

Immunochemical approaches to monitor and modulate the adaptive immune system

Luimstra, J.J.

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Author: Luimstra, J.J.

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Screening for neoantigen-specific CD8⁺ T cells using thermally-exchanged pMHCI multimers

Jolien J. Luimstra¹, Christina Heeke², Jitske van den Bulk³, Brett Hos⁴, Ferry Ossendorp⁴, Noel F.C.C. de Miranda³, Sine R. Hadrup², Jacques Neefjes¹, and Huib Ovaa¹

¹Department of Cell and Chemical Biology, Leiden University Medical Center, Leiden, The Netherlands ²Section for Immunology and Vaccinology, National Veterinary Institute, Technical University of Denmark, Copenhagen, Denmark ³Department of Pathology, Leiden University Medical Center, Leiden, The Netherlands ⁴Department of Immunohematology and Blood Transfusion, Leiden University Medical Center, Leiden, The Netherlands

ABSTRACT

A role for T cell immunity in the clearance of tumor cells has well been established and is effectively put to use in therapies that selectively boost anti-tumor responses. It is proposed that the efficacy of checkpoint blockade immunotherapy largely relies on T cell reactivity to neoantigens: peptides derived from mutated (onco)proteins that are presented on major histocompatibility complex class I. Rapid detection of neoantigen-reactive T cells can support the development of specific immunotherapies as well as monitor response to therapy. In this study we aim to identify responses directed at HLA-A*02:01- or H-2Kb-binding neoantigens predicted from human colorectal cancer patients and from the murine colorectal cancer model MC38, respectively. We generated panels of DNA-barcoded major histocompatibility class I complexes loaded with predicted neoantigens using thermal MHC exchange technology and used them to identify T cell specificities from human and murine cell samples. We provide first evidence of the feasibility of the technique by confirming previously detected viral responses from healthy donors in two separate experiments. However, identification of true mouse or human neoantigens has proven challenging. Low cell counts and presumably the low neoantigen frequencies were bottlenecks in these first tests. Future work will focus on resolving the technical difficulties and on increasing the sensitivity of the technology.

INTRODUCTION

Oncogenesis is accompanied by the occurrence of somatic mutations in cancer cells. DNA nucleotide substitutions as well as insertions or deletions at proteincoding regions can result in the expression of mutated antigens². Presentation of these so-called neoantigens on major histocompatibility complexes (MHCs) on the cell surface flags tumor cells for detection by neoantigen-specific T cells, potentially resulting in tumor clearance³. Due to their somatic origin, later in life, no central tolerance has been raised specifically against neoantigens supporting their potential as immunotherapeutic targets⁴. Unlike traditional tumor-associated antigens (TAAs) originating from overexpressed self-proteins, neoantigens are solely expressed on tumors and therefore neoantigen-based vaccines are expected to less frequently induce autoimmunity⁵. For this reason neoantigens are hot targets in the development of cancer therapeutics^{6,7}. Vaccination with neoantigens through various delivery modes has resulted in therapeutic benefit in a number of preclinical and clinical studies⁸⁻¹¹.

Discovery of neoantigen-directed T cell reactivity in cancer patients is of high interest as it can support immunotherapeutic approaches. Unfortunately,



Figure 1. **Workflow of the anticipated neoantigen screen.** RNA and exomes from HLA-A*02:01⁺ colorectal cancer (CRC) patients are sequenced to identify mutations in expressed proteins. Potential neoantigens are predicted based on their HLA-A*02:01 binding motif. These peptides are then synthesized and loaded on conditional pMHCI multimers through thermal exchange. Consequently, these multimers can be used for screening of neoantigen-specific CD8⁺ T cells from patient material.

the detection of neoantigen-reactive T cells can prove challenging at several levels. Since neoantigens arise from patient-specific mutations they have to be identified on an individual basis¹²⁻¹⁴. Furthermore, most cancer mutations occur outside mutation "hotspots" and affect so-called "passenger" genes that are generally not analyzed in targeted, diagnostic procedures. By performing DNA sequencing of healthy and tumor tissues, somatic mutations can be identified and, in combination with RNA sequencing, transcribed putative neoantigens can be selected for a given cancer. The functional detection of neoantigen-reactive T cells often relies on the selection of mutated peptides predicted to bind a patient's MHC class I alleles^{15,16}. Major efforts contribute to the development of advanced bioinformatic tools and algorithms, but these often fail to achieve accurate prediction¹⁷⁻¹⁹.

Physical measurements, such as mass-spectrometric analyses of peptides eluted from tumor cells or tumor-infiltrating T cells (TILs) or functional assays to

measure cytokine secretion, are used to validate predicted neoantigens, but they require large numbers of cells and often lack sensitivity²⁰. Another strategy is to characterize neoantigen-specific CD8⁺ T cells using pMHCI multimers. By using one fluorescent label per peptide, several multimers can be used simultaneously to identify specific T cells from a larger population using flow cytometry²¹. Conventional preparation of multimers required separate folding with each peptide for every specificity, but the development of several exchange techniques allows for the generation of multiple specificities in parallel²²⁻²⁵. We have recently described a novel exchange techniques in its potential for exchange on MHC



Figure 2. **Overview of generation and use of temperature-exchangeable DNA-barcoded MHCI multimers.** (A) DNA barcodes and MHCI monomers, both biotinylated, are added to fluorescently-labelled streptavidin-conjugated dextran backbones to form temperatureexchangeable DNA-barcoded MHCI multimers. (B) Dextran backbones and MHCI monomers with exchangeable peptide are combined with a specific DNA barcode per well. Each multimers is then loaded with a desired peptide and incubated at set exchange conditions. After exchange is complete, multimers are pooled, concentrated and added to a cellular suspension, from which multimer-positive CD8⁺ T cells are sorted on their fluorescent label. The DNA barcodes are then amplified using PCR and sequenced to identify the specific antigen-responsive T cells in the sample. (Picture adapted from Bentzen et al.¹).

multimers, reducing pre-staining handling time even further²⁶.

In flow cytometry the number of parameters that can be measured simultaneously is limited by the number of fluorophores that can be detected simultaneously. Combinatorial coding has greatly increased the number of combinatorial parameters up to 63, but for large screens this number is insufficient^{27,28}. Bentzen et al. devised a strategy to overcome this restriction by labelling with DNA barcodes¹. Each multimer consists of a PE-labelled dextran backbone that accommodates multiple streptavidin moieties for conjugation of biotinylated MHC monomers and 25-oligonucleotide barcodes. Using this technology over 1000 T cell specificities can be detected from one sample. Labelled T cells are sorted using FACS based on their PE label, followed by amplification of the DNA barcodes using PCR and subsequent analysis with next-generation sequencing (NGS).

In this study, we combined our thermal exchange technology with DNA barcoding to screen for neoantigens in a colorectal cancer (CRC) mouse model (MC38) and in human HLA-A*02:01⁺ patients (Fig. 1). A group of CRC patients exhibit high microsatellite instability, giving rise to a high frequency of mutations and consequently this may result in a high number of neoantigens and increased responsiveness to immunotherapy²⁹. We aim to identify bona fide neoantigens displayed by these patients in order to unravel therapeutic targets for immunotherapy.

RESULTS

HLA-A*02:01 proof-of-principle

As a proof-of-principle we used thermally-exchanged multimers to detect virusspecific CD8⁺ T cells in buffy coats from three healthy HLA-A*02:01⁺ donors. We selected eight common virus epitopes (see Table 1) originating from influenza A virus (IAV), Epstein-Barr virus (EBV), cytomegalovirus (CMV) or HIV, for which specific T cells were previously detected in one or more of the three buffy coats used in this experiment. Because the signal-to-noise ratio would be low when staining with only eight different DNA-barcoded pMHCI multimers, the selection of peptides was included in a larger panel consisting of 48 melanoma antigens (data not shown). This total of 56 peptides were loaded on DNAbarcoded HLA-A*02:01 multimers using thermal peptide exchange as depicted in Figure 2, A and B, and described in the Materials and Methods section. Next, these were used for staining of the buffy coats obtained from the HLA-A*02:01⁺ volunteers. CD8+multimer+ T cells were isolated using FACS and DNA barcodes in this population were identified by next-generation sequencing (NGS). In all three buffy coats, viral responses were detected in earlier studies. Using DNA-barcoded

#	Sequence	Origin	BC83	BC104	BC112
V1	GILGFVFTL	IAV MP1	0.00%	0.06%	0.01%
V2	CLGGLLTMV	EBV LMP2	0.00%	0.04%	0.01%
V3	GLCTLVAML	EBV BMLF1	0.81%	0.17%	1.64%
V4	FLYALALLL	EBV LMP2	0.09%	0.04%	0.02%
V5	NLVPMVATV	CMV pp65	0.01%	0.00%	7.48%
V6	YVLDHLIVV	EBV BRLF1	0.88%	0.11%	0.21%
V7	VLEETSVML	CMV IE1	0.00%	0.00%	0.01%
V8	ILKEPVHGV	HIV Pol	0.00%	0.00%	0.01%

 $\label{eq:table 1} Table \ 1. \ Viral \ epitopes \ used \ for \ thermal \ exchange \ and \ MHCI \ multimer \ staining \ of \ CD8^+ \ T \ cells \ in \ buffy \ coats \ from \ healthy \ volunteers.$

Frequencies indicate estimated percentages of antigen-specific T cells from total CD8⁺ T cells determined by sequencing of DNA barcodes. Values highlighted in bold face and green indicate specificities previously detected in that patient. BC, buffy coat; CMV, cytomegalovirus; EBV, Epstein-Barr virus; HIV, human immunodeficiency virus; IAV, influenza A virus.

thermally-exchanged HLA-A*02:01 multimers we detected all of them in similar frequencies (Table 1, highlighted in bold and marked in green), demonstrating the experimental feasibility of our approach.

Screening for neoantigens predicted from HLA-A*02:01+ CRC patients

After establishing proof-of-principle we set out to validate neoantigens predicted for five HLA-A*02:01-expressing CRC patients. Cancer exomes and transcriptomes were sequenced and compared to healthy tissue to reveal somatic mutations potentially giving rise to neoantigens. From these potential neoantigens, HLA-A*02:01-binding peptides of high and intermediate affinity were predicted using NetMHC, yielding 6, 13, 17, 136 and 336 sequences for patients P1 to P5, respectively (see Table S3 for sequences). The eight common viral epitopes used in the proof-of-principle (Table 1), were included as an experimental control, as well as a non-exchanged negative control. Multimers loaded with the predicted neoantigens or viral antigens were pooled and used to screen for reactive CD8+ T cells from a number of samples obtained from the tumor, peripheral blood or lymph node, as well as buffy coats from two healthy volunteers. Additional TIL subsets were included for patients P2, P3 and P4, based on a study by Duhen et al.³⁰ They described a unique subset of CD8+ TILs present in the tumor microenvironment, but not peripheral blood, that express both CD39 (a T cell exhaustion marker often co-expressed with PD-1) and CD103 (a cadherin involved in cytotoxic lysis)^{31,32}. They found that this subset of T cells is enriched for tumor-reactive T cells. Therefore we included TILs selected for expression of both (double positive, DP), either (single positive, SP) or none (double negative, DN) of these two markers in an attempt to detect higher neoantigen-specific T cell frequencies in the DP subset.

As expected, barcodes corresponding to viral peptides were retrieved in one of the healthy controls and in some of the patient samples (Fig. 3). The peptides corresponding to the top 10 barcode reads increased compared to baseline are listed in Table S4. Consistent with the proof-of-principle experiment, CD8⁺ T cells specific for viral peptides V3, V4 and V6 were detected in buffy coat (BC) 83. Viral antigens were also detected in a number of the patient samples, but not in all of the sample types from the same patient. In patient P3, viral responses were



Figure 3. **Barcodes retrieved from the five human colorectal cancer (CRC) patients included in this study.** Patient samples were stained with a pool of HLA-A*02:01 multimers thermally exchanged for a selection of predicted neoantigens and eight common viral antigens (denoted with V, sequences listed in Table 1). Peptides predicted for patients P1, P2 and P3 were combined for a total of 36, while for patients P4 and P5, respectively, 136 and 336 neoantigens were predicted. Barcodes corresponding to viral antigens were detected in volunteer buffycoat 83 and in a number of patient samples. No significant neoantigen -specific responses were detected. FDR, false discovery rate; PBMCs, peripheral blood mononuclear cells; TIL, tumor-infiltrating lymphocyte; LN, lymph node; DN, double negative TIL subset expressing both CD39 and CD103; DP, double positive TIL subset; SP39⁺, single positive TIL subset expressing CD103.

detected in the lymph node and PBMC (peripheral blood mononuclear cell) samples, but not the TILs. TILs are likely more reactive against tumor antigens than against viral antigens, so this is not remarkable. In patient P2, virus-specific T cells were also detected in the double-negative (supposedly less tumor-reactive) TIL subset. Unfortunately, in none of the samples increased numbers of barcodes corresponding to predicted neoantigens were detected. This is not surprising, since neoantigen frequencies are generally low and hence do not give rise to high T cell numbers as viral antigens do. However, one of the peptides included in this set, TLVIYVARL (#268), was previously picked up in an activation assay using PBMCs from patient P4, but not in this screen. This hit will be validated in co-culture assays to determine if the result emanating from the first assay was a true or false positive.

Screening for MC38 neoantigen-specific CD8⁺ T cells

To screen for neoantigens in the MC38 mouse model, a total of 1020 mutated H-2K^b binders were predicted based on expression profiles in tumor and healthy tissue. Neoantigen-specific responses were analyzed in naïve C57BL/6 mice that were untreated, vaccinated with irradiated MC38 tumor cells, or vaccinated with irradiated MC38 cells in combination with DMXAA (5,6-dimethylxanthenone-4-acetic acid). DMXAA is a murine STING (Stimulator of Interferon Genes) agonist that has demonstrated durable preclinical benefit by activating dendritic cells, anti-tumor CD8⁺T cells and inducing interferon (IFN-)β production^{33,34}. Vaccination with irradiated tumor cells provides TAAs and danger signals (caused by radiation-induced immunogenic cell death) and consequently should result in priming and expansion of tumor-specific T cells. Mice were sacrificed one week after finishing a scheme of three vaccinations with two-week intervals.

In a first test of the experimental set-up, a small selection of 102 potential neoantigens were screened (see Table S5). These predicted neoantigens and OVA peptide SIINFEKL were loaded on DNA-barcoded H-2K^b multimers through thermal exchange and used to stain splenocytes isolated from vaccinated or untreated C57BL/6 mice. A no-peptide control was included as negative control and as experimental control OT-I T cells were spiked into the non-vaccinated sample (1% of total cells) for detection by SIINFEKL-loaded multimers.

After staining of the murine splenocytes, antigen-specific T cells were isolated using FACS. A clear population of multimer⁺ CD8⁺ T cells was visible in the nonvaccinated sample spiked with OT-I cells (Fig. 4, left), which was expected to consist of the SIINFEKL-specific OT-I T cells spiked in to the cell sample. However, even though the barcode corresponding to SIINFEKL (#104) was among the top 10 for the OT-I-spiked sample, only slightly more reads were detected in the sample compared to the baseline. This was the case for most barcodes: in all samples combined only two barcodes were detected above the significance threshold

		Use	ed directly post exc	hange
Sort	t count	204	221	573
	Sample	Non-vaccinated (+OT-I)	Vaccinated (MC38+DMXAA	
	1	#24	#74	#17
	2	#89	#16	#16
ies	3	#63	#64	#64
ificit	4	#60	#68	#63
spec	5	#87	#17	#28
10	6	#70	#20	#21
Top	7	#104	#65	#24
	8	#12	#26	#78
	9	#72	#66	#20
	10	#74	#70	#15

Table 2. Top 10 peptide specificities retrieved from the murine cell samples included in this study.

Conditional H-2K^b multimers were exchanged for 102 predicted neoantigens and OVA peptide SIINFEKL. These were used to stain splenocytes isolated from non-vaccinated mice spiked with OT-I cells, mice vaccinated with irradiated MC38 tumor cells or from mice vaccinated with MC38 cells and DMXAA (5,6-dimethylxanthenone-4-acetic acid). Barcodes corresponding to peptides highlighted in red were detected at significantly increased levels (log fold change \geq 2) compared to baseline reads. OVA peptide SIINFEKL is marked green in bold face; previously detected peptides are marked blue in bold face.

(log fold change \geq 2). This can be explained by the low cell numbers used for staining, and consequently the low number of sorted cells (Table 2). After thawing splenocyte counts were relatively low, so that only 100,000-500,000 cells per condition could be included, when in fact 1,000,000-2,000,000 are preferred. The lower limit of detection is about 20 copies of a specific CD8⁺ T cell and this number is challenging to reach with low numbers of PBMCs. Repeating this screen with more cells will likely yield more relevant and more reproducible data.

DISCUSSION

The discovery of immune checkpoints as anti-cancer targets has sparked the field of cancer immunotherapy. Blocking of inhibitory molecules, such as CTLA-4 or the PD-1/PD-L1 interaction, results in reestablishment of pre-existing immune responses^{35,36}. Accordingly, responses to checkpoint inhibition are highest in cancers with a high mutational burden where more neoantigens can be generated^{37,38}. Vice versa, the efficacy of checkpoint inhibition can be further increased by priming of anti-tumor T cells through neoantigen-based

therapies³⁹. The success of these therapies relies on neoantigens and hence it is important to know their identity. Identification of mutations has become relatively straightforward with the development of NGS, but predicting the immunogenicity of predicted neoantigens is less trivial. In this study we set out to validate predicted neoantigens by characterizing neoantigen-specific immune responses using conditional pMHCI multimers. Thermal exchange technology provides an easy method to generate large numbers of specific MHCI multimers in parallel. Using DNA barcode labeling up to 1000 peptides can be tested from a single sample, thus greatly reducing the sample volume required for analysis. Especially in the tumor field this provides huge benefit compared to conventional multimer staining. It has long been established that peptides with a high affinity for their cognate MHCI are not necessarily more immunogenic and hence potent immunogenic peptides may be missed by applying strict selection parameters^{40,41}. Combining MHCI exchange technology with DNA barcoding allows broadening of the selection criteria to also include less obvious potential neoantigens that would otherwise not be included in screens. The experiments described here are



Figure 4. FACS plots of MC38 splenocytes stained with a pool of 102 thermally-exchanged H-2K^b multimers (used immediately post exchange). CD3⁺CD8⁺multimer⁺ T cells were sorted based on fluorescence of the PE label conjugated to the multimerization backbone. Left: splenocytes isolated from non-vaccinated mice spiked with OT-I cells (1%). The population on the right likely shows OT-I cells stained with H-2K^b multimer exchanged for OVA peptide SIINFEKL. Center: splenocytes from mice vaccinated with irradiated MC38 tumor cells. Right: cells isolated from mice vaccinated with irradiated tumor cells and DMXAA (5,6-dimethylxanthenone-4-acetic acid).

a first step towards implementing DNA barcoding technology in combination with temperature-based MHC exchange technology to increase the throughput of the technology.

The screen performed with HLA-A*02:01 multimers exchanged for viral and melanoma epitopes served as a proof-of-principle, demonstrating that previously detected T cell responses against viral epitopes could be picked up using DNA-barcoded thermally-exchanged multimers. The fact that those same viral responses were detected in our human CRC patient screen was very promising, but in contrast no neoantigen barcodes were retrieved. Peptide #268 (TLVIYVARL) was shown to activate CD8+ T cells in PBMCs from patient P4, but in the pMHCI multimer screen we did not detect its corresponding barcode. This peptide is predicted to weakly bind HLA-A*02:01 and this may affect pMHCI multimer loading, although the predicted affinity of 235 nM is well beyond that of the template peptide IAKEPVHGV, which is 7,288 nM. Determining the exchange efficiency using HPLC can resolve whether impaired loading accounts for not detecting this peptide.

It is known that only few predicted peptides are bona fide neoantigens and that frequencies of neoantigen-specific T cells are low, hampering detection. Furthermore, in our study only a single MHCI allele was included, whereas each individual expresses up to six distinct HLA alleles. Inclusion of pMHCI multimers with additional patient-matched HLAs will undoubtedly increase the neoantigen discovery rate. Advancing thermal exchange technology will allow screening across the full range of HLA haplotypes expressed by each individual patient.

In an attempt to increase neoantigen-specific T cell frequencies, the mice used in our MC38 screen were vaccinated with irradiated MC38 tumor cells, with and without DMXAA. Despite FACS analysis clearly demonstrating a population in the OT-I spiked sample and the barcode corresponding to SIINFEKL turning up in the top 10 of elevated reads, no significant increase in reads compared to baseline was found. Due to the low cell count no T cell specificities were detected above the threshold and repetition of this screen with more cells will be necessary to demonstrate the potential of DNA-barcoded pMHCI screens for neoantigen discovery.

MATERIALS AND METHODS

Ethical approval

All animal experiments were approved by the animal ethics committee of the LUMC, which has been licensed by the Dutch Central Animal Experiments Committee. Experiments were performed by Federation of European Laboratory Animal Science Associations (FELASA)-accredited animal-handlers and monitored by the animal welfare body according to the Dutch Act on animal experimentation (ex art. 14a, b, and c) and EU Directive 2010/63/EU ('On the protection of animals used for scientific purposes').

All patient material was collected under approval by the Medical Ethical Committee of the Leiden University Medical Centre (LUMC, protocol P15.282). Patient samples were anonymized and handled according to the medical ethical guidelines described in the Code of Conduct for Proper Secondary Use of Human Tissue of the Dutch Federation of Biomedical Scientific Societies. This research was conducted according to the recommendations outlined in the Helsinki declaration.

Human cell samples

PBMCs from patients were isolated from heparinized venous blood by use of Ficoll-Amidotrizoate (LUMC Pharmacy, Leiden, NL) density centrifugation. Tumor material and respective healthy colorectal and lymph node samples were obtained during surgery, cut into small fragments and digested using gentleMACS C tubes (Miltenyi Biotec), collagenase D (Roche) and DNAse I (Roche). The digested cells were incubated for 30 min at 37°C interrupted by three runs on the gentleMACS Dissociator (Miltenyi Biotec) and subsequently filtered by use of a 0.7 µm mesh filter. The tumor fragments and single cell digests were cryopreserved for analysis and culturing at later stages.

TIL collection was performed by culturing of tumor fragments in a 24-well plate with T cell medium (IMDM (Lonza BioWhittaker or Thermo Fisher), supplemented with 8% heat-inactivated pooled human serum, penicillin (100 IU/ml), streptomycin (100 μ g/ml) and L-glutamine (4 mM)) and rIL-2 (1000 IU/ml). After 14-21 days of culturing, TILs were harvested and cryopreserved for later use. To increase the number of T cells available for screening, rapid expansion of TILs was performed by culturing with rIL-2 (3000 IU/ml), OKT3 (Miltenyi Biotec, 60 μ g/ml) and irradiated (40 Gy) feeder cells (100-200×) for 4-5 days. Subsequently, culturing was continued up to two weeks in T cell medium supplemented with rIL-2 (3000 IU/ml).

A mixed lymphocyte tumor culture (MLTC) was performed by co-culturing PBMCs with lethally irradiated (100 Gy) tumor fragments in T cell medium. Recombinant human IL-4 was added at day 0 to prevent NK cell outgrowth. PD1⁺ cell selection was performed after day 1 of co-culture. Cells were harvested and stained with PE-conjugated anti-PD1 antibodies (BD Biosciences). Subsequently, MACS was performed by use of magnetic anti-PE beads (Miltenyi Biotec) and magnetic separation (MS) columns (Miltenyi Biotec). PD1⁺ cells and flow through were each cultured with irradiated (40 Gy) feeder cells (100-200×) and high-dose rIL-2 (3000 IU/ml). Culture medium containing rIL-2 was refreshed on alternate days. Cells were cryopreserved after a culturing period of two weeks.

CD39/CD103 double negative (DN), single positive (SN) and double positive (DP) TILs were isolated as described by Duhen et al.³⁰. Briefly, cryopreserved PBMCs and TILs were thawed and enriched for T cells using a T cell enrichment kit (STEMCELLTechnologies)andforTILsusingEpCAMbeads(STEMCELLTechnologies). The enriched fractions were then labeled and sorted on a FACSAria II cell sorter (BD Biosciences). From the TILs memory T cell (CD3+CD4-CD8+CD45RA-CR7+/-) subsets were sorted as CD39-CD103- (DN), CD39-CD103+ (SP), and CD39+CD103+ (DP). For expansion sorted T cell subsets were cultured in complete RPMI 1640 medium supplemented with 2 mM glutamine, 1% (v/v) nonessential amino acids, 1% (v/v) sodium pyruvate, penicillin (50 U/ml), streptomycin (50 µg/ml), and 10% fetal bovine serum (Hyclone).

Sorted T cells were stimulated polyclonally with 1 µg/ml Phytohemagglutinin A (PHA, Sigma) in the presence of irradiated (40 Gy) allogeneic feeder cells (PBMC; 2×10⁵ cells/well) and 10 ng/ml of IL-15 (BioLegend) in a 96-well round-bottom plate (Corning/Costar). T cell lines were maintained in complete medium with IL-15 for 2-3 weeks and then cryopreserved until analysis.

Murine cell samples

Female C57BL/6 mice of 8-10 weeks were purchased form Envigo, Harlan Laboratories and acclimatized for 1 week to the animal facility of the LUMC. The mice were housed in individually-ventilated-cage (IVC) systems in specific pathogen-free conditions and kept at room temperature. MC38 (murine colon carcinoma) cells were cultured in IMDM medium (Lonza) supplemented with 8% Fetal Calf Serum (FCS, Greiner), 100 IU/ml penicillin/streptomycin (Gibco), 2 mM glutamine (Gibco) and 25 mM 2-mercaptoethanol (culture medium). Cell lines were mycoplasma- and MAP-tested before injection. Mice were subcutaneously injected thrice in the right-flank with 5×10^6 irradiated (15,000 rads) MC38 cells in 200 µL of PBS with a two week interval, whereby one group of MC38 injections was adjuvanted with 100 µg of DMXAA (5,6-dimethylxanthenone-4-acetic acid, InvivoGen).

Spleens from the mice were obtained one week after the final injection and mashed on single cell strainers with the blunt end of a 5 ml syringe and washed with culture medium. Cellular precipitates after centrifugation were treated with 5 ml of lysis buffer for 3 minutes at room temperature and subsequently washed with culture medium. Splenocytes were frozen in 10% DMSO in FCS at a concentration of 10×10⁶ cells/ml and stored in liquid nitrogen. Similarly, OT-I/Thy1.1/CD45.2 cells were obtained from the spleens of in-house bred transgenic mice, although samples were enriched for CD8⁺ lymphocytes (Mouse CD8 T Lymphocyte Enrichment Set, BD IMag) and frozen at a concentration of 4×10⁶ cells/mL.

Peptide prediction and synthesis

For exome sequencing, reads were mapped against the human reference genome (hg38) using the Burrows-Wheeler Aligner (BWA-mem version 0.7.15) algorithm with default parameters⁴². Duplicate reads were removed using Picard Tools (http://picard.sourceforge.net). Genome Analysis Toolkit (GATK version 3.8; Broad Institute) was used for base quality recalibration⁴³. Subsequently, single-nucleotide variants and indels were called using a combination of three popular software tools: muTect 2, varScan 2 and Strelka⁴⁴⁻⁴⁶. The resulting vcf files were combined into a single file using GATK CombineVariants. Variants were then functionally annotated using the ensembl Variant Effect Predictor (VEP)⁴⁷. Variants annotated as protein disrupting or altering were further investigated if at least one read with the alternative allele was present in the RNAseq data. Reads generated by RNAseq were mapped against the same hg38 genome build using gsnap⁴⁸. Integrative Genomics Viewer (IGV) was used for visually inspecting variants^{49,50}. Manual review of aligned reads was used to reduce the risk of false positives and incorrect calls⁵¹. Prediction of binding to HLA-A*02:01 was performed for 8-12 amino acid peptide sequences using NetMHC and NetMHCpan. All strong and weak binders were selected for multimer screening. Murine MC38 neoantigen prediction was performed as described by Hos et al.⁵²

Peptides were synthesized in our lab using standard solid-phase peptide synthesis or ordered from Pepscan. Synthesis was performed using Syro I and Syro II synthesizers using *N*-methyl-2-pyrrolidone as solvent. Resins and amino acids were purchased from Nova Biochem. Peptides were purified by reversed-phase HPLC over a preparative Waters X-bridge C18 column in a Waters HPLC system using water/acetonitrile mixtures containing 0.1% TFA. Peptide purity and composition were analyzed sample-wise by LC-MS using a Micromass LCT Premier mass spectrometer (Waters) equipped with a 2795 separation module (Alliance HT) and 2996 photodiode array detector (Waters). The samples were separated using a water/acetonitrile gradient over a Kinetix C18 column (Phenomenex). Analysis was performed using MassLynx 4.1 software (Waters Chromatography).

Multimer preparation

Temperature-exchangeable HLA-A*02:01-IAKEPVHGV and H-2K^b-FAPGNAPAL complexes were expressed and folded essentially as described previously^{24,26,53}, with minor alterations. Folded complexes were concentrated using a 30 kDa MWCO PES Vivaflow 200 protein concentrator system (Sartorius), driven by a Masterflex L/S peristaltic pump. Consequently the buffer was exchanged for 300 mM NaCl and 20 mM Tris•Cl, pH 8 using a NAP-10 column. Samples were filtered using a Spin-X column and biotinylated overnight using BirA ligase, supplemented with ATP, biotin and protease inhibitors. The following day samples were concentrated using Amicon Ultra-15 30 kDa MWCO centrifugal filter units (Merck Millipore)

and purified by gel filtration size exclusion chromatography (300 mM NaCl and 20 mM Tris•Cl, pH 8; Superdex 75 16/600 column, GE Healthcare) on an NGC system (Bio-Rad). After another round of concentration to 2-4 mg/ml using Amicon Ultra-15 30 kDa filters, they were snap-frozen and stored at -80°C in the same buffer supplemented with 15% glycerol. Biotinylation was verified by incubation of biotinylated MHCI monomers with streptavidin, followed by gel filtration chromatography on a Shimadzu Prominence system equipped with a 300 × 7.8 mm BioSep SEC-s3000 column (Phenomenex) using PBS as mobile phase. Data were analyzed using Shimadzu LabSolutions software (version 5.85).

Multimers were assembled as described by Bentzen et al.¹. Briefly, PEand streptavidin-conjugated dextran backbones (Fina Biosolutions, final concentration 6.92×10^{-8} M) were added to 5'-biotinylated AxBy DNA barcodes (DNA Technology, sequences in Table S1 and Table S2), which were titrated per batch of dextran. After incubating for 30 min at 4°C MHCI monomers were added at a final concentration of 30 µg/ml, followed by another 30-min incubation at 4°C. To each well a different peptide was added at a final concentration of 60 µM, and plates were incubated at previously described exchange temperatures (5 minutes at room temperature for H-2K^b and 3 hours at 32°C for HLA-A*02:01). For stability and to saturate unoccupied streptavidin binding sites a solution containing 500 µM D-biotin, 100 µg/ml herring DNA, 0.5% BSA, 2 mM EDTA and 5% glycerol (in PBS) was added and incubated for 20 min on ice.

Barcode-labelled exchangeable multimers were centrifuged at $3300 \times g$ for 5 min at 4°C to sediment aggregates and then pooled at 0.043 µg pMHC per sample. Pools were collected in reservoirs that were pre-saturated for at least 2 hours with 2% BSA to prevent sticking. Using (also pre-saturated) Vivaspin6 or Vivaspin20 centrifugal concentrators (100 kDa MWCO, Sartorius) to a volume of ~80 µl per sample. Concentrated pools were centrifuged for 5 min at 3300 × g before adding to cell suspension. A 5 µl aliquot was stored at -20°C for later use as baseline sample.

pMHCI multimer staining and sorting

Cryopreserved cell suspensions were thawed in and washed with RPMI supplemented with 10% FCS, and subsequently washed with barcode cytometry buffer (BCB; PBS with 0.5% BSA, 100 µg/ml herring DNA, 2 mM EDTA) and incubated with 50 nM dasatinib for 30 min at 37°C. For human samples 2×10⁶ cells and for murine samples ~4×10⁵ cells were stained with pooled DNA-barcoded multimers in 100 µl BCB total volume for 15 min at 37°C. Human samples were stained with antibody mix composed of anti-CD8-V510, dump channel FITC-conjugated antibodies against CD4, CD14, CD16, CD19 and CD40 (all BD Biosciences), and near-IR viability dye (Invitrogen), for 30 min at 4°C. Murine samples were stained with antibody mix composed of anti-CD3-FITC (BioLegend), anti-CD8-BV480

(BD Horizon) and near-IR viability dye (Invitrogen), for 30 min at 4°C. Cells were washed three times with BCB, filtered and fixed in 1% PFA for overnight storage.

Stained cells were washed three times in BCB prior to sorting on a FACSAria or FACSMelody (BD Biosciences) into pre-saturated tubes containing 200 µl BCB. From human samples the population of single, live CD8⁺, dump⁻, PE (multimer)⁺ lymphocytes was sorted using FACSDiva (BD Biosciences) software. From murine samples single, live CD8⁺, CD3⁺, PE (multimer)⁺ lymphocytes were sorted. Further analysis was performed using FACSDiva or FlowJo (FlowJo, LLC) software.

DNA barcode amplification and analysis

DNA barcodes were amplified using a Taq PCR Master Mix Kit with 0.3 μ M appropriate forward- (with a distinct sample ID embedded) and reverse primers comprising Ion Torrent PGM 5' and 3' adaptors. Sorted cells (in less than 20 μ l buffer) and the stored baseline aliquot (diluted 10,000× in H₂O) were amplified using a PCR program with the following conditions: 95°C 10 min; 36 cycles: 95°C 30 s, 60°C 45 s, 72°C 30 s and 72°C 4 min. PCR products were analyzed using gel electrophoresis (E-Gel, Invitrogen), pooled at similar concentrations according to visual inspection and then purified using the QIAquick PCR Purification kit (Qiagen) according to standard procedure. The amplified barcodes were sequenced at Sequetech (USA) or the LUMC Sequence Analysis Support Core (SASC, NL). Sequencing data were analyzed and visualized using the online tool 'Barracoda' (http://www.cbs.dtu.dk/services/barracoda) developed at DTU.

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Author contributions: J.J. Luimstra, J. Neefjes, and H. Ovaa conceived and designed the study with input from N. de Miranda and F. Ossendorp. J. van den Bulk prepared human cell samples and B. Hos prepared murine cell samples. N.F. de Miranda predicted peptides. J.J. Luimstra and C. Heeke generated DNA-barcoded multimers and performed T cell staining experiments. J.J. Luimstra wrote the manuscript with input from all authors.

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SUPPLEMENTARY DATA

Supplementary Table 1. Oligo A sequences used in this study

Oligo A #	Barcode Sequence
A1	CGAGGGCAATGGTTAACTGACACGT
A2	CAGAAAGCAGTCTCGTCGGTTCGAA
A3	TAAGTAGCGGGCATAATGTACGCTC
A5	GGGCTGCGGAGCGTTTACTCTGTAT
A6	AAACGTATGTGCTTTGTCGGATGCC
A7	ATATCATCATAGGCTTAGCGACGTA
A8	AGGAAAATCTGCTACCGCCAATGAT
A9	CTGATTGACTGCATGGAGGCTATAC
A10	GTGGCGACTTCACGATTATCTGAAC
A11	CCTGTATTGAAGGTTCAGTCCTGTT
A12	GGCTCTATAAGGTTTCCTCAAAGGT
A14	AGAGAATATGTCGCTCCCGTTATGT
A15	GCAGTTAGATATGCAGTTACCTGAC
A16	CTTCACCCGAACATGCAGTGTTATT
A17	AAAGCCGTTGCAGTATCGTCTGAGC
A18	GCTGGATGTTAATAACTGCGGTCCG
A19	ACGAGTTGACATGGACGGATCCCTC
A20	TTCATCACTCATTGTTCTGAGTAGG
A21	ATGTTTAATCTAACTTGATGCCTCC
A22	TAATACGCCTGAGGTGTTGGGTTGC
A23	AGTCGGCATTGCTACCATAACTGTT
A24	CCGGACCGCTATTAACCTTGTACTG
A25	CTAGATGCTGCGAACGGAAGCTGTC
A26	TGTTCCAAGCGGTTGAACGATTAGC

Supplementary Table 2. Oligo B sequences used in this study

Oligo B #	Barcode Sequence
B61	GTTAGGTCGGCAGGTCAGTATGACC
B62	CGGGAGTTGGATCTGCGTAGAGTCC
B63	CCGGTTTTATACCCTCGTTCCCCGA
B64	CAGAACTACAGGCTGGCATGGATGC
B65	ATTCTGATGGGTAGAAACCGTTCCC
B66	GAGCGTGAGTTCCATGGAAAATTAC
B67	AGTAAAGGCTCACTGCTATCGCACT
B68	ATTTATTCGCACAATCGCCGAGTGC
B69	TACTCAACGACGTGGGGTAGGATCC
B70	GATATTCGGATCTTGGCTCGGACTG
B71	TTTCCTTGTTCGGATCGGTCGAGAA
B72	TGGAAACGACTGGTGTATGCATTCC
B73	GCTGTCAGTAGCGCCAGTACAATTT
B74	CTTTATGGGATAGCAAGACCTCTCC
B75	CATATGGATTTGTTGCATCCTGATG
B76	TGCAATATGGGTCGCGTTCAGTCGT

Supplementary Table 2 (continued). **Oligo B sequences used in this study**

Oligo B #	Barcode Sequence
B77	TAATTGCCTTGCGGTGCGTGTTGAT
B78	GGCAGGCTAGCTTAGTTGTAGCGGT
B79	CACATACTCAGACTCCCTGTCATAG
B80	TTGATCACAGCACGAATACGTTTCC
B81	TTTGAATAACCTTTCGCCTCTCGTG
B82	TGATTGCTTTGCCCTATAGCTACGT
B83	AGTGAAGTTACCTGGTGTTCCCTTC
B84	GCGGGATGTGCATTGCCAAGTTACC
B85	TTAAGTTGCCCAATTATTGTCCGCC
B86	GACAATGTAGGGGCCGTCTCAAGTA
B87	GCCATAGAGTCTACCGTCACCTCCG
B88	GTGCTACCATCGAGCGGAGGTATTT
B89	GAGTCCGATTGCTTTATCTGCTACC
B90	AATGGGCCTGCTACTCGCCATTATT
B111	CGTTGAAATAGTCGCATCTCTCACG
B113	TAAATGGCCTACATTCGAACGGTTG
B115	GTTATCCGTAGAGCGGTGCAAGTCC
B116	TCTTCGACATCTGGCATCACGACCT
B117	TTGGTTTATGATCACTGAAATGCCC
B118	ATGGGGATAGCCATCAGTTGGGCTA
B120	AATCGTAGTCGTCAGCCGCTAATAA
B121	GTCTTGTCGTGGGACGCATGTATCC
B122	GAAGTGAGGCGCTAACGCTCTAGGG
B124	GGTCATTCTAGTGAACTAATCCCCT
B200	GCTGAGGCGTTCCACTTGGATCGTT
B201	ATTGGGGACTTCCCTTTGCATTCTT
B202	AAATGGGACCGACACACTCTTAGCA
B203	GGCTTTACGGAACCCCGTGACTAGA
B204	AAGGTACTGGGCCGGTCCAATACAG
B205	TAGTAATACATACGCCCAGGCGGTA
B206	TACATGTTCGTTCTGCGTTACTCAC
B207	CTAATCAATGGTCCACGTTCTAGGG
B208	GCTACTACACCCGAGGTCGAGAGGA
B209	GTTCTGCAATTTCAATTCCCGGTCC
B210	AAGGCTTTCTAGCCACGTATGCGAA
B211	TGTACTGAGGGAGTAACTGCCCGTT
B212	ATTGTCAGATGTCGTAGGTCGCCGC
B213	AAATCCATTTATCGGTCTGTCGTGA
B214	AGTCATATAGTTGTATTCTCCCTGC
B215	ATTTGGACAGCATATTGACGTCGGA
B216	CGCATTCCGACAATATCGTGTTGTA
B217	CCCAGAACGTGAGTCAGTGTTCGCA
B218	TCCTTAGTTTTCCGGCTAAATGAGA
B219	GATGTTATTGCTTGCACAACGGCTG

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Supplementary Table 3. **HLA-A*02:01 neoantigen sequences predicted from five colorectal cancer (CRC) patients, with DNA barcode annotations**

Total Description Description 1 ALAAACSA P5 ALB61 59 CLFPLTGI Description AG621 2 ALALVVAMA P5 ALB63 60 CMMGMNWRP P2 AG621 4 ALQDMSTA P5 ALB65 61 FINEMWYI P4 A7663 5 CLAMVVPAPA P5 ALB65 64 FLUPRUKIN P5 A7663 6 FHIFYQLIGA P5 ALB67 65 FMMPVETI P4 A7665 7 FLESISLA P4 ALB66 66 FTEKNLWLI P5 A7866 9 FLESISLA P4 ALB67 68 GLHRQLIYI P4 A7863 10 FLETKLCFA P5 ALB71 69 GLHS0GAYI P5 A7861 12 GLACISISWYA P5 ALB61 71 GMMAQLPCI P4 A7871 13 GLGGSTHMA P4 A2865 75 ILDPSYNI <	#	Sequence	Patient	Barcode	#	Sequence	Patient	Barcode
1 1	1		P5	A1B61	59		P5	A6871
3 ALGSTAPPA P4 A1B63 61 FAHNRNWYI P4 A7861 4 ALQDMSSTA P5 A1B64 62 FLERICADI P5 A7662 5 CLAAWVPAPA P5 A1B65 63 FLINGATIYEKGI P5 A7663 6 FHILYQLLGA P5 A1B66 64 FLIPPRLIKI P5 A7663 7 FLEISIRA P5 A1B67 66 FTKINUVLI P5 A76663 9 FLESSCIAA P4 A1B69 66 FTKINUVLI P5 A7666 10 FUETKLICFA P5 A1B71 68 GLHRQUYPLP P5 A7660 12 GECHIPFA P5 A1B62 70 GMHEATIVAI P5 A7860 13 GLORSPQA P5 A1862 71 GMHMUGGELQU P5 A8861 14 GLGGTHMAA P4 A2B62 77 ILLGFELIVE P5 A8864 12 KLACGIST	2		P5	A1B62	60	CMGGMNWRPI	P2	A6B72
4 ALQDMSSTA P5 A1864 62 FLEENCAD P5 A7862 5 CLAAWVPAPA P5 A1866 63 FLIVGATPYEKGI P3 A7863 6 FHIPYQLLGA P5 A1866 65 FHMMPPETTI P4 A7864 7 FLESSCIAPA P4 A1869 67 FVAPLVPLPI P5 A7869 9 FLPSSCIAPA P4 A1869 67 FVAPLVPLPI P5 A7869 12 GIACGISWYA P5 A1871 69 GIHAVCAVI P4 A7869 13 GLDDRSPQA P5 A1871 69 GIHAVCAVI P5 A7870 14 GLGGTHHMA P4 A2863 74 HILPAGWGEALQI P5 A7871 14 GLGORSPQA P5 A2866 76 ILLYSWCFEFE P5 A8864 15 HUMWKGFEA P4 A2867 71 <llgtflai< td=""> P5 A8867 16 HUMWKGFEA</llgtflai<>	3	ΔΙ GSTΔΡΡΔ	P4	A1863	61	FAHNRNW/YI	P4	A7861
S CLAAWVPAPA P5 A1865 63 FLINGATPYEKGI P3 A7863 6 PHIPYQLLGA P5 A1866 64 FLPPRLKKI P5 A7863 7 FLELSINA P4 A1866 65 FMMPPETI P4 A7863 8 FLPSSCLAP P4 A1868 66 FTEKNUWLI P5 A7867 10 FLEXSLAP P5 A1870 68 GLHRQLLYI P4 A7869 12 GLACLGSWVA P5 A1872 70 GMEEATVAI P5 A7867 13 GLDORSPQA P5 A1861 71 GMIHMLDGI P5 A7867 14 GLGGTHHMA P4 A2863 73 GVPVEGFEI P5 A8862 15 HUYDTLHWA P3 A2865 71 ILLOTHAI P5 A8865 16 HUYDKGFEA P4 A2867 77 ILLOTHAI P5 A8865 17 HLYDTLHWA	4	ALODMSSTA	P5	A1B64	62	FLEENCADI	P5	A7B62
6 PHIFYQLLGA P5 A1866 64 FLPPRLKKI P5 A7864 7 FLELSLAA P5 A1867 65 FMMPPEETI P4 A7865 8 FLPSSCLAPA P4 A1869 67 FVAPLVPLPI P5 A7865 10 FLRTKLCFA P5 A1870 68 GHHRQLLYI P5 A7867 12 GLACLGISWWA P5 A1871 69 GHHRQLLYI P5 A7867 13 GLDDRSPQA P5 A1872 GMMEATVAI P5 A7870 14 GLGGTHHMA P4 A2862 72 GMMAQLPCI P4 A7872 15 GLINKONFFA P5 A2866 76 LUYSWCRI P5 A8863 19 KLAYFLSA P4 A2866 77 LUKTVAIN P5 A8867 21 KLYUFUTLWA P5 A2866 78 LLKWEGOL P5 A8867 22 KMPEMSIKA P4	5	CLAAWVPAPA	P5	A1B65	63	FINGATPYEKGI	P3	A7863
7 PLELSIRA P5 A 1867 65 FMMPPEETI P4 A 7865 8 FLPSSCLAP P4 A 1866 66 FTEKNLWLI P5 A 7867 10 FLRTKLCFA P5 A 1870 68 GLHRQLLYI P4 A 7863 11 FQECHIPFPA P5 A 1872 70 GMEEATVAI P5 A 7869 12 GLACLGISWYA P5 A 1872 70 GMEEATVAI P5 A 7869 13 GLDDRSPQA P5 A 2862 71 GMIMADLPCI P4 A 7872 14 GLGGTHIMA P4 A 2866 75 ILDFSVHI P4 A 7862 15 GLINHONFFA P2 A 2866 76 ILLYSWCRI P5 A 8866 16 HUWRGFEA P4 A 2867 77 ILLGTHLAI P5 A 8866 16 KLWEGLDNA P4 A 2867 78 ILLWHOID P5 A 8867 16	6	FHIFYOLLGA	P5	A1B66	64	FLPPRLKKI	P5	A7B64
8 FLPSSCSLAP P4 A1868 66 FTEKNURUL P5 A7866 9 FLPSSCSLAPA P4 A1869 67 FVARUVPLP P5 A7861 10 FLERKLCFA P5 A1870 68 GHRQLUYL P4 A7865 11 FOECHIPPA P5 A1872 GMHCULYL P5 A7870 12 GLACLGLSWYA P5 A1872 T0 GMHEATVAI P5 A7870 13 GLDDRSPQA P5 A2861 71 GMHMADLPCI P4 A7870 14 GLGGTHHMA P4 A2866 76 HUPSWCIFFE P5 A8863 17 HUVTUTHWA P3 A2866 76 HUSWCIFFE P4 A8863 18 ILGSGTSFA P5 A2866 77 HLICHTAI P5 A8865 20 KLDLKVPKA P5 A2867 RELWENSIKA P4 A8865 21 KLVPGLIDNA P4 A2	7	FLELSLRA	P5	A1B67	65	EMMPPEETI	P4	A7865
9 FLPSCSLAPA P4 A1869 67 FVAPLVPLPI P5 A7867 10 FLERKLCFA P5 A1870 68 GLHRQLLYI P4 A7869 12 GLACLGSWYA P5 A1872 70 GMEEATVAI P5 A7869 13 GLDDRSPQA P5 A2861 72 GMMAQLPCI P4 A7871 14 GLGGTHHMA P4 A2862 72 GMWAQLPCI P4 A7872 15 GLMHGNFFA P2 A2863 73 GLUPSVHI P4 A7872 16 HUYNEKGFEA P4 A2865 76 LUYNCRI P5 A8862 17 HLYDTLHWA P3 A2865 78 LLKMEIQI P5 A8865 20 KLDKVPKA P5 A2867 78 LLKMEIQI P5 A8865 21 KLVFLGLNA P4 A2870 80 IRPPLIPYIVNI P4 A8872 22 KMEMEMSKA <th>8</th> <th>FLPSSCSLA</th> <th>P4</th> <th>A1B68</th> <th>66</th> <th>FTEKNLWLI</th> <th>P5</th> <th>A7B66</th>	8	FLPSSCSLA	P4	A1B68	66	FTEKNLWLI	P5	A7B66
10 FLRTKLCFA P5 A1870 68 GLHRQL(Y) P4 A7869 11 FQECHIPFPA P5 A1871 69 GLHSVGAYI P5 A7869 12 GLACIGLSWYA P5 A2861 71 GMIHMLDGI P5 A7870 13 GLDDRSPQA P5 A2861 71 GMIHMLDGI P4 A7872 14 GLGGTHHMA P4 A2862 73 GVYPYCGFEI P4 A8863 16 HIWPKGFEA P4 A2866 76 ILISPS'HI P4 A8863 17 HLYDTLHWA P3 A2866 76 ILISTFLAI P5 A8863 20 KLDKVPKA P5 A2866 78 ILLKME(QI P5 A8867 21 KLVFGLDNA P4 A2867 80 IRPPLIPYIVNI P4 A8862 22 KMPEMSIKA P4 A2870 80 IRPPLIPYIVNI P4 A8867 23 ILLG	9	FLPSSCSLAPA	P4	A1B69	67	FVAPLVPLPI	P5	A7B67
11 FQECHIPFPA P5 A1871 59 GLHSVGAVI P5 A7869 12 GLACLGLSWYA P5 A1872 70 GMEEATVAI P5 A7870 13 GLDDKSPQA P5 A2861 71 GMIHMLDGI P5 A7871 14 GLGGTHHMA P4 A2862 72 GMWAQLPCI P4 A7872 15 GLMHGNFA P2 A2863 74 HLPAGWGEALQI P5 A8861 16 HIVPKGFEA P4 A2867 76 ILUFSVCRI P5 A8863 17 HLVDTHWA P3 A2867 77 ILLGTFLAI P5 A8863 18 ILOSCYTH P5 A2867 78 ILLGMELAI P5 A8863 21 KLVFGLONA P4 A2870 80 IROPLENVIN P5 A8863 23 KVMLTAPPA P5 A3861 81 INCSCVVI P5 A8863 24 LUSCVTA <th>10</th> <th>FLRTKLCFA</th> <th>P5</th> <th>A1B70</th> <th>68</th> <th>GLHRQLLYI</th> <th>P4</th> <th>A7B68</th>	10	FLRTKLCFA	P5	A1B70	68	GLHRQLLYI	P4	A7B68
12 GLACLGISWYA P5 A1872 13 GLDDRSPQA P5 A2861 71 GMIEATVAI P5 A7871 14 GLGGTHHMA P4 A2863 73 GWYAQLECI P4 A7872 15 GLMHGNFFA P2 A2863 73 GVYPECFEI P5 A8862 17 HLYDTLHWA P3 A2865 76 ILDSYHI P4 A8863 18 ILGSGTFFA P5 A2866 76 ILLYSWCRI P5 A8862 20 KLDKVPKA P5 A2867 78 ILLKMEIQI P5 A8867 21 KLVFGLDNA P4 A2870 70 ILLKMEIQI P5 A8867 22 KMPEMSIKA P4 A2870 71 ILLKMEIQI P5 A8867 23 ILVGLVAA P4 A2871 81 ILVESCVI P5 A8867 24 ILSYTTA P4 A3861 83 KLCQGMHQI	11	FQECHIPFPA	P5	A1B71	69	GLHSVGAYI	P5	A7B69
13 GLDDRSPQA P5 A2861 14 GLGDRHIMA P4 A2862 72 GMIHMLDGI P4 A7872 15 GLMHGMFFA P2 A2863 73 GVVPVEGFEI P5 A8861 16 HIWPKGFEA P4 A2867 74 HLPAGWGFALQI P5 A8863 18 ILGSGTSFA P5 A2866 76 ILUSVCRI P5 A8863 20 KLDKVPKA P4 A2867 78 ILLMMEIQI P5 A8865 21 KLVFLSLAN P4 A2867 78 ILLMMEIQI P5 A8865 22 KMPEMSIKA P4 A2877 81 IVUGSCVVI P5 A8866 23 KVMLTAPPA P5 A2867 81 IVUSCVVI P5 A8869 24 LISPETAA P4 A2872 82 KLAFHIKSI P4 A8862 25 LIEGPLAPA P5 A3864 86 KLINPOKKI <th>12</th> <th>GLACLGLSWYA</th> <th>P5</th> <th>A1B72</th> <th>70</th> <th>GMEEATVAI</th> <th>P5</th> <th>A7B70</th>	12	GLACLGLSWYA	P5	A1B72	70	GMEEATVAI	P5	A7B70
14 GLGGTHHMA P4 A2B62 72 GMWAQLPCI P4 A7B72 15 GLNHGNFFA P2 A2B63 73 GVYPVEGFEI P5 A8B61 16 HIWPKGFEA P4 A2B65 75 ILDPSYHI P4 A8B63 17 HLVDTHWA P3 A2B66 76 ILUSSVFIN P5 A8B63 19 KLAYFSLSA P4 A2B67 77 ILLGTFLAI P5 A8B661 20 KLDKVPKA P5 A2B69 79 ILSDPENNI P5 A8B662 21 KLVFLGIDNA P4 A2B70 80 IRPPLIPYIVNI P4 A8B62 24 LIISGUKA P4 A2B70 80 IRPPLYIVNI P5 A8B61 25 LIELGOLKA P4 A3B62 84 KLINPKIN P4 A8B71 26 LISOGUKA P4 A3B62 87 KLINPKIN P4 A8B71 26 LISOGUKA <th>13</th> <th>GLDDRSPQA</th> <th>P5</th> <th>A2B61</th> <th>71</th> <th>GMIHMLDGI</th> <th>P5</th> <th>A7B71</th>	13	GLDDRSPQA	P5	A2B61	71	GMIHMLDGI	P5	A7B71
15 GUNHGNFFA P2 A2B63 73 GVYPKGFEI P5 A2B61 16 HUVPKGFEA P4 A2B64 74 HLPAGWGEALQI P5 A2B62 17 HLVDTLHWA P3 A2B65 75 ILDPSYHI P4 A2B66 18 ILGSGTSFA P5 A2B66 76 ILUSYUKIN P5 A8B62 20 KLDLKVPKA P5 A2B67 77 ILLGTLAI P5 A8B66 21 KLVPEKJKA P4 A2B67 79 ILGTPENNI P4 A8B67 22 KKMPEMIKA P4 A2B70 80 IRPPLPYIVNI P4 A8B67 23 KVMLTAPPA P5 A2B71 81 IVLGSCVYI P5 A8B67 25 ILFLGPLAPA P5 A3B61 83 KLLAGMHQI P3 A8B72 28 LMAPLSPGA P5 A3B66 85 KLLHTQKVVYI P5 A9B61 29 MLGGLSA	14	GLGGTHHMA	P4	A2B62	72	GMWAQLPCI	P4	A7B72
16 HIWPKGFEA P4 A2864 74 HLPAGWGEALQI P5 A8862 17 HLVDTLHWA P3 A2865 75 ILDPSYHI P4 A8863 18 ILGSGTSFA P5 A2866 75 ILDSYKIR P5 A8865 20 KLDKVPKA P5 A2867 77 ILLGTFLAI P5 A8865 21 KLDKVPKA P5 A2870 80 IRPPLLYIVNI P4 A8867 23 KWMITAPPA P5 A2871 81 IVLGSCVTI P5 A8867 24 LUISEVFTA P4 A2872 82 KIAPIKIKI P4 A8867 25 LIFLGPLAPA P5 A3861 83 KLCQGMHQI P3 A8871 26 LISQGIKA P4 A3862 85 KLINPCKKI P4 A8871 27 LISPEPQA P5 A3866 85 KLINQTKKI P4 A8871 26 LISQGIKA	15	GLNHGNFFA	P2	A2B63	73	GVYPVEGFEI	P5	A8B61
17 HLYDTLHWA P3 A2865 75 ILDPSYHI P4 A2863 18 ILGSGTSFA P5 A2866 76 ILIYSWCRI P5 A8865 20 KLDIKVPKA P5 A2868 77 ILLGTFLAI P5 A8865 21 KLVFLGLDNA P4 A2867 78 ILLKMEIQI P5 A8867 22 KMPEMSIKA P4 A2870 80 IRPPLLPYIVNI P4 A8867 24 UISYFTA P4 A2871 82 KIAFIKISI P5 A88670 25 ILISQTA P4 A2861 83 KLCQGMHQI P3 A8871 26 LISQGIAA P4 A3862 84 KLINPDKKI P4 A8872 27 LISPPEQA P5 A3866 86 KLINQVYI P5 A9863 30 MLIGKDTA P5 A3866 87 KILMPCVYI P5 A9863 31 MLIGKDTA	16	HIWPKGFEA	P4	A2B64	74	HLPAGWGEALQI	P5	A8B62
18 ILGSGTSFA P5 A2866 76 ILUSYUCRI P5 A2864 19 KLAYFSLSA P4 A2867 77 ILLGTFLAI P5 A2866 20 KLUEKVPKA P5 A2867 78 ILLKMEIQI P5 A8866 21 KLVFLGLDNA P4 A2870 80 IRPPLIPYIVNI P4 A8867 22 KMMEMSIKA P4 A2870 80 IRPPLIPYIVNI P4 A8869 23 KVMITAPPA P5 A2861 83 KLCGGMHQI P3 A8871 26 LIISQGLKA P4 A3862 84 KLINPDKKI P4 A8872 28 LMAPLSPGA P5 A3863 85 KLUHTQXVYI P5 A9863 30 MLIGQLSAEA P5 A3867 88 KLUAVSICI P5 A9863 31 MLLPPRPAA P4 A3867 89 LIMPTEWLWIN P5 A9863 32 ML	17	HLYDTLHWA	P3	A2B65	75	ILDPSYHI	P4	A8B63
19 KLAYFSLSA P4 A2B67 77 ILLGTFLAI P5 A2B68 20 KLDKVPKA P5 A2B68 78 ILLKWFIGUI P5 A8B67 21 KLVFLGLDNA P4 A2B69 79 ILSDPENNI P5 A8B67 22 KMPENSKA P4 A2B70 80 IRPPLIPTIVNI P4 A8B67 23 KVMITAPPA P5 A2B71 81 IVLGSCVYI P5 A8B67 24 LIJSQEIKA P4 A3B62 84 KLIAPPLIPVIVNI P4 A8B72 26 LIJSQEIKA P4 A3B63 85 KLIMTGVVYI P5 A9B61 28 IMAGQLSAEA P5 A3B66 86 KLMVEVVI P5 A9B63 30 MILIGKDTA P5 A3B66 89 KIMEIQHFKI P5 A9B66 31 MILPSPAA P4 A3B67 89 KIMEIQHFKI P5 A9B66 32 MIL	18	ILGSGTSFA	P5	A2B66	76	ILIYSWCRI	P5	A8B64
20 KLDKKPKA P5 A2868 78 ILLKMEIQI P5 A8867 21 KLVFLGIDNA P4 A2870 80 IRPPLLPYIVNI P5 A8867 22 KMMEMSIKA P4 A2870 80 IRPPLPYIVNI P4 A8867 24 LISEVFTA P4 A2872 81 IVLGSCVYI P5 A8870 25 LIFLGPLAPA P5 A3861 83 KLCQMHQI P3 A8871 26 LISQGIKA P4 A3862 84 KLINPDKKI P4 A8872 27 LISPPEQA P5 A3863 85 KLINQUYVI P5 A9861 28 LMAPLSPGA P5 A3866 86 KQLAVSICI P5 A9863 30 MLIGKDTA P5 A3866 88 KQLAVSICI P5 A9863 32 MLSASIMYA P5 A3867 90 LIMVVLFU P5 A9867 34 QLILLPRA	19	KLAYFSLSA	P4	A2B67	77	ILLGTFLAI	P5	A8B65
21 KIVFLGLDNA P4 A2869 79 ILSDPENNI P5 A3867 22 KMPEMSIKA P4 A2870 80 IRPPLLPYIVINI P4 A3868 23 KVMLTAPPA P5 A2871 81 IVLGSCVYI P5 A8869 24 LISQGLKA P4 A3861 83 KLCQGMHQI P3 A8871 26 LISQGLKA P4 A3862 84 KLINPOKKI P4 A8872 29 MLGQLSAEA P5 A3865 87 KILHTQKVVI P5 A9863 30 MLIGKDTA P5 A3866 88 KQLAVSICI P5 A9863 31 MLSASIMVA P5 A3866 80 KIMPUIVISI P4 A9866 32 MLSASIMVA P5 A3870 90 LIMVVISI P4 A9866 33 MMMGQFERDA P4 A3869 91 LLAVVIQFQI P5 A9867 34 QLILLIPR	20	KLDLKVPKA	P5	A2B68	78	ILLKMEIQI	P5	A8B66
22 KMPELMSIKA P4 A2870 80 IRPPLIPTIVIII P4 A8869 23 KVMLTAPPA P5 A2871 81 IVLGSCVYI P5 A8869 24 LIISEYFTA P4 A2872 82 KIAFHIKSI P5 A8869 25 LLFIGPLAPA P5 A3861 83 KLCQGMHQI P3 A8871 26 LUSQGLKA P4 A3862 84 KLINPDKKI P4 A8872 27 LLSPPEPQA P5 A3866 85 KLINQKKI P4 A8872 28 LMAPLSPGA P5 A3866 86 KLINQCTKI P5 A9863 30 MLIGKDTA P5 A3866 88 KQUXSICI P5 A9863 31 MLIGKDTA P5 A3867 89 KTGMEILWI P5 A9863 33 MILGKDTA P5 A3869 91 LLAVVIGFQI P5 A9867 34 QLULRPA	21	KLVFLGLDNA	P4	A2B69	79	ILSDPENNI	P5	A8B67
23 KVMLTAPPA P5 A2871 81 IVLGSCV7I P5 A8869 24 LIISEYFTA P4 A2872 82 KIAHIKSI P5 A8870 25 LIFLGPLAPA P5 A3861 84 KLUNPDKKI P4 A8872 27 LISPPEPQA P5 A3863 85 KLLHTQKVVYI P5 A9861 28 LIMAPLSPGA P5 A3865 87 KMEQIKKI P5 A9863 30 MLILGKDTA P5 A3865 87 KMEQIKKI P5 A9863 31 MLIPRPAA P4 A3867 98 KTGMELLWI P5 A98663 32 MLSASIMYA P5 A3867 92 LUIDMEQEI P5 A98663 33 MIMMGQFERDA P4 A3869 91 LIAVVICFQI P5 A98663 34 QLILLPRA P5 A3870 92 LUIDMEQEI P5 A9867 35 RLDSAGPT	22	KMPEMSIKA	P4	A2B70	80	IRPPLLPYIVNI	P4	A8B68
24 LIISEYI A P4 A28/2 82 KIAFHIKI P5 A8870 25 LLFLGPLAPA P5 A3861 83 KLCQGMHQI P3 A8871 26 LLISQGLKA P4 A3862 84 KLINPDKKI P4 A8871 27 LLSPEPQA P5 A3863 85 KLLHTCKVVYI P5 A9861 28 LMAPLSPGA P5 A3866 86 KLINGUMEI P5 A9862 29 MLGQLSAEA P5 A3866 87 KMEQIFKI P5 A9863 30 MLLGKDTA P5 A3866 89 LIMVYLFI P5 A9864 31 MLLQKDTA P5 A3867 89 LIMVYLFI P4 A9866 32 MLSASIMYA P5 A3868 90 LIMVYLFI P4 A9866 33 MMMGQFERDA P4 A3867 91 LLAVVIQFQI P5 A9868 34 QLLLPRA	23	KVMLTAPPA	P5	A2B71	81	IVLGSCVYI	P5	A8B69
Z5 LLFLQFLAPA P5 A3861 83 KLCUGMUQ P3 A8871 Z6 LLISQCIKA P4 A3862 84 KLUNPDKKI P4 A8872 Z7 LLSPEPQA P5 A3863 84 KLUNPDKKI P4 A8872 Z8 LMAPLSPGA P5 A3865 87 KUNQTWI P5 A9862 Z9 MLGQLSAEA P5 A3866 86 KLINQTWIE P5 A9863 30 MULIGRTA P5 A3867 89 KTGMEILLWI P5 A9863 31 MLLPPRPAA P4 A3867 89 KTGMEILLWI P5 A9867 32 MLSASIMYA P5 A3867 91 LLAVVIGFQI P5 A9867 33 MMMGQFEDA P4 A3870 92 LILOVIGFQI P5 A9867 34 QLILLIPRA P5 A3871 93 LLLAVVIGFQI P5 A9867 35 RLYHPDTHHA<	24	LIISEYFTA	P4	A2B72	82	KIAFHIKSI	P5	A8B70
Z6 LLISUGLKA P4 A3862 84 KLINPOKI P4 A8872 Z7 LLSPPEPQA P5 A3863 85 KLINTQKVVI P5 A9861 28 LMAPLSPGA P5 A3865 85 KLINTQKVVI P5 A9862 29 MLGQLSAEA P5 A3866 86 KUNTQKVI P5 A9863 30 MULIGKDTA P5 A3866 88 KQLAVSICI P5 A9863 31 MLLOPRPAA P4 A3867 89 KTGMEILLWI P5 A9865 32 MLSASIMYA P5 A3869 91 LLAVUQFQI P5 A9867 34 QLILLIPRA P5 A3870 92 LIIDLWQFQI P5 A9867 35 RLDLSAGPTA P5 A3872 94 LLPPTEWLI P5 A9867 36 RLMYSMCPA P5 A5861 95 LLPPTEWLIP P5 A9870 37 RMHPDAAA<	25	LLFLGPLAPA	P5	A3B61	83	KLCQGMHQI	P3	A8B71
27 LLSPEPUA P5 A3663 85 KLLHIQKVTI P5 A9661 28 LMAPLSPGA P5 A3664 86 KLINGQTMEI P5 A9661 30 MULIGKDTA P5 A3666 87 KIMEQIFKI P5 A9663 30 MULIGKDTA P5 A3667 89 KTGMEILWI P5 A9663 31 MLLPRAA P4 A3667 89 KTGMEILWI P5 A9663 32 MLSASIMYA P5 A3667 89 KTGMEILWI P5 A9663 34 QLLLLLPRA P5 A3871 91 LLAVVIQFQI P5 A9663 35 RLDHAAA P5 A3871 93 LLLPPTEWLI P5 A98670 36 RLYHPDTHHA P5 A3872 94 LLPPTEWLIPI P5 A9872 39 SLACAPIPA P5 A5863 97 MLHRGLIL P5 A1873 40 SLGOVRRA <th>26</th> <th>LLISQGLKA</th> <th>P4</th> <th>A3B62</th> <th>84</th> <th>KLINPDKKI</th> <th>P4</th> <th>A8B72</th>	26	LLISQGLKA	P4	A3B62	84	KLINPDKKI	P4	A8B72
Ze LinkPLSPGA P3 A3604 80 KLRUGUIKI P3 A3602 29 MLGQLSAEA P5 A3865 87 KMEQLYKI P5 A9863 30 MLILGKDTA P5 A3865 88 KULAVSICI P5 A9864 31 MLLPPRPAA P4 A3867 89 KTGMEILWI P5 A9865 32 MLSASIMYA P5 A3867 89 LIMVVLFSI P4 A9866 33 MMMGQEREDA P4 A3867 90 LLAVVIQFQI P5 A9867 34 QLLLLPRA P5 A3871 93 LLLCVHAKI P5 A9869 35 RLDSAGPTA P5 A3872 94 LLPPTEWLI P5 A9870 36 RLYHPDTHHA P5 A5861 95 LLPPTEWLIP P5 A9871 38 RMWVSMCPA P5 A5862 97 MLHRGLLI P5 A1873 41 SLGOVLRA <th>2/</th> <th></th> <th>P5</th> <th>A3B63</th> <th>85</th> <th>KLLHTQKVVYI</th> <th>P5</th> <th>A9861</th>	2/		P5	A3B63	85	KLLHTQKVVYI	P5	A9861
23 IMILIGKUTA P3 A3603 87 IMILIGKUTA P3 A3603 30 MILIGKDTA P5 A3866 88 KQLAVSICI P5 A9864 31 MILIGKDTA P5 A3866 89 KTGMEILLWI P5 A9865 32 MLSASIMVA P5 A3866 90 LIMVYLFSI P4 A9866 33 MIMMGQFERDA P4 A3867 92 LIIDUIGQI P5 A9867 34 QLLILLPRA P5 A3870 92 LIIDUMEQEI P5 A9867 36 RLYHPDTHHA P5 A3872 93 LILPPTEWLI P5 A9870 37 RMIFIPAAAA P5 A5861 95 LIPPTEWLI P5 A9872 38 RMWVSMCPA P5 A5862 96 LLWIPTEWLIP P5 A9872 39 SLAEPSPPA P2 A5865 97 RUHRGLLI P5 A1873 40 SLA	20		PDE	A3D04	00	KLINGQTIVIEI	PDE	A9802
JU Initional A P3 Abbos Right and a stress a	30	MULGKDTA	P5	A3B66	88		P5	A9B64
12 INLETTURA 14 ABG7 32 MILASIMYA P5 AB68 90 LIMVYLENI P3 A9866 33 MMMGQFERDA P4 A3869 91 LLAVVIQFQI P5 A9867 34 QLULLUPRA P5 A3870 92 LUIDUMEQEI P5 A9869 35 RLDISAGPTA P5 A3872 94 LUPPTEWLI P5 A9869 36 RLYHPDTHHA P5 A3872 94 LUPPTEWLIP P5 A9872 37 RMFIPAAAA P5 A5861 95 LUPPTEWLIP P5 A9872 39 SLAEPSPPA P2 A5863 97 MULATKLTI P4 A1874 41 SLFDSVYGA P5 A5866 100 SLKDSQFSI P5 A1873 42 SLLGGVLRRA P5 A5866 100 SLKDSQFSI P5 A1876 43 SLQPPTLGA P4 A5867 101 SLLL	31	MILLORDIA	P/	A3B67	89	KTGMEILLWI	P5	A9865
33 MMMGQFERDA P4 AB669 91 LLAVV(QFQI P5 A9867 34 QLLLLIPRA P5 A3870 92 LLIDLMEQEI P5 A9867 35 RLDLSAGPTA P5 A3871 93 LLILCVHAKI P5 A9869 36 RLYHPDTHHA P5 A3872 94 LLPPPTEWLI P5 A9870 37 RMFIPAAAA P5 A5861 95 LLPPPTEWLIP P5 A9870 38 RMWVSMCPA P5 A5862 96 LLWILKMEI P5 A9872 39 SLAEPSPPA P2 A5863 97 MLHRGLLI P5 A1873 40 SLAQAPIPA P5 A5865 99 RLFGTWINKI P4 A1874 41 SLFOSVYGA P5 A5866 100 SLKDSQFSI P5 A1876 42 SLLGGVLRA P5 A5866 100 SLKDSQFSI P5 A1876 43 SL	32	MISASIMYA	P5	A3B68	90	LIMVYLESI	P4	A9866
34 QLILLIPRA P5 A3B70 92 LLIDLMEQEI P5 A9B68 35 RLDLSAGPTA P5 A3B71 93 LLIDVIEQEI P5 A9B69 36 RLYHPDTHHA P5 A3B72 94 LLIPPTEWLI P5 A9B70 37 RMFIPAAAA P5 A5B61 95 LLIPPTEWLI P5 A9B71 38 RMWVSMCPA P5 A5B62 96 LLWILLKMEI P5 A9B72 39 SLAEPSPPA P2 A5B63 97 MLHRGLLI P5 A1B73 40 SLAQAPIPA P5 A5B63 98 MMLATKLTI P4 A1B74 41 SLFOSVYGA P5 A5B65 99 RLFGTWINKI P4 A1B74 41 SLGOVLRRA P5 A5B66 100 SLKDSQF51 P5 A1B76 42 SLLGGVLRRA P5 A5B67 101 SLLIPEGI P4 A1B79 46 WLCG	33	MMMGQFERDA	P4	A3B69	91	LLAVVIQFQI	P5	A9B67
35 RLDLSAGPTA P5 A3B71 93 LLILCVHAKI P5 A9B69 36 RLYHPDTHHA P5 A3B72 94 LLPPTEWLI P5 A9B70 37 RMFIPAAAA P5 A5B61 95 LLPPPTEWLIP P5 A9B70 38 RMWVSMCPA P5 A5B62 96 LLWILLKMEI P5 A9B72 39 SLAEPSPPA P2 A5B63 97 MLHRGLUI P5 A1B73 40 SLAQAPIPA P5 A5B64 98 MMLATKLTI P4 A1B74 41 SLFDSVYGA P5 A5B65 99 RLFGTWINKI P4 A1B74 42 SLLGGVLRRA P5 A5B66 100 SLKDSQFSI P5 A1B76 43 SLQPPTLGA P4 A5B67 101 SLLLPEGI P4 A1B77 44 TLAIRFISA P5 A5B69 103 SLSHILTCGI P4 A1B79 46 WLG	34	OLLLLPRA	P5	A3B70	92	LLIDLMEQEI	P5	A9B68
36 RLYHPDTHHA P5 A3B72 94 LLPPPTEWLI P5 A9B70 37 RMFIPAAAA P5 A5B61 95 LLPPPTEWLIPI P5 A9B71 38 RMWVSMCPA P5 A5B62 96 LLWILLKMEI P5 A9B72 39 SLAEPSPPA P2 A5B63 97 MLHRGLLI P5 A1B73 40 SLAQAPIPA P5 A5B64 98 MMLATKLTI P4 A1B74 41 SLFQSVFGA P5 A5B65 99 RLFGTWINKI P4 A1B75 42 SLLGGVLRRA P5 A5B66 100 SLKDSQFSI P5 A1B76 43 SLQPPTLGA P4 A5B67 101 SLLLPEGI P4 A1B77 44 TLAIRFISA P5 A5B69 103 SLSHILTCGI P4 A1B79 46 WLCGWTSSA P5 A5B70 105 SMSSTPLTI P5 A1B80 47 WL	35	RLDLSAGPTA	P5	A3B71	93	LLILCVHAKI	P5	A9B69
37 RMFIPAAAA P5 A5B61 95 LLPPPTEWLIPI P5 A9B71 38 RMWVSMCPA P5 A5B62 96 LLWILLKMEI P5 A9B72 39 SLAEPSPPA P2 A5B63 97 MLHRGLUI P5 A1B73 40 SLAQAPIPA P5 A5B64 98 MMLATKLTI P4 A1B74 41 SLFDSVYGA P5 A5B65 99 RLFGTWINKI P4 A1B75 42 SLLGGVLRA P5 A5B66 100 SLKDSQFSI P5 A1B76 43 SLQGPTLGA P4 A5B67 101 SLLLPEGI P4 A1B77 44 TLAIRFISA P5 A5B69 103 SLSHILTCGI P4 A1B79 46 WLCGWTSSA P5 A5B70 104 SLYYDYEPPI P5 A1B80 47 WLIGLLMPFRA P2 A5B71 105 SMSSTPLTI P5 A1B82 49 Y	36	RLYHPDTHHA	P5	A3B72	94	LLPPPTEWLI	P5	A9B70
38 RMWVSMCPA P5 A5B62 96 LLWILLKMEI P5 A9B72 39 SLAEPSPPA P2 A5B63 97 MLHRGLLII P5 A1B73 40 SLAQAPIPA P5 A5B64 98 MMLATKLTI P4 A1B74 41 SLFDSVYGA P5 A5B65 99 RLFGTWINKI P4 A1B75 42 SLLGGVLRRA P5 A5B66 100 SLKDSQFSI P5 A1B76 43 SLQPPTLGA P4 A5B67 101 SLLLIPEGI P4 A1B77 44 TLAIRFISA P5 A5B68 102 SLPTTPLYFI P5 A1B78 45 VIAASVPRA P5 A5B70 104 SLYYDYEPPI P5 A1B80 47 WLIGLIMPFRA P2 A5B71 105 SIMSSTPLTI P5 A1B81 48 WVLPSLPMA P4 A6B61 107 TLLSPAI P4 A1B83 50 Y	37	RMFIPAAAA	P5	A5B61	95	LLPPPTEWLIPI	P5	A9B71
39 SLAEPSPPA P2 A5B63 97 MLHRGLLLI P5 A1B73 40 SLAQAPIPA P5 A5B64 98 MMLATKLTI P4 A1B74 41 SLFDSVYGA P5 A5B65 99 RLFGTWINKI P4 A1B75 42 SLLGGVLRRA P5 A5B66 100 SLKDSQFSI P5 A1B76 43 SLQPPTLGA P4 A5B67 101 SLLLPEGI P4 A1B77 44 TLAIRFISA P5 A5B68 102 SLPTTPLYFI P5 A1B78 45 VIAASVPRA P5 A5B70 104 SLYYDYEPPI P5 A1B80 47 WLLGLLMPFRA P2 A5B71 105 SMSSTPLTI P5 A1B81 48 WVLPSLPMA P4 A5B72 106 STAAEVVAI P5 A1B82 49 YISRCAPPA P4 A6B61 107 TLLSRPAI P4 A1B83 50 YM	38	RMWVSMCPA	P5	A5B62	96	LLWILLKMEI	P5	A9B72
40 SLAQAPIPA P5 A5B64 98 MMLATKLTI P4 A1B74 41 SLFDSVYGA P5 A5B65 99 RLFGTWINKI P4 A1B75 42 SLLGGVLRRA P5 A5B66 100 SLKDSQFSI P5 A1B76 43 SLQPPTLGA P4 A5B67 101 SLLLPEGI P4 A1B77 44 TLAIRFISA P5 A5B68 102 SLPTPLYFI P5 A1B76 45 VIAASVPRA P5 A5B69 103 SLSHILTCGI P4 A1B79 46 WLCGWTSSA P5 A5B70 104 SLYYDYEPPI P5 A1B80 47 WLLGLLMPFRA P2 A5B71 105 SMSSTPLTI P5 A1B81 48 WVLPSLPMA P4 A6B61 107 TLLSRPAI P4 A1B83 50 YLNLTVLA P5 A6B62 108 TLSPAITSI P5 A1B84 51 YM	39	SLAEPSPPA	P2	A5B63	97	MLHRGLLLI	P5	A1B73
41 SLFDSVYGA P5 A5B65 99 RLFGTWINKI P4 A1B75 42 SLLGGVLRRA P5 A5B66 100 SLKDSQFSI P5 A1B76 43 SLQPPTLGA P4 A5B67 101 SLLLPEGI P4 A1B77 44 TLAIRFISA P5 A5B68 102 SLPTPLYFI P5 A1B78 45 VIAASVPRA P5 A5B69 103 SLSHILTCGI P4 A1B79 46 WLCGWTSSA P5 A5B70 104 SLYYDYEPPI P5 A1B80 47 WLIGLLMPFRA P2 A5B71 105 SMSSTPLTI P5 A1B82 48 WVLPSLPMA P4 A6B61 107 TLSRLPAI P4 A1B83 50 YLNTVLA P5 A6B62 108 TLSPAITSI P5 A1B83 52 YMQWVWGA P4 A6B63 109 TMQPWPCSI P5 A2B73 54 LLP	40	SLAQAPIPA	P5	A5B64	98	MMLATKLTI	P4	A1B74
42 SLLGGVLRRA P5 A5866 100 SLKDSQFSI P5 A1876 43 SLQPPTLGA P4 A5867 101 SLLLPEGI P4 A1877 44 TLAIRFISA P5 A5868 102 SLPTTPLYFI P5 A1878 45 VIAASVPRA P5 A5869 103 SLSHILTCGI P4 A1877 46 WLCGWTSSA P5 A5870 104 SLYDYEPPI P5 A1880 47 WLLGLIMPFRA P2 A5871 105 SMSSTPLTI P5 A1881 48 WVLPSLPMA P4 A5872 106 STAAEVVAI P5 A1882 49 YISRCAPPA P4 A6861 107 TLLSRLPAI P4 A1883 50 YLNLTVLA P5 A6862 108 TLSPAITSI P5 A1884 51 YMQWVWGA P4 A6863 109 TMQPWPCSI P5 A2873 52 Y	41	SLFDSVYGA	P5	A5B65	99	RLFGTWINKI	P4	A1B75
43 SLQPPTLGA P4 A5B67 101 SLLLLPEGI P4 A1877 44 TLAIRFISA P5 A5B68 102 SLPTTPLYFI P5 A1878 45 VIAASVPRA P5 A5B69 103 SLSHILTCGI P4 A1877 46 WLCGWTSSA P5 A5B70 104 SLYPYPEPPI P5 A1880 47 WLLGLMPFRA P2 A5B71 105 SMSSTPLTI P5 A1881 48 WVLPSLPMA P4 A5B72 106 STAAEVVAI P5 A1882 49 YISRCAPPA P4 A6B61 107 TLLSRLPAI P4 A1883 50 YLNLTVLA P5 A6B62 108 TLSPAITSI P5 A1884 51 YMQUVWGA P4 A6B63 109 TMQPWPCSI P5 A2873 52 YMQWVWGA P4 A6B66 111 VLNPYVKHSI P5 A2875 54 L	42	SLLGGVLRRA	P5	A5B66	100	SLKDSQFSI	P5	A1B76
44 TLAIRFISA P5 A5B68 102 SLPTTPLYFI P5 A1B78 45 VIAASVPRA P5 A5B69 103 SLSHILTCGI P4 A1B79 46 WLCGWTSSA P5 A5B70 104 SLYTPLYFI P5 A1B80 47 WLLGLIMPFRA P2 A5B71 105 SIMSSTPLTI P5 A1B81 48 WVLPSLPMA P4 A5B72 106 STAAEVVAI P5 A1B82 49 YISRCAPPA P4 A6B61 107 TLLSRLPAI P4 A1B83 50 YLNLTVLA P5 A6B62 108 TLSPAITSI P5 A1B84 51 YMQUVWGA P4 A6B63 109 TMQPWPCSI P5 A2B73 52 YMQWVWGA P4 A6B65 111 VLNPYVKHSI P5 A2B75 54 LLDPEGIRC P4 A6B66 112 VLVEEVAEKCI P5 A2B76 55 <t< th=""><th>43</th><th>SLQPPTLGA</th><th>P4</th><th>A5B67</th><th>101</th><th>SLLLLPEGI</th><th>P4</th><th>A1B77</th></t<>	43	SLQPPTLGA	P4	A5B67	101	SLLLLPEGI	P4	A1B77
45 VIAASVPRA P5 A5B69 103 SLSHILTCGI P4 A1B79 46 WLCGWTSSA P5 A5B70 104 SLYPPI P5 A1B80 47 WLLGLIMPFRA P2 A5B71 105 SIMSSTPLTI P5 A1B81 48 WVLPSLPMA P4 A5B72 106 STAAEVVAI P5 A1B82 49 YISRCAPPA P4 A6B61 107 TLLSRLPAI P4 A1B83 50 YLNLTVLA P5 A6B62 108 TLSPAITSI P5 A1B84 51 YMQUVWGA P4 A6B63 109 TMQPWPCSI P5 A2B73 52 YMQWVWGA P4 A6B65 111 VLNPYVKHSI P5 A2B75 54 LLDPGIRC P4 A6B66 112 VLVEEVAEKCI P5 A2B76 55 LLDDNQAPF P5 A6B67 113 WLGPGLRMGI P5 A2B77 56 SLDDIIRHDF P5 A6B69 114 WLSRSAFVCI P5 A2B79 <tr< th=""><th>44</th><th>TLAIRFISA</th><th>P5</th><th>A5B68</th><th>102</th><th>SLPTTPLYFI</th><th>P5</th><th>A1B78</th></tr<>	44	TLAIRFISA	P5	A5B68	102	SLPTTPLYFI	P5	A1B78
46 WLCGWTSSA P5 A5B70 104 SLYPYPYEPPI P5 A1B80 47 WLLGLIMPFRA P2 A5B71 105 SMSSTPLTI P5 A1B80 48 WVLPSLPMA P4 A5B72 106 STAAEVVAI P5 A1B82 49 YISRCAPPA P4 A6B61 107 TLLSRLPAI P4 A1B83 50 YLNLTVLA P5 A6B62 108 TLSPAITSI P5 A1B84 51 YMQUVWGA P4 A6B63 109 TMQPWPCSI P5 A2B73 52 YMQWVWGA P4 A6B64 110 VIAGGIWHI P2 A2B74 53 YTDRALAFYA P4 A6B65 111 VLNPYVKHSI P5 A2B75 54 LLDDNQAPF P5 A6B66 112 VLVEEVAEKCI P5 A2B76 55 LLDDNQAPF P5 A6B67 113 WLGPGLRMGI P5 A2B77 56 <	45	VIAASVPRA	P5	A5B69	103	SLSHILTCGI	P4	A1B79
47 WLUGLIMPERA P2 ASB71 105 SMSSTPLTT P5 A1881 48 WVLPSLPMA P4 A5B72 106 STALEVVAI P5 A1882 49 YISRCAPPA P4 A6B61 107 TLLSRLPAI P4 A1883 50 YLNLTVLA P5 A6B62 107 TLLSRLPAI P4 A1884 51 YMDLILASA P4 A6B63 109 TMQPWPCSI P5 A1884 52 YMQWVWGA P4 A6B64 110 VIAGGIWHI P2 A2B73 52 YMQWVWGA P4 A6B65 111 VLMPYVKHSI P5 A2B75 54 LLDEGIRC P4 A6B666 112 VLVEEVAEKCI P5 A2B76 55 LLDDNQAPF P5 A6B67 113 WLGPGLRMGI P5 A2B77 56 SLDDIIRHDF P5 A6B69 114 WLSRSAFYCI P5 A2B78 57 <t< th=""><th>46</th><th>WLCGWISSA</th><th>P5</th><th>A5B70</th><th>104</th><th>SLYYDYEPPI</th><th>P5</th><th>A1B80</th></t<>	46	WLCGWISSA	P5	A5B70	104	SLYYDYEPPI	P5	A1B80
48 WVLPSLPMA P4 ASB72 106 STAREVVAL P5 AB82 49 YISRCAPPA P4 A6B61 107 TLLSRIPAI P4 A1883 50 YINLTVLA P5 A6B62 108 TLSPAITSI P5 A1884 51 YMDLILASA P4 A6B63 109 TMQPWPCSI P5 A2B73 52 YMQWVWGA P4 A6B64 110 VIAGGIWHI P2 A2B73 53 YTDRALAFYA P4 A6B65 111 VLNPYVKHSI P5 A2B75 54 LLDDNQAPF P5 A6B66 112 VLVEEVAEKCI P5 A2B76 55 LLDDNQAPF P5 A6B67 113 WLGPGLRMGI P5 A2B77 56 SLDDIIRHDF P5 A6B69 114 WLSRSAFYCI P5 A2B78 57 YLQKLSVEF P4 A6B69 115 YITAFFCWI P4 A2B79 58 <th< th=""><th>47</th><th>WLLGLLIVIPFRA</th><th>P2</th><th>A5B71</th><th>105</th><th>SIVISSTPLTT</th><th>P5</th><th>A1881</th></th<>	47	WLLGLLIVIPFRA	P2	A5B71	105	SIVISSTPLTT	P5	A1881
45 TISBCAPPA P4 A6861 107 TILSBLFAI P4 A6863 50 YUNLTVLA P5 A6862 108 TLSPAITSI P5 A1884 51 YMDUILASA P4 A6863 109 TMQPWPCSI P5 A1884 52 YMQWVWGA P4 A6864 110 VIAGGIWHI P2 A2874 53 YTDRALAFYA P4 A6865 111 VLNPYVKHSI P5 A2875 54 LLDPGIRC P4 A6866 112 VLVEEVAEKCI P5 A2876 55 LLDDNQAPF P5 A6867 113 WLGPGLRMGI P5 A2877 56 SLDDIIRHDF P5 A6868 114 WLSRSAFYCI P5 A2878 57 YLQKLSVEF P4 A6869 115 YITAFCWI P4 A2879 58 ALAPRSATI P5 A6870 116 YLDLYLIHWPI P5 A2880	48	VICECADDA	P4	A5B72	100		P3	A1882
50 TESPAILSI P3 A6864 51 YMDLILASA P4 A6863 109 TMQPWPCSI P5 A2873 52 YMQWVWGA P4 A6864 110 VIAGGIWHI P2 A2874 53 YTDRALAFYA P4 A6866 110 VIAGGIWHI P2 A2874 54 LLLPEGIRC P4 A6866 111 VLNPYVKHSI P5 A2875 55 LLDDNQAPF P5 A6867 113 WLGPGLRMGI P5 A2877 56 SLDDIIRHDF P5 A6868 114 WLSRSAFYCI P5 A2879 58 ALAPRSATI P5 A6870 116 YLDLYLIHWPI P5 A2880	49		P4	A6862	107		P4	A1805
52 YMQWVWGA P4 A6B64 100 VIAGGIWHI P2 A2B73 53 YTDRALAFYA P4 A6B66 110 VIAGGIWHI P2 A2B74 53 YTDRALAFYA P4 A6B66 111 VLNPYVKHSI P5 A2B75 54 LLLPEGIRC P4 A6B66 112 VLVEEVAEKCI P5 A2B76 55 LLDDNQAPF P5 A6B67 113 WLGPGLRMGI P5 A2B77 56 SLDDIIRHDF P5 A6B68 114 WLSRSAFYCI P5 A2B78 57 YLQKLSVEF P4 A6B69 115 YITAFFCWI P4 A2B79 58 ALAPRSATI P5 A6B70 116 YLDLYLIHWPI P5 A2B80	51	YMDIIIASA	P4	A6863	109	TMOPWPCSI	P5	Δ2R73
53 YTDRALAFYA P4 A6865 111 VLNPYVKHSI P5 A2875 54 LLLPEGIRC P4 A6866 112 VLVEEVAEKCI P5 A2875 55 LLDDNQAPF P5 A6867 113 WLGPGLRMGI P5 A2877 56 SLDDIIRHDF P5 A6868 114 WLSRSAFYCI P5 A2878 57 YLQKLSVEF P4 A6869 115 YITAFFCWI P4 A2879 58 ALAPRSATI P5 A6870 116 YLDLYLIHWPI P5 A2880	52	YMOWVWGA	P4	A6864	110	VIAGGIWHI	P2	A2874
54 LLLPEGIRC P4 A6B66 112 VLVEVAEKCI P5 A2B76 55 LLDDNQAPF P5 A6B67 113 WLGPGLRMGI P5 A2B77 56 SLDDIIRHDF P5 A6B68 114 WLSRSAFYCI P5 A2B78 57 YLQKLSVEF P4 A6B69 115 YITAFFCWI P4 A2B79 58 ALAPRSATI P5 A6B70 116 YLDLYLIHWPI P5 A2B80	53	YTDRALAFYA	P4	A6865	111	VLNPYVKHSI	P5	A2875
55 LLDDNQAPF P5 A6B67 113 WLGPGLRMGI P5 A2B77 56 SLDDIRHDF P5 A6B68 114 WLSRSAFYCI P5 A2B77 57 YLQKLSVEF P4 A6B69 115 YITAFFCWI P4 A2B79 58 ALAPRSATI P5 A6B70 116 YLDLYLIHWPI P5 A2B80	54	LLLPEGIRC	P4	A6B66	112	VLVEEVAEKCI	P5	A2B76
56 SLDDIIRHDF P5 A6B68 114 WLSRSAFYCI P5 A2B78 57 YLQKLSVEF P4 A6B69 115 YITAFFCWI P4 A2B79 58 ALAPRSATI P5 A6B70 116 YLDLYLIHWPI P5 A2B80	55	LLDDNQAPF	P5	A6B67	113	WLGPGLRMGI	P5	A2B77
57 YLQKLSVEF P4 A6B69 115 YITAFFCWI P4 A2B79 58 ALAPRSATI P5 A6B70 116 YLDLYLIHWPI P5 A2B80	56	SLDDIIRHDF	P5	A6B68	114	WLSRSAFYCI	P5	A2B78
58 ALAPRSATI P5 A6B70 116 YLDLYLIHWPI P5 A2B80	57	YLQKLSVEF	P4	A6B69	115	YITAFFCWI	P4	A2B79
	58	ALAPRSATI	P5	A6B70	116	YLDLYLIHWPI	P5	A2B80



Supplementary Table 3 (continued). **HLA-A*02:01 neoantigen sequences predicted from five colorectal cancer (CRC) patients, with DNA barcode annotations**

117 VLLKVCERI P1 A2881 175 HLDTFHISL P5 A88 118 YLQKLSVEFQI P4 A2882 176 HLHESCMLSL P4 A88 119 YLVASOQRPI P1 A2883 177 HLUGCEQL P5 A88 120 YPQLKALPPI P5 A2873 179 HLTHEAAL P4 A88 122 ALLPPPTEWL P5 A3873 180 IIATVLYGPL P5 A88 124 ALPPEVPL P5 A3877 183 ILEDWYHPL P4 A99 126 ALVSSEEL P4 A3878 184 ILPMKIPRQL P5 A99 127 ALWSAVTLL P5 A3879 185 ILTHIECL P5 A99 126 ALVSSEEL P4 A3878 187 IMYACVFCL P5 A99 128 AMAALGUL P5 A3880 186 IMPMINUL P5 A99 131 ASLONLIK <th>#</th> <th>Sequence</th> <th>Patient</th> <th>Barcode</th> <th>#</th> <th>Sequence</th> <th>Patient</th> <th>Barcode</th>	#	Sequence	Patient	Barcode	#	Sequence	Patient	Barcode
118 VLQKLSVEFQI P4 A2882 176 HLHESCNLSL P4 A88 119 YLVASDQRPI P1 A2883 177 HLISQCEQL P5 A88 120 YPQLKALPPI P5 A3873 179 HLTHLEAAL P4 A88 121 ALGPASAL P5 A3873 130 ILATVLYCPL P5 A88 122 ALIPPTEWL P5 A3875 181 ILANTVKPFL P4 A99 124 ALPPTEVL P5 A3876 182 ILDFSVIHPL P4 A99 125 ALSDTQNL P5 A3878 184 ILPMKINPQL P5 A99 126 ALVSSEL P4 A3878 184 ILPMKINQL P5 A99 126 ALVSSEL P4 A3881 187 IMYACVFCL P5 A99 126 ALVSSEL P4 A3881 187 IMYACVFCL P5 A99 127 ALVSAVTHL <th>117</th> <th>YLLKVCERI</th> <th>P1</th> <th>A2B81</th> <th>175</th> <th>HLDTFHLSL</th> <th>P5</th> <th>A8B79</th>	117	YLLKVCERI	P1	A2B81	175	HLDTFHLSL	P5	A8B79
119 VIVASDORPI P1 A2883 177 HUSQCEOL P5 A88 120 VPQLKALPPI P5 A2884 178 HLGIRWPNLPRL P5 A88 121 ALGPAASAL P5 A3873 180 ILATVLYGPL P5 A88 122 ALIPPSTEWL P5 A3875 181 ILATVLYGPL P4 A99 124 ALPRLPVPL P5 A3877 183 ILLMYKIPFL P4 A99 126 ALVKSSEEL P4 A3878 184 ILPMKIPRQL P5 A99 127 ALWSAVTLL P5 A3879 185 ILTHIECL P5 A99 128 AMAALGVL P5 A3880 186 IMPMNIVL P5 A98 131 ASLQNLFKL P4 A3883 189 KISFCPHL P5 A99 132 AVFGHHFSL P5 A3883 190 KISHCPHL P4 A266 133 CLAAEIT	118	YLQKLSVEFQI	P4	A2B82	176	HLHESCMLSL	P4	A8B80
120 YPQLKALPPI P5 A2884 178 HLQIRWPNLPRL P5 A3873 121 ALGPAASAL P5 A3874 180 HLTHLEAAL P4 A88 122 ALLPPATEWL P5 A3875 181 ILATVLYGPL P5 A3875 124 ALPRLPYPL P5 A3877 183 ILLDPSYHIPL P4 A99 125 ALSLDTQNL P5 A3878 184 ILDPSYHIPL P4 A99 126 ALWSAVEL P5 A3879 184 ILDPSYHIPL P4 A99 127 ALWSAVTL P5 A3880 186 IMPMNILVL P2 A99 128 AMAAQVTHPL P4 A3881 188 KISPCHUL P4 A3883 130 AMVAVPMVL P5 A3884 190 KISHCPHL P4 A99 132 AVFGHHFSL P5 A3884 190 KISHCPHL P4 A99 134	119	YLVASDQRPI	P1	A2B83	177	HLISQCEQL	P5	A8B81
121 ALGPAASAL P5 A3B73 179 HLTHLEAAL P4 A88 122 ALIPPATEWL P5 A3B74 180 IIATVLYGPL P5 A3B75 123 ALIPSAPSL P5 A3B76 182 ILANTVLYGPL P4 A99 124 ALPRLPVPL P5 A3B76 182 ILDPSYHIPPL P4 A99 125 ALSDTQNL P5 A3B79 183 ILLMWIKPGL P5 A99 126 ALWSASTLL P5 A3B79 185 ILTHIECL P5 A99 128 AMAALGVL P5 A3B80 186 IMMYACVFCL P5 A99 130 ASUQNLIFKL P4 A3B83 188 KISFENILL P5 A91 131 ASLQNLIFKL P4 A3B73 198 KISFENILL P5 A91 133 CLAAEITRL P4 A5B73 193 KLMKNUH P4 A92 134 CMADG	120	YPQLKALPPI	P5	A2B84	178	HLQIRWPNLPRL	P5	A8B82
122 ALLPPPTEWL P5 A3B74 180 IIATVLYGPL P5 A3B75 123 ALNPSAPSL P5 A3B75 181 ILANTVKPFL P4 A99 124 ALPRLPVPL P5 A3B76 182 ILDPSYHIPPL P4 A99 126 ALVKSSEEL P4 A3B77 183 ILKUVLGPGL P5 A99 127 ALWSAVTL P5 A3B79 185 ILTHIECL P5 A99 128 AMAAALGVL P5 A3B80 186 IMPMINILY P2 A99 130 AMVAVPMVL P5 A3B84 190 KISHCPHL P4 A98 132 AVFGHHFSL P5 A3B84 190 KISHCPHL P4 A99 134 CLAAEITRL P4 A5B73 191 KLEFMAYKWHL P4 A99 132 AFGHHFSL P5 A5B75 193 KLMKNQFPL P5 A100 133 FGMSVC	121	ALGPAASAL	P5	A3B73	179	HLTHLEAAL	P4	A8B83
123 ALMPSAPSL P5 A3B75 181 ILANTYKPFL P4 A99 124 ALPRIPVPL P5 A3B76 182 ILDPSYHIPPL P4 A99 125 ALSIDTQNL P5 A3B77 183 ILKIWLGPGL P5 A99 126 ALVKSSEL P4 A3B78 184 ILPMIRPCL P5 A99 127 ALWSAVTL P5 A3B80 186 IMPMNIRVL P5 A99 130 AMAQVTHPL P4 A3B81 187 IMYACVFCL P5 A99 131 ASLQNLFKL P4 A3B83 189 KISFENLHL P5 A99 132 AVGHHFSL P5 A3B84 190 KISHCPHL P4 A99 133 CLAAEITRL P4 A5B73 191 KLEMAYRWHL P4 A99 134 CMADGSTAL P5 A5B76 194 KLIMKINQFPL P5 A10 135 FGMSVCSWP	122	ALLPPPTEWL	P5	A3B74	180	IIATVLYGPL	P5	A8B84
124 ALPRLPVPL P5 A3876 182 ILDPSYHIPPL P4 A9 125 ALSLDTQNL P5 A3877 183 ILKLWUGPGL P5 A9 126 ALVKSSEEL P4 A3878 184 ILPMKIPRQL P5 A9 127 ALWSAVTLL P5 A3879 185 ILTHIECL P5 A9 128 AMAAALGVL P5 A3880 186 IMPMNILYL P2 A9 130 AMVAVPMVL P5 A3882 188 TILGFGWML P5 A9 131 ASLONLFKL P4 A3883 189 KISFCPHL P5 A9 132 AVFGHHFSL P5 A3884 190 KISHCPHL P4 A9 133 CLAAEITRL P4 A5873 191 KLIKMOPUL P5 A10 134 CHAPDYPUPL P4 A5877 195 KLMKNIQFPL P5 A10 137 FLARPLPVPL	123	ALNPSAPSL	P5	A3B75	181	ILANTVKPFL	P4	A9B73
125 ALSLOTQNI P5 A3877 183 ILKLWIGPGL P5 A91 126 ALVKSSEEL P4 A3879 184 ILPMKIPRQL P5 A91 127 ALWSAVTLI P5 A3879 186 ILPMKIPRQL P5 A91 128 AMAAQUTHPL P4 A3881 186 IMPMNILYL P2 A91 130 AMVAVPMVL P5 A3882 188 INTGGWML P5 A91 131 ASLONLIFKL P4 A3883 190 KISFENLHL P4 A266 133 CLAAEITRL P4 A5873 191 KLIERWAYRWHL P4 A91 134 CMAOGSTAL P5 A5874 192 KLIYCGHLL P2 A91 135 FGOMSVCSWPL P5 A5876 194 KLIMKNICCL P5 A10 136 FLISAML P5 A5879 197 KRLWKRWHL P4 A10 139 FLI	124	ALPRLPVPL	P5	A3B76	182	ILDPSYHIPPL	P4	A9B74
126 ALVKSSEL P4 A3878 184 ILPMKIPRQL P5 A39 127 ALWSAVTL P5 A3879 185 ILTHIECL P5 A99 128 AMAAALGVL P5 A3880 186 IMPMMILYL P2 A99 130 AMVAVPMVL P5 A3881 187 IMYACYFCL P5 A91 131 ASLQNLIFKL P4 A3883 188 KISFENIHL P5 A91 132 AVFGHHFSL P5 A3884 190 KISFENIHL P4 A266 133 CLAAEITRL P4 A5873 191 KLIPEMAYRWHL P4 A99 134 CMADGSTAL P5 A5876 193 KLMKNIQFPL P5 A10 135 FGMSVCSWPL P5 A5877 195 KLQAETEEL P4 A10 136 FLISOKGEL P3 A5878 196 KLITEVISL P4 A10 139 FLIAGAH	125	ALSLDTQNL	P5	A3B77	183	ILKLWLGPGL	P5	A9B75
127 ALWSAVTLL P5 A3879 185 ILTHIECL P5 A39 128 AMAAAUGVL P5 A3880 186 IMPMNILYL P2 A9 129 AMAQUTHPL P4 A3881 187 IMYACVFCL P5 A9 131 ASLQNLLFKL P4 A3883 188 ITLGFGWML P5 A9 132 AVFGHHFSL P5 A3884 190 KISFENLHL P4 A26 133 CLAAETRL P4 A5873 191 KLFEMAYKRWHL P4 A9 134 CMADGSTAL P5 A5875 193 KLIMKINGPPL P5 A10 135 FGMSVCSWPL P5 A5875 193 KLIMKINGPPL P5 A10 136 FIQAMHAL P5 A5875 193 KLIMKINGPPL P5 A10 137 FLARAHL P5 A5878 196 KLTFYLSL P4 A10 138 FLISDKIGEL<	126	ALVKSSEEL	P4	A3B78	184	ILPMKIPRQL	P5	A9B76
128 AMAAQUTHPL P5 A3880 186 IMPMNIL'L P2 A91 129 AMAQVTHPL P4 A3881 187 IMYACVFCL P5 A91 130 AMUAVPMVL P5 A3882 188 TIGFGWML P5 A91 131 ASLQMLFKL P4 A3883 189 KISFENLHL P5 A91 132 AVFGHHFSL P5 A3884 190 KISFCPHLL P4 A91 133 CLAAEITRL P4 A5873 191 KIJERMYKRWHL P4 A91 133 CLAAEITRL P5 A5875 193 KLMKNIQFPL P5 A10 134 CMADGSTAL P5 A5876 194 KLMWWICL P5 A10 135 FGMSVGSWPL P5 A5876 194 KLMKNIQFPL P5 A10 136 FLSQMVHAL P5 A587 195 KLGACHL P5 A10 139 FLLAGAHL </th <th>127</th> <th>ALWSAVTLL</th> <th>P5</th> <th>A3B79</th> <th>185</th> <th>ILTHIIECL</th> <th>P5</th> <th>A9B77</th>	127	ALWSAVTLL	P5	A3B79	185	ILTHIIECL	P5	A9B77
129 AMAQVTHPL P4 A3881 187 IMYACVECL P5 A91 130 AMVANPMVL P5 A3882 188 ITLGFGWML P5 A91 131 ASLQNILFKL P4 A3883 188 ITLGFGWML P5 A91 133 CLAAEITRL P4 A5873 190 KISHCPHIL P4 A26 133 CLAAEITRL P4 A5873 191 KLIFEMAYKRWHL P4 A26 134 CMADGSTAL P5 A5875 193 KLIMKNIQFPL P5 A10 135 FGMSYCSWPL P5 A5875 193 KLMKNIQFPL P5 A10 137 FLARPLWPUPL P4 A5877 195 KLQAETEEL P4 A10 138 FLARPUPUP P4 A5877 196 KLITEYLSL P4 A10 138 FLARPUPWPL P4 A5871 196 KLITEYLSL P4 A10 140	128	AMAAALGVL	P5	A3B80	186	IMPMNILYL	P2	A9B78
130 AMVAVPMVL P5 A3822 188 ITLGFGWML P5 A98 131 ASLQNLLFKL P4 A3883 189 KISFENLHL P5 A98 132 AVFGHHFSL P5 A3884 190 KISHCPHL P4 A266 133 CLAAEITRL P4 A5873 191 KLFEMAYKRWHL P4 A99 134 CMADGSTAL P5 A5875 192 KLIYQGHLL P2 A99 135 FGMSVCSWPL P5 A5875 194 KLMPWNCCL P5 A100 136 FLSDKLGEL P3 A5879 195 KLQAETEEL P4 A100 138 FLASAHL P5 A5879 197 KPLSYPLV P5 A100 140 FLLAGAHL P5 A5881 199 LLACPUPKL P5 A100 141 FLOPGKIL P5 A5882 200 LLAPSGHLL P5 A100 142 FLMMUVW	129	AMAQVTHPL	P4	A3B81	187	IMYACVFCL	P5	A9B79
131 ASLQNLIFKL P4 A3883 189 KISFENLH P5 A9 132 AVFGHHFSL P5 A3884 190 KISHCPHIL P4 A26 133 CLAAEITRI P4 A5873 191 KLFEMAYRRWHL P4 A9 134 CMADGSTAL P5 A5874 192 KLIMKNIQFPL P5 A10 136 FIQQMVHAL P5 A5876 194 KLMKNIQFPL P5 A10 137 FLARPLPWPL P4 A5877 195 KLAACHFL P5 A10 138 FLFSDKLGEL P3 A5878 196 KLTTEYLSL P4 A10 140 FLLKSNIFL P4 A5880 198 LLAACPLHL P5 A10 142 FLMMILTEL P5 A5881 199 LLEVDVFKL P3 A10 142 FLMMILTEL P5 A5883 201 LLEVDVFKL P3 A10 144 FLNVEL<	130	AMVAVPMVL	P5	A3B82	188	ITLGFGWML	P5	A9B80
132 AVFGHHFSL P5 A3884 190 KISHCPHL P4 A261 133 CLAAEITRL P4 A5873 191 KLFEMAYKRWHL P4 A91 134 CMADGSTAL P5 A5874 192 KLIVQGHL P2 A91 135 FGMSVCSWPL P5 A5875 193 KLMKNQFPL P5 A10 136 FIQQMVHAL P5 A5876 194 KLMFWNCL P5 A10 137 FLARPLPWPL P4 A5877 195 KLQAETEEL P4 A10 138 FLLPSDKLGEL P3 A5878 196 KLTTEVLSL P4 A10 140 FLLKNIKEL P5 A5880 198 LLAACPLHL P5 A10 141 FLLPGKKIL P5 A5881 190 LLACVDYRL P3 A10 142 FLMHLYLEL P5 A5883 201 LLPGKKEL P5 A10 144 FLNKPSII	131	ASLQNLLFKL	P4	A3B83	189	KISFENLHL	P5	A9B81
133 CLAAEITRL P4 A5873 191 KLFEMAKRWHL P4 A91 134 CMADGSTAL P5 A5874 192 KLIYQGHLL P2 A91 135 FGMSVCSWPL P5 A5875 193 KLIYARRWHL P2 A91 136 FIQQMVHAL P5 A5876 193 KLIYARRWHL P5 A10 138 FLFSDKLGEL P3 A5878 194 KLIMKNIGPL P5 A10 138 FLLAGAHL P5 A5879 196 KLTEYLSL P4 A10 140 FLLKNIFL P4 A5880 197 KPLLSYPLVL P5 A10 141 FLEKOKIL P5 A5881 199 LLACVDVPKL P3 A10 142 FLMHLYLEL P5 A5882 201 LLAFGBHL P5 A10 143 FLPGSTPSL P5 A6873 203 LLKASTFVL P4 A10 144 FLPNKVUK	132	AVFGHHFSL	P5	A3B84	190	KISHCPHLL	P4	A26B115
134 CMADGSTAL P5 A5874 192 KLIYQGHLL P2 A91 135 FGMSVCSWPL P5 A5875 193 KLIYQGHLL P5 A10 136 FIQQMVHAL P5 A5876 194 KLMPVNCCL P5 A10 137 FLARPLPWPL P4 A5877 195 KLQAETEEL P4 A10 139 FLLAGAHL P5 A5879 197 KPLLSYPLVL P5 A10 140 FLLKNIFL P4 A5880 198 LLAACPLHL P5 A10 141 FLLKKIL P5 A5881 199 LLACAPLHL P5 A10 142 FLMVLVWLP P5 A5882 200 LLAPSGHL P5 A10 143 FLVGNKIL P5 A5883 201 LICQQINFHL P4 A10 144 FLNKPSIL P5 A6873 203 LLKVAISTFYL P4 A10 145 FL9GSTPSL <th>133</th> <th>CLAAEITRL</th> <th>P4</th> <th>A5B73</th> <th>191</th> <th>KLFEMAYKRWHL</th> <th>P4</th> <th>A9B83</th>	133	CLAAEITRL	P4	A5B73	191	KLFEMAYKRWHL	P4	A9B83
135 FGMSVCSWPL P5 ABB75 193 RLMKINUPPL P5 A10 136 FIQQMVHAL P5 A5876 194 KLMKINUPPL P5 A10 137 FLARPLPWPL P4 A5877 195 KLQATTEL P4 A10 138 FLFSDKLGEL P3 A5878 196 KLTTEYLSL P4 A10 140 FLLKNIIFL P4 A5887 197 KPLLSYPLVL P5 A10 141 FLLPGKKIL P5 A5881 198 LLACVDVPKL P3 A10 142 FLMHLYLEL P5 A5882 200 LLASVDVPKL P3 A10 144 FLNGSTSL P5 A5883 201 LLFGKGEL P5 A10 145 FLPGSTPSL P5 A6876 203 LLKKNASTFYL P4 A10 146 FLSTDFTAL P5 A6876 206 LLLVQAL P4 A11 147 FLSHYLQ	134	CMADGSTAL	P5	A5B74	192	KLIYQGHLL	P2	A9B84
136 FIQUMVHAL P3 ABB76 194 KLMPWULCL P3 A10 137 FLARPLPWPL P4 A5877 195 KLQAETEEL P4 A10 138 FLFSDKLGEL P3 A5878 196 KLTTEYLSL P4 A10 139 FLLAGAHL P5 A5879 197 KPLLSYPLVL P5 A10 140 FLLKNIFL P5 A5881 199 LLACPUHL P5 A10 142 FLMHLYLEL P5 A5882 200 LLASPGHL P5 A10 143 FLMVLVWLPL P5 A5883 201 LLFGLKGEL P5 A10 144 FLNKPSIIL P2 A5884 202 LLIQUNFHL P4 A10 145 FLOSTPSL P5 A6873 203 LLKKIASTYL P4 A10 144 FLSHYLQKL P4 A6874 204 LLKVARTPTL P5 A11 147 FLSHYLQKL </th <th>135</th> <th>FGMSVCSWPL</th> <th>P5</th> <th>A5B75</th> <th>193</th> <th>KLIMIKNIQFPL</th> <th>P5</th> <th>A10861</th>	135	FGMSVCSWPL	P5	A5B75	193	KLIMIKNIQFPL	P5	A10861
137 FLARPLPWPL P4 ASB77 195 KLUAGHTEL P4 A10 138 FLFSDKLGEL P3 ASB78 196 KLTTEVLSL P4 A10 139 FLLAGAHL P5 ASB79 197 KPLLSYPLVL P5 A10 140 FLLKNIIFL P4 ASB80 198 LLAACPLHL P5 A10 141 FLDFGKKIL P5 ASB81 199 LLACVDVPL P3 A10 142 FLMHLVLEL P5 ASB82 200 LLASGHL P5 A10 143 FLMVLVWUPL P5 ASB83 201 LLGQINFHL P4 A10 144 FLNSTSL P5 A6B73 203 LLKKIASTFYL P4 A10 145 FLSGSTPSL P5 A6B76 206 LLLCVQALL P4 A10 146 FLSTLPHL P4 A6B76 206 LLLCVQALL P4 A11 148 FLSLVPHL P5 A6B76 206 LLLCVQALL P4 A11 150	136	FIQUIVIVHAL	P5	A5B76	194	KLINIPWINCCL	P5	A10862
136 FLEAGARL P3 A5878 136 KETESL P4 A10 139 FLLAGAHL P5 A5879 197 KPLLSYPLVL P5 A10 140 FLLKNIIFL P4 A5880 198 LLAACPLHL P5 A10 141 FLLPGKKIL P5 A5881 199 LLACPUHL P5 A10 142 FLMHLYLEL P5 A5882 200 LLACPUHL P5 A10 144 FLNKPSIIL P2 A5884 202 LLIQUINFHL P5 A10 145 FLPGSTPSL P5 A6673 203 LLKKIASTFVL P4 A10 146 FLPYLUKL P4 A6875 205 LLLAPHEL P5 A11 147 FLSHYLQKL P4 A6875 206 LLLCVQALL P4 A11 149 FLSTLPHL P2 A6879 209 LLSQICSHL P5 A11 155 FLYNNLVESL	13/	FLARPLPWPL	P4	A5B77	195	KLQAETEEL	P4	A10B63
139 FILLAGARIL P5 A3B79 137 PLISTPUT P5 A1D 140 FLIKNIIFL P4 A5B80 198 LLAACPLHL P5 A10 141 FLIKOKIL P5 A5B81 199 LLACVDVPKL P3 A10 142 FLMHLYLEL P5 A5B82 200 LLAEVDVPKL P3 A10 143 FLMVLVWLPL P5 A5B83 201 LLFGLKGEL P5 A10 144 FLNKPSIIL P2 A5B84 202 LLUQQINFHL P4 A10 145 FLPGSTPSL P5 A6B73 203 LLKKIASTFYL P4 A10 146 FLPPILULL P4 A6B75 205 LLLAUPHEL P5 A11 149 FLSTPHL P2 A6B76 206 LLLQOPPL P5 A11 149 FLYNNLVESL P5 A6B87 209 LLSQICSHL P3 A11 152 FLYNNLVES	138	FLFSDRLGEL	P3	A5B78	196	KLITEYLSL	P4	A10864
140 FLLNNIFL P4 A580 138 LLACPLER P5 A10 141 FLLPGKKIL P5 A5881 199 LLACPLEL P5 A10 142 FLMHYLEL P5 A5882 200 LLAPSGHL P5 A10 143 FLMVLVWLPL P5 A5883 201 LLFGLKGEL P5 A10 144 FLNKHYLEL P5 A5883 201 LLFGLKGEL P5 A10 144 FLNKHYVWLPL P5 A5873 202 LLIQQINFHL P4 A10 145 FLPGSTPSL P5 A6873 203 LLKKIASTFYL P4 A10 146 FLPLLLLL P4 A6875 206 LLLAPHEL P5 A11 148 FLSTPHL P2 A6877 207 LLLQPWCL P5 A11 150 FLTSSLML P4 A6878 208 LLLQOPPL P5 A11 151 FLVQNIHTLAGL P4 A6879 209 LLSQICSHL P3 A11 152 <th>139</th> <th>FLLAGAHL</th> <th>P5</th> <th>A5B79</th> <th>197</th> <th>KPLLSYPLVL</th> <th>P5</th> <th>A10865</th>	139	FLLAGAHL	P5	A5B79	197	KPLLSYPLVL	P5	A10865
141 FLMHUYLEL P3 A35831 139 LLAEVDVFRL P3 A40 142 FLMHLYLEL P5 A5882 200 LLAPSGHLL P5 A10 143 FLMVLWLPL P5 A5883 201 LLFGLKGEL P5 A10 144 FLNKPSIIL P2 A5883 202 LILQQINFHL P4 A10 145 FLPGSTPSL P5 A6873 203 LLKKVASTFYL P4 A10 146 FLPPLILLL P4 A6874 204 LLKVYRTPTL P5 A10 147 FLSHYLQKL P4 A6875 205 LLLCVQALL P4 A11 148 FLSTEPHL P5 A6877 206 LLCVQALL P4 A11 150 FLTTSSLML P4 A6878 208 LILQQPPL P5 A11 151 FLVQNIHTLAGL P4 A6879 209 LLSQICSHL P3 A11 152 FLYNNLVESL P5 A6880 210 LLVDKHKYFL P5 A11	140		P4	A5880	198		20	A10866
142 FLMILTUR P.3 A3562 200 LLAR SOURCE P.3 A40 143 FLMVLVWLPL P5 A5883 201 LLFGLKGEL P5 A40 144 FLNKPSIIL P2 A5884 202 LLIQQINFHL P4 A40 145 FLPGSTPSL P5 A6873 203 LLKKIASTFYL P4 A40 146 FLPPLILLLL P4 A6874 204 LLKVYRTPTL P5 A40 147 FLSHYLQKL P4 A6876 206 LLLCVQALL P4 A11 148 FLSTEPHL P2 A6677 207 LLLPGWCRL P5 A11 150 FLTTSSLML P4 A6878 208 LLLCQPPL P5 A11 151 FLVQNIHTLAGL P4 A6878 208 LLLQQPPL P5 A11 152 FLYNNLVESL P5 A6880 210 LLVDKHKYFL P5 A11 153 F	141		P5	A5001	200		P5	A10B07
143 FLINGEVIEL F3 A3033 201 ELICURCE F3 A3033 144 FLINGEVIEL F13 A3033 202 ELICURCE F3 A40 145 FLPGSTPSL P5 A6B73 203 ELIKIASTFYL P4 A40 146 FLPPLILLLL P4 A6B74 204 ELKVXTPTL P5 A40 147 FLSHYLQKL P4 A6B75 205 ELILAUPHEL P5 A41 149 FLSTLPHL P2 A6B77 207 ELICQQALL P4 A11 150 FLTSLML P4 A6B78 208 ELIQQPPL P5 A11 151 FLVQNIHTLAGL P4 A6B79 209 ELSQICSHL P3 A11 152 FLYNNIVESL P5 A6B80 210 ELVQKHKYFL P5 A11 153 FMFRTWGRML P4 A6B82 213 EMPGSCWRL P5 A11 155 FPM	142		P5	A5883	200		P5	A10B08
145 FLPGSTPSL P5 A6B673 203 LLKKIASTFYL P4 A10 146 FLPPGTPSL P4 A6B74 204 LLKVIATFYL P4 A10 147 FLSHYLQKL P4 A6B75 205 LLLAUPHEL P5 A11 148 FLSLPETAL P5 A6B76 206 LLLCVQALL P4 A11 149 FLSTLPHL P2 A6B77 207 LLPGWCRL P5 A11 150 FLTSSLML P4 A6B78 208 LLQQPPL P5 A11 151 FLVQNIHTLAGL P4 A6B79 209 LLSQICSHL P3 A11 152 FLYNNLVESL P5 A6B80 210 LLVOKHKYFL P5 A11 153 FMFRTWGRML P5 A6B81 211 LLVGSNQWEL P5 A11 154 FMRWIIGL P4 A6B82 212 LMLSAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11	143	FLNKPSIII	P2	A5884	201		P4	A10870
146 FLPPLILILL P4 A6B73 203 LLRMB FIL P4 AAB73 146 FLPPLILILL P4 A6B75 204 LLKVYRTPTL P5 A10 147 FLSHYLQKL P4 A6B75 205 LILLALPHEL P5 A11 148 FLSTLPHL P2 A6B77 207 LLLPGWCRL P5 A11 150 FLTSLML P4 A6B78 208 LLQQPPL P5 A11 150 FLTSLML P4 A6B79 209 LLSQICSHL P3 A11 151 FLVQNIHTLAGL P4 A6B80 210 LLVOKHKYFL P5 A11 153 FMRTWGRML P5 A6B80 211 LLVOSNQWEL P5 A11 154 FMRWIIGL P4 A6B82 212 LMISAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A111 156 FSWSNT	145	FLPGSTPSI	P5	A6873	203		P4	A10B71
147 FLSHYLQKL P4 A6B75 205 LLLALPHEL P5 A11 148 FLSLPETAL P5 A6B76 206 LLLALPHEL P5 A11 149 FLSTLPHL P2 A6B77 207 LLLAPHEL P5 A11 150 FLTTSSLML P4 A6B78 208 LLLQQPPL P5 A11 151 FLVQNIHTLAGL P4 A6B79 209 LLSQICSHL P3 A11 152 FLYNNLVESL P5 A6B80 210 LLVOKHKYFL P5 A11 153 FMRTWGRML P5 A6B80 211 LLVGSNQWEL P5 A11 154 FMRWIIGL P4 A6B82 212 LMISAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIFSPEL P4 A11 157 GLEVSGAF	146	FLPPLLLLLL	P4	A6B74	204	LLKYVRTPTL	P5	A10B72
148 FLSLPETAL P5 A6B76 206 LLLCVQALL P4 A11 149 FLSTLPHL P2 A6B77 207 LLLPGWCRL P5 A11 150 FLTTSSLML P4 A6B78 208 LLLQQPPL P5 A11 151 FLVQNIHTLAGL P4 A6B79 209 LLSQICSHL P3 A11 152 FLYNNLVESL P5 A6B80 210 LLVOKHKYFL P5 A11 154 FMRTWGRML P5 A6B81 211 LLVGSNQWEL P5 A11 155 FPMPNYQAAL P4 A6B82 212 LMISAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIFSPEL P4 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLF	147	FLSHYLOKL	P4	A6B75	205	LLLALPHEL	P5	A11B61
149 FLSTLPHL P2 A6B77 207 LLLPGWCRL P5 A11 150 FLTTSSLML P4 A6B78 208 LLLQQPPPL P5 A11 151 FLVQNIHTLAGL P4 A6B79 209 LLSQICSHL P3 A11 152 FLYNNLVESL P5 A6B80 210 LLVOKHKYFL P5 A11 153 FMFRTWGRML P5 A6B81 211 LLVGSNQWEL P5 A11 154 FMRWIIGL P4 A6B82 212 LMISAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIFSPEL P4 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159	148	FLSLPETAL	P5	A6B76	206	LLLCVQALL	P4	A11B62
150 FLTTSSLML P4 A6B78 208 LLLQQPPPL P5 A11 151 FLVQNIHTLAGL P4 A6B79 209 LLSQICSHL P3 A11 152 FLYNNLVESL P5 A6B80 210 LLVDKHKYFL P5 A11 153 FMFRTWGRML P5 A6B81 211 LLVGSNQWEL P5 A11 154 FMRWIIGL P4 A6B83 212 LMLSAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIFSPEL P4 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHHPSPAL P5 A7B76 217 MLAPPFPPPL P4 A12 160 <t< th=""><th>149</th><th>FLSTLPHL</th><th>P2</th><th>A6B77</th><th>207</th><th>LLLPGWCRL</th><th>P5</th><th>A11B63</th></t<>	149	FLSTLPHL	P2	A6B77	207	LLLPGWCRL	P5	A11B63
151 FLVQNIHTLAGL P4 A6B79 209 LLSQICSHL P3 A11 152 FLYNNLVESL P5 A6B80 210 LLVDKHKYFL P5 A11 153 FMFRTWGRML P5 A6B80 210 LLVDKHKYFL P5 A11 154 FMRWIIGL P4 A6B82 212 LMLSAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPGGSCWRL P5 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHHPSPAL P5 A7B75 217 MLAPPFPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLINTPTTL P5 A12 162	150	FLTTSSLML	P4	A6B78	208	LLLQQPPPL	P5	A11B64
152 FLYNNLVESL P5 A6B80 210 LLVDKHKYFL P5 A11 153 FMFRTWGRML P5 A6B81 211 LLVDKHKYFL P5 A11 154 FMRWIIGL P4 A6B82 212 LMLSAQUCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIFSPEL P4 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHHPSPAL P5 A7B75 217 MLAPPFPPL P4 A11 159 GLHHPSPAL P5 A7B76 218 MLINTPFTL P5 A112 160 GLIDQMHMHL P5 A7B76 218 MLINTPFTL P5 A122 161 <td< th=""><th>151</th><th>FLVQNIHTLAGL</th><th>P4</th><th>A6B79</th><th>209</th><th>LLSQICSHL</th><th>P3</th><th>A11B65</th></td<>	151	FLVQNIHTLAGL	P4	A6B79	209	LLSQICSHL	P3	A11B65
153 FMFRTWGRML P5 A6B81 211 LLVGSNQWEL P5 A11 154 FMRWIIGL P4 A6B82 212 LMLSAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIGSCWRL P5 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHLHPSPAL P5 A7B75 217 MLAPPFPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLINTPFTL P5 A12 161 GLLPQTKTL P5 A7B78 220 MLTAPPASL P5 A12 162 <td< th=""><th>152</th><th>FLYNNLVESL</th><th>P5</th><th>A6B80</th><th>210</th><th>LLVDKHKYFL</th><th>P5</th><th>A11B66</th></td<>	152	FLYNNLVESL	P5	A6B80	210	LLVDKHKYFL	P5	A11B66
154 FMRWIIGL P4 A6B82 212 LMLSAQLCL P4 A11 155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIGSCWRL P5 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHLPSPAL P5 A7B75 217 MLAPPFPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLINTPFTL P5 A12 162 GLNLGPQVAL P5 A7B78 220 MLTAPPASL P5 A12 163 GLPPEPEVPPAL P5 A7B79 221 MLVPGGTRVCQL P5 A12 164	153	FMFRTWGRML	P5	A6B81	211	LLVGSNQWEL	P5	A11B67
155 FPMPNYQAAL P4 A6B83 213 LMPGGSCWRL P5 A11 156 FSWSNTTLL P1 A6B84 214 LMPIGGSCWRL P5 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHLPSPAL P5 A7B75 217 MLAPPFPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLINTPFTL P5 A12 161 GLLPQTKTL P5 A7B76 218 MLNTQDSSILPL P4 A12 162 GLNLGPQVAL P5 A7B78 220 MLTAPPASL P5 A12 163 GLPPEPEVPPAL P5 A7B79 221 MLVPGGTRVCQL P5 A12 164 GLQDQEPSL P5 A7B80 222 MMEAGLSEL P5 A12 165	154	FMRWIIGL	P4	A6B82	212	LMLSAQLCL	P4	A11B68
156 FSWSNTTLL P1 A6B84 214 LMPIFSPEL P4 A11 157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHLHPSPAL P5 A7B75 217 MLAPPFPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLINTPFTL P5 A12 161 GLLPQTKTL P5 A7B76 219 MLNTQDSSILPL P4 A12 162 GLNLGPQVAL P5 A7B78 220 MLTAPPASL P5 A12 163 GLPPEPEVPPAL P5 A7B79 221 MLVPGGTRVCQL P5 A12 164 GLQDQEPSL P5 A7B80 222 MMEAGLSEL P5 A12 165 GLKKIAEL P4 A7881 223 NLEDPIFL P5 A12 165	155	FPMPNYQAAL	P4	A6B83	213	LMPGGSCWRL	P5	A11B69
157 GLEVSGAFPQL P5 A7B73 215 LQAECDQYL P4 A11 158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHLHPSPAL P5 A7B75 217 MLAPPFPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLINTPFTL P5 A12 161 GLPQTKTL P5 A7B77 219 MLINTQDSSILPL P4 A12 162 GLNGPQVAL P5 A7B78 220 MLTAPPASL P5 A12 163 GLPPEPEVPPAL P5 A7B79 221 MLVPGGTRVCQL P5 A12 164 GLQDQEPSL P5 A7B80 222 MMEAGLSEL P5 A12 165 GLKEIAEL P4 A7881 223 NLELDPIFL P5 A12 165 GLQKEIAEL P4 A7882 224 NLELDPIFL P5 A12	156	FSWSNTTLL	P1	A6B84	214	LMPIFSPEL	P4	A11B70
158 GLFSEDGATL P4 A7B74 216 MEKLADIVTEL P5 A11 159 GLHLHPSPAL P5 A7B75 217 MLAPPFPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLLNTPFTL P5 A12 161 GLLPQTKTL P5 A7B77 219 MLNTQDSSILPL P4 A12 162 GLNGPQVAL P5 A7B77 219 MLNTQDSSILPL P4 A12 163 GLPPEPEVPPAL P5 A7B79 220 MLTAPPASL P5 A12 164 GLQDQEPSL P5 A7B80 222 MMEAGLSEL P5 A12 165 GLKEIAEL P4 A7881 223 MLEDPIFL P5 A12 165 GLKEIAEL P4 A7882 224 MLCADIFL P5 A12 165 GLQKEIAEL P4 A7881 223 MLEDPIFL P5 A12	157	GLEVSGAFPQL	P5	A7B73	215	LQAECDQYL	P4	A11B71
159 GLIHHPSPAL P5 A7B75 217 MLAPPPPPL P4 A12 160 GLIDGMHMHL P5 A7B76 218 MLLNTPFTL P5 A12 161 GLLPQTKTL P5 A7B76 219 MLNTQDSSILPL P4 A12 162 GLNGPQVAL P5 A7B76 219 MLNTQDSSILPL P4 A12 163 GLPPEPEVPPAL P5 A7B79 220 MLTAPPASL P5 A12 164 GLQDQEPSL P5 A7B80 222 MMEAGLSEL P5 A12 165 GLQKEIAEL P4 A7881 223 NLELDPIFL P5 A12 165 GLQKEIAEL P4 A7881 223 NLELDPIFL P5 A12 165 GLMEIAEL P4 A7823 234 NLEDPIFL P3 A13	158	GLFSEDGATL	P4	A7B74	216	MEKLADIVTEL	P5	A11B72
160 GLIDGMHMHL PS A/B/6 218 MILNTPFIL PS A/B/2 161 GLIPQTKTL PS A/B/6 218 MILNTPFIL PS A/B/2 161 GLIPQTKTL PS A/B/7 219 MILNTPFIL P4 A12 162 GLNGPQVAL P5 A/B/7 219 MILNTQDSSILPL P4 A12 163 GLPPEPEVPPAL P5 A/B79 220 MILTAPPASL P5 A12 164 GLQDQEPSL P5 A/7B80 222 MMEAGLSEL P5 A12 165 GLQKEIAEL P4 A/7881 223 NIELDPIFL P5 A12 166 GLOKEIAUL P4 A/7881 223 NIELDPIFL P5 A12 165 GLOKEIAUL P4 A/7881 223 NIELDPIFL P5 A12	159	GLHLHPSPAL	P5	A7B75	217	MLAPPEPPPL	P4	A12B61
161 GLLPQTKTL P5 A7B77 219 MLNTQDSSILPL P4 A12 162 GLNGPQVAL P5 A7B78 220 MLTAPPASL P5 A12 163 GLPPEPEVPPAL P5 A7B79 221 MLVPGGTRVCQL P5 A12 164 GLQQEPSL P5 A7B80 222 MMEAGLSEL P5 A12 165 GLQKEIAEL P4 A7881 223 NLELDPIFL P5 A12 166 GLQKEIAEL P4 A7882 223 NLELDPIFL P5 A12 165 GLQKEIAEL P4 A7882 234 NLCEDSLVGL P3 A14	160	GLIDGMHMHL	P5	A7B76	218	MILLNIPFIL	P5	A12B62
162 GLINGPQUAL PS A7B78 220 MILIAPPASL PS A12 163 GLPPEPEVPPAL PS A7B79 221 MILVPGGTRVCQL PS A12 164 GLQQEPSL PS A7B80 222 MMEAGLSEL PS A12 165 GLQKEIAEL P4 A7B81 223 NIELDPIFL PS A12 165 GLQKEIAEL P4 A7B82 234 NIECDSIVGL P3 A14	161	GLLPQTKTL	P5	A7B77	219		P4	A12B63
105 GLPFEFEVFFAL F3 A7B79 221 MILPF0GTNVCQL F3 A12 164 GLQDQEPSL P5 A7B80 222 MMEAGLSEL P5 A12 165 GLQKEIAEL P4 A7B81 223 NLELDPIFL P5 A12 165 GLQKEIAEL P4 A7B82 223 NLELDPIFL P5 A12	162	GLINLGPQVAL	PD	A7B78	220		PD	A12B04
104 GLQDQEPSL P3 A7860 222 InimeAdlscL P3 A12 165 GLQKEIAEL P4 A7881 223 NLELDPIFL P5 A12 165 GLQKEIAEL P4 A7882 234 NLELDPIFL P5 A12 166 GLQKEIAEL P4 A7882 234 NLEDDIFL P5 A12	164	GLODOEDSI	PD	A7D79	221		PDE	A12B05
100 OLQULIALL F4 A7001 223 NULLUPIIL F5 A12	165	GLQDQEPSL	P3	A7B00	222		P5	A12B00
	166	GLRMGIGLNI	P5	Δ7882	223	NIGPSIVGI	P2	A12B68
167 GI RTEAPPTI P4 A7883 225 NIMI CENEKI P5 A12	167	GIRTEAPPTI	P4	A7R83	225	NMICENEKI	P5	A12869
168 GLSAOHVPSL P5 A7B84 226 NMSKVETGL P5 A12	168	GLSAOHVPSL	P5	A7B84	226	NMSKVETGL	P5	A12B70
169 GLSSEGOSL P5 A8B73 227 NVLSSLWYL P5 A12	169	GLSSEGOSL	P5	A8B73	227	NVLSSLWYL	P5	A12B71
170 GLTEPVLIWL P4 A8B74 228 PLSEVLHFL P5 A12	170	GLTEPVLIWL	P4	A8B74	228	PLSFVLHFL	P5	A12B72
171 GMGGSTITL P5 A8B75 229 QLGKEDLGL P4 A14	171	GMGGSTITL	P5	A8B75	229	QLGKEDLGL	- P4	A14B61
172 GMHSRLSSL P4 A8B76 230 QLQIIFLEL P5 A14	172	GMHSRLSSL	P4	A8B76	230	QLQIIFLEL	P5	A14B62
173 GMLTVIGQGL P5 A8B77 231 RLHTWSQGL P4 A14	173	GMLTVIGQGL	P5	A8B77	231	RLHTWSQGL	P4	A14B63
174 GVHPSLAPL P5 A8B78 232 RLLDSEEPL P5 A14	174	GVHPSLAPL	P5	A8B78	232	RLLDSEEPL	P5	A14B64

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Supplementary Table 3 (continued). **HLA-A*02:01 neoantigen sequences predicted from five colorectal cancer (CRC) patients, with DNA barcode annotations**

#	Sequence	Patient	Barcode	#	Sequence	Patient	Barcode
233	RIMTHYCAMI	P5	A14B65	291	YIFTII SSI	P4	A10B75
234	RIPRPAHAI	P5	A14B66	292	YI DSIGNI PEEI	P5	A10B76
235	RLSSSELSPL	P5	A14B67	293	YLIFKPDVML	P4	A10B77
236	RLWPVLDPCCPL	P5	A14B68	294	YLKIKHLLL	P3	A10B78
237	RMAATRTSL	P5	A14B69	295	YLNTNPVCGL	P4	A10B79
238	RMQGLGFLL	P5	A14B70	296	YQAQLRISL	P5	A10B80
239	RPLLALVNSL	P5	A14B71	297	YTLVPSTVAL	P3	A10B81
240	RVYPRPRVAL	P5	A14B72	298	YTYLTIFDL	P5	A10B82
241	SELSPLTPRL	P5	A15B61	299	YVLPRALSL	P2	A10B83
242	SIYPPPRAL	P4	A15B62	300	YYLMTVMERL	P5	A10B84
243	SLHFLCWSL	P5	A15B63	301	ALIPLPGM	P4	A11B73
244	SLIFGLILKL	P5	A15B64	302	FCLLVVVVLM	P5	A11B74
245	SLLEKVSKKRL	P5	A15B65	303	FLAKDPHPM	P5	A11B75
246	SLLPSCCAL	P5	A15B66	304	FLFTVPIEDM	P5	A11B76
247	SLLRQPVQL	P5	A15B67	305	FLTGIPLSM	P5	A11B77
248	SLLSCPPFL	P4	A15B68	306	FLVLSMPAM	P4	A11B78
249	SLNWPEALPHL	P5	A15B69	307	ILLWILLKM	P5	A11B79
250	SLPAGPSAL	P5	A15B70	308	ILNSLPSSM	P4	A11B80
251	SLPCTPLWL	P5	A15B71	309	ILSMEKIPPM	P4	A11B81
252	SLPSTQLPL	P5	A15B72	310	KMICRGMTM	P4	A11B82
253	SLQNLLFKL	P4	A16B61	311	RLHRLILPM	P5	A11B83
254	SLVGTQTLL	P5	A16B62	312	RLQPMISVRM	P4	A11B84
255	SLVPRGTPL	P5	A16B63	313	RLYQSVLSM	P5	A12B73
256	SLVSFLMHL	P5	A16B64	314	RMLETVLRM	P4	A12B74
257	SLYPQNMTL	P4	A16B65	315	RMVWVELEM	P5	A12B75
258	SMAPTQTCL	P4	A16B66	316	SLDDWSLIYM	P3	A12B76
259	SMCPAGTWCL	P5	A16B67	317	SLRMLVQPEM	P5	A12B77
260	SQSEQGLLL	P5	A16B68	318	TQMSNLVNM	P4	A12B78
261	SQTPVPPGL	P5	A16B69	319	YVQAFQVGM	P5	A12B79
262	STFGMSVCSWPL	P5	A16B70	320	TLIDFFCEDKKP	P5	A12B80
263	TLAGLHVHL	P5	A16B71	321	FLMRKRWPS	P5	A12B81
264	TLAQPELFL	P2	A16B72	322	FLQSHVPKS	P5	A12B82
265	TLGFGWIMLIL	P5	A17861	323	RPLWCLLPPS	P4	A12883
266	TLLLKAPTL	P5	A17862	324	AIIDFSVWI	P5	A12884
207		P4	A17B03	325		PD	A14B73
200		P4	A17865	320		PD	A14D74
205	TMGGYCGYI	P3	A17865	229		P.5	A14B75
270	TMNDSKHKI	P5	A17B67	320	FPLVALLWDT	P5	Δ1/B77
272		P/	A17B68	320	HI HHHI PTT	P5	Δ1/B78
273	TMVOGPAGI	P4	A17B69	330		P5	Δ14B79
274	TVI SOGWEI	P5	A17870	332	KMPPEVSTT	P5	A14B80
275	VELMKHEAWI	P4	A17871	333	VIIKKIAST	P4	A14B81
276	VIESGALLGL	P4	A17B72	334	VVMGVCPFT	P5	A14B82
277	VLDPEGIRGL	P5	A18B61	335	WLIPIAMAT	P5	A14B83
278	VLILGTKRL	P5	A18B62	336	YLAFFPPT	P5	A14B84
279	VLQKKRILL	P5	A18B63	337	YLLARYYYT	P5	A15B73
280	VLREKVPCL	P5	A18B64	338	YLTIFDLLET	P5	A15B74
281	VLSMTTRIFL	P5	A18B65	339	YPLPPWPWST	P5	A15B75
282	VLSSLWYLNL	P5	A18B66	340	AINDVLWACV	P5	A15B76
283	VLTQLVLNL	P5	A18B67	341	ALDLYHVLV	P5	A15B77
284	VLVESKLRGL	P5	A18B68	342	ALGLDVIDQV	P1	A15B78
285	WLCSPAPWL	P5	A18B69	343	ALKIPQGQRV	P4	A15B79
286	WLGMALIPL	P4	A18B70	344	ALKQYACTV	P5	A15B80
287	WLGTLWPSL	P5	A18B71	345	ALMPPSPLPSRV	P5	A15B81
288	WLLQKSPQL	P4	A18B72	346	ALPHLLLLV	P5	A15B82
289	WLNTKMKFFL	P5	A10B73	347	ALPQLEHQV	P5	A15B83
290	YCLFAASLLL	P4	A10B74	348	ALRPHPAAV	P5	A15B84

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Supplementary Table 3 (continued). **HLA-A*02:01 neoantigen sequences predicted from five colorectal cancer (CRC) patients, with DNA barcode annotations**

#	Sequence	Patient	Barcode	#	Sequence	Patient	Barcode
349	ALSEALWVV	P4	A16B73	407	KLQGAVCVV	P5	A20B111
350	ALSKHLTNPFLV	P5	A16B74	408	KLSLFIVCTV	P5	A20B113
351	ALSWRNVPV	P5	A16B75	409	KLSVEFQIV	P4	A3B111
352	ALTEELHQKV	P5	A16B76	410	KMDLDGMLTV	P5	A3B113
353	ALVWLKDPV	P4	A16B77	411	KQVMLQLYV	P5	A3B115
354	AMIVEQPEV	P5	A16B78	412	KVGDILQAV	P5	A3B116
355	APLDLRLAWV	P5	A16B79	413	KVSGTLLTV	P4	A3B117
356	AQHCLLLLV	P5	A16B80	414	LFSYMQWV	P4	A3B118
357	AQIQRPIQV	P5	A16B81	415	LLAAWAAPSGV	P5	A3B120
358	AQSGPLSFV	P5	A16B82	416	LLGSPDPEGV	P5	A3B121
359	CLSPMGLGV	P5	A16B83	417	LLHILSFVV	P5	A3B122
360	CMNEHWMPV	P5	A16B84	418	LLLAVRSFV	P5	A3B124
361	ELWAVDHLQV	P5	A17B73	419	LLLKFTASV	P5	A21B111
362	FHLCSVATRV	P4	A17B74	420	LLSEHAVIV	P5	A21B113
363	FLCEKEQIV	P4	A17B75	421	LLSRVEILPV	P4	A5B111
364	FLGNMFHV	P5	A17B76	422	LLTDLTSWGV	P5	A5B113
365	FLINTFEGV	P5	A17B77	423	LLVIEKNLMV	P5	A5B115
366	FLKFLQGV	P5	A17B78	424	LMTAKIVGNV	P5	A5B116
367	FLLGMATV	P4	A17B79	425	LMVDPSHEV	P5	A5B117
368	FLQGVALAV	P5	A17B80	426	LMVSAGRGLWAV	P3	A5B118
369	FLRGCAPSWV	P5	A17B81	427	LTNAGMLEV	P5	A5B120
370	FLRLQVEGV	P4	A17B82	428	LVMKGQIPV	P5	A5B121
371	FLSHYLQKLSV	P4	A17B83	429	MIISRHLASV	P4	A5B122
372	FQNRGEAAV	P5	A17B84	430	MLDVDLDEV	P4	A5B124
373	FQVLVRILPV	P5	A18B73	431	MLHKSIPV	P5	A22B111
374	FSAPPNSLV	P5	A18B74	432	MLNVNLDPPV	P5	A22B113
375	GLAVTYGV	P5	A18B75	433	MLVPGGTRV	P5	A6B111
376	GLDFFWKQEV	P5	A18B76	434	MMMRNQENV	P5	A6B113
377	GLGEPKQPV	P4	A18B77	435	NLEEPPSSV	P5	A6B115
378	GLGSFVVGV	P5	A18B78	436	NLQAMSLYV	P5	A6B116
379	GLLPLASTV	P5	A18879	437	NLYGMSKVAV	P4	A6B117
380	GLPLAMAQV	P4	A18B80	438	PLVHITEEV	P4	A6B118
302	GLYFERMERY	P5	A18881	439	QIFFITFFV	P5	A6B120
382	GLVEEPIVIEDV	P5	A18882	440	QLAGKRIGV	P5	
202	GMEHESTDV	P4	A10B05	441		PD 20	A6B122
205	GMELLETLY	P5	A18884	442		P5	A00124
386	GVV/TSGPGV	P5	A1B111	443		P/	A23B111
387		P4	A1B115	445	RIFEIAHV	P5	Δ7R111
388		P5	A1B116	446	REFICISGV	P5	A7B113
389	HLLWRLPAPV	P4	A1B117	447	RLLGOTDMAV	P4	A7B115
390	HI SEKALEV	P4	A1B118	448	RIMAGOOOV	P4	A7B116
391	HTYSSIPVV	P1	A1B120	449	RLOPMISV	P4	A7B117
392	IIAGGASLV	P5	A1B121	450	RLTQMSNLV	P4	A7B118
393	ILASGFIDV	P5	A1B122	451	RMKRLPVAV	P5	A7B120
394	ILGEGRAEAV	P5	A1B124	452	RMQCVAVFAV	P5	A7B121
395	ILLVNSLKV	P5	A26B116	453	RQLPQMSKV	P5	A7B122
396	ILSAITQPV	P5	A19B113	454	RSFDEVEGV	P5	A7B124
397	ILSALRVSPV	P5	A2B111	455	RTGPHILIV	P5	A24B111
398	ILYPDEVACMV	P5	A2B113	456	SLAECGARGV	P4	A24B113
399	IMGKMEADPEV	P3	A2B115	457	SLASWDVPV	P5	A8B111
400	ITITFVTAV	P3	A2B116	458	SLCRLWPV	P5	A8B113
401	ITSAAIYHV	P5	A2B117	459	SLHGHVAAV	P4	A8B115
402	IVAAGVASGV	P5	A2B118	460	SLIEFDTLV	P5	A8B116
403	KAFFGPVYYV	P5	A2B120	461	SLILSFQRV	P4	A8B117
404	KIVAYMYLV	P1	A2B121	462	SLLHTTFPHRQV	P5	A8B118
405	KLAIHVGLAV	P5	A2B122	463	SLPMIATV	P5	A8B120
406	KLESPALKQV	P5	A2B124	464	SLPSSMEIAV	P4	A8B121

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Supplementary Table 3 (continued). **HLA-A*02:01 neoantigen sequences predicted from five colorectal cancer (CRC) patients, with DNA barcode annotations.** V, viral epitope

#	Sequence	Patient	Barcode
465	SLPVTSLSSV	P5	A8B122
466	SLQWPLKSRV	P4	A8B124
467	SLRTDCLLAV	P5	A25B111
468	SLVPEREKMLV	P5	A25B113
469	SLWYLNLTV	P5	A9B111
470	SMFVGSDTV	P5	A9B113
471	SMRECALHTV	P5	A9B115
472	SMTCKVMTSWAV	P5	A9B116
473	SQMDGLEV	P5	A9B117
474	SQVQLAIQV	P5	A9B118
475	SVFPNILNV	P4	A9B120
476	TALDVLANV	P5	A9B121
477	TETFALILYV	P5	A9B122
478	TLEERTSSV	P5	A9B124
479	TLGAALPPWPV	P4	A26B111
480	TLGAMDLGV	P5	A26B113
481	TLRQTTSVPV	P5	A19B115
482	TLSVIRDYLV	P5	A19B116
483	TLVEELITV	P5	A19B117
484	VIGAVVATV	P4	A19B118
485	VISAISEAV	P5	A19B120
486	VLAENVNMCV	P5	A19B121
487	VLKPCLIPV	P5	A19B122
488	VLKPFLFTV	P5	A19B124
489	VLLQSESGTAPV	P5	A22B115
490	VLLVLVLAV	P4	A22B116
491	VLMGCWLEV	P5	A22B117
492	VLSKGEIVV	P5	A22B118
493	WLASGRPCV	P5	A20B115
494	WLIVLTOLV	P5	A20B116
495	WLPKMPPFV	P5	A20B117
496	WLRELTSIV	P3	A20B118
497	WMTMDHLLV	P5	A20B120
498	WVLAALLAV	P5	A20B121
499	YLAHTVNAYKLV	P5	A20B122
500	YLEQLKMTV	P3	A20B124
501	YLGDILLAV	P5	A23B115
502	YLPPGFMFKV	P3	A23B116
503	YLPRTMDFGINV	P5	A23B117
504	YLSGRQKFWV	P2	A23B118
505	YMACKDEGCKLV	P3	A21B115
506	YQSAGITGV	P5	A21B116
507	YTWLGAMPV	P4	A21B117
508	SLWGNPTQY	P5	A21B118
#	Sequence	Origin	Barcode
 V1	GILGEVETI	FLU MP1	A21B120
V2		FRV I MD2	Δ21R121
V2	GICTIVAMI	FRV RMI F1	Δ21R122
V4	FLYALALLI	FRV I MP2	Δ21Β122
V5		CMV nn65	A210124
V6		EBV BBI E1	A248115

V7

V8

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VLEETSVML

ILKEPVHGV

No peptide control

CMV IE1

HIV Pol

A24B117

A24B118

A25B115



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this	BC	83	12	V6	V3	V4								0.0
led in	ient 5		PBMCs	#457	#418	#114	#494	#398	#64	#109	#256	#319	#436	
includ	Pat		TILS	#128	#474	#64	#480	#410	#446	#398	#2	#79	#354	+00 0
ients i		ets	SP39	#115	N6	#490	#328	#24	#19	#367	#118	#414	#438	, , ,
c) pati	nt 4	TIL subs	DN	V4	#19	#276	#115	6	#31	#490	#118	#52	#448	t pos
r (CRC	Patieı		DP	#52	V4	06#	#19	#343	#353	#115	#438	#367	<u>#51</u>	20402
cance			N	V4	N6	#115	#343	#490	#363	#449	#306	#19	#215	
sctal c			TILS	V4	#115	V6	#31	#19	#490	#52	#448	#53	#191	m o q
colore		ts	SP103	#400	N6	#502	#110	#186	#496	77	#117	#500	#504	+ unit
man (TIL subse	SP39	#400	#502	#264	#117	#186	#316	#119	9N	#209	#138	~:+!~
ve hu	ient 3		DN	#502	#117	9N	#264	#400	#186	V3	#316	#119	#404	2 FO.C
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d from			PBMCs	V6	V1	V3	V2	V4	#502	#404	#264	#400	#209	of UI
rieve			TILS	#63	#264	#209	#117	#399	#110	#149	#186	9N	#316	000
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cificiti		TIL subse	DN	V5	V3	V6	٧7	٧4	#502	#209	#400	#264	#119	bodi
e spe	nt 2		DP	#264	#110	#400	#119	V 6	#502	#186	#404	V5	#117	
eptid	Patie		N	V5	V6	V3	٧2	#186	#83	#264	77	V1	#15	
p 10 p			PBMCs	V5	77	V3	V6	#199	#186	#294	#209	V1	#399	10+100
e 4. To			TILS	V5	#264	#400	#117	#404	#149	V 6	#186	#119	#209	, fivo
y Table	ent 1		PBMCs	V5	V3	V1	V4	V2	#502	#117	#400	V6	#110	or from
entary	Patie		TILS	#15	#110	#209	#264	#224	#199	#400	#83	#63	#316	- umc
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highlighted in red were detected at significantly increased levels (log fold change \geq 2) compared to baseline reads; peptides in yellow at slightly increased levels (1 \leq log fold change \leq 2). Underlined peptides in bold are peptides predicted specifically for that patient. TIL, tumor-infiltrating lymphocyte; PBMC, peripheral blood mononuclear cell; LN, lymph node; DP, double positive TIL subset expressing both CD39 and CD103; DN, double negative; SP39⁺, single positive expressing CD39, SP103⁺, single positive expressing CD103. neoantigens and common viral antigens (denoted with V, sequences listed in Table 1 and Table S3). Barcodes corresponding to peptides a poor of FILA-A וובמ אורו various samples from five patients were

#	Sequence	Barcode		#	Sequence	Barcode
1	SIIVFNLL	A1B212	-	53	TFLFFALL	A6B202
2	IVFNLLEL	A1B213		54	RGLIRYRL	A6B203
3	FVIDFKPL	A1B200		55	AVIGYSLL	A6B205
4	KFNFKTAL	A1B201		56	VTLKPPFL	A6B204
5	ALPVRFSL	A1B202		57	SSSTAAAL	A6B206
6	MARPWGLL	A1B203		58	SNHVLGHL	A6B207
7	RHCWYLAL	A1B205		59	LSVEPFRL	A6B208
8	FSLQFALL	A1B204		60	LGYSSVGL	A6B209
9	SSMVPSAL	A1B206		61	VGLPWVTL	A6B210
10	FALLMGTL	A1B207		62	VSRHHRAL	A6B211
11	RNRRIFAL	A1B208		63	RTVLRLLSL	A7B200
12	SPFLLITL	A1B209		64	VVIAIFIIL	A7B201
13	LAPIKFAL	A1B210		65	YSMGKDAGL	A7B202
14	VNSIHALL	A1B211	_	66	VAVLPVLSL	A7B203
15	ASASLSRL	A2B200	_	67	IGACKAMNL	A7B205
16	VSLWPDLL	A2B201	_	68	VGQSVWLGL	A7B204
17	TAIELGTL	A2B202	_	69	VMIAGKVAL	A7B206
18	STPQLLPL	A2B203		70	CVVPFTDLL	A7B207
19	VLESYLNL	A2B205		71	IVGHFYGGL	A7B208
20	VGPRYDFL	A2B204		72	VAQTPHGFL	A7B209
21	KILTFDRL	A2B206		73	LDFGFWHEL	A7B210
22	LTFDRLAL	A2B207		74	IANFQLCPL	A7B211
23	EAERFANL	A2B208		75	ISRDLASML	A8B200
24	VTVFVNNL	A2B209		76	VKRTRFLRL	A8B201
25	PMFLFKTL	A2B210		77	SHPRRHRRL	A8B202
26	SASRYALL	A2B211	_	78	STQMHRALL	A8B203
27	SSIKVVGL	A3B200	_	79	TQMHRALLL	A8B205
28	VNMDGASL	A3B201	_	80	VQKKFSRNL	A8B204
29	TVVGLSNL	A3B202	_	81	ISYDPDTCL	A8B206
30	TGSVFGEL	A3B203	_	82	SMPSAKVSL	A8B207
31	ANVLFFGL	A3B205	_	83	LGVCMYGML	A8B208
32	QILVFLIL	A3B204	_	84	LAQKIHQNL	A8B209
33	LGVLFSQL	A3B206	_	85	LYLSSRSLL	A8B210
34	YMYVPTAL	A3B207	_	86	CSYLPELPL	A8B211
35	LGSIFSTL	A3B208	_	87	QVFKVIGNL	A9B200
36	RSVLHGCL	A3B209	_	88	ASLLPSMPL	A9B201
37	FINLYGLL	A3B210	_	89	WNCPFSQRL	A9B202
38	IHPVMSTL	A3B211	_	90	QLYLLCCQL	A9B203
39	AALSPASL	A5B200	_	91	VQLASRSLL	A9B205
40	VQFMSCNL	A5B201	_	92	MSYFLQGTL	A9B204
41	GAFVLQLL	A5B202	_	93	SSPYSLHYL	A9B206
42	SSFVPVGL	A5B203	_	94	STSFNFNSL	A9B207
43	TSIGMLYL	A5B205	_	95	QVVKYHRVL	A9B208
44	RLYETFNL	A5B204	_	96	VVKYHRVLL	A9B209
45	FTPSHPPL	A5B206	_	97	GSWAYCRAL	A9B210
46	RTLCVGNL	A5B207	_	98	KLYTRYAFL	A9B211
47	LAIMTQHL	A5B208	_	99	ASIIVFNLL	A1B214
48	AWVPFGGL	A5B209	_	100	IIVFNLLEL	A1B215
49	FSYIVELL	A5B210	_	101	GKILTFDRL	A1B216
50	LTFFHSGL	A5B211	_	102	GGKILTFDRL	A1B217
51	FTFLFFAL	A6B200	_	103	No peptide control	A1B219
52	VVWFFTFL	A6B201		104	SIINFEKL	A1B218

Supplementary Table 5. H2-K^b neoantigen sequences predicted from MC38 mice, with DNA barcode annotations

