

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	Flow cytometry data were collected with CytExpert v2.3. IF data was collected with LASX v4.5 IHC and H&E data were collected with Zen v3.8. Western blot images were collected with Image Lab Touch Software v3.01 (BioRad). CRISPR screen reads were generated using NextSeq 1000/2000 Control Software (v. 1.2.036376) (Illumina) and demultiplexed using DRAGEN (v.3.7.4) (Illumina).
Data analysis	Flow cytometry data were analyzed using FlowJo v10. Imaging data were processed and analyzed using Imaris v10 and FlowJo v10. Single cell sequencing files were processed and aligned to mm10, and count matrices were generated using Cell Ranger (v6.0.0). Further analyses were performed in R using the Seurat package (v4). Gene set enrichment analysis was done using the FGSEA workflow. Data analysis was performed on Microsoft Excel v16.80 and Prism v10. GSEA software (v4.0.3) Western blot images were analyzed with Image Lab v6.1 (Bio-Rad). CRISPR screen reads were extracted from fastq files and normalized using custom perl scripts and Bowtie2 (version 2.2.9).

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](#)

Cell line and single cell RNA seq data was uploaded to the Gene Expression Omnibus (GEO) under accession number GSE253435.

Repertoire sequencing data and CRISPR screen score (CSS) data used in this study are provided in Figshare (<https://figshare.com/s/dc9ea731f2c72b19b4f3>)

Source data are provided with this paper.

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

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
☒	☒ 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

Antibodies used for Flow cytometry:

Fixable Viability Dye eFluor 780 (ebiosciences) 1:1000
 BV786 or BUV395–conjugated anti-B220 (RA3-6B2; BD), 1:400
 BUV395–conjugated anti-CD4 (RM4-5; BD), 1:400
 Pacific blue or Alexa Fluor 647–conjugated GL7 (GL-7; BioLegend), 1:400
 BV650 conjugated anti-IgD (11- 26c.2a; BioLegend), 1:400
 PerCP Cy5.5 or PE-Cy7–conjugated anti-CD38 (90; BioLegend), 1:400
 PE-Cy7, PE or BV421–conjugated anti-Fas (Jo2; BD), 1:400
 FITC, PerCP-Cy5.5 or Alexa Fluor 700–conjugated anti-CD45.2 (104; BioLegend), 1:400
 PE-Cy7 or PerCP-Cy5.5–conjugated anti-CD45.1 (A20; BioLegend), 1:400
 BV786–conjugated anti-CD86 (GL-1; BioLegend), 1:100
 PE–conjugated, APC–conjugated anti-CXCR4 (2B11; ebiosciences), 1:100
 Alexa Fluor 647–conjugated anti-c-Myc (Y69; Abcam), 1:400
 PE–conjugated anti-Cyclin D3 (DCS-22; Biolegend), 1:400
 FITC or APC conjugated anti-BrdU (BU20A; eBioscience), 1:100
 p-AKT S473 (D9E; Cell Signaling; 1:400)
 pRPS6 Ser240/244 (D68F8; Cell Signaling) 1:400
 AF647–conjugated anti-rabbit IgG (Invitrogen)1:1000

For Immunohistochemistry experiments:

biotinylated anti-GL7 (GL7; Biolegend), 1:400
 biotinylated anti-B220 (RA3-6B2; Biolegend), 1:200
 biotinylated anti-CD35 (8C12; BD Biosciences), 1:200
 unlabeled polyclonal goat anti-mouse IgD (Cedarlane) 1:1000

For Immunofluorescence experiments

SparkRed 718–conjugated anti-B220 (RA3-6B2; BioLegend) 1:200
 AF488–conjugated anti-IgD (11-26c.2a; BioLegend) 1:100
 AF647–conjugated GL7 (GL-7; BioLegend) 1:100
 biotin–conjugated anti-CD35 (8C12; BD) 1:200
 biotin–conjugated anti-LYVE1 (ALY7, eBioscience) 1:200
 rabbit anti-Myc (D3N8F; Cell Signaling) 1:400
 rabbit anti-phospho-ribosomal protein S6 (pRPS6) (Ser240/244) (D68F8; Cell Signaling) 1:800
 BV421–conjugated streptavidin (BD) 1:400
 AF555–conjugated anti-rabbit IgG (Invitrogen)1:200
 JOPRO-1 (Invitrogen) 1:10,000

For Western blot experiments:

MYC (D3N8F; Cell Signaling; 1:2000)
 CCND3 (DCS22; Cell Signaling; 1:2000)
 Actin (13E5; Cell Signaling; 1:4000)
 p-P70S6K T389 (108D2; Cell Signaling; 1:2000)
 P70S6K (polyclonal rabbit antibody #9202; Cell Signaling; 1:2000)
 p-RPS6 S235/6 (D57.2.2E; Cell Signaling; 1:4000)
 RPS6 (5G10; Cell Signaling; 1:4000)
 p-AKT S473 (D9E; Cell Signaling; 1:4000)
 p-AKT T308 (D25E6; Cell Signaling; 1:4000)
 p-CCND3 T283 (E1V6W; Cell Signaling; 1:2000)

Validation

All antibodies used in this study are from widely used commercial sources and have been previously described in the literature and validated by the vendors. Validation data and citation information are available on the manufacturer's website (links below). Appropriate antibody dilutions were performed based on preliminary experiments and intensity of fluorescent signals. Dilutions for flow cytometry antibodies are referred to a staining volume of 40 ul per sample (~1 × 10⁶ cells).

Antibodies used for Flow cytometry:

Fixable Viability Dye eFluor 780 (ebiosciences) 1:1000
<https://www.thermofisher.com/order/catalog/product/65-0865-14>

BV786 or BUV395–conjugated anti-B220 (RA3-6B2; BD), 1:400

<https://wwwbdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/buv395-rat-anti-mouse-cd45r-b220.563793>

<https://wwwbdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/bv786-rat-anti-mouse-cd45r-b220.563894>

BUV395-conjugated anti-CD4 (RM4-5; BD), 1:400

<https://wwwbdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/buv395-rat-anti-mouse-cd4.568375>

Pacific blue or Alexa Fluor 647–conjugated GL7 (GL-7; BioLegend), 1:400

<https://www.biolegend.com/en-gb/products/pacific-blue-anti-mouse-human-gl7-antigen-t-and-b-cell-activation-marker-antibody-9580>

<https://www.biolegend.com/en-gb/products/alexa-fluor-647-anti-mouse-human-gl7-antigen-t-and-b-cell-activation-marker-antibody-8602>

BV650 conjugated anti-IgD (11- 26c.2a; BioLegend), 1:400

<https://www.biolegend.com/en-gb/products/brilliant-violet-650-anti-mouse-igd-9031>

PerCP Cy5.5 or PE-Cy7–conjugated anti-CD38 (90; BioLegend), 1:400

<https://www.biolegend.com/en-gb/products/pe-cyanine7-anti-mouse-cd38-antibody-3926>

<https://www.biolegend.com/en-gb/products/percp-cyanine5-5-anti-mouse-cd38-antibody-9563>

PE-Cy7, PE or BV421-conjugated anti-Fas (Jo2; BD), 1:400

<https://wwwbdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/bv421-hamster-anti-mouse-cd95.562633>

<https://wwwbdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/pe-cy-7-hamster-anti-mouse-cd95.557653>

<https://wwwbdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/pe-hamster-anti-mouse-cd95.554258>

FITC, PerCP-Cy5.5 or Alexa Fluor 700-conjugated anti-CD45.2 (104; BioLegend), 1:400

<https://www.biolegend.com/en-gb/products/fitc-anti-mouse-cd45-2-antibody-6>

<https://www.biolegend.com/en-gb/products/percp-cyanine5-5-anti-mouse-cd452-antibody-4271>

<https://www.biolegend.com/en-gb/products/alexa-fluor-700-anti-mouse-cd45-2-antibody-3393>

PE-Cy7 or PerCP-Cy5.5–conjugated anti-CD45.1 (A20; BioLegend), 1:400

<https://www.biolegend.com/en-gb/products/pe-cyanine7-anti-mouse-cd45-1-antibody-4917>

<https://www.biolegend.com/en-gb/products/percp-cyanine5-5-anti-mouse-cd45-1-antibody-4269>

BV786–conjugated anti-CD86 (GL-1; BioLegend), 1:100

<https://www.biolegend.com/en-gb/products/brilliant-violet-785-anti-mouse-cd86-antibody-12818>

PE-conjugated, APC- conjugated anti-CXCR4 (2B11; ebiosciences), 1:100

<https://www.thermofisher.com/antibody/product/CD184-CXCR4-Antibody-clone-2B11-Monoclonal/12-9991-82>

<https://www.thermofisher.com/antibody/product/CD184-CXCR4-Antibody-clone-2B11-Monoclonal/17-9991-82?imgelid=1023016>

Alexa Fluor 647–conjugated anti-c-Myc (Y69; Abcam), 1:400

<https://www.abcam.com/products/primary-antibodies/alexa-fluor-647-c-myc-antibody-y69-ab190560.html>

PE-conjugated anti-Cyclin D3 (DCS-22; Biolegend), 1:400

<https://www.biolegend.com/en-gb/products/pe-anti-cyclin-d3-antibody-14405>

FITC or APC conjugated anti-BrdU (BU20A; eBioscience), 1:100

<https://www.thermofisher.com/antibody/product/BrdU-Antibody-clone-BU20A-Monoclonal/11-5071-42>

<https://www.thermofisher.com/antibody/product/BrdU-Antibody-clone-BU20A-Monoclonal/17-5071-42>

p-AKT S473 (D9E; Cell Signaling; 1:400)

<https://www.cellsignal.com/products/primary-antibodies/phospho-akt-ser473-d9e-xp-rabbit-mab/4060>

pRPS6 Ser240/244 (D68F8; Cell Signaling) 1:400

<https://www.cellsignal.com/products/primary-antibodies/phospho-s6-ribosomal-protein-ser240-244-d68f8-xp-rabbit-mab/5364>

AF647-conjugated anti-rabbit IgG (Invitrogen)1:1000

<https://www.thermofisher.com/antibody/product/Goat-anti-Rabbit-IgG-H-L-Highly-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A-21245>

For Immunohistochemistry experiments:

biotinylated anti-GL7 (GL7; Biolegend), 1:400

<https://www.biolegend.com/en-gb/products/biotin-anti-mousehuman-gl7-antigen-t-and-b-cell-activation-marker-antibody-15161>

biotinylated anti-B220 (RA3-6B2; Biolegend), 1:200

<https://www.biolegend.com/en-gb/products/biotin-anti-mouse-human-cd45r-b220-antibody-444>

biotinylated anti-CD35 (8C12; BD Biosciences), 1:200

<https://wwwbdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/>

biotin-rat-anti-mouse-cd35.553816

unlabeled polyclonal goat anti-mouse IgD (Cedarlane) 1:1000
<https://www.cedarlanelabs.com>

For Immunofluorescence experiments
 SparkRed 718-conjugated anti-B220 (RA3-6B2; BioLegend) 1:200
<https://www.biolegend.com/en-gb/products/spark-red-718-anti-mouse-human-cd45r-b220-antibody-22290>

AF488-conjugated anti-IgD (11-26c.2a; BioLegend) 1:100
<https://www.biolegend.com/en-gb/products/alexa-fluor-488-anti-mouse-igd-7092>

AF647-conjugated GL7 (GL-7; BioLegend) 1:100
<https://www.biolegend.com/en-gb/products/alexa-fluor-647-anti-mouse-human-gl7-antigen-t-and-b-cell-activation-marker-antibody-8602>

biotin-conjugated anti-CD35 (8C12; BD) 1:200
<https://www.bdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/biotin-rat-anti-mouse-cd35.553816>

biotin-conjugated anti-LYVE1 (ALY7, eBioscience) 1:200
<https://www.thermofisher.com/antibody/product/LYVE1-Antibody-clone-ALY7-Monoclonal/13-0443-82>

rabbit anti-Myc (D3N8F; Cell Signaling) 1:400
<https://www.cellsignal.com/products/primary-antibodies/c-myc-n-myc-d3n8f-rabbit-mab/13987>

rabbit anti-phospho-ribosomal protein S6 (pRPS6) (Ser240/244) (D68F8; Cell Signaling) 1:800
<https://www.cellsignal.com/products/primary-antibodies/phospho-s6-ribosomal-protein-ser240-244-d68f8-xp-rabbit-mab/5364>

BV421-conjugated streptavidin (BD) 1:400
<https://www.bdbiosciences.com/en-us/products/reagents/flow-cytometry-reagents/research-reagents/single-color-antibodies-ruo/bv421-streptavidin.563259>

AF555-conjugated anti-rabbit IgG (Invitrogen) 1:200
<https://www.thermofisher.com/antibody/product/Goat-anti-Rabbit-IgG-H-L-Cross-Adsorbed-Secondary-Antibody-Polyclonal/A-21428>

JOPRO-1 (Invitrogen) 1:10,000
<https://www.thermofisher.com/order/catalog/product/Y3603>

For Western blot experiments:
 MYC (D3N8F; Cell Signaling; 1:2000)
<https://www.cellsignal.com/products/primary-antibodies/c-myc-n-myc-d3n8f-rabbit-mab/13987>

CCND3 (DCS22; Cell Signaling; 1:2000)
<https://www.cellsignal.com/products/primary-antibodies/cyclin-d3-dcs22-mouse-mab/2936>

Actin (13E5; Cell Signaling; 1:4000)
<https://www.cellsignal.com/products/primary-antibodies/b-actin-13e5-rabbit-mab/4970>

p-P70S6K T389 (108D2; Cell Signaling; 1:2000)
<https://www.cellsignal.com/products/primary-antibodies/phospho-p70-s6-kinase-thr389-108d2-rabbit-mab/9234>

P70S6K (polyclonal rabbit antibody #9202; Cell Signaling; 1:2000)
<https://www.cellsignal.com/products/primary-antibodies/p70-s6-kinase-antibody/9202>

p-RPS6 S235/6 (D57.2.2E; Cell Signaling; 1:4000)
<https://www.cellsignal.com/products/primary-antibodies/phospho-s6-ribosomal-protein-ser235-236-d57-2-2e-xp-rabbit-mab/4858>

RPS6 (5G10; Cell Signaling; 1:4000)
<https://www.cellsignal.com/products/primary-antibodies/s6-ribosomal-protein-5g10-rabbit-mab/2217>

p-AKT S473 (D9E; Cell Signaling; 1:4000)
<https://www.cellsignal.com/products/primary-antibodies/phospho-akt-ser473-d9e-xp-rabbit-mab/4060>

p-AKT T308 (D25E6; Cell Signaling; 1:4000)
<https://www.cellsignal.com/products/primary-antibodies/phospho-akt-thr308-d25e6-xp-rabbit-mab/13038>

p-CCND3 T283 (E1V6W; Cell Signaling; 1:2000)
<https://www.cellsignal.com/products/primary-antibodies/phospho-cyclin-d3-thr283-e1v6w-rabbit-mab/53966>

Eukaryotic cell lines

Policy information about [cell lines and Sex and Gender in Research](#)

Cell line source(s)	NUDUL1 Human diffuse large B cell line ATCC CRL-2969 OCI-Ly8 Human diffuse large B cell line NCI Dogkit Human diffuse large B cell line DMSZ The Platinum E (Plat-E) retroviral packaging cell line was a gift from Susan R. Schwab at New York University. 293FT Transformed Human kidney cell line Thermo Fisher R70007
Authentication	We used a “DNA fingerprinting” method to test for the presence or absence of 16 common copy number variants allowing the detection of cross-contamination.
Mycoplasma contamination	All cell line tested negative for mycoplasma using the MycoAlert Mycoplasma Detection Kit (Lonza). Cell lines were tested regularly and preventative treatment was undertaken using MycoZap (Lonza) and Plasmocin (InvivoGen).
Commonly misidentified lines (See ICLAC register)	No cell lines used in this study among commonly misidentified lines.

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	Male and female mus musculus were used. In bone marrow chimeras experiments, animals were irradiated between 6 and 10 weeks of age and analyzed 7–10 weeks following irradiation (Fig. 1e,f,g, Fig. 2, Fig. 3e–g, j–l, Fig. 4l, Fig. 6b–e, g–h, k–l, Fig. 7d–f, ED Fig. 2b–f, ED Fig. 3, ED Fig. 4i–j, ED Fig. 6a–c, e,g, ED Fig. 7b–d, g h–i). Most other experiments were performed on adult animals between 7 and 20 weeks of age (Fig. 1d, h–l, Fig. 3a–d, h, m, Fig. 6f, i–j, ED Fig. 2a, f, g, ED Fig. 4a–h, ED Fig. 6d). Aging cohorts of Galpha13 deficient and littermate control mice were analyzed between 10 and 25 months of age (Fig. 1a–c and ED Fig. 1). Some glutamine supplementation experiments were started on mice that were 8 months old and analyzed after 10 weeks of treatment (Fig. 7g and ED Fig. 7j). All mice were on a C57BL/6 background. Mice were housed in a specific pathogen–free environment (except in gnotobiotic experiments) in ventilated microisolator cages with 12 h light and 12 h dark cycles at 72 F and 40–60% relative humidity. All mouse experiments received approval by the National Cancer Institute Animal Care and Use Committee (NCI-ACUC) and were performed in accordance with NCI-ACUC guidelines and under approved protocol LYMB-001. Adult B6-Ly5.1/Cr (B6.SJL-PtprcaPepcb/BoyCrCrI; Stock number 564) mice at least 6 weeks of age were from Charles River Frederick Research Model Facility. Cr2-cre (B6.CgTg(Cr2-cre)3Cgn/J; Stock number 006368), Aicdacre (B6.129P2-Aicdatm1(cre)Mnz/J; Stock number 007770), Rosa26LSL-Cas9 (B6J.129(B6N)-Gt(ROSA)26Sortm1(CAG-cas9*, -EGFP)Fezh/J; Stock number 026175), Rosa26Cas9 (B6(C)-Gt(ROSA)26Sore1.1(CAG-cas9*, -EGFP)Rsky/J; Stock number 028555) and Mb1-cre (B6.C(Cg)-Cd79atm1(cre)Reth/EhobJ; Stock number 020505) mice were from The Jackson Laboratory. Gna13f/f mice were from S. Coughlin (University of California, San Francisco, San Francisco, CA). S1pr2-creERT2 BAC-transgenic and Rosa26LSL-tdTomato were from T. Okada (RIKEN, Yokohama City, Kanagawa, Japan)
Wild animals	This study did not utilize wild animals.
Reporting on sex	Male and female mice were used in this study. Littermates that were also sex-matched were used whenever possible to control for co-variates.
Field-collected samples	This study did not utilize field-collected samples.
Ethics oversight	National Cancer Institute Animal Care and Use Committee (NCI-ACUC). Protocol number: LYMB-001

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

Plants

Seed stocks	Not applicable
Novel plant genotypes	Not applicable
Authentication	Not applicable

Flow Cytometry

Plots

Confirm that:

- ☒ The axis labels state the marker and fluorochrome used (e.g. CD4-FITC).
- ☒ The axis scales are clearly visible. Include numbers along axes only for bottom left plot of group (a 'group' is an analysis of identical markers).
- ☒ All plots are contour plots with outliers or pseudocolor plots.
- ☒ A numerical value for number of cells or percentage (with statistics) is provided.

Methodology

Sample preparation	Mesenteric lymph node, peripheral lymph node or peyer's patch cell suspensions were generated by mashing the organs through 70-mm cell strainers in RPMI containing 2% (v/v) FBS, antibiotics (penicillin (50 IU/ml) and streptomycin (50 mg/ml); Cellgro) and 10 mM HEPES, pH 7.2 (Cellgro).
Instrument	Beckman Coulter Cytoflex LX for cell analysis. Sony MA900 for cell sorting.
Software	Data was collected using CytExpert v2.3 (Beckman Coulter). Data was analyzed with Flowjo v10 (Treestar)
Cell population abundance	In all flow cytometry experiments, 300,000 to 1,000,000 events were recorded per sample. For repertoire sequencing, 8,000 to 42,000 GC B cells were sorted into RLT buffer (Qiagen). GC B cells were sorted as single live cells that were B220+, CD4-, IgDlo, CD38lo, Fas+ and GL7+. For single cell RNA sequencing experiments, ~12,000 cells per sample were sorted into PBS + 0.08% BSA.
Gating strategy	Relevant examples of gating strategies are shown in the main and supplemental figures.
☒ Tick this box to confirm that a figure exemplifying the gating strategy is provided in the Supplementary Information.	