nature portfolio

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Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed	
☐	☒	The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒	A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☒	☐	A description of all covariates tested
☐	☒	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Commercial: Nikon Elements (vAR 5.11.00) was used to acquire immunofluorescence image stacks, Molecular Machines & Industries software (v1.0) was used to perform laser cutting, and Microsoft Paint (v5.1) was used to calibrate screen capture data from laser cutting experiments. Other custom codes/GUIs were used in Brillouin microscopy and micro-indentation data collection.
Data analysis	Commercial: MATLAB R2022a, Rhino 7. Open Source: FIJI v1.0 (ImageJ2 v2.14.0), Bayesian force inference code published by Kong et al. (see Methods), Kangaroo2. Other custom codes/GUIs were used in Voronoi analysis, curvature and shell height calculation/representation, shape index maps, see Methods for details. Code is available at https://github.com/ahug030/kidney_jamming.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

All data necessary to evaluate conclusions of this study are presented in the paper and supporting information. Raw image stacks are available upon request due to prohibitive file sizes. Source data files are available at https://github.com/ahug030/kidney_jamming.

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	N/A
Reporting on race, ethnicity, or other socially relevant groupings	N/A
Population characteristics	N/A
Recruitment	N/A
Ethics oversight	N/A

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences ☐ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	Sample size is typically set by animal and embryo availability per experiment day.
Data exclusions	No data were excluded from the analysis.
Replication	Experiments were replicated or pooled among kidneys depending on experiment requirements. Replicate information is stated for each experiment in the figure legends.
Randomization	Sample allocation was random.
Blinding	Investigators were not blinded to group allocation during data collection and/or analysis since both were typically performed by the same researcher and since analysis generally ran into tens of hours to days per experiment. Automated analysis was used wherever possible to reduce potential for bias.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☐	☒ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☐	☒ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Antibodies

Antibodies used

Primary antibodies and dilutions included rabbit anti-Six2 (1:600, 11562-1-AP, Proteintech, RRID: AB_2189084), mouse anti-E-cadherin (1:200, clone 34, 610404, BD Biosciences, RRID: AB_397787), rat anti-E-cadherin (1:100, ab11512, abcam, RRID:AB_298118), mouse anti-calbindin D-28K (1:100, clone CB-955, C9849, Sigma, RRID: AB_476894), mouse anti-pan-cytokeratin (1:200, clone 11, C2931, Sigma, RRID:AB_258824), and goat anti-jagged 1 (1:150, AF599, R&D Systems, RRID: AB_2128257). Secondary antibodies (all raised in donkey) were used at 1:300 dilution and include anti-rabbit AlexaFluor 647 (A31573, ThermoFisher, RRID: AB_2536183), anti-rabbit AlexaFluor 555 (A31570, ThermoFisher, RRID: AB_2536180), anti-mouse AlexaFluor 555 (A31572, ThermoFisher, RRID: AB_162543), anti-goat AlexaFluor 488 (A11055, ThermoFisher, RRID: AB_2534102), anti-rat AlexaFluor Plus 555 (A48270, ThermoFisher, RRID: AB_2896336), anti-rabbit AlexaFluor 488 (A21206, ThermoFisher, RRID: AB_2535792), and anti-rat AlexaFluor Plus 405 (A48268, ThermoFisher, RRID: AB_2890549). Other counterstains included 1:40 AlexaFluor 647 phalloidin (A22287, ThermoFisher) and 20 µg ml-1 AlexaFluor 488-labeled peanut (Arachis hypogaea) agglutinin lectin (PNA, L21409, Sigma).

Validation

Antibodies were used in this study to provide anatomical contrast in whole-mount immunofluorescence assays. Antibodies gave signal consistent with previous understanding of developing kidney anatomy and use in previous publications (Prahl et al., Developmental Cell, 2023; Lindstrom et al., Journal of the American Society of Nephrology, 2018; O'Brien et al., eLife, 2018; Combes et al., Nature Protocols, 2014; Short et al., Developmental Cell, 2014). Other validation data is available at vendor websites.

Animals and other research organisms

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research, and Sex and Gender in Research

Laboratory animals

E14-17 embryos were collected from wild-type timed pregnant CD-1 mice (Charles River Laboratories, RRID:IMSR_CRL:022) and stages were confirmed by limb anatomy. Mice were housed in standard ventilated cages (single occupancy) in a conventional rodent facility at 72 degrees F, 50% humidity, with free access to water and food and kept on a 12 hour light cycle. Pregnant breeders were 8-10 weeks old upon receipt.

Wild animals

No wild animals were used in this study.

Reporting on sex

Kidneys were analyzed without regard to embryo sex. Sexual dimorphism appears to be small for a range of anatomical features in mouse embryonic kidney (Short & Smyth, Scientific Reports, 2015). We treated sex as one contributor to experimental variability in this paper.

Field-collected samples

No field-collected samples were used in this study.

Ethics oversight

Mouse protocols followed National Institutes of Health guidelines and were approved by the Institutional Animal Care and Use Committee of the University of Pennsylvania (protocol # 80700).

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Plants

Seed stocks

N/A

Novel plant genotypes

N/A

Authentication

N/A