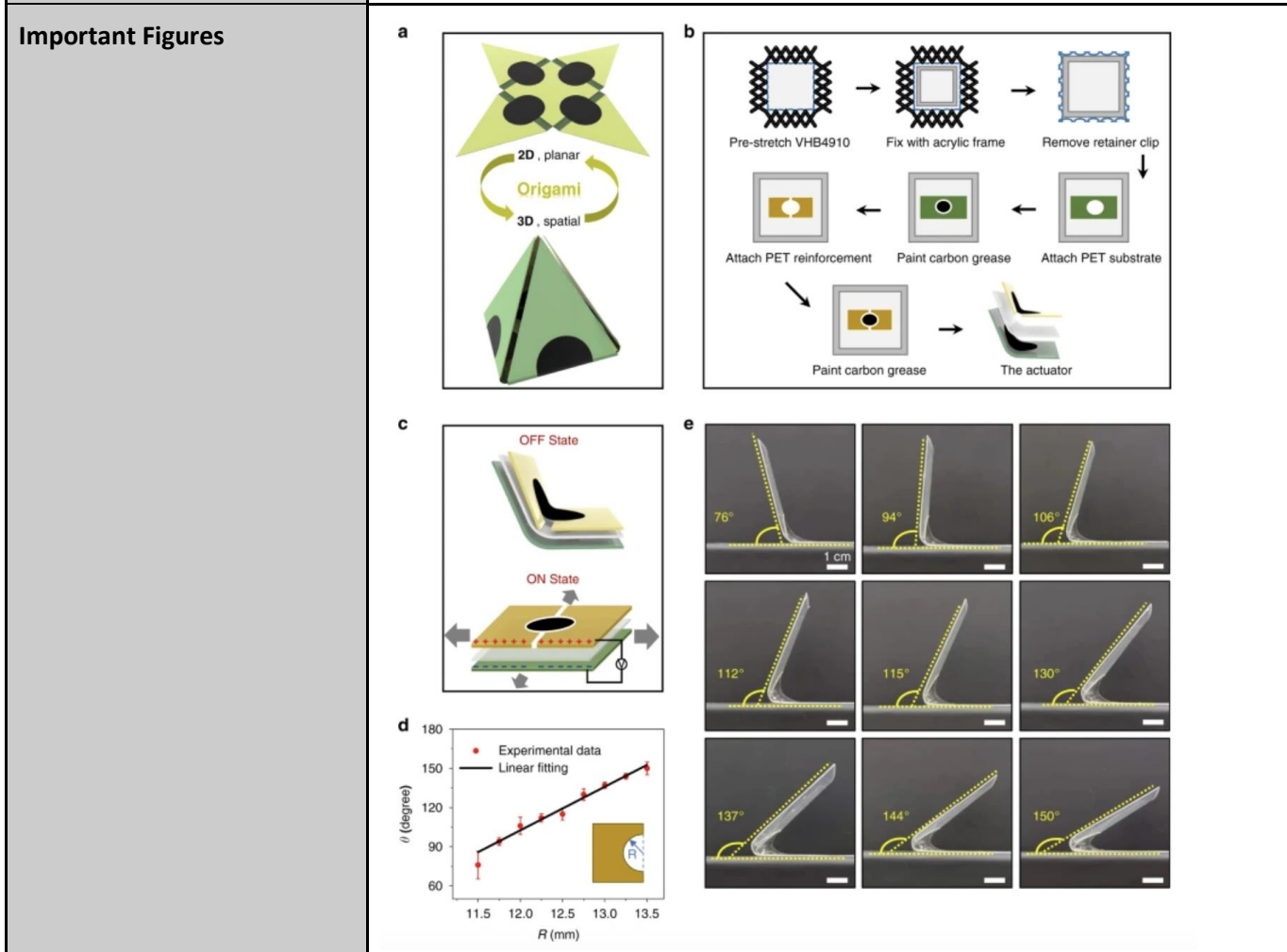


Figure 1. Schematic diagram of robots. Fabrication process of the soft actuator is depicted (b) as well as an expanded layered structure of soft actuator (c).

**VOCAB: (w/definition)**

Dielectric elastomer - A soft material that changes shape under an electric field  
 Programmable actuation - Controlled motion through pre-designed electrical inputs

**Cited references to follow up on**

Dielectric elastomer actuators  
 Origami based assembly methods

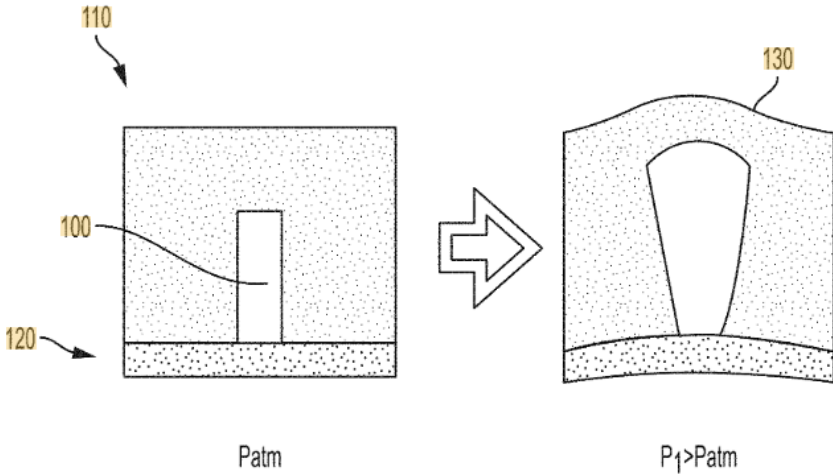
<b>Follow up Questions</b>	<p>How does dielectric control compare to pneumatic or magnetic actuation in origami robots?</p> <p>Can fold pattern optimisation improve actuator efficiency?</p>
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## Patent #1 Notes: Origami-Based Soft Robotic Actuators and Methods of Use

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Origami-Based Soft Robotic Actuators and Methods of Use
<b>Source citation (APA Format)</b>	Tolley, M. T., Shepherd, R. F., & Whitesides, G. M. (2017). <i>Origami-based soft robotic actuators and methods of use</i> (U.S. Patent No. 9,623,403). United States Patent and Trademark Office. <a href="https://patents.google.com/patent/US9623403B2">https://patents.google.com/patent/US9623403B2</a>
<b>Original URL</b>	<a href="https://patents.google.com/patent/US9623403B2">https://patents.google.com/patent/US9623403B2</a>
<b>Source type</b>	U.S. Utility patent
<b>Keywords</b>	origami actuator, soft robotics, pneumatic actuation, foldable structures
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- This patent introduces origami-inspired soft actuators that use folding geometries to convert pneumatic pressure into controlled linear, bending, or twisting motion. The designs emphasise geometric constraint rather than rigid joints to guide motion.</li> <li>- The methodology details fabrication using elastomeric materials with embedded fold lines, pressure controlled chambers, and experimental validation showing repeatable actuation and load-bearing capability.</li> </ul>
<b>Research Question/Problem/ Need</b>	How can origami folding principles be embedded into soft materials to achieve predictable, programmable actuation without rigid mechanisms?

<b>Important Figures</b>	 <p>Figure 1. Cross section of actuator's flexible body. The limiting wall (130) is shown to expand once at least one fluid channel is arranged correctly.</p>
<b>VOCAB: (w/definition)</b>	
<b>Cited references to follow up on</b>	Zhao et al. (2021). Soft robotics: Research, challenges, and prospects
<b>Follow up Questions</b>	How does actuator efficiency scale with fold complexity? Can these actuators be miniaturised for swarm robotics?

## Patent #2 Notes: Inverse Origami Design for Soft Robotic Development

Article notes should be on separate sheets

### KEEP THIS BLANK AND USE AS A TEMPLATE

<b>Source Title</b>	Inverse Origami Design for Soft Robotic Development
<b>Source citation (APA Format)</b>	Sun, D., & Hu, Q. (2024). <i>Inverse origami design for soft robotic development</i> (U.S. Patent Application No. US20240165869A1). United States Patent and Trademark Office. <a href="https://patents.google.com/patent/US20240165869A1/en">https://patents.google.com/patent/US20240165869A1/en</a>
<b>Original URL</b>	<a href="https://patents.google.com/patent/US20240165869A1/en">https://patents.google.com/patent/US20240165869A1/en</a>
<b>Source type</b>	U.S. patent application
<b>Keywords</b>	origami design, soft robotics, crease pattern generation, inverse origami
<b>#Tags</b>	
<b>Summary of key points + notes (include methodology)</b>	<ul style="list-style-type: none"> <li>- Introduces a computational system for inverse origami design, meaning it generates flat crease patterns automatically from desired 3D shapes, which is a major challenge when designing origami robots with specific functions.</li> <li>- The method includes components for parameter extraction of the target shape, pattern generation of crease layout, and fabrication instructions, enabling a top-down origami approach that reduces design complexity and enables more rapid manufacture of soft robots based on origami geometry.</li> <li>- Describes folding patterns tailored to improve motion transfer and stiffness differentiation between facets and creases; also mentions how actuators like SMA or</li> </ul>

electrostatic actuators can be installed at specific crease locations for motion.

**Research Question/Problem/ Need** How can the design of origami-based soft robots be automated so that designers don't have to manually iterate crease patterns to achieve complex 3D shapes with desired mechanical functionality?

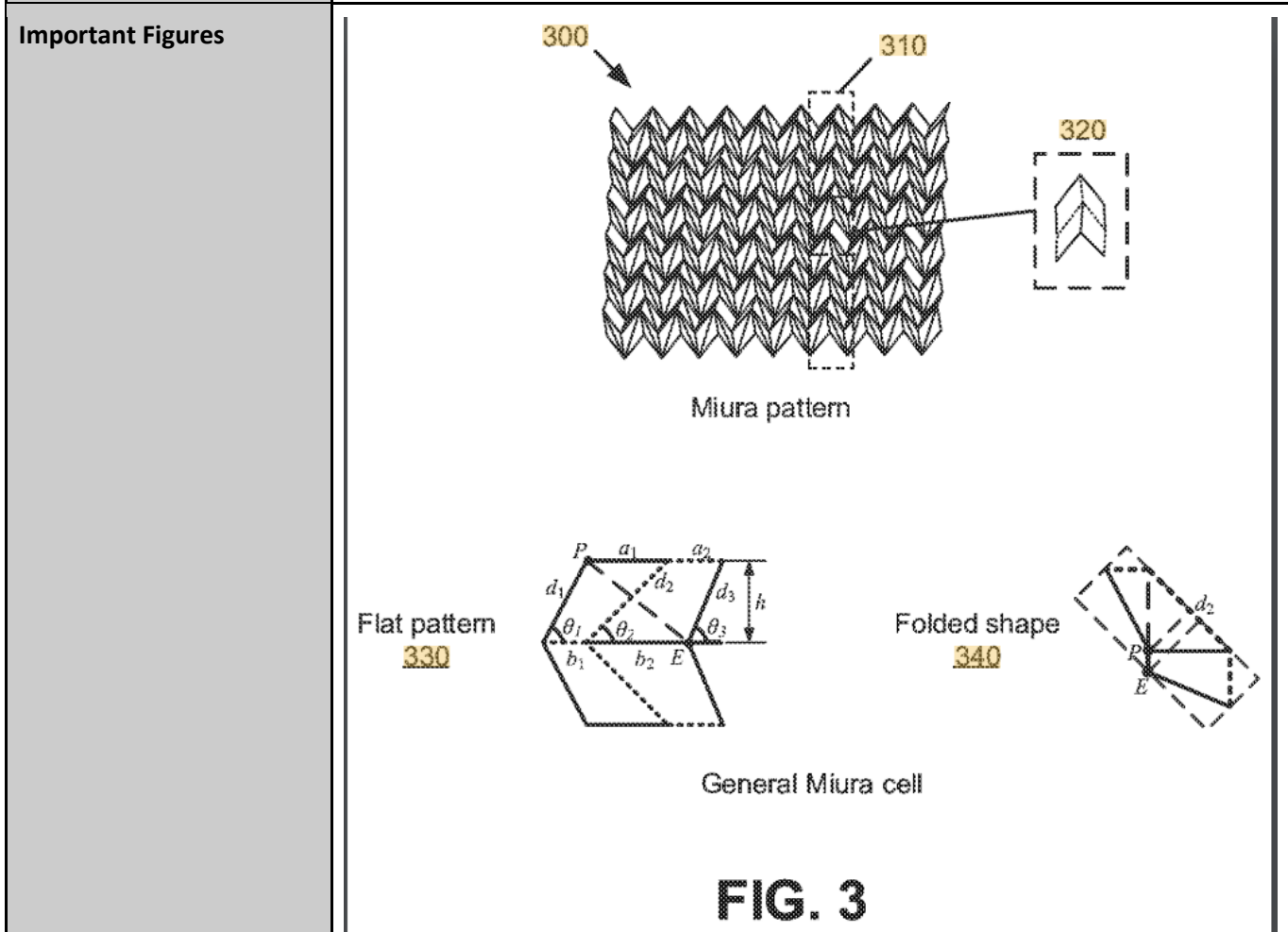


Figure 3. Depiction of Miura ori pattern cell. Both the crease pattern (330) and folded shape (340) are shown, individually and part of the overall tessellation.

**VOCAB: (w/definition)** Inverse origami design - generating a crease pattern *from* a desired folded shape rather than designing a pattern and then folding it experimentally  
 Crease pattern - the layout of mountain/valley lines on a flat sheet used to fold 3D structures  
 Electrostatic actuator - an actuator that uses electric fields to produce motion via electrostatic forces

**Cited references to follow up on** Park et al. (2018) Development of a hybrid gripper with soft material and rigid structures

**Follow up Questions**

How does inverse crease generation compare with other computational origami design tools such as those used in architectural origami?

Can this inverse design approach be extended to generate patterns that are directly optimised for actuation, such as for specific locomotion behaviours like crawling or rolling?