

BioPhi: A platform for antibody design, humanization and humanness evaluation based on natural antibody repertoires and deep learning

Humanization results: 25 sequence pairs

Legend:

- Line 1: Nearest human germline to experimentally humanized sequence
 - Line 2: Experimentally humanized sequence
 - Line 3: Parental sequence
 - Line 4: Sequence humanized by Sapiens (3 iterations)
 - Line 5: Nearest human germline to Sapiens humanized sequence

Parental and humanized sequences are colored in red gradient based on number of non-human overlapping 9-mers at given position (based on OASis relaxed identity)

Germline sequences are colored in green when the humanized sequence matches germline.

CDR and Vernier regions are shown using dark and light grey border around parental sequence

AntiCD28

Heavy chain

EVQLVQSGGGLVQPGGLSLRLSCAGSFTFSSYAMHWVRQAPGKGLEWVAI GTGGGYA DSVKGRFTISRDNAKNSLYLQMNSLRAEDMAVYYCAR-----YFDYWQGQT LTVVSS IGHV3/0R16-10*02,IGHJ4*01
 EVQLVQSGGGLVQPGGLSLRLSCAGSFTFSDYGVHWRQAPGKGLEWVAI WAGGGTNYASSVMGRFTISRDNAKNSLYLQMNSLRAEDMAVYYCARDKGYSYYY SMDYWQGQT LTVVSS Humanized (Experimental)
 EVKLQQSGPGLVTPSQSLSTCTVSGFSLSDYGVHWRQSPGQLEWLGVIA WAGGGTNYNSALMSRSKISKD NSKSQVFLKMNSLQADDTAVYYCARDKGYSYYY SMDYWQGQT S VTVSS Parental
 QVQLQESGPGLVKPSQTLSTCTVSGGSLSDYGVHWRQSPGKGLEWLGVIA WAGGGTNYNSALMSRSVLSLDTSKSQVSLKLNLTAA DDTAVYYCARDKGYSYYY SMDYWQGQT LTVVSS Humanized (Sapiens^3)
 QVQLQESGPGLVKPSFTI SLTCTVSGGSTSSYYWSLBDPPGKGL FWTGTYTGS GNTN YPSL KSRV TSVDT SKNQFSI KI SSVA DDTAVYYCAR-----YYGMDWQGQT LTVVSS TGHV4-4*08, TGH16*01

Light chain

DIVMTQSPDSLAVSLGERATINCKSSOSVLYNNKNYLAWYQQKPGQPPKLLIYASTRESGPDRFGSGSGTDFTLTISSLQAEDVAVYYCQOYY---YTFGQGTLKEIK IGKV4-1*01, IGKJ2*01
 DIVMTQSPDSLAVSLGERATINCRASESVEYYTSLMAWYQQKPGQPPKLLIYAASNVESGPDRFGSGSGTNFLSTISSLQAEDVAVYYCQOSRKYVPTFQGQGTLKEIK Humanized (Experimental)
 DIETLQSPASLAVSLGQRATISCRASESVEYYTSLMQWYQQKPGQPPKLLIIFAASNVESGPAPRFSGSGSGTNFLN1HPVDEDDVAMYFCQOSRKYVPTFQGGTKLEIK Parental
 DIVMTQSPASLAVSPGERATISCRASESVEYYTSLMQWYQQKPGQPPKLLIYAASNVESGPDRFGSGSGTDFTLTISRVQADDVAVYYCQOSRKYVPTFQGQGTLKEIK Humanized (Sapiens^3)
 DIVMTQSPDSLAVSLGERATINCKSSOSVLYNNKNYLAWYQQKPGQPPKLLIYASTRESGPDRFGSGSGTDFTLTISSLQAEDVAVYYCQOYY---YTFGQGTLKEIK IGKV4-1*01, IGKJ2*01

Bevacizumab

Heavy chain

Light chain

```

DIQMTQSPSSLSASVGDRVTITCRASQGINSYLAWFQQPKGPKAPSILYAASSLQSGVPSRFSFGSGSGTDFTLTISSLQPEDFATYYCQQYNS--WTFQGQTKVEIK IGKV1-16*01, IGKV1-16*01
DIQMTQSPSSLSASVGDRVTITCSAQDISNLYNWWQQPKGPKAPVKLIYFTSSLHSGVPSRFSFGSGSGTDFTLTISSLQPEDFATYYCQQYSTVPWTFGQGQTKVEIK Humanized (Experimental)
DIQMTQTSSSLASLGDRVIISCAQDISNLYNWWQQPKDPGTVKVLIFYFTSSLHSGVPSRFSFGSGSGTDFYSLTISNLEPEDIATYYCQQYSTVPWTFGGGTKLEIK Parental
DIQMTQSPSSLSASVGDRVTITCSAQDISNLYNWWQQPKGPKAPKLIIYFTSSLHSGVPSRFSFGSGSGTDFTLTISSLQPEDIATYYCQQYSTVPWTFGQGQTKVEIK Humanized (Sapiens^3)
DIQMTQSPSSLSASVGDRVTITCQAOSDINLYNWWQQPKGPKAPKLIIYDASNLLETGVPSRFSFGSGSGTDFFTISSLQPEDIATYYCQQYDN--WTFQGQTKVEIK IGKV1-33*01, IGKV1-33*01

```

Campath

Heavy chain

QVQLQESGPLVKPSQTLSTCTVSGGSIGDYYWSWIRQPPGKGLEWIGIYIYS---GSTYNNPSLKSRTISVDTSKNQFSLKLSVTAAADTAVYYCAR-----YFDYWQGTLTVSS IGHV4-30-4*01, IGKJ4*01
QVQLQESGPLVRPSQTLSTCTVSGFTFTDFYMNWVQPPGRGLEWIGFIRDKAKGTYTEYNPSVKGRVTMLVDTSKNQFSLRLSSVTAADTAVYYCAREGHTAAPFDYWGQGSLTVSS Humanized (Experimental)
EVKLQESGGGLVQPGGSLRLSCAGSFTFTDFYMNWIRQAPGKLEWVGIFIRDKAKGTYTEYNPSVKGRFTISRDNNTQNMLYLQMNTLRAEDTAVYYCAREGHTAAPFDYWGQGVMVTVSS Parental
EVQLVESGGGLVQPGGSLRLSCAASGFTSDFYMNWIRQAPGKGLEWVGIFIRDKAKGTYTEYNPSVKGRFTISRDDSKNSLYLQMNSLRAEDTAVYYCAREGHTAAPFDYWGQGTLTVSS Humanized (Sapiens^3)
EVQLVESGGGLVQPGGSLRLSCAASGFTSDYYMSWIRQAPGKGLEWVGIFRNKANGGTE-TTSVKGRFTISRDDSKSITYLQMNSLRAEDTAVYYCAR-----YFDYWQGTLTVSS IGHV3-71*01, IGKJ4*01

Light chain

DIQMTQSPSSLASAVGDRVTITCQASQDISSYLNWYQQKPGKAPKLLIYDASNLTGVPSRSGSGSGTDFTFTISSLQPEDIATYYCQYDN--WTFQGQGTKEIK IGKV1-33*01, IGKJ1*01
DIQMTQSPSSLASAVGDRVTITCKASQNIDKYLNWLWYQQKPGKAPKLLIYNTNNLQQTGVPSRSGSGSGTDFTFTISSLQPEDIATYYCQYDN--WTFQGQGTKEIK Humanized (Experimental)
DIKMTQSPSFLSASVGDRVTLNCKASQNIDKYLNWLWYQQKPGKAPKLLIYNTNNLQQTGVPSRSGSGSGTDFTFTISSLQPEDIATYYCQYDN--WTFQGQGTKEIK Parental
DIQMTQSPSSLASAVGDRVTITCKASQNIDKYLNWLWYQQKPGKAPKLLIYNTNNLQQTGVPSRSGSGSGTDFTFTISSLQPEDFATYFCLOHISRPRTFGQGTLKLEIK Humanized (Sapiens^3)
DIQMTQSPSSLASAVGDRVTITCRASQISSYLNWYQQKPGKAPKLLIYASSLQSGVPSRSGSGSGTDFTFTISSLQPEDFATYYCQSYS--YTFQGQGTKEIK IGKV1-39*01, IGKJ2*01

Certolizumab

Heavy chain

EVQLVESGGGLVQPGGSLRLSCAASGFTSSYAMSWVRQAPGKLEWVSAISGSGSTYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAR-----YFDYWQGTLTVSS IGHV3-23*04, IGHJ4*01
EVQLVESGGGLVQPGGSLRLSCAASGYVFTDYGMNWVIRQAPGKGLEWMGWINTYIGEPIYADSVKGRFTISLDTSKSTAYLQMNSLRAEDTAVYYCARGYRSYAMDYWGQGTLTVSS Humanized (Experimental)
QIQLVQSGPELKKPGETVKISCKASGTYFTDYGMNWVQKAPGKAFKWMGWINTYIGEPIYVDDFKGRFAFSLETSASTAFLQINNLKNEDTATYFCARGYRSYAMDYWGQGTSVTVSS Parental
EVQLVQSGSELKKPGASVKISCKASGTYFTDYGMNWVQKAPGKAFKWMGWINTYIGEPIYVDDFKGRFAFSLETSASTAFLQINNLKNEDTATYFCARGYRSYAMDYWGQGTSVTVSS Humanized (Sapiens^3)
EVQLVQSGSELKKPGASVKISCKASGTYFTSYAMNWVRQAPGKLEWMGWINNTNGNPTYAQGFTGRFVFSLDTSVSTAYLQICSLKAEDTAVYYCAR-----YFDYWQGTLTVSS IGHV7-4-1*01, IGHJ4*01

Light chain

DIQMTQSPSSLASAVGDRVTITCRASQGISNYLWFQQKPGKAPKSLIYASSLQSGVPSRSGSGSGTDFTFTISSLQPEDFATYYCQSYS--WTFQGQGTKEIK IGKV1-16*01, IGKJ1*01
DIQMTQSPSSLASAVGDRVTITCKASQNVTNAWYQQKPGKAPKALIYASFLYSGVPRFSGSGSGTDFTFTISSLQPEDFATYYCQYNIYPLTFGQGTLKVEIK Humanized (Experimental)
DIVMTQSQKFMSTSVGDRVSVTCKASQNVTNAWYQQKPGQSPKALIYASFLYSGVPRFSGSGSGTDFTFTISSLQPEDFATYYCQYNIYPLTFGQGTLKLEIK Parental
DIQMTQSPSSLASAVGDRVTITCKASQNVTNAWYQQKPGKAPKLLIYASFLYSGVPRFSGSGSGTDFTFTISSLQPEDFATYYCQYNIYPLTFGQGTLKLEIK Humanized (Sapiens^3)
DIQMTQSPSSLASAVGDRVTITCRASQGISSWLAWYQQKPGKAPKLLIYASSLQSGVPSRSGSGSGTDFTFTISSLQPEDFATYYCQQANS--YTFQGQGTKEIK IGKV1-12*01, IGKJ2*01

Clazakizumab

Heavy chain

EVQLVESGGGLVQPGGSLRLSCAASGFTVSSNYMSWVRQAPGKLEWSVIYSGGSTYYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAR-----AEYFQHWQGQGTTLTVSS IGHV3-66*01, IGHJ1*01
EVQLVESGGGLVQPGGSLRLSCAASGFLSNYYWTWVRQAPGKLEWGIYIGSDETAYATSAIGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCARDSSDWDAKFLNLWGQGTLTVSS Humanized (Experimental)
QSLEESGGRLVTGTPPTPLTCASGFSLSNYYWTWVRQAPGKLEWIGIYIGSDETAYATWAIGRFTISKTSTTVDLKMTSLTAADTATYFCARDSSDWDAKFLNLWGQGTLTVSS Parental
EVQLVESGGGLVQPGESLRSLCTASGFSLSNYYWTWVRQAPGKLEWISIYIGSDETAYATWAIGTISIDSKNTVYLKMTSLTAADTAVYFCARDSSDWDAKFLNLWGQGTLTVSS Humanized (Sapiens^3)
EVQLVESGGGLVQPGGSLRLSCAASGFTVSSNYMSWVRQAPGKLEWSVIYSGGSTYYADSVKFTISRDNSKNTLYLQMNSLRAEDTAVYYCAR-----AEYFQHWQGQGTTLTVSS IGHV3-66*01, IGHJ1*01

Light chain

DIQMTQSPSSLASAVGDRVTITCRASQISSYLNWYQQKPGKAPKLLIYASSLQSGVPSRSGSGSGTDFTFTISSLQPEDFATYYCQSYS---LTFGGGTKEIK IGKV1-39*01, IGKJ4*01
AIQMTQSPSSLASAVGDRVTITCQASQSIINNELSWYQQKPGKAPKLLIYRASTLASGVPSRSGSGSGTEFTLTISLQPDDFATYYCQGYSLRNIDNAFGGGTKVEIK Humanized (Experimental)
AYDMTQTPASVAAVGGTVTIKCQASQSIINNELSWYQQKPGQRPKLLIYRASTLASGVSSRFKGSGSGTEFTLTISLQPDDFATYYCQGYSLRNIDNAFGGGTEVVK Parental
DIQMTQSPSSLASAVGDRVTITCQASQSIINNELSWYQQKPGKAPKLLIYRASTLASGVPSRSGSGSGTEFTLTISLQPDDFATYYCQGYSLRNIDNAFGGGTKVEIK Humanized (Sapiens^3)
DIQMTQSPSSLASAVGDRVTITCRASQISSYLNWYQQKPGKAPKLLIYASSLQSGVPSRSGSGSGTDFTFTISSLQPEDFATYYCQSYS---LTFGGGTKEIK IGKV1-39*01, IGKJ4*01

Crizanlizumab

Heavy chain

Light chain

DIQMTQSPSSLSASVGDRVTITCRASQI----SSYLNWYQQKPGKAPKLLIYAASSLQSGVPSRFSGSGSGTDFTLTISSLQPEDFATYYCQQSYS--LTFGGTKVEIK IGKV1-39*01, IGKJ4*01
 DIQMTQSPSSLSASVGDRVTITCKASQSVYDGHSYMWYQQKPGKAPKLLIYAASNLESGVPSRFSGSGSGTDFTLTISSLQPEDFATYYCQQSDENPLTFGGTKVEIK Humanized (Experimental)
 DIVLTQSPASLASLGQRATISCKASQSVYDGHSYMWYQQKPGQPPKLLIYAASNLESGIPARFSGSGSGTDFTLNIHVEEADATYYCQQSDENPLTFGTGKLEIK Parental
 DIVLTQSPASLASVSPGERATISCKASQSVYDGHSYMWYQQKPGQPPKLLIYAASNLESGVPDFRSGSGSGTDFTLTISRVAEDAVAYCQQSDENPLTFGTGKLEIK Humanized (Sapiens^3)
 DIVMTQSPDSLAVSLGERATINCKSSQSYLNNKLYAWYQQKPGQPPKLLIYWASTRESGVPDFRSGSGSGTDFTLTISSLQAEADVAYYYCQQYS--YTFGTGKLEIK IGKV4-1*01, IGKJ2*01

Eculizumab

Heavy chain

Light chain

```

DIQMTQSPSSLSASVGRVTITCQASQDINSYLNWYQQPKGKAPKLLIYDASNLGETGVPSRFSGSGSGTDFTTISSLQPEDIATYYCQYDN--WTFQGQTKVEIK IGKV1-33*01, IGKJ1*01
DIQMTQSPSSLSASVGRVTITCGASENIYGALNWYQQPKGKAPKLLIYGATNLADGVPSRFSGSGSGTDFTLTISSLQPEDFATYYCONVLNPLTFQGQTKVEIK Humanized (Experimental)
DIQMTQSPASLSASVGETVTITCGASENIYGALNWYQRKQGKSPQLLIYGATNLADGMSRFSGSGSGRQYLLKISSLHPPDVATYYCONVLNPLTFQAGTKLELK Parental
DIQMTQSPSSLSASVGRVTITCGASENIYGALNWYQQPKGKAPKLLIYGATNLADGVPSRFSGSGSGTDFTLTISSLQPEDFATYYCONVLNPLTFQGQTKLEIK Humanized (Sapiens^3)
DIQMTQSPSSLSASVGRVTITCQASQDINSYLNWYQQPKGKAPKLLIYDASNLGETGVPSRFSGSGSGTDFTTISSLQPEDIATYYCQYDN--YTFQGQTKLEIK IGKV1-33*01, IGKJ2*01

```

Etaracizumab

Heavy chain

Light chain

Herceptin

Heavy chain

Light chain

AIQLTQS PSSLSAS VGRVTITCRAS QGK ISSALW YQQ KPGK APKA LLIY DASS L EGVPSR FSGS GSGT DFTL TISS L QP EFDAT YYCQ FN S -- WFG QG GTK VEIK IGKV1-13*02, IGKJ1*01
 DIQMTQSPSSLSAS VGRVTITCRAS QD VNTA VAW YQQ KPGK APKA LLIY SASF LESV GP SRSF GSGT DFTL TISS L QP EFDAT YYCQ HYY TPT PFG QG GTK VEIK Humanized (Experimental)
 DIVMTQSHKF MTSVGDRV SITCK ASQDV NTAV A WYQQ KPGH SPK LLIY SASF RY TGVP DRFT GNRS GT DFTL TISS VQA EDL AVY YYCQ HYY TPT PFG QG GTK VEIK Parental
 DIQMTQSPSF LSAS VGRVTI TCK ASQDV NTAV A WYQQ KPGK APKA LLIY SASF RY TGVP SRSF GSGS GSGT DFTL TISS L QP EFDAT YYCQ HYY TPT PFG QG GTK VEIK Humanized (Sapiens^3)
 DIQMTQSPSSLSAS VGRVTITCRAS QSI SSY LN WYQQ KPGK APKA LLIY AASS L QGP SRSF GSGS GSGT DFTL TISS L QP EFDAT YYCQ S YS -- LT FG QG GTK VEIK IGKV1-39*01, IGKJ4*01

Idarucizumab

Heavy chain

QVQLQESQGPLVKPSETLSLCTVSGGSISSYYWSIRQPPGKLEWIGIYTGSTNTNPSLKSRTVTSVDTSKNQFLSKLSSVTAADTAVYCAR-----YFDYWQGTLVTVSS IGHV4-4*08,IGHJ4*01
 QVQLQESQGPLVKPSETLSLCTVSGFSLTSYIVDWRQPPGKLEWIGVIWAGGSTGYNSALRSRSLSTKDTSKNQFLSKLSSVTAADTAVYCASAAYYSYNYDGFAYWGQGTLVTVSS Humanized (Experimental)
 QVQLQESQGPLVAPSQRLSITCTSGFSLTSYIVDWRQSPGKLEWLGLVIWAGGSTGYNSALRSRSLSTKSNSKSQVFLQMSNLQDDTAIYYCASAAYYSYNYDGFAYWGQGTLVTVSA Parental
 QVQLQESQGPLVKPSETLSLCTVSGGSLTSYIVDWRQSPGKLEWLGLVIWAGGSTGYNSALRSRSLISLDTSKSQVFLQNSLTAADTDIAIYYCARAAYYSYNYDGFAYWGQGTLVTVSS Humanized (Sapiens^3)
 QVQLQESQGPLVKPSETLSLCTVSGGSISSYYWSIRQPPGKLEWIGIYTGSTNTNPSLKSRTVTSVDTSKNQFLSKLSSVTAADTAVYCAR-----YFDYWQGTLVTVSS IGHV4-4*08,IGHJ4*01

Light chain

DVVMTQSPSLSPVTLGQPASISCRSSQLVYSDGNTYLWNFQQRPGQSPRRLIYKVSNRDSGVPDFRSFGSGSTDFTLKISRVEAEDVGYYCMQGTH--LTFGGGTKEIK IGKV2-30*01, IGKJ4*01
 DVVMTQSPSLSPVTLGQPASISCKSSQSLLYTDGKTYLYWFQQRPGQSPRRLIYLVSKLDGSVPDFRSFGSGSTDFTLKISRVEAEDVGYYCLQSTHFPTFGGGTKEIK Humanized (Experimental)
 DVVMTQTPLTLSVTIGQPASISCKSSQSLLYTNKGKTYLYWLLQRPGQSPKRRIYLVSKLDGSVPDFRSFGSGSTDFTLKISRVEAEDVGYYCLQSTHFPTFGGGTKEIK Parental
 DVVMTQSPSLSVTPGQPASISCKSSQSLLYTNKGKTYLYWFQQRPGQSPRRLIYLVSKLDGSVPDFRSFGSGSTDFTLKISRVEAEDVGYYCLQSTHFPTFQQGKLEIK Humanized (Sapiens^3)
 DVVMTQSPSLSPVTLGQPASISCRSSQLVYSDGNTYLWNFQQRPGQSPRRLIYKVSNRDSGVPDFRSFGSGSTDFTLKISRVEAEDVGYYCMQGTH--YTFGQGTKEIK IGKV2-30*01, IGKJ2*01

Ixekizumab

Heavy chain

QVQLVQSGAEVKPGSSVKVSKCAGSGTFSYYAISWVRQAPGQGLEWMGGIPIFGTANYAQKFQGRVTITADESTSTAYMELSSLRSEDATAVYCCAR-----YFDYWQGTLTVSS IGHV1-69*01,IGHJ4*01
 QVQLVQSGAEVKPGSSVKVSKCAGSGTSFYDHIIHWVRQAPGQGLEWMGVINPMTGTTDYNQRFKGRVTITADESTSTAYMELSSLRSEDATAVYCCARYDYFTGTGVYWGQGTLTVSS Humanized (Experimental)
 QVQLQOSRPELVLKPGASVKISCKSAGSYFSTDYNNNNWVKQSONGKSLEWIGVINPNYGTTDYNQRFKGKATLTDQSSRTAYMLQNLNLTSEDASAVYYCVIYDYATGTGGYWQGSPLTVSS Parental
 QVQLVQSGPELKKPGASVKVSKCAGSYFSTDYNNNNWVRQAPGQGLEWMGVINPNTGTTDYNQRFKGRVTLDRDSIRTALEYMLNLSLTSEDATAVYCCVIYDYATGTGGYWQGTLTVSS Humanized (Sapiens^3)
 QVQLVQSGAEVKPGASVKVSKCAGSYFTGYYIHWVRQAPGQGLEWMGVINPNSGTYAQKFQGRVTMTRDTSISTAYMELSSLRSDDTAVYCCAR-----YFDYWQGTLTVSS IGHV1-2*02,IGHJ4*01

Light chain

Ligelizumab

Heavy chain

Light chain

Lorvotuzumab

Heavy chain

QVQLVESGGGVQPGRSRLRSCAASGFTSSYGMHWVRQAPGKGLEWVAISYDGNSKYYADSVKGRFTISRDNNSKNTLYLQMNSLRAEDTAVYYCAR-----YFDYWQGQTLTVSS IGHV3-30*03,IGHJ4*01
QVQLVESGGGVQPGRSRLRSCAASGFTSSFGMHWVRQAPGKGLEWVAYISSGSFTIYYADSVKGRFTISRDNNSKNTLYLQMNSLRAEDTAVYYCARMRKGYAMDYWGQGTLTVSS Humanized (Experimental)
DVQLVESGGVLVPGGSRKLSCAASGFTSSFGMHWVRQAPEKGLEWVAYISSGSFTIYHADTVKGRFTISRDNPKNTLFQMLTSLRAEDTAHYYCARMRKGYAMDYWGQGTTVSS Parental
EVQLVESGGGLVQPGGSRKLSCAASGFTSSFGMHWVRQAPGKGLEWSYISSGSFTIYHADTVKGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCARMRKGYAMDYWGQGTTVSS Humanized (Sapiens³)
EVQLVESGGGLVQPGGSRRLSCAASGFTSSYSNIVWRQAPGKGLEWVSYISSSSSTIYYADSVKGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCAR-----DAFDYWQGQMTVTVSS IGHV3-48*01,IGHJ3*01

Light chain

DVVMTQSPSLSPVTLGQPASICRSSQSQLVHSDGNTYLWNFQQRPGQSPRRLIYKVSNRDSGPVDRFSGSGSTDFTLKISRVAEADGVYYCMQGHIH-WTFQGQGTKVEIK IGKV2-30*02, IGKV1J1*01
 DVVMTQSPSLSPVTLGQPASICRSSQIIHSDGNTYLEWFQQRPGQSPRRLIYKVSNRFSGPVDRFSGSGSTDFTLKISRVAEADGVYYCFQGSHVPHTFGQGTKVEIK Humanized (Experimental)
 DVLMTQTPLSLPVLGQASICRSSQIIIHSDGNTYLEWFQKPGQSPKLIIYKVSNRFSGPVDRFSGSGSTDFTLMISRVAEADLGYYCFQGSHVPHTFGGGTKLEIK Parental
 DVVMTQTPLSLPVTLGQPASICRSSQIIHSDGNTYLEWLQKPGQSPQLLIYKVSNRFSGPVDRFSGSGSTDFTLKISRVAEADGVYYCFQGSHVPHTFGQGTKLEIK Humanized (Sapiens^3)
 DIVMTQTPLSLSPVTPGQPASICSSQSQLLHSQDGKTYLYWQKPGQSPQLLIYEVSRSRFSGPVDRFSGSGSTDFTLKISRVAEADGVYYCMQGHIH-YTFQGQGTKLEIK IGKV2-29*02, IGKV2J2*01

Mogamulizumab

Heavy chain

Light chain

```

DIVMTQSPSLPVTGEPASICRSSQSLHSNGNYLWYLOKPGQSPQLLIYLGNSRASGVVPDRFGSGSGTDFTLKISRVAEADVGYYCMQALQ--WTFQGTKEIK IGKV2-28*01, IGKJ1*01
DVLMTQSPSLPVTGEPASICRSSRNIVHINGDTYLEWYLOKPGQSPQLLIYKVSNRFSGVVPDRFGSGSGTDFTLKISRVAEADVGYYCFQGSLLPWTFGQGTKEIK Humanized (Experimental)
DVLMTQPLSLPVSLGDQASISCRSSRNIVHINGDTYLEWYLRPGQSPKLLIYKVSNRFSGVVPDRFGSGSGTDFTLKISRVAEADLGVYYCFQGSLLPWTFGGGTRLEIR Parental
DVVMTQSPSLPVTGLGPASICRSSRNIVHINGDTYLEWYLRPGQSPQLLIYKVSNRFSGVVPDRFGSGSGTDFTLKISRVAEADVGYYCFQGSLLPWTFGQGTRELIK Humanized (Sapiens^3)
DVVMTQSPSLPVTGLGPASICRSSQSLVHSQDNTYLWFF0ORPGQSPRLIYKVSNRDSGVVPDRFGSGSGTDFTLKISRVAEADVGYYCMQGTH--ITFGQTRLEIK IGKV2-30*02, IGKJ5*01

```

Omalizumab

Heavy chain

Light chain

DIQMTQSPSSLSASVGDRVTITCRASQSI----SSYLNWYQQKPGKAPKLLIYAASSLQSGVPSRFSGSGSTDFTLTISSLQPEDFATYYCQQSYS--WTFQGQTKVEIK IGKV1-39*01, IGKJ1*01
 DIQLTQSPSSLSASVGDRVTITCRASQSYDGDSYMWNWYQQKPGKAPKLLIYAASYLESGVPSRFSGSGSTDFTLTISSLQPEDFATYYCQQSHEDPYTFQGQTKVEIK Humanized (Experimental)
 DIQLTQSPASLAvgLQRATISCKASQSVYDGDSYMWNWYQQKPGQPPIIIYAASYLGSEIPARFSGSGSTDFTLNIHPVEEDAATFYCQQSHEDPYTFGAGTKLEIK Parental
 DIVLTQSPDSLAVSPGERATISCKASQSYDGDSYMWNWYQQKPGQPPIIIYAASYLGSGVPDRFSGSGSTDFTLTISRVAEDAVYYCQQSHEDPYTFQGQTKLEIK Humanized (Sapiens^3)
 DIVMTQSPDSLAVSLGERATINCKSSQSYLNNKNLYAWYQQKPGQPPIIIYWASTRSGVPDFRSGSGSTDFTLTISSLQAEADAVYYCQQYYS--WTFQGQTKLEIK IGKV4-1*01, IGKJ2*01

Palivizumab

Heavy chain

QVTLRESGPALVKPQTQLTLCFSGFLSTSGMSGVIRQPPGKALEWLADIWDDDKYTSKLTRLTISKDTSKNQVLTMTNMDPVDTATYYCARI--YWYFDLWGRGLTVTSS IGHV2-70*01,IGHJ2*01
 QVTLRESGPALVKPQTQLTLCFSGFLSTSGMSGVIRQPPGKALEWLADIWDDDKDYNPSLKSRLTISKDTSKNQVVLKVTNMDPVDTATYYCARSMITNWYFDVWGAGTTVSS Humanized (Experimental)
 QVLEQESGPGLQPSQTLSTCSFGFLSTSGMSGVIRQPSGEGLEWLADIWDDDKDYNPSLKSRLTISKDTSSNQVFLKITGVDTADATYYCARSMITNWYFDVWGAGTTVSS Parental
 QVTLKESGPTLVKPTQTQLTLCFSGFLSTSGMSGVIRQPPGKALEWLADIWDDDKDYNPSLKSRLTISKDTSKNQVLTMTNMDPVDTATYYCARSMITNWYFDVWGRLTVTSS Humanized (Sapiens^3)
 QVTLKESGPTLVKPTQTQLTLCFSGFLSTSGMSGVIRQPPGKALEWLADIWDDDKRYSGPLSKSLRTIKDTSKNQVLTMTNMDPVDTATYYCAHR--YWYFDLWGRGLTVTSS IGHV2-5*09,IGHJ2*01

Light chain

Pembrolizumab

Heavy chain

QVQLVQSGAEVKPGASVKVSKASGYTFTYMMWVRQAPGQGLEWMGWINPNSGGNTYAOKFQGRVTMRTDTISAYMELSLRSDTAVYYCAR-----YFDYWGQGTIVTVSS IGHV1-2*02,IGHJ4*01
 QVQLVQSGEVVKPGASVKVSKASGYTFTYMMWVRQAPGQGLEWMGGINPSNGGNTNFNEKFKNRTLTTDSSSTAYMELKSLQFDDTAVYYCARRDYRFDMGFDYWGQGTIVTVSS Humanized (Experimental)

 QVQLQQPGAEVLVKPGTSVKLSCASKASGYTFNYYMMWVKQRPGQGLEWIGGINPSNGGNTNFNEKFKNKATLTVDDSSSTTYMQQLSSLTSEDASVYCTRDRYRFDMGFDYWGQGTIVTVSS Parental
 QVQLVQSGAEVKPGASVKVSKASGYTFTYMMWVRQAPGQGLEWMGGINPSNGGNTNFNEKFKNRTLTTDSSSTAYMELKSLQFDDTAVYYCARRDYRFDMGFDYWGQGTIVTVSS Humanized (Sapiens^3)
 QVQLVQSGAEVKPGASVKVSKASGYTFTYMMWVRQAPGQGLEWMGGINPSNGGNTNFNEKFKNRTLTTDSSSTAYMELKSLQFDDTAVYYCARRDYRFDMGFDYWGQGTIVTVSS TGHV1-46*01 TGHJ4*01

Light chain

Pertuzumab

Heavy chain

Light chain

Pinatuzumab

Heavy chain

Light chain

DIQMTQSPSSLSASVGRVTITCRASQSI----SSYLNWYQQKPGKAPKL^{LY}IASLQSGVPSRFSGSGSGTDFTLT^ISSLQQPEDFATY^CQQSYS--WTFQGQT^KVEIK IGKV1-39*01, IGKJ1*01
 DIQMTQSPSSLSASVGRVTITCRSSQ^{S1}VHSVGNTFLEWYQQKPGKAPKL^{LY}IYKVSNRFSGVPSRFSGSGSGTDFTLT^ISSLQQPEDFATY^CCFQGSQFPYTFQGQT^KVEIK Humanized (Experimental)
 DILMTQTPLS^LPVSLGDQASISCRSSQ^{S1}VHSNGNTFLEWY^LQKPGQSPK^LLIYKVSNRFSGV^DPRFSGSGSGTDF^TLKISRVEAEDLGYYCFQGSQFPYTFGGGT^KVEIK Parental
 DIVMTQTPLS^LPVTLGQ^PASISCRSSQ^{S1}VHSNGNTFLEWY^LQKPGQSPQ^LLIYKVSNRFSGV^DPRFSGSGSGTDF^TLKISRVEAEDVGYYCFQGSQFPYTFGGGT^KVEIK Humanized (Sapiens^3)
 DIVMTQTPLS^LS^TPGQ^PASISCKSSQ^{S1}LLHSDGKT^LY^WY^LQKPGQSPQ^LLIYEVSNRFSGV^DPRFSGSGSGTDF^TLKISRVEAEDVGYYCMQS^IQ---LTFGGGT^KVEIK IGKV2D-29*02, IGKJ4*01

Refanezumab

Heavy chain

QVQLVQSGSELKKPGASVKVSKASGYTFTSYAMINWRQAPGQGLEMWGINTNTGPNTYAOGFTGRFVFSLDTSVSTAYLQISSLKAEDTAVYYCAR-----**YYYYYGMDVWQGQTTVTVSS** IGHV7-4-1*02,IGHJ6*01
QVQLVQSGSELKKPGASVKVSKASGYTFTNYGMNWVRQAPGQGLEMWGINTYTGEPTYADDFTGRFVFSLDTSVSTAYLQISSLKAEDTAVYYCARNPINYGGINYEGYVMDYWQGQTLTVSS Humanized (Experimental)
EIOLVQSGPELKPGETNKISCKASGYTFTNYGMNWVKQAPGKGLKWMGWINTYTGEPTYADDFTGRFAFSLETSASTAYLQISNLKNEDTATYFCARNPINYGGINYEGYVMDYWQGQTLTVSS Parental
QVQLVQSGSELKKPGASVKVSKASGYTFTNYGMNWVRQAPGQGLEMWGINTYTGEPTYADDFTGRFVFSLDTSVSTAYLQISSLKAEDTAVYYCARNPINYGGINYEGYVMDYWQGQTLTVSS Humanized (Sapiens^3)
QVQLVQSGSELKKPGASVKVSKASGYTFTSYAMINWRQAPGQGLEMWGINTNTGPNTYAOGFTGRFVFSLDTSVSTAYLQISSLKAEDTAVYYCAR-----**YYYYYGMDVWQGQTTVTVSS** IGHV7-4-1*02,IGHJ6*01

Light chain

Reslizumab

Heavy chain

Light chain

```

DIQMTQSPSSLSASVGDRVTITCRASQSISSYLNWQQPKGPKAPKLIYAASSLQGVPSRFSGSGSGTDFTLTISSLQPEDFATYCCQSQS--WTFGQGTKVEIK IGKV1-39*01, IGKJ1*01
DIQMTQSPSSLSASVGDRVTITCLAEGISSYLAWYQQPKGPKAPKLIYGANSLQTGVPSRFSGSGSATDYTLTISSLQPEDFATYCCQSQSYFPNTFQGGTKVEVK Humanized (Experimental)
DIQMTQSPASSASLGETISECLAEGISSYLAWYQQPKGPKSPLLIYGANSLQTGVPSRFSGSGSATQYSLKISSMQPEEGDYFCQSYKFPNTFGAGTKLEK Parental
DIQMTQSPSSLSASVGDRVTITCLAEGISSYLAWYQQPKGPKAPKLIYGANSLQTGVPSRFSGSGSGTDFTLTISSLQPEDFATYCCQSQSYFPNTFQGGTKLEIK Humanized (Sapiens^3)
DIQMTQSPSSLSASVGDRVTITCRASQSISSYLNWQQPKGPKAPKLIYAASSLQGVPSRFSGSGSGTDFTLTISSLQPEDFATYCCQSQS--YTFGQGTKLEIK IGKV1-39*01, IGKJ2*01

```

Rovalpituzumab

Heavy chain

Light chain

Solanezumab

Heavy chain

EVQLLESGGGLVQPGGSLRLSCAASGFTFSSYMSWVRQAPGKGLEWVSIYSGGSSTYYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAK-DYWQGQTLTVSS IGHV3-23*03,IGHJ4*01
 EVQLVESGGGLVQPGGSLRLSCAASGFTFSSYMSWVRQAPGKGLEWVSIYSGGSSTYYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAK-DYWQGQTLTVSS Humanized (Experimental)
 EVKLVESGGGLVQPGGSLKLSCAVSGFTFSSYMSWVRQTPKRLLEVAQINSVGNSTYYPPDTVKGRFTISRDNAEYTLQLMGSGLRSDDTATYYCASGDYWQGQTLTVSS Parental
 EVQLVESGGGLVQPGGSLRLSCAASGFTFSSYMSWVRQAPGKGLEWVSIYSGGSSTYYADSVKGRFTISRDNSKNTLYLQMSSLRRAEDTAVYYCASGDYWQGQTLTVSS Humanized (Sapiens^3)
 EVQLLESGGGLVQPGGSLRLSCAASGFTFSSYMSWVRQAPGKGLEWVSIYSGGSSTYYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAK-DYWQGQTLTVSS IGHV3-23*03,IGHJ4*01

Light chain

DVVMQTQPLSLPVTLGQPASISCRSSQSLIYSDGNAYLHWYLQKPGQSPRLLIYKVSNRFSGVPDFRGSGSGTDFTLKISRVEAEDVGVVYCYMOTH--WTFQGOTKVEIK Humanized (Sapiens^3)
 DVVMQTQPLSLPVTLGQPASISCRSSQSLIYSDGNAYLHWFLQKPGQSPRLLIYKVSNRFSGVPDFRGSGSGTDFTLKISRVEAEDVGVVYCYQSHTHPWTFGOTKVEIK Humanized (Experimental)
 DVVMQTQPLSLPVSLGDQASISCRSSQSLIYSDGNAYLHWFLQKPGQSPKLLIYKVSNRFSGVPDFRGSGSGTDFTLKISRVEATEDLGVYFCQSHTHPWTGGGTKEIK Parental
 DVVMQTQPLSLPVTLGQPASISCRSSQSLIYSDGNAYLHWYLQKPGQSPRLLIYKVSNRFSGVPDFRGSGSGTDFTLKISRVEAEDVGVVYCYQSHTHPWTFGOTKVEIK Humanized (Sapiens^3)
 DVVMQTQPLSLPVTLGQPASISCRSSQSLIYSDGNAYLHWYLQKPGQSPRLLIYKVSNRFSGVPDFRGSGSGTDFTLKISRVEAEDVGVVYCYQSHTHPWTFGOTKVEIK Humanized (Experimental)

Talacotuzumab

Heavy chain

```

EVQLVQSGAEVKPGESLRISCKGSGYSFTSYWISWRQMPGKLEWMGRIDPSDSTYNSPSPQGQVTISADKSISTAYLQWSSLKASDTAMYYCAR---AEYFQHWGQGTLTVSS IGHV5-10-1*04,IGHJ1*01
EVQLVQSGAEVKPGESLKISCKGSGYSFTDYYMKWWRQMPGKLEWMGDIIPSNGATFYQNQFKFGQVTISADKSISTTYLQWSSLKASDTAMYYCARSHLLRASWFAYWGQGTMVTVSS Humanized (Experimental)
EVQLQSGPELVKPGASVKMSCKASGYTFTDYYMKWVKQSHGKSLWEIGIDIIPSNGATFYQNQFKKGATLTVDRSSSTAYMHLNSLTSEDAVYYCTRSHLLRASWFAYWGQGTLTVSA Parental
EVQLVQSGAEVKPGASVKMSCKASGYTFTDYYMKWWRQAPGQGLEWMGDIIPSNGATFYQNQFKGRVTLRTDTSTSTAYMELNSLTSEDAVYYCARSHLLRASWFAYWGQGTLTVSS Humanized (Sapiens^3)
EVQLVQSGAEVKPGASVKMSCKASGYTFTSYMMHWVRQAPGQGLEWMGIINPSGGTSYAQKFQGRVTMRTDTSTVYMEMLSSLRSEDAVYYCAR---AEYFQHWGQGTLTVSS IGHV1-46*01,IGHJ1*01

```

Light chain

DIVMTQSPDSLAVSLGERATINCKSSQSVYSSNNKYLAWYQQKPGOPPKLILYWASTRESGPDRFSGSGTDFTLTTSSLQAEDDVAVYYCQQY—YTFGQGTKTLEIK IGKV4-1*01, IGKJ2*01
 DIVMTQSPDSLAVSLGERATINCESSQSLNNSGNQKNYLTWYQQKPGOPPKLILYWASTRESGPDRFSGSGTDFTLTTSSLQAEDDVAVYYCQNDYSYPTFGQGTKTLEIK Humanized (Experimental)
 DFVMTQSPSSPLTVTAGEKVTMSCKSSQSLNNSGNQKNYLTWYLKPGOPPKLILYWASTRESGPDRFTGSGTDFTLTTISSVQAEDDVAVYYCQNDYSYPTFGGGTKTLEIK Parental
 DIVMTQSPDSLAVSLGERATINCKSSQSLNNSGNQKNYLTWYQQKPGOPPKLILYWASTRESGPDRFSGSGTDFTLTTSSLQAEDDVAVYYCQNDYSYPTFGQGTKTLEIK Humanized (Sapiens^3)
 DIVMTQSPDSLAVSLGERATINCKSSQSVYSSNNKYLAWYQQKPGOPPKLILYWASTRESGPDRFSGSGTDFTLTTSSLQAEDDVAVYYCQQY—YTFGQGTKTLEIK IGKV4-1*01, IGKJ2*01

Tocilizumab

Heavy chain

Light chain

```

DIQMTQSPSSLSASVGDRVTITCQASQDIISYLNWYQQKPGKAPKLLIYDASNLTGVPSRFSGSGSGTDFFTITSSLQPEDIATYYCQCYD--WTFQGQTKVEIK IGKV1-33*01, IGKJ1*01
DIQMTQSPSSLSASVGDRVTITCRASQDISSYLNWYQQKPGKAPKLLIYYTSRLHSGVPSRFSGSGSGTDFFTITSSLQPEDIATYYCQCGNTLPYTFFQGQTKVEIK Humanized (Experimental)
DIQMTQTSSLSASLGDRVTICRASQDISSYLNWYQQKPDTIKLLIYYTSRLHSGVPSRFSGSGSGTDYSLTINNLEQEDIATYFCCQGNTLPYTFFGGGTKLEIN Parental
DIQMTQSPSSLSASVGDRVTITCRASQDISSYLNWYQQKPGKAPKLLIYYTSRLHSGVPSRFSGSGSGTDFFTITSSLQPEDATYYCQCGNTLPYTFFQGQTKLEIK Humanized (Sapiens^3)
DIQMTQSPSSLSASVGDRVTITCRASQSISSYLNWYQQKPGKAPKLLIYAASSLQGVPSRFSGSGSGTDFFTITSSLQPEDATYYCQSY--YTFQGQTKLEIK IGKV1-39*01, IGKJ2*01

```