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Supplemental material

Concurrent impact of de novo mutations on cranial and cortical development in nonsyndromic craniosynostosis

Kiziltug et al.

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Table S1: Nonsyndromic CS disorder risk genes

ABCC1
ARHGEF18
DVL3
KIAA0100
KMT5B
TMEFF1
NAA25
NKX6-1
NME5
PCNT
SMAD6
SPRY1
TCF12
THRA
ZCCHC11
ACBD5
CPED1
DCAF13
GPRC5A
KIAA1211
MESP1
MRPS14
SMARCD2
SPRY4
ZNF622
ARAP3
DUS3L
FBXO27
KIAA1841
KPNA2
KRI1
MACF1
MADD
SLC25A21
SLC35E2B
TTC12
VPS13C
ABCC5
ACADM
AGAP3
ASB5
AXIN1
CACNA1H
CATSPER4

CCBL2
COL11A1
CSF2RB
EDEM1
EFNA5
EXTL3
GAK
H2AFV
HELZ2
HERC2
IVD
KCNH1
KCNH3
KCNN4
MAPK7
MARCO
MEMO1
MTHFD1
NPHP4
PEPD
PSD2
PSMC2
PSMC5
RASAL2
RCCD1
SETX
SI
SLC12A2
SLC12A6
SLC2A14
SLC4A3
SLC5A2
SMURF1
TBCB
TENM2
THBS1
TSC1
ZNF778
ATAD5
CAPN1
ZC3H7A
ZNF469

Table S2: Autism risk genes

ADNP
AKAP9
ANK2
ARID1B
ASH1L
BCL11A
BTRC
C16orf13
CACNA2D3
CCSER1
CHD2
CHD8
CMPK2
CTTNBP2
CUL3
DDX3X
DNMT3A
DSCAM
DYRK1A
ERBIN
ETFB
FAM98C
FOXP1
GABRB3
GIGYF1
GRIN2B
ILF2
INTS6
KATNAL2
KDM5B
KDM6B
KMT2C
KMT2E
KMT5B
MFRP
MLANA
MYT1L
NCKAP1
NRXN1
P2RX5
PHF2
POGZ
PRKAR1B
PTEN

RANBP17
RAPGEF4
SCN2A
SETD5
SHANK2
SHANK3
SMURF1
SPAST
SYNGAP1
TBR1
TCF7L2
TMEM39B
TNRC6B
TRIP12
TSPAN4
USP45
WAC
WDFY3
CAPN12
GRIA1
MYO5A
PCM1
SLC6A1
UIMC1
ZNF559
ADNP
MED13L
ANKRD11
TLK2
DEAF1
CTNNB1
KCNQ3
SRPRA
TBL1XR1
RORB
RAI1
DYNC1H1
DPYSL2
AP2S1
PAX5
MKX
SIN3A
MBD5
MAP1A
STXBP1
CELF4

PHF12
PPP2R5D
TM9SF4
PHF21A
PRR12
SKI
ASXL3
SMARCC2
CREBBP
TCF4
CACNA1E
GNAI1
TCF20
FOXP2
NSD1
LDB1
EIF3G
KIAA0232
VEZF1
GFAP
IRF2BPL
ZMYND8
SATB1
RFX3
SCN1A
PPP5C
TRIM23
TRAF7
ELAVL3
GRIA2
LRRC4C
NUP155
NR3C2
NACC1
PTK7
PPP1R9B
GABRB2
HDLBP
TAOK1
UBR1
TEK
KCNMA1
CORO1A
HECTD4
NCOA1
DIP2A

Table S3: Developmental disorder risk genes

ARID1B
ANKRD11
DDX3X
ADNP
KMT2A
SYNGAP1
SCN2A
DYRK1A
SETD5
MECP2
ASXL3
STXBP1
KCNQ2
PPP2R5D
MED13L
CTNNB1
SATB2
WDR45
TCF4
EP300
FOXP1
CDK13
SMC1A
PURA
TBL1XR1
GATAD2B
HDAC8
PACS1
SLC6A1
AHDC1
GNAO1
HNRNPU
KANSL1
CSNK2A1
KAT6B
GRIN2B
CHD2
ALG13
KAT6A
CDKL5
POGZ
MEF2C
EHMT1
GNAI1
CASK

IQSEC2
SMAD4
CTCF
CREBBP
SMARCA2
NAA10
CHAMP1
PPM1D
NSD1
COL4A3BP
DNM1
CNKSR2
CNOT3
KIF1A
SCN1A
MSL3
KCNH1
KCNQ3
BCL11A
EEF1A2
WAC
PTEN
ZBTB18
PDHA1
NFIX
CHD8
GABRB3
USP9X
DYNC1H1
SUV420H1
FOXG1
TCF20
SCN8A
PUF60
ZC4H2
MYT1L
CHD4
TRIO
ITPR1
BRAF
PPP2R1A
PTPN11
SET
AUTS2
SLC35A2
KDM5B

ASXL1
UPF3B
PHF21A
PRR12
SKI
ASXL3
SMARCC2
CREBBP
TCF4
CACNA1E
GNAI1
TCF20
FOXP2
NSD1
LDB1
EIF3G
KIAA0232
VEZF1
GFAP
IRF2BPL
ZMYND8
SATB1
RFX3
SCN1A
PPP5C
TRIM23
TRAF7
ELAVL3
GRIA2
LRRC4C
NUP155
NR3C2
NACC1
PTK7
PPP1R9B
GABRB2
HDLBP
TAOK1
UBR1
TEK
KCNMA1
CORO1A
HECTD4
NCOA1
DIP2A

Table S4: Schizophrenia risk genes

AKT1
MAGI2
CHRNA7
GRIN2B
HTR2A
NOS1
RELN
SRR
CSMD1
TCF4
SHANK3
NRXN1
RTN4R
SP4
SETD1A
PPP3R1
SYNGAP1
MDK
NRG3
CNR1
DISC1
GRM5
GSK3B
ZDHHC8
APOE
NR4A2
SLC6A3
DTNBP1
PPP1R1B
KMO
CPLX2
BACE1
MBP
TAAR1
MAP6
PTGS2
PLCB1
LRRTM1
MAP2K7
NLGN2
SLC6A1
YWHAH
MTOR
AVPR1A

ZIC2
GNAS
BECN1
CHI3L1
COMT
DRD3
BRD1
DAOA
DISC2
ANK3
GRIA1
GRM3
NRG1
HLA-DRB1
MTHFR
NCAM1
NOTCH4
NRGN
PDE4B
ABCB1
PRODH
SLC1A1
TBX1
CACNA1C
ZNF804A
FOXP2
FEZ1
NOS1AP
SRGAP3
SYN2
MED12
CHRNA5
HLA-DQB1
VRK2
HLA-A
NDE1
DLG2
GABBR1
MIR137HG
ARVCF
TCF7L2
FYN
CNNM2
YWHAE
TSPAN18
TSNARE1

MPC2
ITIH3
NTRK3
PBRM1
MAD1L1
DCC
ESR2
NKAPL
HLA-B
MSRA
ATP2A2
OPCML
BCL9
TNXB
UFD1
DDR1
CACNB2
PGBD1
RAI1
CHRNA3
ABCA13
FGFR1
NLGN1
TNIK
TENM4
GPM6A
ITIH1
ZKSCAN4
PDE4D
BCL11A
PPP2R2B
AMBRA1
CACNA1B
ALDH1A2
DOCK4
SDCCAG8
LRRK2
CTNNA2
EML5
DPYD
RTKN2
PSD3
TMEM245
APOL2
GJA5
GJA8

PCDH17
HFE
HHAT
CYP26B1
ADAMTSL3
ZSCAN31
SOX5
MEGF10
SLC25A12
CEACAM21
PLAA
CDC25C
OLIG2
KLF12
CHRM1
CHRNA4
ADCYAP1
TPH2
CNP
CRP
ADRA1A
CYP1A2
CYP2D6
DAO
ACE
DLG4
DNMT1
DRD1
DRD2
DRD4
EGF
EGR3
MARK2
C9orf72
ERBB4
ESR1
F2
FHIT
PLCL2
FMR1
ANKK1
GABRB2
GAD1
CNTNAP2
GDNF
GLUL

DAOA-AS1
GRIN2A
NR3C1
GRM2
GRM7
HTR1A
HTR2C
HTR6
IFNG
IL1A
IL1B
IL2
IL4
IL6
IL10
KCNN3
LEP
MIR137
MAG
MAOA
MAOB
MMP9
NPY
NTF3
PIP4K2A
PLA2G1B
PLA2G4A
AHI1
PPP3CC
VPS35
PRL
PSD
SLC17A7
RTN4
PVALB
BDNF
S100B
CCL2
NPAS3
SLC1A2
SLC6A4
SLC6A9
SLC18A2
SOD2
SST
TNF

TPH1
FZD3
APOL4
ST8SIA2
NDEL1
SYN3
PLA2G6
CCK
CHRFAM7A
HOMER1
CNTF
DLG1
ERBB3
MLC1
GFAP
HPGDS
GNAO1
GSTM1
NDUFV2
OXTR
ACTB
CLDN5
TP53
VIPR2
CCKAR
PDLIM5
CYFIP1
GAD2
GSTT1
HLA-C
HSPA1A
HTR3A
IL3
NTRK2
PCM1
PIK3CA
AVP
SOX10
TLR4
TSNAX
VEGFA
ADORA2A
CREB1
CMYA5
NTNG1
ARC

GABRB3
GRIK3
ERVW-1
HINT1
HTR1F
HTR7
KCNH2
MAP2
MOG
NTS
PAH
PIK3CB
PLXNA2
SLC12A5
SLC1A3
SLC12A2
SLC18A1
SYP
CALM1
QKI
CLOCK
SIGMAR1
CAMKK2
CHL1
CHRM4
CTNNB1
DLG3
EGR1
FABP7
ADNP
GRIA2
GRID1
GRIK1
GRM1
GRM8
GSTP1
HDAC1
HDAC2
HSPA1B
HTR5A
IL18
NTRK1
OPRM1
PCNT
BAG1
NUFIP2

SOD1
SREBF1
VGF
XBP1
PIP4K2C
HDAC3
PICK1
CACNG2
CPLX1
UHMK1
CSF2
NCAN
DDC
NQO1
AGA
GABRA1
SULT4A1
GAP43
GRIA4
GRIK2
GRIK4
HMOX1
HP
HTR4
APOD
AR
LTA
MET
MIR346
NEFL
PDE4A
PIK3C3
PLP1
FXYD6
PON1
GNB1L
PPARA
SLC17A6
SLC6A2
SMARCA2
SP1
NTNG2
SELENBP1
SYNGR1
HTR3B
CDC42

DGCR2
SIRPB1
CHGB
GRIN3A
ADCYAP1R1
CNR2
CSF2RA
CTLA4
ADRA2A
CYP3A4
DNM1
EGR2
MYT1L
ASTN2
ACSL6
NCS1
GABRG2
PDE7B
GCLM
GLS
MCHR1
GPX1
GRIN2C
GRIN2D
HK1
HSPA1L
IL6R
IPO5
MIR30E
NRN1
MAPK1
MAPK3
PSEN2
KIF17
PTPRZ1
PINK1
SLC1A4
SREBF2
TF
TGFB1
TNFRSF1A
TYR
TET1
PTPN5
DLGAP1
NDST3

LINC00271
ERVK-18
ACTR2
CTCF
PPARGC1A
CHAT
CLU
CCR5
ADM
SLC32A1
CRYZ
MAPK14
CSF2RB
CYP2E1
EFNB2
EGR4
ELAVL2
SIRT1
LHX6
MDGA1
B3GAT1
GLO1
GNAL
GRN
GSTM2
ICAM1
IL3RA
IL10RA
AQP4
JUN
KCNQ2
KPNA3
NPSR1
MIR206
KMT2A
MTNR1B
MYO9B
OPA1
OXT
PAFAH1B1
PAX6
PDYN
RAPGEF6
PI4KA
ULK4
RCBTB1

PTGS1
RARA
CCND1
RHD
SLC1A5
SLC1A6
SLC6A12
TBP
TGM2
TLR3
TNFRSF1B
TYROBP
VDR
VIP
VSNL1
XRCC1
CALB1
DGCR6
PPP1R9B
DDO
PLA2G4C
RGS9
PHOX2B
ERDA1
NRXN3
CARTPT
HDAC4
ARHGEF11
TSNAX-DISC1
RANBP9
PRSS16
SEMA3A
ADARB1
PEMT
LILRB1
CHGA
CHRM2
CHRNB2
CSMD2
CKB
ACSM1
CRH
CSNK1E
CTNND2
ADRB3
CYP3A5

DBI
AGER
DNMT3B
ENO2
EPHX2
ALDH1A1
FAAH
FABP3
FABP5
FGFR2
ADNP2
SYT11
DICER1
FOLH1
RASD2
AMACR
ALOX12
STH
GABRA6
GABRB1
NALCN
GC
GCH1
NPAS4
GFRA2
NPTN
CACNG5
GCLC
GNB3
HTR3E
GRB2
GRIA3
GRM4
GSK3A
GSN
GSTA1
HCRTR1
HLA-DPB1
HRH2
HSPA9
HTC2
HTR1D
IGF2
IL2RA
IMPA2
KCNS3

BLOC1S3
LASP1
LMX1A
LMX1B
LPL
LRP2
LSAMP
MIR17
ARRB2
SMAD5
MDH1
MICB
MIF
MTHFD1
MTNR1A
MYH9
ATF4
NDUFS1
ATM
NEUROG1
NGFR
NQO2
NNMT
NPAS2
NPY1R
NTSR1
OPRK1
OTX2
PAK2
PAWR
SHANK1
MED15
PDGFRB
ACP1
PITX3
PLAT
PLG
PNOC
TREM1
DYM
PRKCA
SLC7A10
PANX2
CDC42SE2
LYRM4
MIR432

PTPN1
PTPRA
PRODH2
CACNG8
NPS
BCL2
REST
RGS2
RGS10
CTXN3
SAT1
BID
SRSF1
ETNPPL
SLC6A13
SLC25A1
STX1A
SYN1
TACR1
TACR3
TAP2
TDO2
NR2E1
TTR
UCP2
SCGB1A1
VLDLR
ZNF74
SLC30A3
LRP8
ST8SIA4
PLA2G7
CAMK2B
ESS2
TRRAP
STON2
IL18R1
HCAR3
MBD2
TOP3B
HPS4
SLC6A5
DCLK1
DLGAP2
CD163
SNAP29

ARHGAP18
SLC25A27
PRDX6
HDAC9
PLA2G4B
DLG2-AS1
MIR2682
HNRNPA3P1
CDK5
CDKN1C
AKR1A1
CDC42EP3
GAS2L1
IGF2BP2
CSPG5
B3GNT2
SRSF10
PTPN21
CHEK1
FSTL1
KLK8
PADI2
CHRM5
GABARAP
BTBD9
C1QTNF3
MSS51
ADK
ADORA1
CLVS2
B3GAT2
CREBBP
CREM
CRMP1
R3HDML
CSNK1D
HAPLN3
CNIH3
PDIK1L
CTRL
CTSK
GRK3
ADSS2
DGKH
DBN1
SLC30A8

SNX31
DIO3
DLX1
JAG1
DUSP6
ABCA1
EIF2S1
FBXO45
EMX2
EN1
EN2
ALDH3A1
ACSL4
FBP1
HNRNPA3
ALDH3B1
FCGR2A
SEMA3D
FGF2
PLEKHA6
SBNO2
MYO16
NFASC
FLNB
VPS39
FN1
LARS2
SIRT5
GRIP1
DAAM2
CABIN1
PADI4
ALK
FRA7G
FUT8
GABRA5
GABRR1
HSPA12A
AUTS2
FBXL21P
OFCC1
GFRA1
GFRA3
AP3M1
CNPPD1
TRMT2A

DKK4
DKK3
GLS2
IL17C
GPR78
MCAT
GLRA2
IFNL3
PLA2G4D
GRK6
GPS1
GRB10
GRIK5
DROSHA
GSS
GSTT2
DNMT3L
IL19
PSAT1
H1-4
H1-5
H2AX
HAGH
HLA-J
HMGA1
APBA2
APC
HRH1
HCAR2
CYP26C1
IDE
APOH
FAS
IL2RG
IL12B
ITGB3
JAG2
JARID2
NDUFS7
KCNB1
KCNH1
KCNJ3
KCNJ10
KCNQ3
KDR
KIF2A

ARHGAP1
LCN2
LIFR
FADS1
LINC02694
LRP1
MIR107
MIR130B
MIR185
MBNL1
MC5R
ME2
CD99
ASAH1
ACHE
TRPM1
MMP3
MOBP
MIR326
ATP6
MTR
RNR2
MYO5B
NDP
NDUFV1
NPAS1
MIR382
CLDN11
GEMIN4
CALY
PCDH8
PCK1
DCDC2
MSRB1
GHRL
PDZK1
PHB
SERPINI1
FXYD1
PMP2
SLC38A2
DGCR8
MAGEL2
DLL4
PPARG
PPIA

PNPO
PI4K2B
PARL
SOX6
WDR11
MCTP2
ST6GALNAC1
PAG1
GABRQ
MAPK8
B2M
PLSCR4
TIGAR
PTGDS
PTGER3
GJD2
MIR497
PTPN6
PEX19
RANBP1
RBP1
RELA
ELOVL5
ERVK-8
S100A9
ATXN2
BIK
PKNOX2
SDHA
SHMT1
SHOX2
USP46
AGXT2
WNK4
WNK3
SLC6A11
SLIT3
SNCB
SPTBN2
SRD5A2
BRCA1
BRCA2
STXBP1
BSG
VAMP1
VAMP2

VAMP7
BTC
TAC1
KLF5
TAP1
TAPBP
SNORD103C
BTG1
TCP1
TFAP2A
TGFBR2
THBS1
TIMP4
TLR2
TSPAN8
C1QA
C1QB
TPI1
TPT1
C4BPA
C4BPB
WNT2
XRCC4
CACNA1F
CCDC86
RETREG2
PALB2
PANK2
CCDC68
ADAM12
LMAN2L
TXNDC5
ADAMTS12
BRAP
CASP3
KREMEN1
KAT8
GNPAT
MCHR2
RGS5
CGNL1
ITGA8
DIXDC1
CAV1
YWHAZP5
TNFSF13

CBS
CDK5R1
PER3
HERC2
CCND2
H2BC11
NAV1
NAV2
EFCAB11
MPZL1
TMSB10
MAGI1
GPR50
NUMBL
CD14
CADPS2
NRXN2
FADS2
HOMER2
AKAP5
ENTPD4
CD48
CELSR1
SH3PXD2A
RIMS2
ARHGAP32
RAPGEF5
RIMS3
RB1CC1
SETDB1
SEPTIN7
SV2A
OXSR1
A1BG
DEL22Q11.2
ERVW-4
NPRL2
CELF2
CETN1
CHD4
ADCY7
SLC26A7
KCTD12
SLC26A8
OR4C46
COL3A1

FAM3D
CP
TEKT5
ZNF480
ZNF565
SLC23A3
SPATA5
LPAR1
EIF5
HTR3D
ADGRF4
TRAK1
CFAP65
GABRA4
GABRD
ALS2CL
BLOC1S1
DAZAP1
CBLIF
LAMA1
GRIN1
SAP30BP
HLA-E
APOA4
CCDC137
ZNF530
INPP5A
ITGAM
KPNA1
GPR153
LAMA2
MIR219A2
LMOD2
MIR328
DFNB47
ND4
PLLP
SDF4
CDK16
PML
UGT1A3
RNANC
SBNO1
EDEM2
SEPTIN11
RGS12

FASTKD5
ACOT6
ST3GAL1
SNAP25
KCNH6
NRIP1
CASP4
KDM2B
BHLHE40
UNC5C
SOCS2
CCNA2
ESAM
ADAMTS3
PITPNM1
MAGEC1
YWHAZ
GOT2
HIVEP2
PPP3CB
NCSTN
CHST3
ACTR3
CTSC
KDM1A
ZNF521
NGF
ATP5F1C
PPM1G
KDM5C
ASH2L
SLCO6A1
USH1G
SLC39A8
KALRN
NT5C2
ITIH4
MECP2
RBFOX1
AS3MT
ATXN1
ZNF365
SATB2
SYNE1
QPCT
RENBP

CALB2
EHMT1
CALN1
AKT3
BTN3A2
EFNA5
CTNNA3
HLA-DQA1
MMP16
FURIN
MRTFA
RAP1A
SNCA
TMTC1
DGKZ
CACNA1I
GABBR2
SNAP91
FOXO6
MSH5-SAPCD1
RBM12
DLC1
CIB2
CLCN3
FAT3
MSI2
DECR1
DNMT3A
PDXDC1
FOXO3
ZFPM2
SF3B1
NEGR1
SPATS2L
FOXP1
HLA-DMA
HLA-DOB
HLA-DRB5
STT3A
KIT
KLC1
ARHGAP4
ARSA
MEF2C
NFATC3
PRKN

NOSIP
PIK3C2A
LRP1B
ATF7IP
ANKS1B
CAMK1D
ADCK1
SLC4A10
NLGN4X
PITPNM2
ZSWIM6
CADM3
RARG
RTN1
ST3GAL3
BCL11B
UPF3B
PCDH15
TCF20
YWHAG
CACNA1D
PRRC2A
SPHKAP
FXR1
CUL3
TAOK2
SEC24C
ZEB2
TRANK1
ZBED4
MIR29B2CHG
SLC8A1-AS1
ZSCAN16-AS1
CADM3-AS1
ACTG1P22
LINC00240
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BMP6
IQCJ
SLC16A1
SMN1
SMN2
SNRPN
SORL1
DST
SPARC
SPN
SPR
SRF
SRM
SRPRA
SRY
SSTR5
STAR
STRN
STXBP3
SULT2A1
ADAM17
TAL1
TBCD
HNF1B
ZEB1
BTN1A1
TRGVB
TCTA

ACTC1
PRDX2
TERT
TFPI
TGFB2
TGFBI
THAS
THBD
THRA
THRB
TIMP1
TIMP2
TIMP3
TKT
TLR1
TLR5
TOP1
TPO
TPP2
TRC-GCA24-1
CCT3
TRIO
TSC2
C5
TTN
SNORD118
POTEF
MEIKIN
OIP5-AS1
CCR2
TYRP1
UBE2D1
UBE3A
SUMO1
UCP1
VPS51
VCAM1
BEST1
TRPV1
VRK1
DAGLA
WNT1
WNT3
WNT7A
XPC
XRCC3

YY1
YWHAB
ZNF45
CACNA1A
DNALI1
PSS
CACNB4
IL1R2
FZD5
SLC25A20
GGCT
NUP37
DEK
PLEKHF1
EFHD2
MMEL1
EPM2A
SLC52A2
AIMP2
SNIP1
ZNF750
ALG9
HDAC11
NANOG
CNTNAP3
SYNDIG1
DNAJC5
SRCIN1
ZBP1
CALR
SLC7A5
SLC38A1
NETO1
MIA
CAMP
USP9X
H4C9
PICALM
FZD1
FZD7
CASP1
H3C6
CHST9
H4C1
H4C4
H4C6

H4C12
H4C11
H4C3
H4C8
H4C2
H4C5
H4C13
H4C14
LOH19CR1
PLA2G10
TMPRSS13
ULK1
STX7
ATP13A4
BBOX1
NR0B2
SARNP
CDC42BPA
LMNB2
PHF5A
FBH1
UBASH3B
ATCAY
TRIM5
BCAS1
SLC22A16
RUNX1
USO1
KCNK5
RIPK2
CES2
KYAT1
TMEM11
CCN6
DLEU2
KAT2B
NR1I2
FUBP1
EIF2S2
ENDOU
SNURF
BSN
WASF1
LMLN
SLC25A14
CCNH

CCRL2
MAP7
CLDN12
CLDN1
CCT6A
ATP6V0D1
INA
P2RX6
PKDCC
ISX
CHURC1
ARHGEF2
CD4
ZMYM3
XPR1
VAPB
ASB16
CD8B
PIWIL1
MARCHF9
CD19
MS4A1
KLF4
TRIP13
TRIP4
TGM5
TCEAL1
LHX2
KIF3B
COX5A
GRAP2
ZRANB2
GSTO1
ARHGEF6
CABP1
CD36
CHST10
TBX4
ADAMTS4
ADAMTS2
TBPL1
CD38
GOSR1
NRG2
CCL4L2
ABCG1

IQCB1
CD59
CD68
VGLL4
RAPGEF2
ULK2
GPRIN2
CD79A
ZSCAN12
FRMPD4
TOX
KIAA0513
PCLAF
RNF40
SFI1
DNAJC6
KIAA0319
ARNT2
WDR1
NR1H4
THOC1
HNRNPDL

Table S5: Height risk genes

ACAN
ADAM28
ADAMTS10
ADAMTS17
ADAMTS3
ADAMTSL3
AK092571
AKD1
AL117656
AL161980
ANKRD13B
ATP6V1E2
B3GNT8
BC030091
BMP2
BMP6
BNC2
BRCA1
C17orf42
C17orf82
C20orf199
C3orf63
C6orf1
C6orf173
CCDC100
CCDC108
CCDC66
CCDC91
CDK2AP1
CDK6
CLIC4
CLPS
CPN1
CWF19L1
CYP19A1
DDX27
DNM3
DTL
DYM
ECM2
EFEMP1
EIF2AK3
ESR1
ETV6

EXOSC5
FAM173A
FANCE
FARP2
FBLN2
FBXW11
FGFR4
FLI1
FNDC3B
FOLH1
FRS2
FUBP3
GDF5
GH1
GHSR
GNA12
GNPTAB
GPC5
H1FX
HAGHL
HDLBP
HHIP
HLA-__B
HMGA1
HMGA2
HSS00017874
HSS00085450
HSS00174467
ID4
IGF1R
IGF2BP2
IGF2BP3
IHH
INSR
INTS7
ITPR3
JMJD4
KCNQ1
L3MBTL3
LIN28
LIN28B
LPAR1
LRRC37B
LTBP1
LTBP2
LUZP1

MC4R
MEF2C
MFAP2
MICA
MKL2
MSTP9
MTMR11
MYO9B
N4BP2L2
NFATC4
NFIC
NME2
NOG
NPPC
NPR3
NSD1
NUCB2
PAPPA
PAPPA2
PCSK5
PDS5B
PEX2
PFAAP5
PIP4K2B
PIP5K2B
PITX1
PKN2
PML
PPA2
PPAP2A
PPARD
PPIF
PRKCZ
PRKG2
PSMB3
PTCH1
PTPRJ
QSCN6L1
QSOX2
REST
RMI1
RNF135
RPL5
RUNX2
RYBP
SCMH1

SLBP
SLC22A4
SLC22A5
SLC23A3
SLC39A13
SLIT3
SMPD2
SNAP47
SOCS2
SOCS5
STAT2
STK36
TBX2
TCF19
TEAD1
TGFB2
TMEM4
TNS1
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ZBTB24
ZNF142
ZNF311
ZNXF1

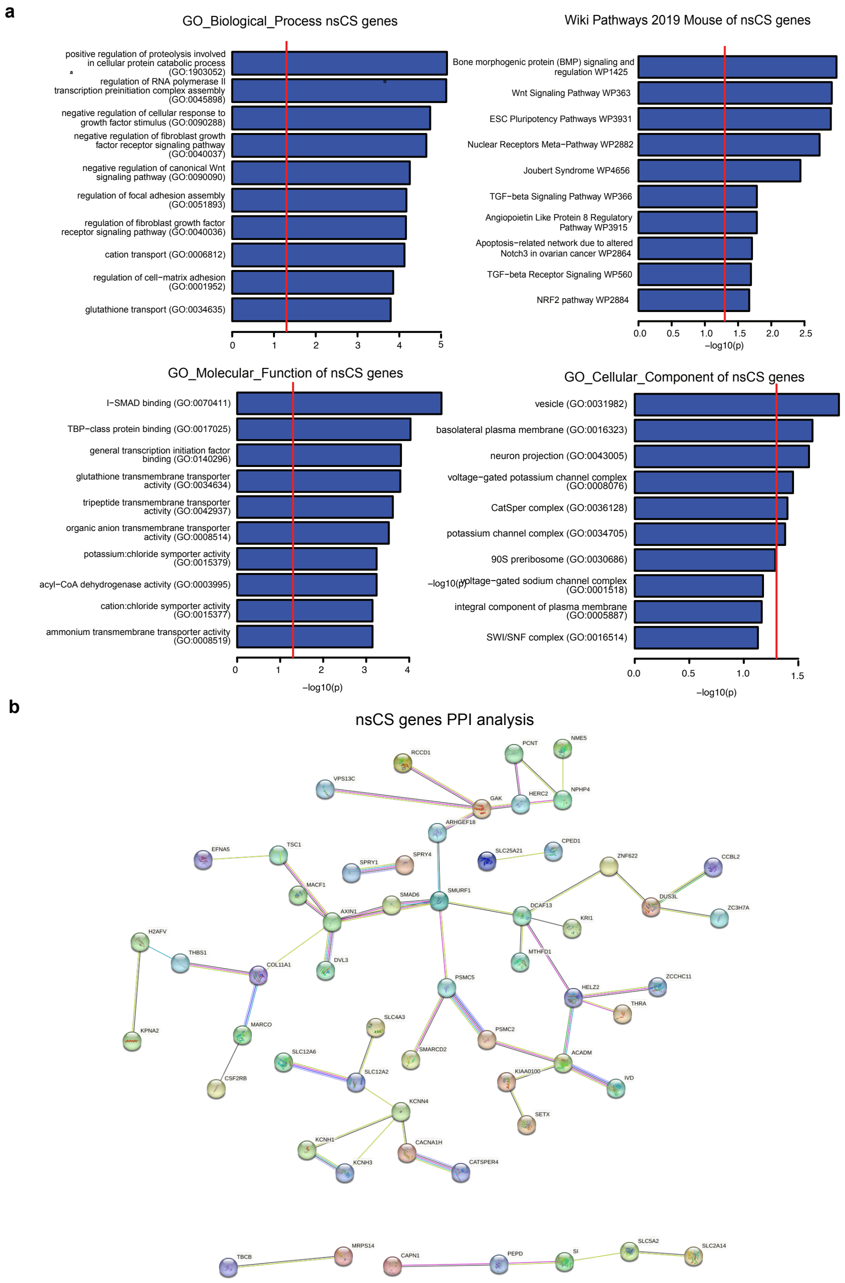
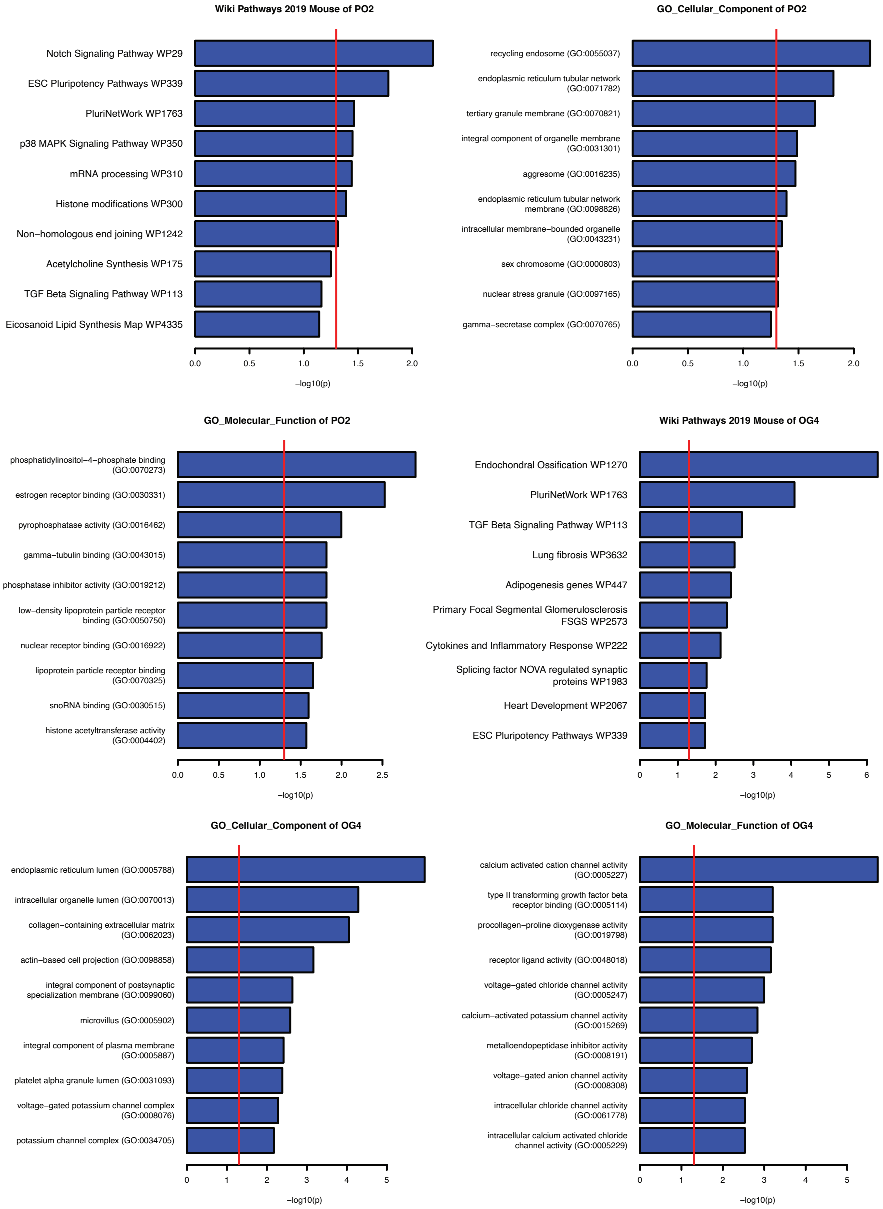


Figure S1: Pathway and protein-protein interaction analyses of nsCS genes.

a) Wiki pathway, GO biological processes, cellular component and molecular function analyses for nsCS genes. Dotted red line indicates threshold p-value of 0.05.
b) Protein-protein interactions for nsCS genes. See Szklarczyk D, Kirsch R, Koutrouli M, et al. The STRING database in 2023: protein-protein association networks and functional enrichment analyses for any sequenced genome of interest. *Nucleic Acids Res*. 2023;51(D1):D638-D646.



Wiki Pathways 2019 Mouse of PO2

GO_Cellular_Component of PO2

GO_Molecular_Function of PO2

Wiki Pathways 2019 Mouse of OG4

GO_Cellular_Component of OG4

GO_Molecular_Function of OG4

Figure S2: Pathway analyses of cell types enriched with nsCS genes in scRNAseq developing suture dataset.

Wiki pathway, GO cellular component and molecular function analyses for top genes in nsCS-enriched proliferative and mature osteogenic clusters. Dotted red line indicates threshold p-value of 0.05.

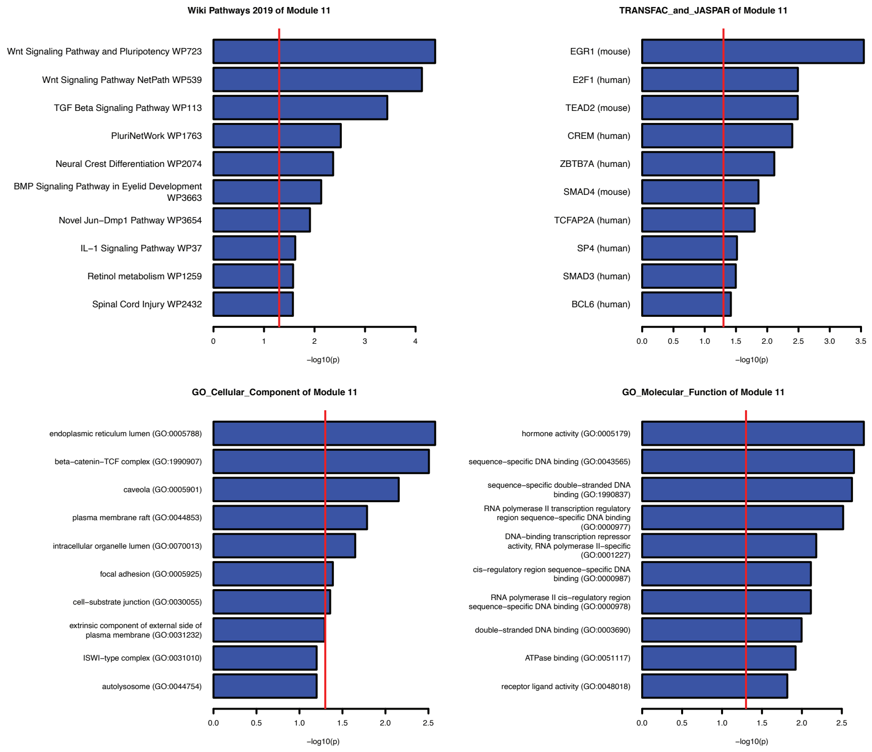


Figure S3: Pathway analyses of modules enriched with nsCS genes in scRNAseq developing suture dataset.

Wiki pathway, TRANSFAC/JASPAR transcription factor, GO cellular component and molecular function analyses for top genes in nsCS-enriched module 11. Dotted red line indicates threshold p-value of 0.05.

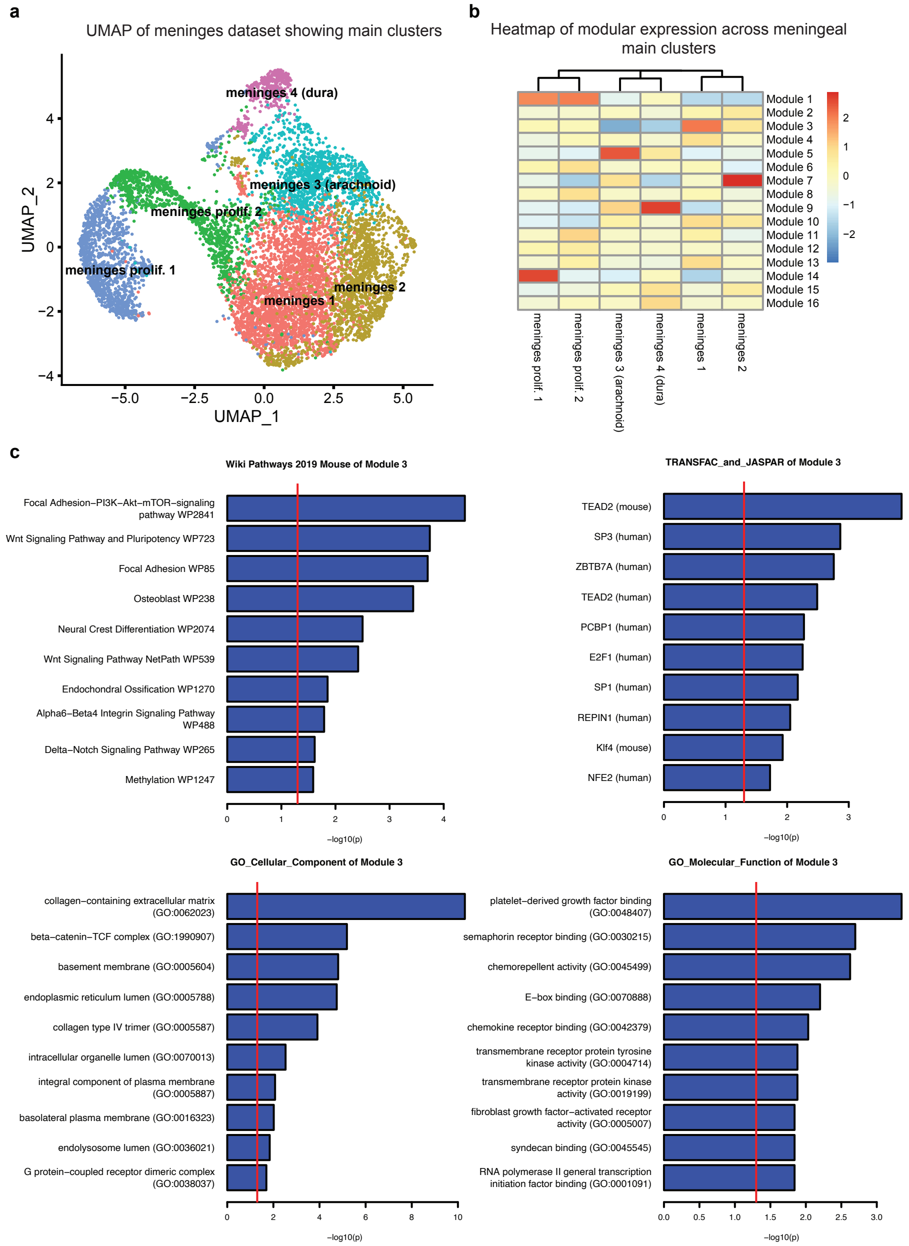


Figure S4: scRNAseq developing meninges dataset clustering, modular mapping and pathway analyses.

a) UMAP clustering of developing mouse meninges cells.
b) Heatmap of gene co-expression modules across individual cell types in developing mouse meninges.
c) Wiki pathway, TRANSFAC/JASPAR transcription factor, GO cellular component and molecular function analyses for top genes in nsCS-enriched module 3. Dotted red line indicates threshold p-value of 0.05.

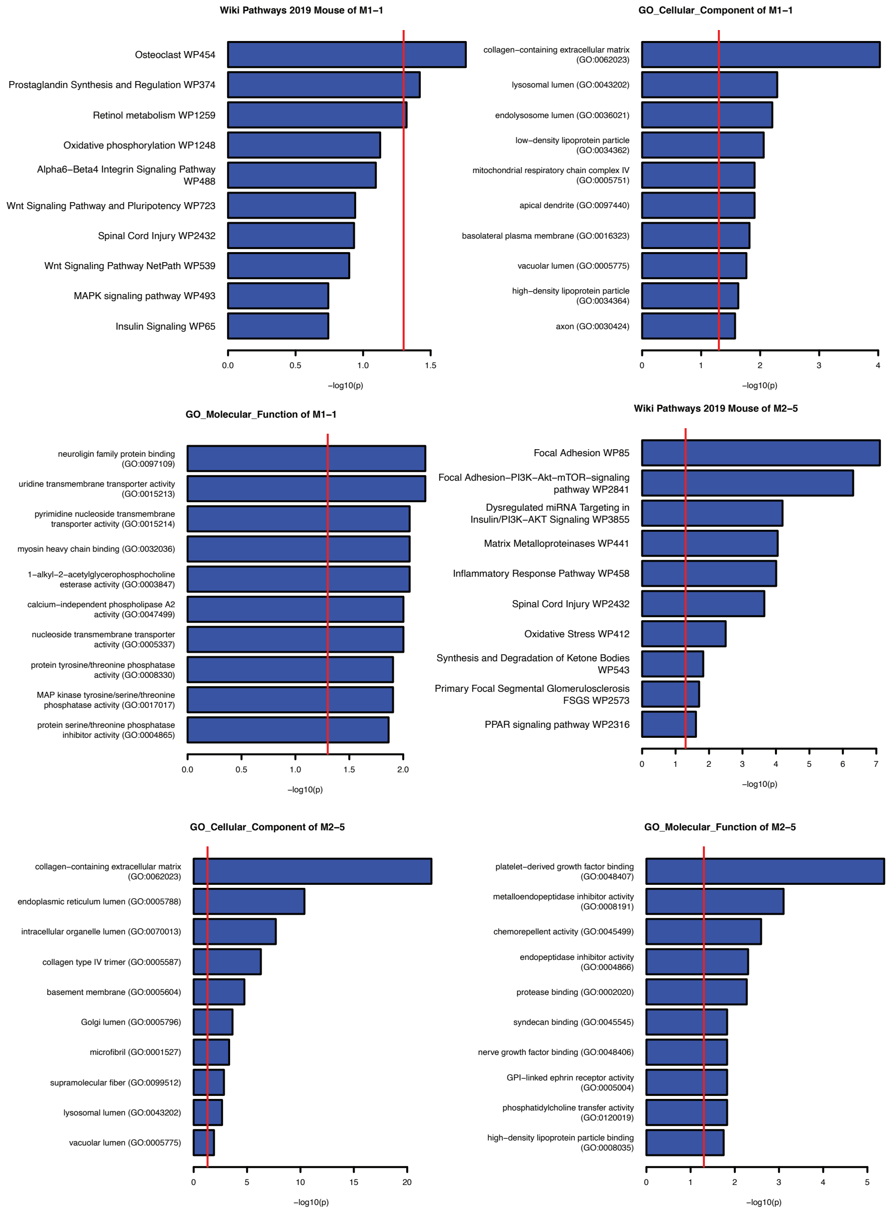


Figure S5: Pathway analyses of cell types enriched with nsCS genes in scRNAseq developing suture dataset.

Wiki pathway, GO cellular component and molecular function analyses for top genes in nsCS-enriched M1-1 and M2-5 pial fibroblast clusters. Dotted red line indicates threshold p-value of 0.05.

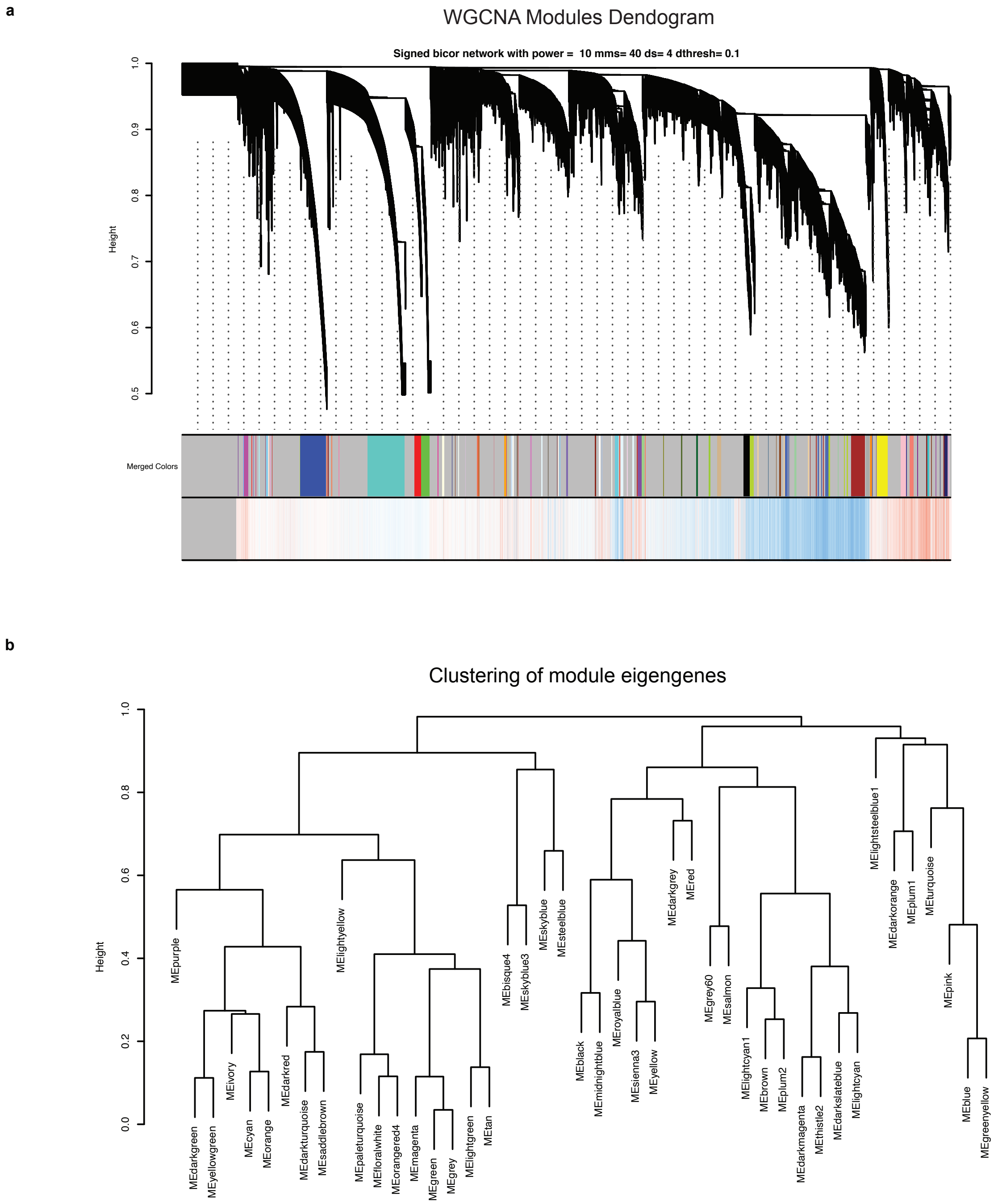


Figure S6: Weighted gene co-expression network analysis (WGCNA) of developing human brain bulkRNA dataset.

a) Gene clustering dendrogram constructed via hierarchical clustering of adjacency-based dissimilarity. The colored row below the dendrogram indicates module membership identified by the dynamic tree cut method.

b) Hierarchical clustering of module eigengenes summarizing the relationships between modules constructed during clustering analysis. Branches of the dendrogram demonstrate eigengenes that are positively correlated and therefore grouped together.

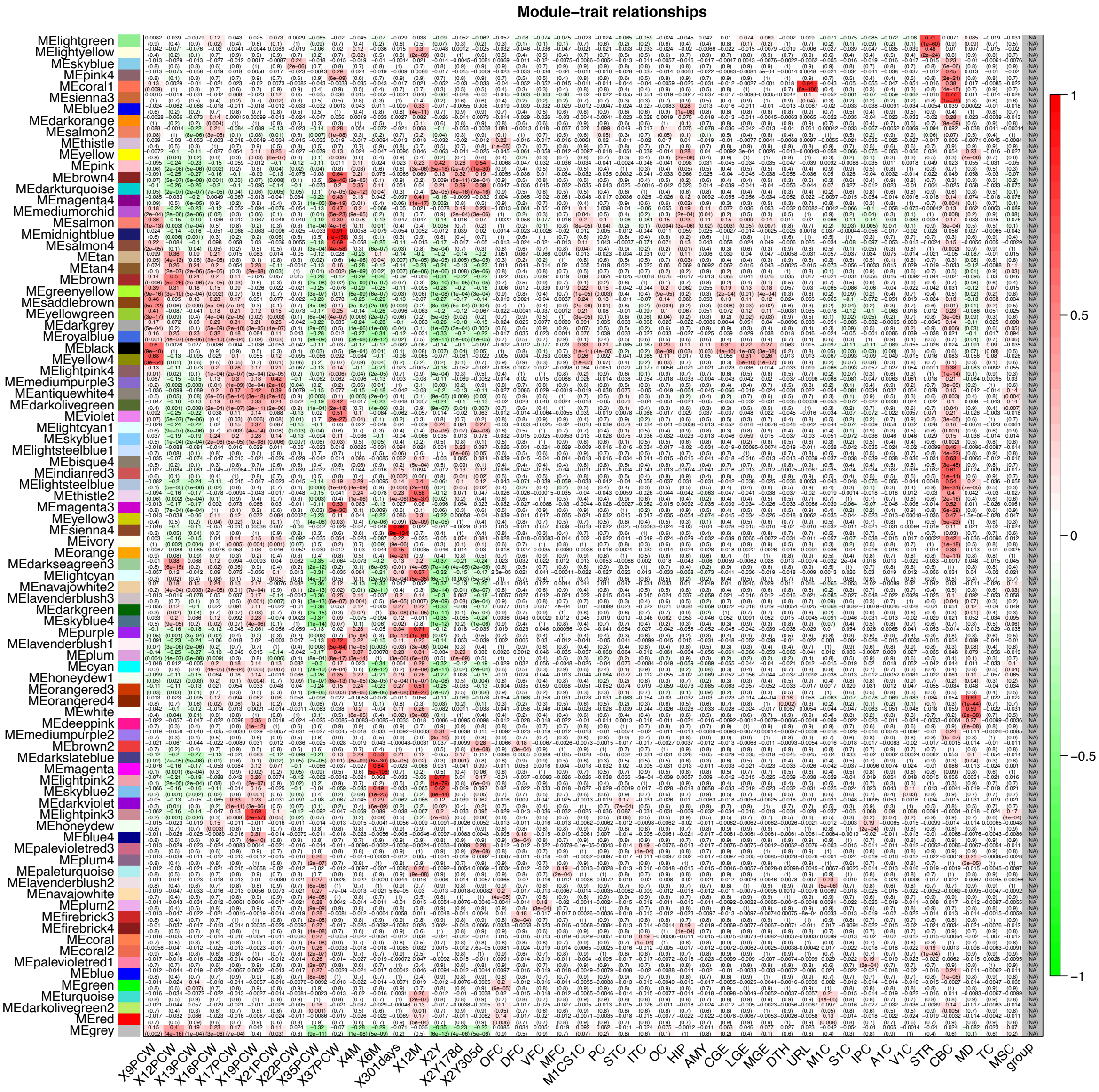


Figure S7: Module-trait relationships in weighted gene co-expression network analysis (WGCNA) of developing human brain bulkRNA dataset.

Module-trait relationships describing spatiotemporal characteristics of each gene-co-expression module. Each row corresponds to a module Eigengene and each column to a timepoint or spatial region. Each cell contains the corresponding correlation in the first line and the P-value in the second line. The table is color-coded by correlation according to the color legend.

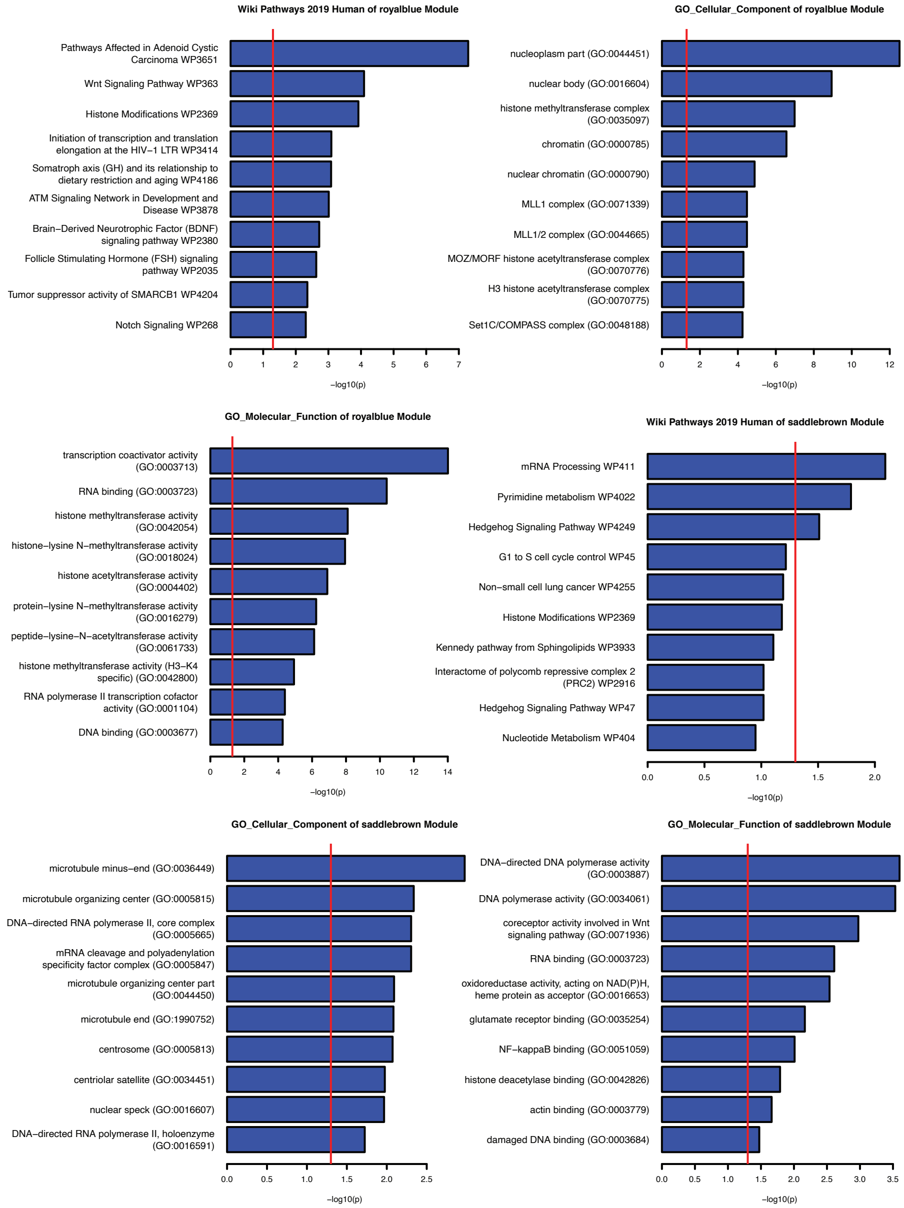


Figure S8: Pathway analyses of WGCNA modules enriched with nsCS genes in developing human brain bulkRNA dataset.

Wiki pathway, GO cellular component and molecular function analyses for top genes in nsCS-enriched royalblue and saddlebrown modules. Dotted red line indicates threshold p-value of 0.05.

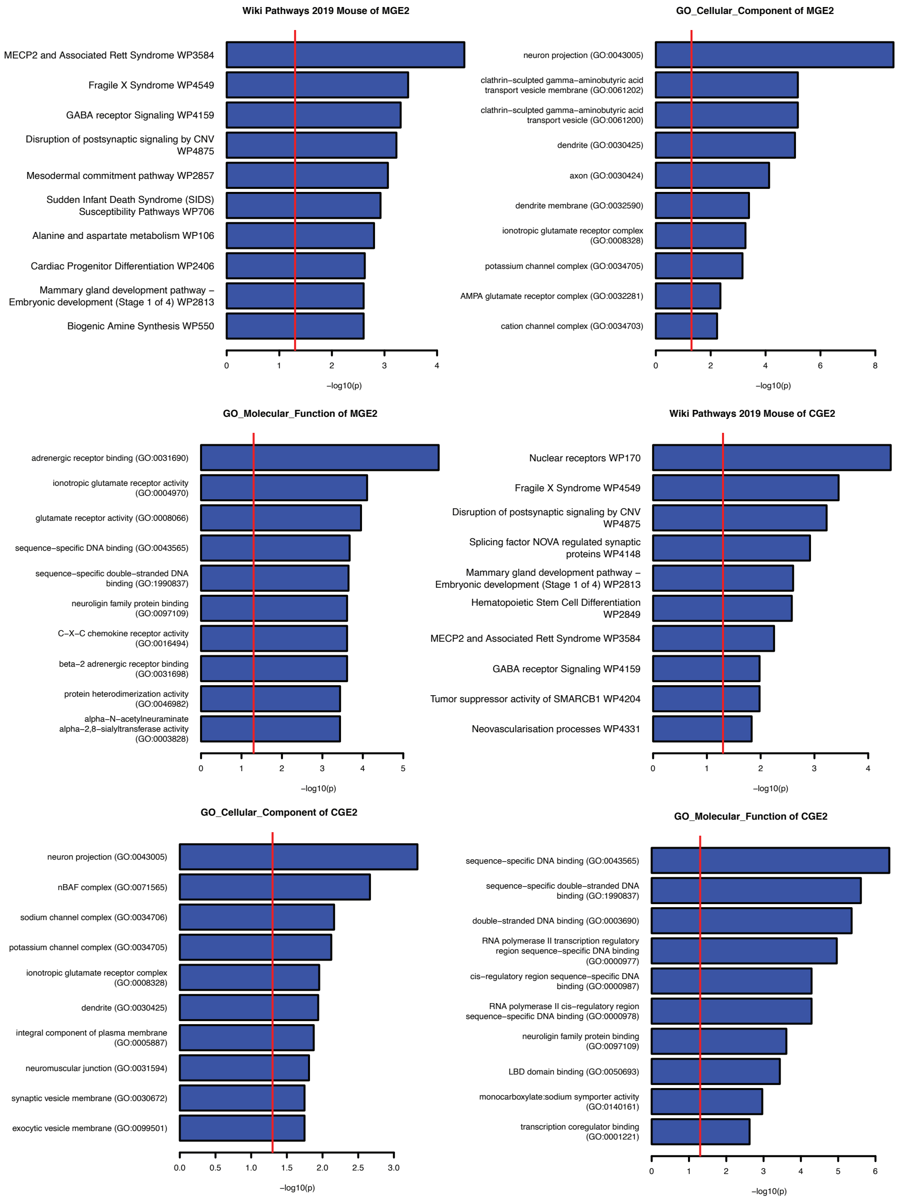


Figure S9: Pathway analyses of cell types enriched with nsCS genes in scRNAseq developing human brain dataset.

Wiki pathway, GO cellular component and molecular function analyses for top genes in nsCS-enriched IN-CTX-MGE2 and IN-CTX-CGE2 clusters. Dotted red line indicates threshold p-value of 0.05.

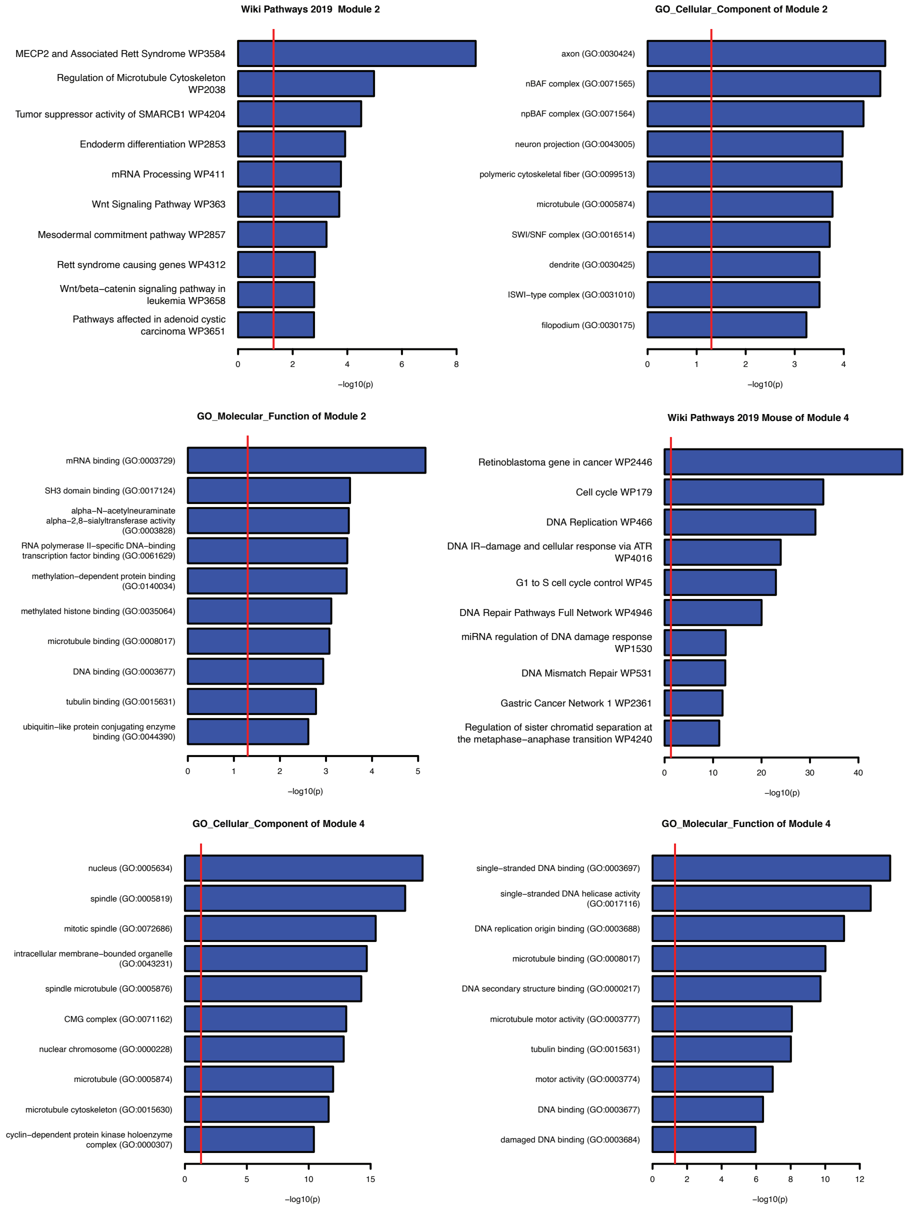


Figure S10: Pathway analyses of modules enriched with nsCS genes in scRNAseq developing human brain dataset.

Wiki pathway, GO cellular component and molecular function analyses for top genes in nsCS-enriched modules 2 and 4. Dotted red line indicates threshold p-value of 0.05.