

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 (<i>n</i>) 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 <i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>
☐	☐ 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. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> value noted <i>Give P values as exact values whenever suitable.</i>
☒	☐ 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 <i>d</i> , Pearson's <i>r</i>), 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	no software was used for data collection
Data analysis	All code used in this manuscript can be found at https://github.com/jaleesr/SenePy . The versions of the required software can be found in this repository at https://github.com/jaleesr/SenePy/blob/main/PAPER_CODE/freeze.txt .

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](#)

We used multiple publicly available datasets to develop, validate, and apply senePy. Under the Gene Expression Omnibus, they can be found at GSE132042 [<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE132042>] (tabula muris senis), GSE201333 [<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE201333>] (tabula sapiens), GSE115469 [<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE115469>] (human liver), GSE134355 [<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE134355>] (human cell landscape), GSE185553 [<https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE185553>] (human hippocampus),

GSE185277 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE185277] (human hippocampus), GSE198323 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE198323] (human hippocampus), GSE121611 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE121611] (human lung), GSE122960 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE122960] (human lung), GSE155182 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE155182] (p16 reporter), GSE222951 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE222951] (hepatocyte tumorigenesis), GSE130727 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE130727] (in vitro senescence), GSE180750 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE180750] (lung senolysis), GSE184348 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE184348] (muscle senolysis), GSE176092 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE176092] (heart spatial), GSE148612 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE148612] (brain spatial), and GSE171524 [https://www.ncbi.nlm.nih.gov/geo/query/acc.cgi?acc=GSE171524] (lethal COVID-19). Human skin aging data is available in the Genome Sequence Archive under HRA000395 [https://ngdc.cncb.ac.cn/gsa-human/browse/HRA000395]. Human heart data are available at www.heartcellatlas.org. The data generated in this study are provided in the Supplementary Information and the Source Data file available at 10.5281/zenodo.14775758.

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	this information has not been collected
Reporting on race, ethnicity, or other socially relevant groupings	this information has not been collected
Population characteristics	this information has not been collected
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](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	The sample sizes were determined based on previously conducted and published experiments (GSE132042, GSE115469, GSE134355, GSE185553, GSE185277, GSE198323, GSE121611, GSE122960, GSE155182, GSE222951, GSE130727, GSE180750, GSE184348, GSE176092, GSE148612, GSE171524, HRA000395, the human heart cell atlas, and tabula sapiens.)
Data exclusions	No data were excluded.
Replication	We validated our main findings using multiple independent datasets.
Randomization	This is not applicable because analysis was performed on previously deposited data.
Blinding	Blinding was not possible because analysis used previously deposited data.

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

Plants

Seed stocks

Report on the source of all seed stocks or other plant material used. If applicable, state the seed stock centre and catalogue number. If plant specimens were collected from the field, describe the collection location, date and sampling procedures.

Novel plant genotypes

Describe the methods by which all novel plant genotypes were produced. This includes those generated by transgenic approaches, gene editing, chemical/radiation-based mutagenesis and hybridization. For transgenic lines, describe the transformation method, the number of independent lines analyzed and the generation upon which experiments were performed. For gene-edited lines, describe the editor used, the endogenous sequence targeted for editing, the targeting guide RNA sequence (if applicable) and how the editor was applied.

Authentication

Describe any authentication procedures for each seed stock used or novel genotype generated. Describe any experiments used to assess the effect of a mutation and, where applicable, how potential secondary effects (e.g. second site T-DNA insertions, mosaicism, off-target gene editing) were examined.