

## 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

- |                                     |                                     |  |
|-------------------------------------|-------------------------------------|--|
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> | The exact sample size ( $n$ ) for each experimental group/condition, given as a discrete number and unit of measurement  |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> | A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly  |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> | The statistical test(s) used AND whether they are one- or two-sided<br><i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>   |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | A description of all covariates tested   |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons  |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> | 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) |
| <input type="checkbox"/>            | <input checked="" type="checkbox"/> | For null hypothesis testing, the test statistic (e.g. $F$ , $t$ , $r$ ) with confidence intervals, effect sizes, degrees of freedom and $P$ value noted<br><i>Give <math>P</math> values as exact values whenever suitable.</i>                            |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings   |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes   |
| <input checked="" type="checkbox"/> | <input type="checkbox"/>            | 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

Data analysis

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](#)

Single-cell RNA-seq data generated in this study are available via the BioProject accession number PRJNA1186658 [<https://www.ncbi.nlm.nih.gov/bioproject/?term=PRJNA1186658>]. The processed single cell object is available via Zenodo [<https://doi.org/10.5281/zenodo.14170959>]. This paper analyzes existing, publicly available data: GSE119945 40 [<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE119945>] and GSE164528 27 [<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE164528>]. All other data generated in this study are provided in the Supplementary Information/Source Data file.

## 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

Reporting on race, ethnicity, or other socially relevant groupings

Population characteristics

Recruitment

Ethics oversight

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](https://www.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

Data exclusions

Replication

Randomization

Blinding

## 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
<input type="checkbox"/>	<input checked="" type="checkbox"/> Antibodies
<input checked="" type="checkbox"/>	<input type="checkbox"/> Eukaryotic cell lines
<input checked="" type="checkbox"/>	<input type="checkbox"/> Palaeontology and archaeology
<input type="checkbox"/>	<input checked="" type="checkbox"/> Animals and other organisms
<input checked="" type="checkbox"/>	<input type="checkbox"/> Clinical data
<input checked="" type="checkbox"/>	<input type="checkbox"/> Dual use research of concern
<input checked="" type="checkbox"/>	<input type="checkbox"/> Plants

### Methods

n/a	Involved in the study
<input checked="" type="checkbox"/>	<input type="checkbox"/> ChIP-seq
<input checked="" type="checkbox"/>	<input type="checkbox"/> Flow cytometry
<input checked="" type="checkbox"/>	<input type="checkbox"/> MRI-based neuroimaging

### Antibodies

Antibodies used

Commercial antibodies:  
Rabbit anti-PPARG, Cell Signaling Technology, Cat# 2443, RRID:AB\_823598; 1:100  
Rabbit anti-OSR1, Sigma-Aldrich, Cat# HPA015525, RRID:AB\_1854822; 1:100

Chicken anti-GFP, Aves Labs, Cat# GFP-1020, RRID:AB\_10000240); 1:800  
 Rabbit anti-FABP4, Abcam, Cat# ab66682, RRID:AB\_1310219; 1:300  
 Mouse anti-Myosin Heavy Chain, Millipore, Cat# 05-716-I, RRID:AB\_309930; 1:800  
 Sheep anti-EBF2, R&D Systems, Cat# AF7006, RRID:AB\_10972102; 1:20  
 Hamster anti-PECAM1, DSHB, Cat# 2H8, RRID:AB\_2161039; 1:250  
 Rabbit anti- $\alpha$ -SMA, Abcam Cat# ab5694, RRID:AB\_2223021; 1:250  
 Rabbit anti-Perilipin A/B, Sigma-Aldrich, Cat# P1873, RRID:AB\_532267; 1:300  
 Rabbit anti-UCP1, Sigma-Aldrich Cat# U6382; 1:200  
 Donkey anti-rabbit, Alexa Fluor 488, Thermo Fisher Scientific, Cat# A32790, RRID:AB\_2762833; 1:500  
 Donkey anti-rabbit, Alexa Fluor 568, Thermo Fisher Scientific, Cat# A10042, RRID:AB\_2534017; 1:500  
 Donkey anti-rabbit, Alexa Fluor 647, Thermo Fisher Scientific, Cat# A32795, RRID:AB\_2762835; 1:500  
 Donkey anti-mouse, Alexa Fluor 568, Thermo Fisher Scientific Cat# A10037, RRID:AB\_11180865; 1:500  
 Donkey anti-mouse, Alexa Fluor 680, Thermo Fisher Scientific Cat# A32788, RRID:AB\_2762831; 1:500  
 Goat anti-hamster, Alexa Fluor 568, Thermo Fisher Scientific, Cat# A78960, RRID:AB\_2925783; 1:500  
 Goat anti-hamster, Alexa Fluor 647, Thermo Fisher Scientific, Cat# A78962, RRID:AB\_2925785; 1:500  
 Goat anti-guinea pig, Alexa Fluor 568, Thermo Fisher Scientific, Cat# A-11075, RRID:AB\_2534119; 1:500  
 Goat anti-guinea pig, Alexa Fluor 647, Thermo Fisher Scientific, Cat# A-21450, RRID:AB\_2535867; 1:500  
 Anti-sheep Alexa Fluor 568, Thermo Fisher Scientific, Cat# A-21099, RRID:AB\_2535753; 1:500  
 Goat anti-chicken, Alexa Fluor 488, Thermo Fisher Scientific, Cat# A-11039, RRID:AB\_2534096; 1:500  
 ; 1:500  
 Gifted antibodies:  
 Guinea pig anti-PAX7, C. Birchmeier, Max Delbrück Centre Berlin; 1:100

## Validation

Commercial antibodies: validation available on the company website  
 Rabbit anti-PPARG, <https://www.cellsignal.com/products/primary-antibodies/pparg-81b8-rabbit-mab/2443?srltid=AfmBOoq9nmhYHlvXoAkkqWtW5dt6Q2hxq5XmqCxHqx2nfAUTr3KmM8v3>  
 Rabbit anti-OSR1, <https://www.proteinatlas.org/ENSG00000143867-OSR1/summary/antibody>  
 Chicken anti-GFP, [https://www.antibodiesinc.com/products/anti-green-fluorescent-protein-antibody-gfp?utm\\_source=biocompare&utm\\_medium=affiliate&utm\\_campaign=product](https://www.antibodiesinc.com/products/anti-green-fluorescent-protein-antibody-gfp?utm_source=biocompare&utm_medium=affiliate&utm_campaign=product)  
 Rabbit anti-FABP4, <https://www.abcam.com/en-us/products/primary-antibodies/fabp4-antibody-ab66682?srltid=AfmBOoqeOscD7CKVu6gH9V2-9kmB-ciim8ljMMDbOJ0g8S2fmPeHJP7Z>  
 Mouse anti-Myosin Heavy Chain, [https://www.merckmillipore.com/AT/de/product/Anti-Myosin-Heavy-Chain-Antibody-clone-A4.1025\\_MM\\_NF-05-716-I-25UL?ReferrerURL=https%3A%2F%2Fwww.google.com%2F](https://www.merckmillipore.com/AT/de/product/Anti-Myosin-Heavy-Chain-Antibody-clone-A4.1025_MM_NF-05-716-I-25UL?ReferrerURL=https%3A%2F%2Fwww.google.com%2F)  
 Sheep anti-EBF2, [https://www.rndsystems.com/products/human-mouse-ebf-2-antibody\\_af7006](https://www.rndsystems.com/products/human-mouse-ebf-2-antibody_af7006)  
 Hamster anti-PECAM1, <https://dshb.biology.uiowa.edu/2H8>  
 Rabbit anti- $\alpha$ -SMA, [https://www.abcam.com/en-us/products/primary-antibodies/alpha-smooth-muscle-actin-antibody-ab5694?srltid=AfmBOoo-ubZJRBMMWYUjObe\\_NHHnC-6dlxDMqPPuqWjNP1d-cX7vz7u1](https://www.abcam.com/en-us/products/primary-antibodies/alpha-smooth-muscle-actin-antibody-ab5694?srltid=AfmBOoo-ubZJRBMMWYUjObe_NHHnC-6dlxDMqPPuqWjNP1d-cX7vz7u1)  
 Rabbit anti-Perilipin A/B, [https://www.sigmaaldrich.com/AT/de/product/sigma/p1873?srltid=AfmBOorhxx-C3ZpPr1xU0wUuvM7sDKdSLBG127YzYsejpXvXiAUf\\_YfT](https://www.sigmaaldrich.com/AT/de/product/sigma/p1873?srltid=AfmBOorhxx-C3ZpPr1xU0wUuvM7sDKdSLBG127YzYsejpXvXiAUf_YfT)  
 Rabbit anti-UCP1, <https://www.sigmaaldrich.com/AT/de/product/sigma/u6382>  
 Donkey anti-rabbit, Alexa Fluor 488, <https://www.thermofisher.com/antibody/product/Donkey-anti-Rabbit-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A32790TR>  
 Donkey anti-rabbit, Alexa Fluor 568, <https://www.thermofisher.com/antibody/product/Donkey-anti-Rabbit-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A10042>  
 Donkey anti-rabbit, Alexa Fluor 647, <https://www.thermofisher.com/antibody/product/Donkey-anti-Rabbit-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A32795TR>  
 Donkey anti-mouse, Alexa Fluor 568, <https://www.thermofisher.com/antibody/product/Donkey-anti-Mouse-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A10037>  
 Donkey anti-mouse, Alexa Fluor 680, <https://www.thermofisher.com/antibody/product/Donkey-anti-Mouse-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A32788>  
 Goat anti-hamster, Alexa Fluor 568, <https://www.thermofisher.com/antibody/product/Goat-anti-Syrian-Hamster-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A78960>  
 Goat anti-hamster, Alexa Fluor 647, <https://www.thermofisher.com/antibody/product/Goat-anti-Syrian-Hamster-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A78962>  
 Goat anti-guinea pig, Alexa Fluor 568, <https://www.thermofisher.com/antibody/product/Goat-anti-Guinea-Pig-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A-11075>  
 Goat anti-guinea pig, Alexa Fluor 647, <https://www.thermofisher.com/antibody/product/Goat-anti-Guinea-Pig-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A-21450>  
 Anti-sheep Alexa Fluor 568, <https://www.thermofisher.com/antibody/product/Goat-anti-Guinea-Pig-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A-21450>  
 Goat anti-chicken, Alexa Fluor 488, <https://www.thermofisher.com/antibody/product/Goat-anti-Chicken-IgY-H-L-Secondary-Antibody-Polyclonal/A-11039>  
 Gifted antibodies:  
 Guinea pig anti-PAX7, Zhang et al. 2021 doi: 10.1038/s41467-021-21631-4

## 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

Mouse lines: Osr1tm1(EGFP/cre/ERT2)Amc/J, received from A.P. McMahon, Los Angeles, CA, USA; Gt(ROSA)26Sortm4(ACTB-tdTomato,-EGFP)Luo/J received from A. Kispert, Hannover, Germany. Myf5tm3(cre)Sor received from C. Bichmeier, Gerlin, Germany; B6.Cg-Pax7tm1(cre/ERT2)Gaka/J received from G. Kardon, Salt Lake City, UT, USA. All maintained on a C57Bl6 background. Female mice aged 8-24 weeks were bred for experiments involving embryos; embryonic stages used are indicated in all figure panels. 11-week-old mice were used for all experiments involving adult subjects.

### Wild animals

No wild animals were used in this study

### Reporting on sex

Male and female mice were assigned into the experimental groups based on genotype, sex-based analysis was not performed due to low animal numbers.

### Field-collected samples

No field collected samples were used in this study

### Ethics oversight

Animal experiments were performed in accordance with the European Union legislation for the protection of animals used for scientific purposes. Animal maintenance and experimentation was approved by the Landesamt für Gesundheit und Soziales Berlin under license numbers ZH120, G0240/11, G0268/16 and G0250/17. Mouse lines were maintained in an enclosed, pathogen-free facility at a temperature of 22°C, 55% of humidity, and 12 h light / dark cycles.

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

## Plants

### Seed stocks

No plant material was used in this study

### Novel plant genotypes

No plant material was used in this study

### Authentication

No plant material was used in this study