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(54) Title: COMPOSITIONS AND METHODS FOR DIAGNOSING AND TREATING INFLAMMATORY BOWEL DISEASE AND RELATED DISORDERS

(57) Abstract: The present invention features biomarkers capable of diagnosing inflammatory bowel disease and methods of using such biomarkers to diagnose and selecting treatments for inflammatory bowel diseases.



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COMPOSITIONS AND METHODS FOR DIAGNOSING AND TREATING INFLAMMATORY BOWEL DISEASE AND RELATED DISORDERS

CROSS-REFERENCE TO RELATED APPLICATION

5 This application claims the benefit of the following U.S. Provisional Application No.:
61/138,309, filed December 17, 2008, the entire contents of which are incorporated herein by
reference.

STATEMENT OF RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH

10 This work was supported by the following grants from the National Institutes of Health,
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BACKGROUND OF THE INVENTION

15 Crohn's disease (CD) and ulcerative colitis (UC) are chronic, idiopathic and clinically
heterogeneous intestinal disorders collectively known as inflammatory bowel disease (IBD). At
present, a combination of clinical, endoscopic and radiological criteria is used to differentiate CD
from US. Because the symptoms of Crohn's disease are similar to other intestinal disorders,
such as ulcerative colitis, it can be difficult to diagnose. Ulcerative colitis causes inflammation
20 and ulcers in the top layer of the lining of the large intestine. In Crohn's disease, all layers of the
intestine may be involved, and normal healthy bowel can be found between sections of diseased
bowel. Complications of Crohn's disease include intestinal blockages, which may require
surgery, as well as fistulas and fissures. To avoid such complications, it is important to get an
accurate diagnosis early in the course of the illness to ensure that appropriate therapies are
25 selected. Current diagnostic methods for inflammatory bowel disease are invasive and patients
typically find these tests unpleasant. To improve patient compliance, diagnostic accuracy, and
early and appropriate treatment selection, new methods for distinguishing among inflammatory
bowel diseases are required.

SUMMARY OF THE INVENTION

As described below, the present invention features biomarkers capable of diagnosing a subject as having inflammatory bowel disease and methods of using such biomarkers to diagnose, monitor and select appropriate treatments for said subject.

5 In one aspect, the invention provides a microchip containing at least about 85, 90, 95 or 100% of the *E. coli* proteome.

In another aspect, the invention features a microchip containing a set of biomarkers for characterizing an inflammatory bowel disease (IBD) in a subject, where the set is selected from any one or more of *E. coli* polypeptides delineated herein, pairs and sets of polypeptides features
 10 in Tables 2-5, 7, and Figure 5, or any of (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC,
 15 oppF, pbuX, pheP, phsE, pneC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yejF, yfjY, ygeD, yggF, yggH, yghK, yghT, ygiQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjff, yjfp, yjfy, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, yzgL, rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV),
 20 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dggA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD,
 25 ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ,

ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, yrbB, (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygiR, yhiN, yjgT, yojI, and/or yphD, or fragments thereof.

In another aspect, the invention features a microchip containing a set of biomarkers for characterizing Crohn's disease in a subject, where the set is any one or more of *E. coli*

polypeptides rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, yrbB, (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pneC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yejF, yfjY, ygeD, ygfF, yggH, yghK, yghT, ygjQ, yhaH, yhaO,

yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjff, yjfp, yjfY, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and/or yzgL, or fragments thereof.

In one embodiment of the above aspect, the set is any one or more of *E. coli* polypeptides
 5 rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS,
 10 hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA,
 15 ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, and yrbB, or fragments thereof.

In another aspect, the invention features a microchip containing a set of biomarkers for distinguishing Crohn's Disease from ulcerative colitis, the set containing *E. coli* polypeptides
 20 era, ybaN, yhgN, focA, ga bT and ycdG, or fragments thereof.

In another aspect, the invention features a microchip containing a set of biomarkers for diagnosing ulcerative colitis, where the set is any one or more of *E. coli* polypeptides (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjffH, yjiI, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch,
 25 maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygjR, yhiN, yjgT, yojI, yphD, (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY,
 30 JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pnuC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO,

sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yejF, yfjY, ygeD, ygfF, yggH, yghK, yghT, ygjQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, 5 yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjff, yjfp, yjfY, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and yzgL, or fragments thereof. In one embodiment, the set of biomarkers is any one or more of (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, 10 folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefl, yeiO, ygjR, yhiN, yjgT, yojI, and yphD, or fragments thereof.

In yet another aspect, the invention features a microchip containing a set of biomarkers for distinguishing Crohn's disease from ulcerative colitis, the chip containing a set of 15 biomarkers that is any one or more of rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, 20 glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, 25 yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgl, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, yrbB, (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, 30 focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG,

yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefl, yeiO, ygjR, yhiN, yjgT, yojl, and yphD, or fragments thereof.

In various embodiments of the above aspects, the microarrays further contain one or more biomarkers any one or more of antibodies that specifically bind chitobioside IgA (ACCA), laminaribioside IgG (ALCA), manobioside IgG (AMCA), Man α -1,3 Man α -1,2 Man (Σ Man3), Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) pANCA, antineutrophil cytoplasmic antibody, yeast oligomanna, *Saccharomyces cerevisiae*, ASCA, bacterial outer membrane porin C (OmpC), *Pseudomonas fluorescens* bacterial sequence I2, and bacterial flagellin (Cbir).

In one embodiment of the above aspects, the *E. coli* polypeptide induces an immune response when injected into a subject.

In still another aspect, the invention features a microchip containing a polypeptide, polypeptide set, or polypeptide pair delineated in any of Tables 2-5, 7, or Figure 5.

In another aspect, the invention features a method for characterizing a condition associated with a dysregulated immune response to a polypeptide in a subject (e.g., human), the method involving contacting a microarray containing a set of polypeptides with sera derived from the subject, and detecting differential antibody binding to a polypeptide on the microarray in the subject sera relative to a control, where detection of differential antibody binding identifies the subject as having a condition associated with a dysregulated immune response to a .

In another aspect, the invention features a method for diagnosing a subject as having or having a propensity to develop inflammatory bowel disease, the method involving contacting an array containing a set of *E. coli* polypeptides with sera derived from the subject, and detecting differential antibody binding to the polypeptide on the array in the subject sera relative to a healthy control, thereby characterizing inflammatory bowel disease in the subject. In one embodiment, antibodies that bind an *E. coli* polypeptide are any one or more of (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pneC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA,

ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yejF, yfjY, ygeD, ygfF, yggH, yghK, yghT, ygjQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjfF, yjfP, yjfY, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and yzgL. In another embodiment, antibodies that bind an *E. coli* polypeptide are any one or more of rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yfjV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhci, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, and yrbB. In yet another embodiment, antibodies that bind an *E. coli* polypeptide are any one or more of (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygiR, yhiN, yjgT, yojI, and yphD. In one embodiment, an increase in levels of antibodies that specifically bind one or more *E. coli* polypeptides any one or more of rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yfjV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE,

phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, and yrbB identifies the subject as having Crohn's disease.

In various embodiments of the above aspects, an increase in levels of antibodies that specifically bind one or more *E. coli* polypeptides any one or more of (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefl, yeiO, ygjR, yhiN, yjgT, yojI, and yphD identifies the subject as having ulcerative colitis. In other embodiments, an increase in levels of antibodies that specifically bind one or more *E. coli* polypeptides any one or more of (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pnuC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yejF, yfjY, ygeD, ygfF, yggH, yghK, yghT, ygjQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjfF, yjfP, yjfY, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and yzgL identifies the subject as a healthy control.

In another aspect, the invention features a method for diagnosing Crohn's disease, the method involving contacting an array containing a set of *E. coli* polypeptides with sera derived from the subject, and detecting in said subject's sera greater immunogenic reactivity to era than

to ybaN, greater immunogenic reactivity to yhgN than to focA, and/or greater immunogenic reactivity to gabT than to ycdG, thereby identifying the subject as having Crohn's Disease.

In another aspect, the invention features a method for diagnosing ulcerative colitis in a subject, the method involving contacting an array containing a set of *E. coli* polypeptides with
 5 sera derived from the subject, and detecting in said subject's sera greater immunogenic reactivity to relE > cysE/wcaB, pyrI > yjgK, lnt > ybiO, ftsE > pssR, yhgN > yhfG, yafN > dsbB, yihI > yabK, 421#15 > yhdN, hisP > rplO, cml > nuoM, yieC > nuoI, thereby identifying the subject as having ulcerative colitis.

In another aspect, the invention features a method for diagnosing ulcerative colitis, the
 10 method involving contacting an array involving a set of *E. coli* polypeptides with sera derived from the subject, and detecting in said subject's sera greater immunogenic reactivity to frvX than to yidX identifies a subject as having ulcerative colitis.

In another aspect, the invention features a method for selecting an appropriate treatment for a subject, the method involving contacting a microarray delineated herein with subject sera
 15 and detecting binding to a polypeptide that identifies the subject as having inflammatory bowel disease, thereby indicating that inflammatory bowel disease therapy is appropriate for said subject. In one embodiment, the subject is identified as having Crohn's disease or ulcerative colitis.

In another aspect, the invention features a method for selecting surgery for a subject, the
 20 method involving contacting a microarray of any of claims 1-11 with subject sera and detecting binding to a polypeptide that identifies the subject as having inflammatory bowel disease, thereby indicating that surgery is appropriate for said subject. In one embodiment, the method detects greater immunogenic reactivity to era than to ybaN, greater immunogenic reactivity to yhgN than to focA, and/or greater immunogenic reactivity to gabT than to ycdG. In another
 25 embodiment, the method detects relE > cysE/wcaB, pyrI > yjgK, lnt > ybiO, ftsE > pssR, yhgN > yhfG, yafN > dsbB, yihI > yabK, 421#15 > yhdN, hisP > rplO, cml > nuoM, and/or yieC > nuoI.

In embodiments of the previous aspects, the method further involves detecting an antibody that specifically binds any one or more of chitobioside IgA (ACCA), laminaribioside IgG (ALCA), manobioside IgG (AMCA), Man α -1,3 Man α -1,2 Man (Σ Man3), Man α -1,3 Man
 30 α -1,2 Man α -1,2 Man (Σ Man4) pANCA, antineutrophil cytoplasmic antibody, yeast oligomanna,

Saccharomyces cerevisiae, ASCA, bacterial outer membrane porin C (OmpC), *Pseudomonas fluorescens* bacterial sequence I2, and bacterial flagellin.

In another aspect, the invention features a method for selecting an appropriate treatment method for a subject, the method involving contacting a microarray delineated herein with
5 subject sera and detecting binding to a polypeptide that identifies the subject as not having inflammatory bowel disease, thereby indicating that inflammatory bowel disease therapy is not appropriate for said subject.

In another aspect, the invention features a method for monitoring the condition of a subject having Crohn's disease, the method involving contacting an array containing a set of *E.*
10 *coli* polypeptides with sera derived from the subject, and detecting in said subject's sera immunogenic reactivity to era relative to ybaN, immunogenic reactivity to yhgN relative to focA, and immunogenic reactivity to gabT relative to ycdG, where a reduction in said immunogenic reactivity identifies an improvement in the subject's condition, and an increase in said immunogenic reactivity identifies a worsening in the subject's condition.

In yet another aspect, the invention features a method for monitoring the condition of a subject having ulcerative colitis, the method involving contacting an array containing a set of *E.*
15 *coli* polypeptides with sera derived from the subject, and detecting in said subject's sera immunogenic reactivity to frvX relative to yidX, where a reduction in said immunogenic reactivity identifies an improvement in the subject's condition, and an increase in said
20 immunogenic reactivity identifies a worsening in the subject's condition.

In another aspect, the invention features a method for determining whether a therapy is efficacious for a subject, the method involving contacting a microarray of any previous aspect with subject sera collected at a first time and detecting binding to a polypeptide that identifies the
25 subject as having inflammatory bowel disease, and contacting a microarray of any previous aspect with subject sera collected at a second time and detecting binding to a polypeptide that identifies the subject as having inflammatory bowel disease, where detection of a reduction in binding at the second time relative to the first indicates that said therapy is efficacious and a failure to detect a reduction in binding indicates that said therapy is not efficacious.

In another aspect, the invention features a kit containing a microarray of any previous
30 aspect, and instructions for use of the array in diagnosing inflammatory bowel disease, Crohn's disease, or ulcerative colitis.

In various embodiments of the above aspect, or any other method delineated herein, binding is detected in an immunoassay (e.g., ELISA). In other embodiments of the above aspects, the control is a healthy subject, a subject with Crohn's disease, or a subject with ulcerative colitis. In other embodiments of the above aspects, the detecting is of differential binding of a pair of antibodies to a pair of polypeptides on the array (i.e., comparing binding of one antibody to one polypeptide relative to the binding of the other antibody to the other polypeptide). In other embodiments of the above aspects, the array comprises cell wall polypeptides, intracellular polypeptides, and macromolecular complex polypeptides. In other embodiments, an increase in subject antibody binding to a polypeptide relative to healthy control antibody binding identifies the polypeptide as immunogenic in subjects having a dysregulated immune response to the polypeptide. In still other embodiments, the condition is any one or more of inflammatory bowel disease, Crohn's disease, ulcerative colitis, and indeterminate colitis. In various embodiments of the above aspects, the array comprises at least about 85, 90, 95, or 100% of the *E. coli* proteome. In still other embodiments, the polypeptides are differentially immunogenic in healthy controls, Crohn's disease, and/or ulcerative colitis. In still other embodiments, the method further involves detecting an antibody that specifically binds any one or more of chitobioside IgA (ACCA), laminaribioside IgG (ALCA), manobioside IgG (AMCA), Man α -1,3 Man α -1,2 Man (Σ Man3), Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) pANCA, antineutrophil cytoplasmic antibody, yeast oligomanna, *Saccharomyces cerevisiae*, ASCA, bacterial outer membrane porin C (OmpC), *Pseudomonas fluorescens* bacterial sequence I2, and bacterial flagellin. In still other embodiments, the methods further involve stool sample analysis, colonoscopy, sigmoidoscopy, barium x-ray, computerized axial tomography, and/or capsule endoscopy. In still other embodiments, the method identifies the subject as a healthy control or as not having Crohn's disease or ulcerative colitis. In other embodiments of the above aspects, the invention features a microchip containing a polypeptide, polypeptide set, or polypeptide pair delineated in any of Tables 2-5, 7, or Figure 5; accordingly, the invention further provides for the detection of differential immunogenicity between pairs of polypeptides or sets of polypeptides relative to a control (e.g., healthy control, UC, or CD)

The invention provides compositions and methods useful for the diagnosis of inflammatory bowel diseases, including distinguishing Crohn's disease from healthy controls and ulcerative colitis. Compositions and articles defined by the invention were isolated or

otherwise manufactured in connection with the examples provided below. Other features and advantages of the invention will be apparent from the detailed description, and from the claims.

Definitions

5 By "inflammatory bowel disease" is meant a disease characterized by inflammation of the small and/or large intestines.

By "Crohn's disease" is meant an inflammatory bowel disease characterized by chronic inflammation of the gastrointestinal tract.

10 By "ulcerative colitis" is meant an inflammatory bowel disease characterized by inflammation of the rectum and/or large intestine.

By "agent" is meant any small molecule chemical compound, antibody, nucleic acid molecule, or polypeptide, or fragments thereof.

By "ameliorate" is meant decrease, suppress, attenuate, diminish, arrest, or stabilize the development or progression of a disease.

15 By "alteration" is meant a change (increase or decrease) in the expression levels or activity of a gene or polypeptide as detected by standard art known methods such as those described herein. As used herein, an alteration includes a 10%-100% change in expression levels (e.g., 10, 20, 30, 40, 50, 60, 75, 80, 85, 90, 95, 100%) change in expression levels.

20 By "derived from" is meant isolated from or having the sequence of a naturally-occurring sequence (e.g., a cDNA, genomic DNA, synthetic, or combination thereof).

By "microarray" is meant an organized collection of at least two proteins or polypeptides affixed to a solid support. In some embodiments, a polypeptide microarray contains at least a polypeptide or fragment thereof (e.g., 10, 20, 30, 40, 50, 75, or 100 amino acids) listed in any of Figure 5 and Tables 2-5, and 7. A microarray contains at least 2, 5, 10, 25, 50, 75, 100, 150, 200, 250, or 300 polypeptide or nucleic acid molecule members. Frequently, the surface of the microarray comprises a plurality of addressable locations, each of which location has the adsorbent bound there.

30 By "biomarker" is meant a polypeptide, polynucleotide, or other molecule that is altered in level or activity in a disease state relative to the level or activity present in a healthy control, or from one disease type (such as Crohn's) from another (such as UC). In one embodiment, a biomarker is a polypeptide that is differentially immunogenic, i.e., that induces an immune

response that differs between healthy control subjects and subjects having a disease or disorder. In another embodiment, a biomarker is a serum antibody that binds to a polypeptide where the serum antibody is differentially present in a subject having a disease or disorder relative to a healthy control subject or a subject not having the disease or disorder.

5 In this disclosure, "comprises," "comprising," "containing" and "having" and the like can have the meaning ascribed to them in U.S. Patent law and can mean "includes," "including," and the like; "consisting essentially of" or "consists essentially" likewise has the meaning ascribed in U.S. Patent law and the term is open-ended, allowing for the presence of more than that which is recited so long as basic or novel characteristics of that which is recited is not changed by the
10 presence of more than that which is recited, but excludes prior art embodiments.

 "Detect" refers to identifying the presence, absence or amount of an analyte to be detected.

 By "detectable label" is meant a composition that when linked to a molecule of interest renders the latter detectable, via spectroscopic, photochemical, biochemical, immunochemical, or
15 chemical means. For example, useful labels include radioactive isotopes, magnetic beads, metallic beads, colloidal particles, fluorescent dyes, electron-dense reagents, enzymes (for example, as commonly used in an ELISA), biotin, digoxigenin, or haptens.

 "Diagnostic" means identifying the presence or nature of a pathologic condition. While a particular diagnostic method may not provide a definitive diagnosis of a condition, it suffices if
20 the method provides a positive indication that aids in diagnosis.

 By "differentially immunogenic" is meant that a polypeptide induces an altered immune response in a subject having a disease relative to the immune response that the polypeptide induces in a healthy control or a subject not having the disease, or a subject having one type of disease (such as CD) relative to a subject having another disease (such as UC) or vice versa.
25 This difference may be either an increase or a decrease in immune response when compared to control conditions. Preferably, the increase or decrease is at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or even 100%.

 By "disease" is meant any condition or disorder that damages or interferes with the normal function of a cell, tissue, or organ.

30 The invention provides a number of targets that are useful for the development of highly specific drugs to treat inflammatory bowel disease characterized by the methods delineated

herein. In addition, the methods of the invention provide a facile means to identify therapies that are safe for use in eukaryotic host organisms. In addition, the methods of the invention provide a route for analyzing virtually any number of compounds for effects on a disease described herein with high-volume throughput, high sensitivity, and low complexity.

5 By "dysregulated immune response to a pathogen" is meant an excessive or undesirable immune response that causes cell, tissue or organ damage.

By "*E. coli* polypeptide" is meant a protein that naturally occurs in *E. coli*. Such polypeptides are available in Genbank (<http://www.ncbi.nlm.nih.gov/sites/entrez>) or in the *E. coli* genome and proteome database (<http://genprotec.mbl.edu/>).

10 By "fragment" is meant a portion of a polypeptide. This portion contains, preferably, at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, or 90% of the entire length of the reference polypeptide. A fragment may contain 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100, 200, 300, 400, 500, 600, 700, 800, 900, or 1000 amino acids.

By "function" is meant any biological activity of a polypeptide or polynucleotide. In one
15 embodiment, a polypeptide is an antibody. In another embodiment, a biological activity is immunogenicity.

As used herein, the terms "gene" and "recombinant gene" refer to nucleic acid molecules comprising an open reading frame encoding a marker protein.

By "immunological assay" is meant an assay that relies on an immunological reaction, for
20 example, antibody binding to an antigen. Examples of immunological assays include ELISAs, Western blots, immunoprecipitations, and other assays known to the skilled artisan.

By "polypeptide" is meant any chain of amino acids, regardless of length or post-translational modification (for example, glycosylation or phosphorylation). In one example, an antibody is a polypeptide.

25 By an "isolated polypeptide" is meant a polypeptide of the invention that has been separated from components that naturally accompany it. Typically, the polypeptide is isolated when it is at least 60%, by weight, free from the proteins and naturally occurring organic molecules with which it is naturally associated. Preferably, the preparation is at least 75%, more preferably at least 90%, and most preferably at least 99%, by weight, a polypeptide of the
30 invention. An isolated polypeptide of the invention may be obtained, for example, by extraction from a natural source, by expression of a recombinant nucleic acid encoding such a polypeptide;

or by chemically synthesizing the protein. Purity can be measured by any appropriate method, for example, column chromatography, polyacrylamide gel electrophoresis, or by HPLC analysis.

By "microarray" is meant an organized collection of at least two polypeptides, polynucleotides, or fragments thereof affixed to a solid support. A polypeptide microarray
5 contains one or more polypeptides (e.g., 10, 20, 30, 40, 50, 75, or 100 amino acids) delineated herein. A microarray contains at least 1, 2, 3, 4, 5, 6 polypeptide or nucleic acid molecules delineated herein.

"Monitoring" refers to recording changes in a varying parameter (e.g. monitoring progression of a disease).

10 As used herein, "obtaining" as in "obtaining an agent" includes synthesizing, purchasing, or otherwise acquiring the agent.

By "pathogen" is meant a bacteria, mycobacteria, fungi (including yeast), virus, or other microbe associated with disease. Exemplary pathogen's include various *E. coli* strains, *C. difficile*, *B. fragilis*, *E. coli* LF-82 and *H. hepaticus*, all of which have been demonstrated to be
15 pathogenic to IBD. In certain embodiments, the term pathogen is applied to microbes that are not typically associated with disease in healthy individuals, but that are associated with disease in individuals having a dysregulated immune response (e.g., *E. coli* K-12 in Crohn's disease and ulcerative colitis).

By "portion" is meant a fragment of a protein or nucleic acid that is substantially identical
20 to a reference protein or nucleic acid. In some embodiments the portion retains at least 50% 75%, or 80%, or more preferably 90%, 95%, or even 99% of the biological activity of the reference protein or nucleic acid described herein.

By "reduces" is meant a negative alteration of at least 10%, 25%, 50%, 75%, or 100%.

By "reference" is meant a standard or control condition.

25 As used herein, "sample" or "biological sample" refers to anything, which may contain an analyte (e.g., polypeptide, polynucleotide, or fragment thereof) for which an analyte assay is desired. The sample may be a biological sample, such as a biological fluid or a biological tissue. Examples of biological fluids include urine, blood, plasma, serum, saliva, semen, stool, sputum, cerebral spinal fluid, tears, mucus, amniotic fluid or the like. In one embodiment, a biological
30 sample is blood, plasma or serum.

By "a set" is meant a group having more than one member. The set may be composed of 2, 4, 5, 8, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 125, 150, 200, 250, or 300 polypeptide, nucleic acid molecule, or chemical compound members.

As used herein, the term "sensitivity" is the percentage of marker-detected subjects with a particular disease.

By "specifically binds" is meant an agent (e.g., antibody) which recognizes and binds a polypeptide of the invention, but that does not substantially recognize and bind other molecules.

As used herein, the term "specificity" is the percentage of subjects correctly identified as having a particular disease. For example, the specificity is calculated as the number of subjects with a particular disease as compared to normal healthy subjects.

By "subject" is meant a mammal, including, but not limited to, a human or non-human mammal, such as a bovine, equine, canine, ovine, rodent, or feline.

By "specifically binds" is meant a compound or antibody that recognizes and binds a polypeptide of the invention, but which does not substantially recognize and bind other molecules in a sample, for example, a biological sample, which naturally includes a polypeptide of the invention.

As used herein, "obtaining" as in "obtaining an agent" includes synthesizing, purchasing, or otherwise acquiring the agent.

Ranges provided herein are understood to be shorthand for all of the values within the range. For example, a range of 1 to 50 is understood to include any number, combination of numbers, or sub-range from the group consisting 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or 50.

As used herein, the terms "treat," "treating," "treatment," and the like refer to reducing or ameliorating a disorder and/or symptoms associated therewith. It will be appreciated that, although not precluded, treating a disorder or condition does not require that the disorder, condition or symptoms associated therewith be completely eliminated.

Unless specifically stated or obvious from context, as used herein, the term "or" is understood to be inclusive. Unless specifically stated or obvious from context, as used herein, the terms "a", "an", and "the" are understood to be singular or plural.

Unless specifically stated or obvious from context, as used herein, the term “about” is understood as within a range of normal tolerance in the art, for example within 2 standard deviations of the mean. About can be understood as within 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.5%, 0.1%, 0.05%, or 0.01% of the stated value. Unless otherwise clear from context, all numerical values provided herein are modified by the term about.

The recitation of a listing of chemical groups in any definition of a variable herein includes definitions of that variable as any single group or combination of listed groups. The recitation of an embodiment for a variable or aspect herein includes that embodiment as any single embodiment or in combination with any other embodiments or portions thereof.

Any compositions or methods provided herein can be combined with one or more of any of the other compositions and methods provided herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram showing the overall strategy used for the identification of novel serological biomarkers for inflammatory bowel disease using *E. coli* whole proteome chip. To fabricate the whole proteome chip, > 4,000 *E. coli* proteins were cloned and expressed. These proteins were purified using high-throughput protein purification protocol and printed onto FullMoon slides using a ChipWriter Pro robot. 134 patient sera were collected from the Johns Hopkins Hospital for this analysis. These sera were screen by *E. coli* proteome chips. Two-level of data analyses were performed: (i) global IBD analysis was performed to identify differentially immunogenic proteins in healthy control, CD and ulcerative colitis using Significance Analysis of Microarray (SAM) and Gene Ontology (GO) enrichment analysis; and (ii) serological IBD biomarkers discovery using k-TSP algorithm.

Figures 2A and 2B show representative images of *E. coli* proteome chips and a scatter plot, respectively. The proteome chip in Figure 2A was probed with sera from Crohn's Disease patients and healthy controls, respectively. Two *E. coli* proteome chips probed with sera from a Crohn's Disease (CD) patient (left panel) and a healthy control (HC) (right panel). To identify the proteins that can be recognized by reactive serum antibodies, each *E. coli* protein chip was incubated with a serum from healthy control or Crohn's Disease, as illustrated in Figure 1. Cy3-labeled anti-human immunoglobulin antibodies were then probed on the chips, allowing visualization of immunoreactive protein spots. The immunogenic profiles of both the IBD

patients and healthy control were acquired by the resulting fluorescent signals. Green spots are spots of *E. coli* protein in the chips detected by serum antibodies, representing immunogenic reactions. The intensity of the protein spots reflects immunogenicity of the proteins. Middle panel shows some representative images of immunogenic spots of three pairs of specific proteins (see more information of these proteins in Figure 5 and Tables 1-3) from these proteome chips. Every *E. coli* protein is spotted in duplicate on the chip. Crohn's Disease vs ulcerative colitis vs healthy control can be distinguished by comparing the signal intensities between protein spots on the *E. coli* proteome chips. Figure 2B is a scatter plot showing duplicate spots are highly correlated with each other ($R=0.985$). Each point is the plot of the original protein spot expression vs. the technical replicate protein spot expression. All 4265 proteins of a single array are displayed in this scatter plot.

Figure 3 shows global immunogenic profiles of IBD patients' sera against *E. coli* proteins. Figure 3A is a heatmap of 273 differentially immunogenic proteins between healthy controls (HC) and Crohn's Disease (CD) samples identified by SAM analysis. Yellow and blue colors indicate high and low immunogenic response, respectively. Figure 3B is a heatmap of the 188 differentially immunogenic proteins between Crohn's Disease and ulcerative colitis samples identified by SAM analysis; and Figure 3C illustrates 33 differentially immunogenic proteins between healthy controls and ulcerative colitis samples as identified by SAM analysis. Each row corresponds to a protein and each column corresponds to a sample. The expression level for each protein is normalized across the samples such that the mean is 0 and the standard deviation is 1. Blue and yellow indicates high and low immunogenic proteins, respectively. Figure 3D is a Venn diagram of these differentially immunogenic proteins showing only limited overlapping among healthy control vs Crohn's Disease vs ulcerative colitis.

Figure 4 is a graph showing the distribution of the cellular component terms in the highly immunogenic response proteins of healthy controls (HC), CD and ulcerative colitis. Six Cellular Component terms from the Gene Ontology were examined. Cell projection term contains flagellum and fimbrium proteins. The main messages include: 1) approximately 80% of the highly immunogenic proteins are either membrane proteins in healthy control ($p < 0.0001$), compared to only ~37% of the top immunogenic proteins in Crohn's Disease patients (not statistically significant); 2) conversely, ~30% of top immunogenic proteins in Crohn's Disease patients are intracellular proteins ($p < 0.05$) compared to only ~7% in healthy control (not

statistically significant); 3) a significant higher percentage of cell wall proteins (~26%) are immunogenic in ulcerative colitis ($p < 0.05$) compared to those in healthy control and Crohn's Disease (not significant); and 4) a significant percentage of macromolecular complex proteins (~16%; $p < 0.05$) in Crohn's Disease compared to those in healthy control or ulcerative colitis (not statistically significant). No statistically significant enrichment of proteins of periplasmic space and cell projection were found in healthy control, Crohn's Disease and ulcerative colitis.

Figure 5 includes three heat maps showing that k-TSP identified the top three pairs of biomarkers that can discriminate controls from Crohn's Disease patients. Each column represents the immunogenic reactivity by individual IBD patients or healthy control. Within a column, each row represents ratio of the immunogenic reactivity of a top scoring pair of proteins. The expression values represented are the ratio of immunogenic reactivity (fluorescent signal or intensity) to protein X divided by the signals to protein Y, referred to as the TSP ratio (X and Y being example proteins). If the immunogenic reactivity of a patient to protein X was greater than the reactivity to protein Y, the box will appear yellow, and blue for vice versa (see examples below). Figure 5A depicts the classifier for healthy control vs Crohn's Disease (yellow = CD, blue = HC). For example, if immunogenic reaction against era is $>$ ybaN, the subject is identified as having Crohn's Disease and shows as yellow (light shading). If not, then its indicative of a healthy control (blue) (dark shading). Figure 5B displays healthy control vs. ulcerative colitis classifier (yellow = ulcerative colitis, blue = healthy control). For example, if immunogenic reaction against relE is $>$ cysE_wcaB, the subject is identified as having ulcerative colitis and shows as yellow. If not, then its indicative of it is classified as a healthy control (blue). Figure 5C shows the Crohn's Disease vs. ulcerative colitis classifier (yellow = ulcerative colitis, blue = Crohn's Disease). If frvX is $\geq$ yidX, it is a ulcerative colitis (yellow), or else a CD (blue). See representative images of some of those protein pairs in Fig. 2. Figure 5D shows representative protein spots that were differentially recognized by sera from Crohn's Disease vs ulcerative colitis, respectively. This figure shows the relative immunogenic reactivity (fluorescent signals) of frvX and yidX by serum antibodies from a CD and ulcerative colitis patient.

Figures 6A-6C are scatter plots showing the immunogenic reactivity (signal) of the samples to era and ybaN individually (Figures 6A & B, respectively) and the TSP ratio (era/ybaN). Figures 6C shows that immunogenic reactivity to era or ybaN alone (the top scoring pair in the HC vs CD k-TSP classifier) does not allow for class separation of the data; no

threshold level would clearly separate healthy controls from Crohn's Disease. However, the ratio of the two features (top-scoring pair ratio) results in clear separation in the data lending well to classification Figure 6C. Similar results were found when scatter plot analysis were done for the other two TSP pairs from the HC vs Crohn's Disease classifier as shown in Fig. 5A.

5 Figure 7 scatter plots of immunoreactivity of OmpC and fliC, respectively, which were carried out as described in Figure 6C. The present study found that OmpC and fliC (Cbir), two of the known serological markers, performed poorly in the present study. The scatter plots display the normalized immunogenic signal to each protein for every serum sample. The samples are separated along the x-axis according to class (healthy control, CD, and ulcerative
10 colitis). Both statistical analysis and visual inspection demonstrate that antibodies against neither protein are capable of discriminating among the classes.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides biomarkers for use in serological testing for inflammatory
15 bowel disease, and methods of using such markers to distinguish among intestinal disorders and selected effective therapies.

The invention is based, at least in part, on the discovery of new serological markers using a whole *E. coli* proteome microarray as a novel high-throughput proteomic approach to screening and identifying IBD markers. Each protein array, which contains 4,256 *E. coli* K12 proteins,
20 was screened using individual serum from healthy controls (n = 39) and clinically well-characterized patients with IBD [66 Crohn's disease (CD) and 29 ulcerative colitis (UC)]. Proteins that could be recognized by serum antibodies were visualized and quantified using Cy3-labeled goat anti-human antibodies. Surprisingly, SAM (significant analysis of microarray) analysis identified a total of 417 *E. coli* proteins that were differentially recognized by serum
25 antibodies between healthy controls and Crohn's Disease or ulcerative colitis. Among those, 169 proteins were identified as highly immunogenic in healthy controls, 186 proteins are highly immunogenic in Crohn's Disease, only 19 in ulcerative colitis. Using a supervised learning algorithm (k-Top Scoring Pairs), two sets of serum antibodies were identified that were novel biomarkers for specifically distinguishing Crohn's Disease from healthy controls (accuracy:
30 86±4%; p<0.01), and Crohn's Disease from ulcerative colitis (accuracy: 80 ±2%; p<0.01), respectively. The Set 1 antibodies recognized three pairs of *E. coli* proteins: era vs ybaN, yhgN

vs *focA*, and *gabT* vs *ycdG* and the Set 2 antibodies recognized *yidX* vs *frvX*. The specificity and sensitivity of Set 1 antibodies were $81\pm5\%$ and $89\pm3\%$, respectively, while those of set 2 antibodies were $84\pm1\%$ and $70\pm6\%$, respectively. Serum antibodies identified for distinguishing healthy controls vs ulcerative colitis were only marginal, since their accuracy, specificity and sensitivity were $66\pm5\%$, $69\pm5\%$, and $61\pm7\%$, respectively ($p<0.04$). Taken together, novel sets of serological biomarkers have been identified for diagnosis of Crohn's disease vs healthy control and Crohn's disease vs ulcerative colitis.

The use of biomarkers is particularly important because Crohn's disease and ulcerative colitis share many symptoms, both clinically and histologically. This makes the diagnosis of these two diseases difficult. The differences between Crohn's disease and ulcerative colitis exist at many levels. Crohn's disease may occur anywhere along the digestive tract from the mouth to the anus (although in most cases distal ileum and colon are affected). In ulcerative colitis, the large intestine (colon) is typically the only site that is affected. Second, the pattern of inflammation may be different. Ulcerative colitis tends to be continuous throughout the inflamed area, while Crohn's disease exhibits skipped lesions or ranulomas (intermittent patterns between inflamed and healthy-looking tissues. Third, there can be difference in the degree of tissue penetration. In ulcerative colitis, the colonic mucosal lining is ulcerated, but this does not extend beyond the mucosal lining. In Crohn's, such ulceration is typically deeper and may extend to virtually any layers of colon wall. Finally, the complications associated with the disease may differ. In Crohn's disease patients may experience complications, such as fistulizing and structuring. These complications are much less frequent in ulcerative colitis. In up to 15% Crohn's patients, extra-intestinal manifestations of disease can also occur. These may include inflammation in tissues or organs outside the gastrointestinal tract. Interestingly, smoking is bad and of a risk factor for Crohn's disease but protective or therapeutic for UC.

Inflammatory Bowel Disease

Serological testing is a non-invasive method for diagnosing IBD, and differentiating ulcerative colitis from Crohn's disease (Li et al., (2008) *World J. Gastroenterol.* 14, 5115-5124; Peyrin-Biroulet et al. (2007) *Inflamm. Bowel. Dis.* 13, 1561-1566; Vermeire et al. (2008) *Gastroenterol. Clin. North Am.* 37, 429-438). Several serological IBD biomarkers have been identified in the past decade, and some have been used in the clinics of IBD (Li et al., (2008)

World J. Gastroenterol. 14, 5115-5124; Peyrin-Biroulet et al. (2007) Inflamm. Bowel. Dis. 13, 1561-1566; Vermeire et al. (2008) Gastroenterol. Clin. North Am. 37, 429-438). Many of these antibodies are produced on intestinal exposure to normal commensal bacteria in genetically susceptible individuals. Although it is not known whether these antibodies are pathogenic or not, they are specific to patients with either Crohn's disease or ulcerative colitis, and may reflect a dysregulated immune inflammatory response to intestinal bacterial antigens (Xavier (2007) Nature 448, 427-434, Strober (2002) Annu. Rev. Immunol. 20, 495-549; Blumberg (1999) Curr. Opin. Immunol. 11, 648-656; Papp et al., (2007) Inflamm. Bowel. Dis. 13, 984-992). Work on several experimental animal models of IBD have led to the suggestion that the pathogenesis of IBD may be the result of an aberrant immune response to normal commensal bacteria in genetically susceptible individuals. In fact, most of the major serological biomarkers being used in IBD clinics are antibodies to microbial antigens, including yeast oligomannan (anti-*Saccharomyces cerevisiae*, ASCA), bacterial outer membrane porin C (OmpC), *Pseudomonas fluorescens* bacterial sequence I2 (anti-I2), and most recently bacterial flagellin (CBir 1) (Li et al., (2008) World J. Gastroenterol. 14, 5115-5124; Peyrin-Biroulet et al. (2007) Inflamm. Bowel. Dis. 13, 1561-1566; Vermeire et al. (2008) Gastroenterol. Clin. North Am. 37, 429-438)). All of these anti-microbial antibodies show preponderance in patients with Crohn's Disease. However, ASCA has been identified in up to 5% of patients with ulcerative colitis.

In comparison, IBD-specific pANCA or antineutrophil cytoplasmic antibody with perinuclear highlighting was first described in 1990. Although generally considered an autoantibody, the specific antigenic stimulation for pANCA production remains unclear. This auto-antibody is present in up to 70% of patients with ulcerative colitis, and in up to 20% of patients with CD. Recently, a panel of five new anti-glycan antibodies have been identified, including anti-chitobioside IgA (ACCA), anti-laminaribioside IgG (ALCA), anti-manobioside IgG (AMCA), and antibodies against chemically synthesized (Σ) two major oligomannose epitopes, Man α -1,3 Man α -1,2 Man (Σ Man3) and Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) (Li (2008) World J. Gastroenterol. 14, 5115-5124, 13, 15). If desired, these conventional biomarkers may be used in combination with the new serological biomarkers delineated herein (e.g., Figure 5 and Tables 2-5, and 7).

Collectively, these antibodies are not generally present in either children or adults with non-IBD disease, and may represent serological markers of intestinal inflammation specific to

ulcerative colitis or Crohn's disease. Though encouraging, none of the current commercially available biomarker tests/assays, including all of those mentioned above, can be used as stand-alone tools in clinics, and therefore they are currently only recommended as an adjunct to endoscopy in diagnosis and prognosis of the disease (Li (2008) World J. Gastroenterol. 14, 5115-5124; 16, 17). Therefore, additional specific and sensitive IBD biomarkers are needed.

Proteomic technologies, such as 2-dimensional gel electrophoresis, various variations of mass spectrometry and protein chip (array) technology are now proving to be powerful tools in biomarker discovery and are beginning to be utilized in IBD biomarker discovery (Li (2008) World J. Gastroenterol. 14, 5115-5124;18). These technologies enable robust, and/or large-scale and high-throughput identification and analysis of differential protein expression when comparing disease to control. Blood-based (serum or plasma-based) proteomics hold particular promises for biomarker discovery of various human diseases such as neurodegenerative diseases and cancers (Goldknopf (2008) Expert Rev. Proteomics. 5, 1-8; Maurya et al., (2007) Anticancer Res. 27, 1247-1255; Veenstra et al. (2005) 4, 409-418.-21). Antigen microarrays are also powerful tools that allow high-throughput serum analysis of aberrant immune responses in autoimmune diseases, as well as efficient discovery of biomarkers for infectious pathogens. The present invention provides methods of using an *E. coli* proteome microarray to characterize differential immune responses (serum anti-*E. coli* antibodies) among patients clinically classified as having Crohn's disease, ulcerative colitis and healthy controls. In addition, the invention provides novel IBD-specific anti microbial antibodies, particularly anti-*E. coli* antibodies, which are present in IBD patients and were identified by screening the sera with *E. coli* protein arrays.

Serum Antibody Biomarkers

The present invention provides serum antibody biomarkers that are differentially present in subjects having an inflammatory bowel disease, such as Crohn's disease or ulcerative colitis. These serum antibody biomarkers specifically bind to particular *E. coli* polypeptides, which are delineated in Figure 5 and Tables 2-5, and 7. In particular, the invention provides that serum antibody biomarkers of the invention may be used individually or in combination with other markers to provide a method of diagnosing an inflammatory bowel disease. In one embodiment, the diagnosis of an inflammatory bowel disease involves distinguishing an inflammatory bowel disease from healthy controls. In certain embodiments, biomarkers comprises the pairs and sets

of *E. coli* polypeptides delineated in Figures 5A, 5B, and 5C and Table 7 and the corresponding serum antibodies. In another embodiment, the diagnosis of an inflammatory bowel disease involves distinguishing Crohn's disease from ulcerative colitis. The invention further provides methods for selecting or monitoring the efficacy of a therapeutic regimen in a subject having a
5 inflammatory bowel disease. Inflammatory bowel diseases include, but are not limited to Crohn's disease, ulcerative colitis, and indeterminate colitis.

Serum antibody biomarkers that are differentially present in samples of subjects having a inflammatory bowel disease and healthy control subjects find application in methods and kits for diagnosing an inflammatory bowel disease, such as Crohn's disease or ulcerative colitis, or
10 distinguishing inflammatory bowel disease from healthy control. Accordingly, methods are provided for identifying inflammatory bowel disease in a subject, which involve detecting a differential presence of a serum antibody biomarker in subjects with a inflammatory bowel disease in a biological sample (e.g., blood, sera, plasma) obtained from the subject. The amount
15 of one or more serum antibody biomarkers found in a test sample compared to a control, or the presence or absence of one or more serum antibody biomarkers in the test sample provides useful information regarding the inflammatory bowel disease status of the patient.

The serum antibody biomarkers can be measured in different types of biological samples. Preferably, the sample is a blood sample.

20 **Detection Methods**

The invention provides methods of detecting one or more serum antibody biomarkers associated with a inflammatory bowel disease or control markers in a blood sample obtained from a subject. The invention specifically describes the use of immunoassays to detect serum antibody biomarkers that specifically bind certain polypeptides or that measure the relative
25 immune reaction against certain polypeptides. For example, the invention provides for the detection of greater immunogenic reactivity to era than to ybaN, greater immunogenic reactivity to yhgN than to focA, and greater immunogenic reactivity to gabT than ycdG. When each of these differential immunogenic reactivities is present then the subject is identified as having Crohn's Disease. In another example, the detection of greater immunogenic reactivity to frvX
30 than to yidX identifies a subject as having ulcerative colitis.

In other embodiments, the invention provides at Table 7 methods for distinguishing Crohn's disease, ulcerative colitis, and healthy controls. In particular, microarrays comprising *E. coli* polypeptides delineated herein are useful for measuring immunogenic reactivity present in subject sera. Measurements can be relative to the immunogenic reactivity of another *E. coli* polypeptide. In one embodiment, the method provides that the following pairs can be used to measure relative levels of immunogenic reactivity.

For example, era > ybaN = Crohn's disease (CD)

The sequence of *E. coli* polypeptides are known in the art and can be identified in public databases by searching on the gene or polypeptide name. For example, the *E. coli* era polypeptide is NCBI Reference Sequence: AAA03242.1. The amino acid sequence of an exemplary era polypeptide is provided below.

```

1 msidksycgf iaivgrpnvg kstllnklg qkisitsrka qttrhrivgi htegayqaiy
61 vdtpglhmee krainrlmnk aasssigdve lvifvvegtr wtpddemvln kregkapvi
121 lavnkvdnvq ekadllphlq flasqmnfld ivpisaetgl nvdtiaaivr khlpeathhf
181 pedyitdrsq rfmaseiire klmrflgaei pysvtveier fvsnerggyd inglilvere
241 gqkkmvignk gakiktigie arkdmqemfe apvhlelvwk vksgwadder alrslgyvdd
301 1

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The sequence of an exemplary *E. coli* ybaN polypeptide (NCBI Reference Sequence: AP_001117.1) is provided below:

```

1 mqriiliig wlavvltglg vvlpvlpttp fillaawcfa rssprrfawl lyrswfgsyl
61 rfwqkhamp rgvkprail illtfaislw fvqmpwvril llvilacllf ymwripvide
121 kqekh

```

In another example, yhgN > focA = CD. The sequence of an exemplary *E. coli* yhgN (NCBI Reference Sequence: AP_004357) is provided below:

```

1 mneiisaavl lilimdplgn lpifmsvlkh tepkrrraim vrelliallv mlvflfagek
61 ilaflslrae tvsisggiil fliaikmifp sasgnssglp ageepfivpl aiplvagpti
121 latlmlslshq ypnqmghlvi alllawggtf villqssfl rllgekgvna lerlmglilv
181 mmatqmflgd irmwmkg

```

The sequence of an exemplary *E. coli* focA (NCBI Reference Sequence: AP_001534) is provided below:

```

1 mkadnpfdll lpaamakvae eagvykatkh plktfylait agvfisiafv fyitattgtg
61 tmpfgmaklv ggicfslgli lcvvcgadlf tstvlivak asgritwgql aknwlrvyfg
121 nlvgallfvl lmwlsgeymt angqwglnvl qtadhkvht fieavclgil anlmvclavw
181 msysgrslmd kafimvlpva mfvasgfehs ianmfimpmg ivirdfaspe fwtavgsape
241 nfshltvmnf itdnlipvti gniigggllv gltywviylr endhh

```

For example, gabT > ycdG = CD. The sequence of an exemplary *E. coli* gabT (NCBI Reference Sequence: AP_003235.1) is provided below:

```

1 mnsnkelmqr rsqaiprgvg qihpifadra encrvdveg reyldfaggi avlntghlhp
61 kvvaaveaql kklstcfqv layepylelc eimnqkvpqd fakktllvtt gseavenavk

```

121 iaraatkrsg tiafsgayhg rthytlaltg kvnpysagmg lmpghvyral ypcplhgise
 181 ddaiasihri fkndaapedi aaiviepvqg eggfyasspa fmqrllalcd ehgimliade
 241 vqsgagrtgt lfameqmgva pdlttfaksi aggfpagvt graevmdava pgglggtyag
 301 npiacvaale vlkvfeqenl lqkandlgqk lkdgllaiae khpeigdvrg lgamiaiel
 5 361 edgdhnpda kltaeivara rdkglillsc gpyynvrlil vpltiadaqi rqqleisqc
 421 fdeakq

The sequence of an exemplary *E. coli* ycdG (NCBI Reference Sequence: AP_001637.1)

is provided below.

1 mamfgfphwq lkststesgv vapderlpfa qtavmgvqha vamfgatvlm pilmgldpnl
 10 61 silmsgigtl lfffitggrv psylgssaaf vgvviaatgf ngqginpnis ialggiiacg
 121 lvytviglvv mkigtrwier lmpvvvtgav vmaignlap iavksvsasa fdswmavmtv
 181 lciglavavft rgmiqrllil vglivacilly gvmtnlvlgk kavdftlvsh aawfglphfs
 241 tpaingqamm liapvavilv aenlghlkav agmtgrnmdp ymgrafvvgd latmlsgsvg
 301 gsgvttyaen igvmavtkvy stlvfvaaav iamllgfspk fgalihtipa aviggasivv
 15 361 fgliavagar iwvqnrvids qngnlimvav tlvlgagdfa ltlggftlvg igtatfgail
 421 lnallsrklv dvpppevvhq ep

In other examples yidX (NCBI AP_004097) > frvX = UC; relE (NCBI ABD51640.1) >
 cysE/wcaB (NCBI CAQ33933.1) = UC; lnt (NCBI AP_001306.1) > ybiO (NCBI AP_001439.1
 20)= UC; ftsE (NCBI AP_004329.1) > pssR (NCBI F65179) = UC; yhgN (NCBI AP_004357.1) >
 yhfG (NCBI AP_004427.1) = UC; yafN (NCBI AP_000885.1) > dsbB (NCBI AP_001810.1) =
 UC; yihI (NCBI AP_003942.1) > yabK (NCBI AAC73178.1) = UC
 421#15 > yhdN (NCBI AAC76318.1) = UC; hisP (NCBI AAC75366.1) > rpLO (NCBI
 AAC76326.1) = UC; cml (NCBI P12056.1) > nuoM (NCBI AP_002875.1) = UC; yieC (NCBI
 25 AAC76743.1) > nuoI (NCBI AP_002879.1) = UC.

One of skill in the art will recognize that any suitable method can be used to detect the
 serum antibody biomarkers described herein. Successful practice of the invention can be
 achieved with one or a combination of methods that can detect and/or quantify the markers.
 Such methods include, without limitation, hybridization-based methods including those
 30 employed in microarrays, mass spectrometry (e.g., laser desorption/ionization mass
 spectrometry), fluorescence (e.g. sandwich immunoassay), surface plasmon resonance,
 ellipsometry, atomic force microscopy, and 2-dimensional gel electrophoresis. Methods may
 further include, one or more of electrospray ionization mass spectrometry (ESI-MS), ESI-
 MS/MS, ESI-MS/(MS)_n, matrix-assisted laser desorption ionization time-of-flight mass
 35 spectrometry (MALDI-TOF-MS), surface-enhanced laser desorption/ionization time-of-flight
 mass spectrometry (SELDI-TOF-MS), desorption/ionization on silicon (DIOS), secondary ion
 mass spectrometry (SIMS), quadrupole time-of-flight (Q-TOF), atmospheric pressure chemical
 ionization mass spectrometry (APCI-MS), atmospheric pressure photoionization mass

spectrometry (APPI-MS), quadrupole mass spectrometry, fourier transform mass spectrometry (FTMS), and ion trap mass spectrometry. In one preferred embodiment, detection methods employ a microchip array comprising immunogenic pathogen (e.g., *E. coli*) polypeptides.

5 Microarrays

As described herein, collections of immunogenic *E. coli* polypeptides may be used to identify serum antibody biomarker profiles that are associated with inflammatory bowel disease. These collections preferably include polypeptides that are differentially immunogenic (e.g., polypeptides that induce serum antibody biomarkers in healthy controls, but not in inflammatory
10 bowel disease, or polypeptides that induce serum antibody biomarkers in inflammatory bowel disease or ulcerative colitis, but not in healthy controls). Such polypeptides of the invention are useful as hybridizable array elements in a microarray. Polypeptides useful in arrays of the invention include, but are not limited to, those polypeptides delineated in Figure 5 and Tables 2-5, and 7. The array elements are organized in an ordered fashion such that each element is
15 present at a specified location (i.e., an addressable location) on the substrate. Useful substrate materials include membranes, composed of paper, nylon or other materials, filters, chips, glass slides, and other solid supports. The ordered arrangement of the array elements allows hybridization patterns and intensities to be interpreted as levels of particular serum antibody biomarkers. Methods for making polypeptide microarrays are described, for example, by Ge
20 (Nucleic Acids Res. 28: e3. i-e3. vii, 2000), MacBeath et al., (Science 289:1760-1763, 2000), Zhu et al. (Nature Genet. 26:283-289), and in U.S. Pat. No. 6,436,665, hereby incorporated by reference.

Serum antibody biomarkers associated with inflammatory bowel disease may be analyzed using protein microarrays comprising the entire *E. coli* proteome, or comprising as few as one,
25 two, three, four, five, or six *E. coli* proteins. Typically, protein microarrays feature a protein, or fragment thereof, bound to a solid support. Suitable solid supports include membranes (e.g., membranes composed of nitrocellulose, paper, or other material), polymer-based films (e.g., polystyrene), beads, or glass slides. For some applications, proteins are spotted on a substrate using any convenient method known to the skilled artisan (e.g., by hand or by inkjet printer).
30 Preferably, such methods retain the biological activity or function of the protein bound to the substrate (Ge et al., supra; Zhu et al., supra).

The protein microarray is hybridized with blood, serum, or plasma derived from a subject. The sample comprises antibodies that specifically bind an *E. coli* polypeptide, thereby acting as probes. Probes can also include antibodies, candidate peptides, nucleic acids, or small molecule compounds derived from a peptide, nucleic acid, or chemical library. Hybridization conditions (e.g., temperature, pH, protein concentration, and ionic strength) are optimized to promote specific interactions. Such conditions are known to the skilled artisan and are described, for example, in Harlow, E. and Lane, D., *Using Antibodies : A Laboratory Manual*. 1998, New York: Cold Spring Harbor Laboratories. After removal of non-specific probes, specifically bound probes are detected, for example, by fluorescence, enzyme activity (e.g., an enzyme-linked calorimetric assay), direct immunoassay, radiometric assay, or any other suitable detectable method known to the skilled artisan.

The biochip surfaces may, for example, be ionic, anionic, hydrophobic; comprised of immobilized nickel or copper ions, comprised of a mixture of positive and negative ions; and/or comprised of one or more antibodies, single or double stranded nucleic acids, proteins, peptides or fragments thereof, amino acid probes, or phage display libraries. Many protein biochips are described in the art. These include, for example, protein biochips produced by CIPHERGEN Biosystems (Fremont, CA), Packard BioScience Company (Meriden CT), Zyomyx (Hayward, CA) and Phyllos (Lexington, MA). Examples of such protein biochips are described in the following patents or patent applications: U.S. Patent 6,225,047 (Hutchens and Yip, "Use of retentate chromatography to generate difference maps," May 1, 2001); International publication WO 99/51773 (Kuimelis and Wagner, "Addressable protein arrays," October 14, 1999); U.S. Patent 6,329,209 (Wagner et al., "Arrays of protein-capture agents and methods of use thereof," December 11, 2001) and International publication WO 00/56934 (Englert et al., "Continuous porous matrix arrays," September 28, 2000).

Serum antibody biomarkers may be captured with capture reagents (e.g., target polypeptides) immobilized to a solid support, such as a biochip, a multiwell microtiter plate, a resin, or nitrocellulose membranes that are subsequently probed for the presence of proteins. Capture can be on a chromatographic surface or a biospecific surface. For example, a serological sample containing the serum antibody biomarkers may be contacted with the active surface of a biochip for a sufficient time to allow binding. Then, unbound molecules are washed

from the surface using a suitable eluant, such as phosphate buffered saline. In general, the more stringent the eluant, the more tightly the proteins must be bound to be retained after the wash.

Upon capture on a biochip, analytes can be detected by a variety of detection methods selected from, for example, a gas phase ion spectrometry method, an optical method, an electrochemical method, atomic force microscopy and a radio frequency method. Gas phase ion spectrometry methods are described herein. Of particular interest is the use of mass spectrometry, and in particular, SELDI. Optical methods include, for example, detection of fluorescence, luminescence, chemiluminescence, absorbance, reflectance, transmittance, birefringence or refractive index (e.g., surface plasmon resonance, ellipsometry, a resonant mirror method, a grating coupler waveguide method or interferometry). Optical methods include microscopy (both confocal and non-confocal), imaging methods and non-imaging methods. Immunoassays in various formats (e.g., ELISA) are popular methods for detection of analytes captured on a solid phase. Electrochemical methods include voltametry and amperometry methods. Radio frequency methods include multipolar resonance spectroscopy.

Mass spectrometry (MS) is a well-known tool for analyzing chemical compounds. Thus, in one embodiment, the methods of the present invention comprise performing quantitative MS to measure serum antibody biomarkers present in a serological sample. The method may be performed in an automated (Villanueva, *et al.*, *Nature Protocols* (2006) 1(2):880-891) or semi-automated format. This can be accomplished, for example with MS operably linked to a liquid chromatography device (LC-MS/MS or LC-MS) or gas chromatography device (GC-MS or GC-MS/MS). Methods for performing MS are known in the field and have been disclosed, for example, in US Patent Application Publication Nos: 20050023454; 20050035286; USP 5,800,979 and references disclosed therein.

The protein fragments, whether they are peptides derived from the main chain of the protein or are residues of a side-chain, are collected on the collection layer. They may then be analyzed by a spectroscopic method based on matrix-assisted laser desorption/ionization (MALDI) or electrospray ionization (ESI). The preferred procedure is MALDI with time of flight (TOF) analysis, known as MALDI-TOF MS. This involves forming a matrix on the membrane, e.g. as described in the literature, with an agent which absorbs the incident light strongly at the particular wavelength employed. The sample is excited by UV, or IR laser light into the vapour phase in the MALDI mass spectrometer. Ions are generated by the vaporization

and form an ion plume. The ions are accelerated in an electric field and separated according to their time of travel along a given distance, giving a mass/charge (m/z) reading which is very accurate and sensitive. MALDI spectrometers are commercially available from PerSeptive Biosystems, Inc. (Framingham, Mass., USA) and are described in the literature, e.g. M.

5 Kussmann and P. Roepstorff, cited above.

Diagnostics

Levels of particular serum antibody biomarkers have been correlated with a particular inflammatory bowel disease state, and thus are useful in diagnosis. In one embodiment, a patient
10 having a inflammatory bowel disease will show an alteration in the expression of one or more serum antibody biomarkers delineated herein. In another embodiment, a patient having a inflammatory bowel disease will have a particular expression profile that includes significantly altered expression of two or more serum antibody biomarkers. Alterations in serum antibody biomarkers levels are detected using methods known to the skilled artisan and described herein.

15 If desired, biomarkers delineated herein are used alone or in combination with convention biomarkers, which include anti-glycan antibodies (e.g., anti-chitobioside IgA (ACCA), anti-laminaribioside IgG (ALCA), anti-manobioside IgG (AMCA)), antibodies against chemically synthesized (Σ) two major oligomannose epitopes, Man α -1,3 Man α -1,2 Man (Σ Man3) and Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) (Li (2008) World J. Gastroenterol. 14, 5115-5124; 13,
20 15), IBD-specific pANCA or antineutrophil cytoplasmic antibody, antibodies to microbial antigens (e.g., yeast oligomanna (anti-*Saccharomyces cerevisiae*, ASCA), bacterial outer membrane porin C (OmpC), *Pseudomonas fluorescens* bacterial sequence I2 (anti-I2), and antibodies against bacterial flagellin).

In one embodiment, *E. coli* polypeptides or fragments derived from these polypeptides
25 may be used as targets in a microarray. The microarray is used to assay the level of large numbers of serum antibody biomarkers simultaneously and to identify alterations in the overall or relative levels of expression. Such information can be used to diagnose a inflammatory bowel disease or a subject having a propensity to develop such a condition.

In one embodiment, an increased level of a serum antibody biomarker that specifically
30 binds frvX relative to the level of serum antibody biomarker that binds yidX identifies a subject as having ulcerative colitis. In another embodiment an increased level of serum antibody

biomarker binding to era relative to ybaN, increased serum antibody biomarker binding to yhgN relative to focA, and/or increased serum antibody biomarker binding to gabT relative to ycdG identifies a subject as having Crohn's Disease. A variety of protocols for measuring an alteration in the expression of such polypeptides are known, including immunological methods (such as ELISAs and RIAs), and provide a basis for diagnosing an inflammatory bowel disease.

In additional embodiment of the methods of the present invention, multiple markers are measured. The use of multiple markers increases the predictive value of the test and provides greater utility in diagnosis, treatment selection, patient stratification and patient monitoring. The process detects serum antibody biomarker profiles formed by the analysis of multiple markers.

Such analysis may improve the sensitivity and specificity of tests delineated herein. Subtle variations in data from clinical samples indicate that certain patterns of serum antibody biomarker expression can predict phenotypes such as the presence or absence of a certain disease, a particular stage of disease progression, or a positive or adverse response to drug treatments.

Data generated by detection of serum antibody biomarkers can be analyzed using any suitable means. In one embodiment, data is analyzed with the use of a programmable digital computer. The computer program generally contains a readable medium that stores data. This data can indicate the number of serum antibody biomarkers detected, including the strength of the signal generated by each marker. Data analysis can include the steps of determining signal strength of a marker detected. When the sample is measured and data is generated, the data is then analyzed by a computer software program

As indicated above, the invention provides methods for aiding a human inflammatory bowel disease diagnosis using one or more serum antibody biomarkers, as specified herein. These markers can be used alone, in combination with other markers in any set, or with entirely different markers in aiding human inflammatory bowel disease diagnosis. The serum antibody biomarkers are differentially present in samples of a subject having or having a propensity to develop a inflammatory bowel disease and a healthy control subject in whom inflammatory bowel disease is undetectable. For example, some of the serum antibody biomarkers are expressed at an elevated level and/or are present at a higher frequency in human inflammatory bowel disease subjects than in normal subjects, while some of the serum antibody biomarkers are expressed at a decreased level and/or are present at a lower frequency in human inflammatory

bowel disease subjects than in normal subjects. Therefore, detection of one or more of these markers in a person would provide useful information regarding the probability that the person may have an inflammatory bowel disease.

The detection of a marker is then correlated with a probable diagnosis of inflammatory
5 bowel disease. In some embodiments, the detection of the mere presence or absence of a marker, without quantifying the amount thereof, is useful and can be correlated with a probable diagnosis of inflammatory bowel disease. The measurement of markers may also involve quantifying the markers to correlate the detection of markers with a probable diagnosis of inflammatory bowel disease. Thus, if the amount of the markers detected in a subject being tested is different
10 compared to a control amount (i.e., higher or lower than the control, depending on the marker), then the subject being tested has a higher probability of having inflammatory bowel disease.

The correlation may take into account the amount of the serum antibody biomarkers in the sample compared to a control amount of the serum antibody biomarkers (up or down regulation of the marker or markers) in normal subjects or in subjects where inflammatory bowel
15 disease is undetectable. A control can be, e.g., the average or median amount of marker present in comparable samples of normal subjects. The control amount is measured under the same or substantially similar experimental conditions as in measuring the test amount. As a result, the control can be employed as a reference standard, where the normal phenotype is known, and each result can be compared to that standard, rather than re-running a control.

Accordingly, a serum antibody biomarkers profile may be obtained from a subject sample
20 and compared to a reference marker profile obtained from a reference population, so that it is possible to classify the subject as belonging to or not belonging to the reference population. The correlation may take into account the presence or absence of the markers in a test sample and the frequency of detection of the same markers in a control. The correlation may take into account
25 both of such factors to facilitate determination inflammatory bowel disease status.

Any marker, individually, is useful in aiding in the determination of inflammatory bowel disease status. First, the selected serum antibody biomarkers is detected in a subject sample using the methods described herein (e.g. microarray analysis). Then, the result is compared with a control that distinguishes inflammatory bowel disease status from non-inflammatory bowel
30 disease status. As is well understood in the art, the techniques can be adjusted to increase sensitivity or specificity of the diagnostic assay depending on the preference of the diagnostician.

While individual serum antibody biomarkers are useful diagnostic markers, in some instances, a combination of markers provides greater predictive value than single markers alone. The detection of a plurality of markers (or absence thereof, as the case may be) in a sample can increase the percentage of true positive and true negative diagnoses and decrease the percentage of false positive or false negative diagnoses. Thus, one method of the present invention provides for the measurement of more than one marker.

Optionally, methods described herein may be combined with any conventional method for the diagnosis of IBD (e.g., stool sample analysis, colonoscopy or sigmoidoscopy, barium x-ray, computerized axial tomography, and or capsule endoscopy).

Monitoring

Methods of characterizing inflammatory bowel disease in a subject are also useful in managing subject treatment based on the subject's status. The invention provides for such methods where the serum antibody biomarkers (or specific combinations of markers) are measured before and again after subject management. In these cases, the methods are used to monitor the status of the inflammatory bowel disease, e.g., response to inflammatory bowel disease treatment, amelioration of the disease or progression of the disease.

For example, markers of the invention (e.g., antibodies that bind an E. coli polypeptide listed in Figure 5 and Tables 2-5, and 7) can be used to monitor a subject's response to certain treatments of inflammatory bowel disease. The level or function of a marker delineated herein may be measured before treatment, during treatment, or following the conclusion of a treatment regimen. Preferably, multiple measurements (e.g., 2, 3, 4, 5) are made at one or more of those times. Measurements are made, for example, using an immunoassay, microarray or other method to determine the expression profile of one or more serum antibody biomarkers. Such monitoring may be useful, for example, in assessing the efficacy of a particular drug in a patient. Therapeutics that normalize the levels of a serum antibody biomarker (e.g., that increase or reduce levels to correspond to levels present in a healthy control subject) are taken as particularly useful in the invention.

Kits

In one aspect, the invention provides kits for monitoring and diagnosing inflammatory bowel disease, wherein the kits can be used to detect the markers described herein. For example, the kits can be used to detect any one or more of the markers differentially present in samples of inflammatory bowel disease subjects vs. normal subjects. If desired a kit of the invention includes any one or more of the *E. coli* polypeptides listed in Figure 5 and Tables 2-5, and 7. In one embodiment, the kit comprises a set of biomarkers for distinguishing Crohn's Disease from healthy control, the set comprising era, ybaN, yhgN, focA, ga bT and ycdG. In another embodiment, the kit comprises the set of biomarkers for distinguishing Crohns from UC, which is yidx/frvx. If desired, the kit comprises reagents suitable for measuring conventional IBD biomarkers, including anti-glycan antibodies (e.g., anti-chitobioside IgA (ACCA), anti-laminaribioside IgG (ALCA), anti-manobioside IgG (AMCA)), antibodies against chemically synthesized (Σ) two major oligomannose epitopes, Man α -1,3 Man α -1,2 Man (Σ Man3) and Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) (Li (2008) World J. Gastroenterol. 14, 5115-512413, 15), IBD-specific pANCA or antineutrophil cytoplasmic antibody, antibodies to microbial antigens (e.g., yeast oligomanna (anti-*Saccharomyces cerevisiae*, ASCA), bacterial outer membrane porin C (OmpC), *Pseudomonas fluorescens* bacterial sequence I2 (anti-I2), and antibodies against bacterial flagellin (Cbir).

The kits of the invention have many applications. For example, the kits can be used to distinguish between inflammatory bowel disease and control, to determine if a subject has a Crohn's Disease or ulcerative colitis, or to determine that the subject does not have inflammatory bowel disease, thus aiding in inflammatory bowel disease diagnosis. The kits can also be used to identify compounds that modulate expression of one or more of the serum antibody biomarkers in an animal model of inflammatory bowel disease.

The kits of the invention may include instructions for the assay, reagents, testing equipment (test tubes, reaction vessels, needles, syringes, etc.), standards for calibrating the assay, and/or equipment provided or used to conduct the assay. Reagents may include acids, bases, oxidizing agents, marker species. The instructions provided in a kit according to the invention may be directed to suitable operational parameters in the form of a label or a separate insert.

The kits may also include an adsorbent, wherein the adsorbent retains one or more markers selected from one or more of the markers described herein, and written instructions for use of the kit for detection of an inflammatory bowel disease. Such a kit could, for example, comprise: (a) a substrate comprising an adsorbent thereon, wherein the adsorbent is suitable for binding a serum antibody biomarkers, and (b) instructions to detect the serum antibody biomarkers by contacting a sample with the adsorbent and detecting the serum antibody biomarkers retained by the adsorbent. Accordingly, the kit could further comprise a detection reagent.

Optionally, the kit may further comprise a standard or control information so that the test sample can be compared with the control information standard to determine if the test amount of a marker detected in a sample is a diagnostic amount consistent with a diagnosis of inflammatory bowel disease.

Selection of a Treatment Method

After a subject is diagnosed as having inflammatory bowel disease a method of treatment is selected. Because inflammatory bowel disease typically involves an excessive or undesirable immune response, therapies often involve treatment with immunosuppressive agents. Such therapies would not be appropriate for a subject that has irritable bowel syndrome. Thus, the invention provides methods for selecting an appropriate therapy for a subject, the method involving identifying a subject as having inflammatory bowel disease, Crohn's disease or ulcerative colitis, and administering to the subject a therapeutic treatment appropriate for that disease. Exemplary treatments for IBD include but are not limited to aminosalicylates, immunomodulators, infliximab, adalimumab, certolizumab, and/or antibiotics.

Biomarkers identified herein are useful for identifying subjects in need of surgery. In particular embodiments, pairs and sets of biomarkers delineated in Tables 2-5, 7, and Figure 5 are useful alone or in combination with existing biomarkers to identify subjects that could benefit from surgery.

***E. coli* polypeptides and Analogs**

Also included in the invention are *E. coli* polypeptides or fragments thereof that are modified in ways that enhance or do not inhibit their ability to bind a serum antibody. In one

embodiment, the invention provides methods for optimizing an *E. coli* amino acid sequence or nucleic acid sequence by producing an alteration. Such changes may include certain mutations, deletions, insertions, or post-translational modifications. In one preferred embodiment, the *E. coli* amino acid sequence is modified to enhance protease resistance. Accordingly, the invention further includes polypeptides of other yeast or bacteria having at least 85%, 90%, 95% or greater sequence identity to an *E. coli* polypeptide delineated herein. In other embodiments, the invention includes analogs of any naturally-occurring polypeptide of the invention. Analogs can differ from the naturally-occurring the polypeptide of the invention by amino acid sequence differences, by post-translational modifications, or by both. Analogs of the invention will generally exhibit at least 85%, more preferably 90%, and most preferably 95% or even 99% identity with all or part of a naturally-occurring amino, acid sequence of the invention. The length of sequence comparison is at least 10, 13, 15 amino acid residues, preferably at least 25 amino acid residues, and more preferably more than 35 amino acid residues. Again, in an exemplary approach to determining the degree of identity, a BLAST program may be used, with a probability score between e^{-3} and e^{-100} indicating a closely related sequence. Modifications include *in vivo* and *in vitro* chemical derivatization of polypeptides, e.g., acetylation, carboxylation, phosphorylation, or glycosylation; such modifications may occur during polypeptide synthesis or processing or following treatment with isolated modifying enzymes. Analogs can also differ from the naturally-occurring polypeptides of the invention by alterations in primary sequence. These include genetic variants, both natural and induced (for example, resulting from random mutagenesis by irradiation or exposure to ethanemethylsulfate or by site-specific mutagenesis as described in Sambrook, Fritsch and Maniatis, Molecular Cloning: A Laboratory Manual (2d ed.), CSH Press, 1989, or Ausubel et al., supra). Also included are cyclized peptides, molecules, and analogs which contain residues other than L-amino acids, e.g., D-amino acids or non-naturally occurring or synthetic amino acids, e.g., .beta. or .gamma. amino acids.

In addition to full-length polypeptides, the invention also includes fragments of any one of the polypeptides of the invention. As used herein, the term "a fragment" means at least 5, 10, 13, or 15 amino acids in length. In other embodiments a fragment is at least 20 contiguous amino acids, at least 30 contiguous amino acids, or at least 50 contiguous amino acids, and in other embodiments at least 60 to 80 or more contiguous amino acids. Fragments of the invention

can be generated by methods known to those skilled in the art or may result from normal protein processing (e.g., removal of amino acids from the nascent polypeptide that are not required for biological activity or removal of amino acids by alternative mRNA splicing or alternative protein processing events).

5

Screening Assays

Methods of the invention are useful for the high-throughput low-cost screening of candidate agents that bind an *E. coli* polypeptide described herein. A candidate agent that specifically binds to a *E. coli* is then isolated and tested for activity in an *in vitro* assay or *in vivo* assay. If desired, the candidate agent comprises a detectable label. In one embodiment, such polypeptides are subsequently screened for an effect on bacterial proliferation or as agents that block antibody binding to a *E. coli* polypeptide listed herein. One skilled in the art appreciates that the effects of a candidate agent on a cell is typically compared to a corresponding control cell not contacted with the candidate agent. Thus, the screening methods include comparing the effect of a candidate agent with an untreated control cell.

In one embodiment, candidate compounds may be identified by first assaying those that specifically bind to an *E. coli* polypeptide of the invention. Such an interaction can be readily assayed using any number of standard binding techniques and functional assays (e.g., those described in Ausubel et al., supra). For example, a candidate compound may be tested *in vitro* for interaction and binding with a polypeptide of the invention and its ability to modulate bacterial proliferation may be assayed by any standard assays (e.g., those described herein)

In one particular example, a candidate compound that binds to an *E. coli* polypeptide may be identified using a chromatography-based technique. For example, a recombinant *E. coli* polypeptide of the invention may be purified by standard techniques from cells engineered to express the polypeptide, or may be chemically synthesized, once purified the peptide is immobilized on a column. A solution of candidate agents is then passed through the column, and an agent that specifically binds the polypeptide or a fragment thereof is identified on the basis of its ability to bind to polypeptide and to be immobilized on the column. To isolate the agent, the column is washed to remove non-specifically bound molecules, and the agent of interest is then released from the column and collected. Agents isolated by this method (or any other appropriate method) may, if desired, be further purified (e.g., by high performance liquid

chromatography). In addition, these candidate agents may be tested for their ability to reduce bacterial proliferation or block serum antibody binding to an *E. coli* polypeptide. Agents isolated by this approach may also be used, for example, as therapeutics to treat or prevent inflammatory bowel disease (e.g., Crohn's, ulcerative colitis). Compounds that are identified as binding to a an
5 *E. coli* polypeptide with an affinity constant less than or equal to 1 nM, 5 nM, 10 nM, 100 nM, 1 mM or 10 mM are considered particularly useful in the invention.

Such agents may be used, for example, as a therapeutic to combat the pathogenicity of an bacterial pathogen. Optionally, agents identified in any of the above-described assays may be confirmed as useful in conferring protection against the development of a pathogen infection in
10 any standard animal model and, if successful, may be used as anti-pathogen therapeutics.

Each of the protein sequences provided herein may also be used in the discovery and development of antipathogenic compounds (e.g., antibiotics). The *E. coli* protein, upon expression, can be used as a target for the screening of drugs to treat or prevent IBD.

15 **Test Compounds and Extracts**

In general, candidate agents are identified from large libraries of natural product or synthetic (or semi-synthetic) extracts or chemical libraries or from polypeptide or nucleic acid libraries, according to methods known in the art. Those skilled in the field of drug discovery and development will understand that the precise source of test extracts or compounds is not critical
20 to the screening procedure(s) of the invention. Agents used in screens may include known those known as therapeutics for the treatment of pathogen infections. Alternatively, virtually any number of unknown chemical extracts or compounds can be screened using the methods described herein. Examples of such extracts or compounds include, but are not limited to, plant-, fungal-, prokaryotic- or animal-based extracts, fermentation broths, and synthetic compounds, as
25 well as the modification of existing polypeptides.

Libraries of natural polypeptides in the form of bacterial, fungal, plant, and animal extracts are commercially available from a number of sources, including Biotics (Sussex, UK), Xenova (Slough, UK), Harbor Branch Oceanographics Institute (Ft. Pierce, Fla.), and PharmaMar, U.S.A. (Cambridge, Mass.). Such polypeptides can be modified to include a protein transduction
30 domain using methods known in the art and described herein. In addition, natural and synthetically produced libraries are produced, if desired, according to methods known in the art,

e.g., by standard extraction and fractionation methods. Examples of methods for the synthesis of molecular libraries can be found in the art, for example in: DeWitt *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* 90:6909, 1993; Erb *et al.*, *Proc. Natl. Acad. Sci. USA* 91:11422, 1994; Zuckermann *et al.*, *J. Med. Chem.* 37:2678, 1994; Cho *et al.*, *Science* 261:1303, 1993; Carrell *et al.*, *Angew. Chem. Int. Ed. Engl.* 33:2059, 1994; Carell *et al.*, *Angew. Chem. Int. Ed. Engl.* 33:2061, 1994; and Gallop *et al.*, *J. Med. Chem.* 37:1233, 1994. Furthermore, if desired, any library or compound is readily modified using standard chemical, physical, or biochemical methods.

Numerous methods are also available for generating random or directed synthesis (e.g., semi-synthesis or total synthesis) of any number of polypeptides, chemical compounds, including, but not limited to, saccharide-, lipid-, peptide-, and nucleic acid-based compounds. Synthetic compound libraries are commercially available from Brandon Associates (Merrimack, N.H.) and Aldrich Chemical (Milwaukee, Wis.). Alternatively, chemical compounds to be used as candidate compounds can be synthesized from readily available starting materials using standard synthetic techniques and methodologies known to those of ordinary skill in the art. Synthetic chemistry transformations and protecting group methodologies (protection and deprotection) useful in synthesizing the compounds identified by the methods described herein are known in the art and include, for example, those such as described in R. Larock, *Comprehensive Organic Transformations*, VCH Publishers (1989); T. W. Greene and P. G. M. Wuts, *Protective Groups in Organic Synthesis*, 2nd ed., John Wiley and Sons (1991); L. Fieser and M. Fieser, *Fieser and Fieser's Reagents for Organic Synthesis*, John Wiley and Sons (1994); and L. Paquette, ed., *Encyclopedia of Reagents for Organic Synthesis*, John Wiley and Sons (1995), and subsequent editions thereof.

Libraries of compounds may be presented in solution (e.g., Houghten, *Biotechniques* 13:412-421, 1992), or on beads (Lam, *Nature* 354:82-84, 1991), chips (Fodor, *Nature* 364:555-556, 1993), bacteria (Ladner, U.S. Patent No. 5,223,409), spores (Ladner U.S. Patent No. 5,223,409), plasmids (Cull *et al.*, *Proc Natl Acad Sci USA* 89:1865-1869, 1992) or on phage (Scott and Smith, *Science* 249:386-390, 1990; Devlin, *Science* 249:404-406, 1990; Cwirla *et al.* *Proc. Natl. Acad. Sci.* 87:6378-6382, 1990; Felici, *J. Mol. Biol.* 222:301-310, 1991; Ladner *supra.*).

In addition, those skilled in the art of drug discovery and development readily understand that methods for dereplication (e.g., taxonomic dereplication, biological dereplication, and

chemical dereplication, or any combination thereof) or the elimination of replicates or repeats of materials already known for their activity should be employed whenever possible.

When a crude extract is found to have *E. coli* polypeptide binding activity further fractionation of the positive lead extract is necessary to isolate molecular constituents responsible for the observed effect. Thus, the goal of the extraction, fractionation, and purification process is the careful characterization and identification of a chemical entity within the crude extract that treats or prevents IBD or acts as an antibiotic. Methods of fractionation and purification of such heterogenous extracts are known in the art. If desired, compounds shown to be useful as therapeutics are chemically modified according to methods known in the art.

The present invention provides methods of treating inflammatory bowel disease and/or disorders or symptoms thereof which comprise administering a therapeutically effective amount of a pharmaceutical composition comprising a compound of the formulae herein to a subject (e.g., a mammal such as a human). Thus, one embodiment is a method of treating a subject suffering from or susceptible to a inflammatory bowel disease or disorder or symptom thereof.

The method includes the step of administering to the mammal a therapeutic amount of an amount of a compound herein sufficient to treat the disease or disorder or symptom thereof, under conditions such that the disease or disorder is treated.

The methods herein include administering to the subject (including a subject identified as in need of such treatment) an effective amount of a compound described herein, or a composition described herein to produce such effect. Identifying a subject in need of such treatment can be in the judgment of a subject or a health care professional and can be subjective (e.g. opinion) or objective (e.g. measurable by a test or diagnostic method). As used herein, the terms "treat," "treating," "treatment," and the like refer to reducing or ameliorating a disorder and/or symptoms associated therewith. It will be appreciated that, although not precluded, treating a disorder or condition does not require that the disorder, condition or symptoms associated therewith be completely eliminated. As used herein, the terms "prevent," "preventing," "prevention," "prophylactic treatment" and the like refer to reducing the probability of developing a disorder or condition in a subject, who does not have, but is at risk of or susceptible to developing a disorder or condition.

The therapeutic methods of the invention (which include prophylactic treatment) in general comprise administration of a therapeutically effective amount of the compounds herein,

such as a compound of the formulae herein to a subject (e.g., animal, human) in need thereof, including a mammal, particularly a human. Such treatment will be suitably administered to subjects, particularly humans, suffering from, having, susceptible to, or at risk for a disease, disorder, or symptom thereof. Determination of those subjects "at risk" can be made by any
5 objective or subjective determination by a diagnostic test or opinion of a subject or health care provider (e.g., genetic test, enzyme or protein marker, Marker (as defined herein), family history, and the like). The compounds herein may be also used in the treatment of any other disorders in which inflammation of the intestine may be implicated.

In one embodiment, the invention provides a method of monitoring treatment progress.

10 The method includes the step of determining a level of diagnostic marker (Marker) (e.g., any target delineated herein) or diagnostic measurement (e.g., screen, assay) in a subject suffering from or susceptible to a inflammatory bowel disease, or disorder or symptoms thereof associated with intestinal inflammation. The level of Marker determined in the method can be compared to known levels of Marker in either healthy normal controls or in other afflicted patients to
15 establish the subject's disease status. In preferred embodiments, a second level of Marker in the subject is determined at a time point later than the determination of the first level, and the two levels are compared to monitor the course of disease or the efficacy of the therapy. In certain preferred embodiments, a pre-treatment level of Marker in the subject is determined prior to beginning treatment according to this invention; this pre-treatment level of Marker can then be
20 compared to the level of Marker in the subject after the treatment commences, to determine the efficacy of the treatment.

The practice of the present invention employs, unless otherwise indicated, conventional techniques of molecular biology (including recombinant techniques), microbiology, cell biology, biochemistry and immunology, which are well within the purview of the skilled artisan. Such
25 techniques are explained fully in the literature, such as, "Molecular Cloning: A Laboratory Manual", second edition (Sambrook, 1989); "Oligonucleotide Synthesis" (Gait, 1984); "Animal Cell Culture" (Freshney, 1987); "Methods in Enzymology" "Handbook of Experimental Immunology" (Weir, 1996); "Gene Transfer Vectors for Mammalian Cells" (Miller and Calos, 1987); "Current Protocols in Molecular Biology" (Ausubel, 1987); "PCR: The Polymerase
30 Chain Reaction", (Mullis, 1994); "Current Protocols in Immunology" (Coligan, 1991). These techniques are applicable to the production of the polynucleotides and polypeptides of the

invention, and, as such, may be considered in making and practicing the invention. Particularly useful techniques for particular embodiments will be discussed in the sections that follow.

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the assay, screening, and therapeutic methods of the invention, and are not intended to limit the scope of what the inventors regard as their invention.

EXAMPLES

10 Example 1: Identification of IBD serological markers from *E. coli* proteome chips.

Sera was collected from 134 individuals (29 healthy control, 66 CD and 39 ulcerative colitis) from the Johns Hopkins Medical Institutes (Table 1).

Table 1. Demographic and clinical information of IBD Patient and healthy controls.

Patient Data/Characteristics	CD (n = 66)	UC (n = 29)	HC (n = 39)
Gender: female %	55	53	43
Age: mean/st dev (yrs)	36.7 ± 13.1	38 ± 14.5	47 ± 12.4
Age at diagnosis: mean (yrs)	36.7	28	
Duration of disease (yrs)	12.3	8.9	
Extraintestinal disease: n (%)	7 (11)	3 (10)	
Surgery: n (%)	46 (70)	4 (12)	
Ethnicity: n (%)			
African American	29 (44)	10 (34)	
Caucasian	35 (53)	22 (75)	
Hispanic	2 (3)	0	
Smoking: n (%)			
Past or present	17 (26)	5 (17)	
Nonsmoker	40 (60)	18 (62)	
Unknown	9 (14)	9 (35)	
Medications: n (%)			
Antibiotics	23 (35)	4 (14)	
5-ASA	49 (74)	26 (90)	
Corticosteroids	16 (24)	9 (35)	
AZA/6-MP	26 (39)	17 (59)	
Methotrexate	0	1 (3)	
Infliximab	15 (23)	2 (7)	
Crohn's Disease Subtype: n (total)			
Nonstricturing and nonpenetrating	18 (27)		
Penetrating	26 (40)		
Stricturing	14 (21)		
Penetrating and stricturing	8 (12)		
Ulcerative Colitis: n (total)			
Left Sided Colitis		13 (45)	
Pancolitis		18 (62)	

To identify potential biomarkers for IBD diagnosis, the antibody repertoire of the IBD patients was profiled using the *E. coli* proteome chips that each contained more than 4,200 individual proteins (see schematic illustration of our strategy in (Figure 1). Since each protein was spotted in duplicate on the chip, the reproducibility of duplicates of each protein was first analyzed. As shown in Figure 2A, the visual appearance of duplicate spots was very similar. As shown in Figure 2B in scatter plot, the duplicate spots of each protein were highly correlated, indicating the good quality of the array manufacturing. To recognize those reactive antibodies on the chips, the chips were probed with Cy3-labeled anti-human immunoglobulin antibodies. The

immunogenic profiles of both the IBD patients and healthy control were acquired by the resulting fluorescent signals. CD vs ulcerative colitis vs healthy control can be distinguished by comparing the signal intensities between protein spots on the *E. coli* proteome chips (see Figure 2A, which shows visual appearance of two representative chips probed with sera from CD and healthy control, respectively). Two-level of data analyses were performed with these immunogenic profiles (i) to identify differential immunogenic responses among CD vs ulcerative colitis vs healthy control using Significance Analysis of Microarray (SAM) and Gene Ontology (GO) enrichment analysis; and (ii) to construct robust classifiers to distinguish CD vs ulcerative colitis vs healthy control using k-TSP method.

Example 2: Global Immunogenic Profiles of IBD Against *E. coli*.

Sera samples from healthy control subjects (n = 39), patients with Crohn's Disease (n = 66), and patients with ulcerative colitis (n = 29) (Table 1) were used to compare differences between healthy control and IBD immunogenic profiles. To investigate the differential global changes in immunogenic response to *E. coli* proteins among healthy control vs Crohn's Disease vs ulcerative colitis, SAM was employed as described herein above for the immunogenic profiles. For convenience, the *E. coli* proteins that were differentially recognized by serum antibodies from healthy control, Crohn's Disease or ulcerative colitis are referred to as "differentially-expressed immunogenic proteins" throughout. Heat maps shown in Figures 3A-C present a visual illustration of the differentially immunogenic proteins for each phenotype. 273 differentially immunogenic proteins were identified by SAM when compared healthy control with CD samples. 81 proteins are highly immunogenic in CD samples and 192 are highly immunogenic in healthy control samples (Figure 3A). Conversely, 188 proteins have different immunogenic responses in the IBD subtypes, 51 and 137 are highly immunogenic in ulcerative colitis and CD samples, respectively (Figure 3B). When healthy control and ulcerative colitis samples are compared, only 27 and 6 proteins are discriminatory and highly immunogenic in healthy control and ulcerative colitis samples, respectively (Figure 3C). A full list of the immunogenic *E. coli* proteins in Figures 3A-C can be found in Tables 2-4, respectively.

Table 2. SAM ANALYSIS OF HEALTHY CONTROLS (HC) VERSUS CROHN'S DISEASE (CD) (see Fig. 3A)

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yfiC	Hypothetical protein yfiC /// predicted S-adenosyl-L-methionine-dependent methyltransferase	---	---	8168 // methyltransferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation
era	GTP-binding protein Era	50875 // cellular physiological process // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation /// 3676 // nucleic acid binding // inferred from electronic annotation /// 3723 // RNA binding // inferred from electronic annotation /// 5525 // GTP binding // inferred from electronic annotation
ygbD	nitric oxide reductase	6118 // electron transport // inferred from electronic annotation	---	15036 // disulfide oxidoreductase activity // inferred from electronic annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 16731 // oxidoreductase activity, acting on iron-sulfur proteins as donors, NAD or NADP as acceptors
yjH	KpLE2 phage-like element; predicted endoglucanase with Zn-dependent exopeptidase domain	---	---	16787 // hydrolase activity // inferred from electronic annotation
aidA	DNA-3-methyladenine glycosylase II /// 3-methyl-adenine DNA glycosylase II	6281 // DNA repair // inferred from electronic annotation /// 6284 // base-excision repair // inferred from electronic annotation /// 6974 // response to DNA damage stimulus //	---	5515 // protein binding // inferred from physical interaction /// 3677 // DNA binding // inferred from electronic annotation /// 3905 // alkylbase DNA N-glycosylase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yhcl	yhcl /// nanK	N-acetylmannosamine kinase inferred from electronic annotation /// 5975 // carbohydrate metabolism // inf 5975 // carbohydrate metabolism // inferred from electronic annotation /// 6051 // N- acetylmannosamine metabolism // inferred from electronic annotation	---	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 9384 // N- acetylmannosamine kinase activity // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation
fliS	fliS	flagellar protein FliS 9296 // flagellum biogenesis // inferred from electronic annotation	9288 // flagellum (sensu Bacteria) // inferred from electronic annotation /// 19861 // flagellum // inferred from electronic annotation	---
infC	infC	Translation initiation factor IF- 3 6412 // protein biosynthesis // inferred from electronic annotation /// 6413 // translational initiation // inferred from electronic annotation /// 6417 // regulation of protein biosynthesis	3743 // translation initiation factor activity // inferred from electronic annotation /// 3723 // RNA binding // inferred from electronic annotation	

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
metB	metB	cystathionine gamma-synthase		
		// inferred from electronic annotation /// 6445 // regulation of 6520 // amino acid metabolism // inferred from electronic annotation /// 8652 // amino acid biosynthesis // inferred from electronic annotation /// 9086 // methionine biosynthesis // inferred from electronic annotation	---	3962 // cystathionine gamma- synthase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation
purM	purM	phosphoribosylaminoimidazole synthetase		
		6164 // purine nucleotide biosynthesis // inferred from electronic annotation /// 6189 // 'de novo' IMP biosynthesis // inferred from electronic annotation	5737 // cytoplasm // inferred from electronic annotation	3824 // catalytic activity // inferred from electronic annotation /// 4641 // phosphoribosylformylglycinamide cyclo-ligase activity // inferred from electronic annotation /// 16874 // ligase activity // inferred from electronic annotation
argC	argC	N-acetyl-gamma-glutamyl- phosphate reductase		
		6520 // amino acid metabolism // inferred from electronic annotation /// 6526 // arginine biosynthesis // inferred from	5737 // cytoplasm // inferred from electronic annotation	3942 // N-acetyl-gamma-glutamyl- phosphate reductase activity // inferred from electronic annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 16620 // oxidoreductase activity, acting on the aldehyde or oxo group of do

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		electronic annotation /// 8652 // amino acid biosynthesis // inferred from electronic annotation /// 9085 // lysine biosynthesis // inf ---		
phnB	phnB			---
	PhnB protein /// hypothetical protein			
torA	torA	6118 // electron transport // inferred from electronic annotation	42597 // periplasmic space // inferred from electronic annotation	16491 // oxidoreductase activity // inferred from electronic annotation /// 30151 // molybdenum ion binding // inferred from electronic annotation /// 50626 // trimethylamine-N-oxide reductase (cytochrome c) activity // inferred from electronic annotation 5515 // protein binding // inferred from physical interaction /// 51082 // unfolded protein binding // inferred from electronic annotation
ibpB	ibpB	6457 // protein folding // inferred from electronic annotation /// 6986 // response to unfolded protein // inferred from electronic annotation /// 50821 // protein stabilization // inferred from electronic annotation	---	
	16 kDa heat shock protein B /// heat shock chaperone			
hycF	hycF	6118 // electron transport // inferred from electronic annotation /// 6810 // transport //	---	5506 // iron ion binding // inferred from electronic annotation /// 9055 // electron carrier activity // inferred from electronic annotation /// 46872 // metal ion binding // inferred from
	hydrogenase 4 Fe-S subunit /// formate hydrogenlyase complex iron-sulfur protein			

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
ycbF	ycbF	inferred from electronic annotation 6457 // protein folding // inferred from electronic annotation /// 7047 // cell wall organization and biogenesis // inferred from electronic annotation	9289 // fimbrium // inferred from electronic annotation /// 30288 // periplasmic space (sensu Proteobacteria) // inferred from electronic annotation /// 42597 // periplasmic space // inferred from electronic annotation	electronic annotation /// 51536 // iron-sulfur cluster binding // 5515 // protein binding // inferred from electronic annotation /// 51082 // unfolded protein binding // inferred from electronic annotation
ssi6 yjhE	hypothetical protein KpLE2 phage-like element; predicted membrane protein (pseudogene)	--- 6810 // transport // inferred from electronic annotation	--- 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	--- 5215 // transporter activity // inferred from electronic annotation
ygeW	ygeW	6207 // 'de novo' pyrimidine base biosynthesis // inferred from electronic annotation /// 6520 // amino acid metabolism //	4070 // aspartate carbamoyltransferase activity // inferred from electronic annotation /// 16597 // amino acid binding // inferred from electronic annotation /// 16743 // carboxyl- and carbamoyltransferase activity // inferred from electronic annotation	

81 Highly immunogenic proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
			inferred from electronic annotation		
hofH	hofH /// gspH	Putative general secretion pathway protein H precursor /// predicted general secretory pathway component, cryptic	6810 // transport // inferred from electronic annotation /// 15628 // type II protein secretion system // inferred from electronic annotation	15627 // type II protein secretion system complex // inferred from electronic annotation	8565 // protein transporter activity // inferred from electronic annotation
rfd	rfd /// wecC	UDP-N-acetyl-D- mannosamine dehydrogenase /// UDP-N-acetyl-D- mannosaminuronic acid dehydrogenase	6118 // electron transport // inferred from electronic annotation	---	16491 // oxidoreductase activity // inferred from electronic annotation
yjH	yjH	KpLE2 phage-like element; predicted oxidoreductase	6118 // electron transport // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation	---	16491 // oxidoreductase activity // inferred from electronic annotation
yjS	yjS	Hypothetical protein yjS	---	---	5488 // binding // inferred from electronic annotation
ftn	ftn	Ferritin 1 /// ferritin iron storage protein (cytoplasmic)	6826 // iron ion transport // inferred from electronic annotation /// 6879 // iron ion homeostasis // inferred from electronic annotation	---	4322 // ferroxidase activity // inferred from electronic annotation /// 5488 // binding // inferred from electronic annotation /// 5506 // iron ion binding // inferred from electronic annotation /// 8199 // ferric iron binding // inferred from electronic
ybbQ	ybbQ	2-hydroxy-3-oxopropionate reductase	6098 // pentose- phosphate shunt //	---	4616 // phosphogluconate dehydrogenase (decarboxylating)

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		inferred from electronic annotation /// 6573 // valine metabolism // inferred from electronic annotation /// 46487 // glyoxylate metabolism // inferred from electronic annotation ---		activity // inferred from electronic annotation /// 8442 // 3- hydroxyisobutyrate dehydrogenase activity // inferred from electronic annotation /// 8679 // 2-hydroxy-3- oxopropionate reductase activit
ppdB	ppdB	---	---	---
	Prepilin peptidase dependent protein B precursor ///			
	hypothetical protein			
fimC	fimC	6457 // protein folding // inferred from electronic annotation /// 7047 // cell wall organization and biogenesis // inferred from electronic annotation	9289 // fimbrium // inferred from electronic annotation /// 30288 // periplasmic space (sensu Proteobacteria) // inferred from electronic annotation /// 42597 // periplasmic space // inferred from electronic annotation	5515 // protein binding // inferred from electronic annotation /// 51082 // unfolded protein binding // inferred from electronic annotation
dgxA	dgxA	---	---	---
fumB	fumB	6091 // generation of precursor metabolites and energy // inferred from electronic annotation /// 6099		3824 // catalytic activity // inferred from electronic annotation /// 4333 // fumarate hydratase activity // inferred from electronic annotation /// 5506 // iron ion binding // inferred from electronic annotation
	hypothetical protein			
	Fumarate hydratase class I, anaerobic /// anaerobic class I fumarate hydratase (fumarase B)			

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
(thiS)	thiS	sulfur carrier protein ThiS		
		// tricarboxylic acid cycle // inferred from electronic annotation		/// 16829 // lyase activity // inferred from electronic annotation
yjeJ	yjeJ	6790 // sulfur metabolism // inferred from electronic annotation	---	---
cedA	cedA	Hypothetical protein yjeJ /// hypothetical protein Cell division activator cedaA /// cell division modulator	---	---
		7049 // cell cycle // inferred from electronic annotation /// 51301 // cell division // inferred from electronic annotation	---	---
cysW	cysW	sulfate/thiosulfate transporter subunit		
		6810 // transport // inferred from electronic annotation /// 8272 // sulfate transport // inferred from electronic annotation	9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 15116 // sulfate transporter activity // inferred from electronic annotation /// 15563 // uptake permease activity // inferred from electronic annotation
ycgQ	ycgQ	Putative electron transfer flavoprotein subunit ycgQ	---	9055 // electron carrier activity // inferred from electronic annotation /// 50660 // FAD binding // inferred

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
rpsR	rpsR	30S ribosomal protein S18	6412 // protein biosynthesis // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation /// 3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred from electronic annotation /// 19843 // rRNA binding // inferred from electronic annotation
narY	narY	nitrate reductase 2 (NRZ), beta subunit	6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 42126 // nitrate metabolism // inferred from electronic annotation /// 42128 // nitrate assimilation // inferred from electronic annotation	5506 // iron ion binding // inferred from electronic annotation /// 8940 // nitrate reductase activity // inferred from electronic annotation /// 9055 // electron carrier activity // inferred from electronic annotation /// 16491 // oxidoreductase activity
citB	citB	Transcriptional Regulatory protein dpiA /// DNA-binding response regulator in two-component regulatory system with citA	5737 // cytoplasm // inferred from electronic annotation	156 // two-component response regulator activity // inferred from electronic annotation /// 3677 // DNA binding // inferred from electronic annotation /// 30528 // transcription regulator activity //

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		annotation /// 6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA- dependent // inferred from electronic annotation ---		inferred from electronic annotation
yjbR	Protein yjbR /// hypothetical protein	---	---	---
ybbA	Hypothetical ABC transporter ATP-binding protein ybbA /// predicted transporter subunit: ATP-binding component of ABC superfamily	6810 // transport // inferred from electronic annotation	---	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 5525 // GTP binding // inferred from electronic annotation /// 16887 // ATPase activity // inferred from electronic annotation 4364 // glutathione transferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 9055 // electron carrier activity // inferred from electronic annotation /// 15035 // protein disulfide oxidoreductase activity // inferred from electronic annotation
gst	Glutathione S-transferase /// glutathionine S-transferase	---	---	
grxC	Glutaredoxin 3	6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 9263 // deoxyribonucleotide biosynthesis // inferred from	---	

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
cysD	sulfate adenylyltransferase subunit 2	electronic annotation /// 45454 // cell redox homeostasis // infer 103 // sulfate assimilation // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation /// 8652 // amino acid biosynthesis // inferred from electronic annotation /// 19344 // cysteine biosynthesis // inferred from electronic annotation 6281 // DNA repair // inferred from electronic annotation /// 6974 // response to DNA damage stimulus // inferred from electronic annotation ---	---	4781 // sulfate adenylyltransferase (ATP) activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 16779 // nucleotidyltransferase activity // inferred from electronic annotation
radC	DNA repair protein RadC	---	---	---
citG	2-(5"-triphosphoribosyl)-3'-dephosphocoenzyme-A synthase /// triphosphoribosyl-dephospho-CoA transferase	---	---	16740 // transferase activity // inferred from electronic annotation /// 46917 // triphosphoribosyl-dephospho-CoA synthase activity // inferred from electronic annotation
fdhE	formate dehydrogenase	6118 // electron	---	5506 // iron ion binding // inferred

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
	accessory protein FdhE	transport // inferred from electronic annotation		from electronic annotation /// 9055 // electron carrier activity // inferred from electronic annotation /// 20037 // heme binding // inferred from electronic annotation
fecB	fecB	6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6826 // iron ion transport // inferred from electronic annotation /// 6827 // high affinity iron ion transport // inferred from electronic annotation	42597 // periplasmic space // inferred from electronic annotation	5381 // iron ion transporter activity // inferred from electronic annotation /// 5506 // iron ion binding // inferred from electronic annotation
	KpLE2 phage-like element; iron-dicitrate transporter subunit			
yhgH	yhgH /// gntX	Hypothetical protein yhgH /// gluconate periplasmic binding protein with phosphoribosyltransferase domain, GNT I system membrane channel protein component of Pn transporter	9116 // nucleoside metabolism // inferred from electronic annotation 6810 // transport // inferred from electronic annotation /// 15716 // phosphonate transport // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 15604 // phosphonate transporter activity // inferred from electronic annotation
(phnE)	phnE		5887 // integral to plasma membrane // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation ///	

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
cysJ	Sulfite reductase [NADPH] flavoprotein alpha-component /// sulfite reductase, alpha subunit, flavoprotein	103 // sulfate assimilation // inferred from electronic annotation /// 6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 8652 // amino acid biosynthesis // inferred from electronic annotation	16021 // integral to membrane // inferred from electronic annotation ---	5515 // protein binding // inferred from physical interaction /// 4783 // sulfite reductase (NADPH) activity // inferred from electronic annotation /// 5506 // iron ion binding // inferred from electronic annotation /// 9055 // electron carrier activity /
445#15	ygaX Putative transport protein /// predicted transporter	6810 // transport annotation	16020 // membrane // 16021 // integral to membrane ---	5215 // transporter activity
fba	fba /// fbaA fructose-bisphosphate aldolase /// fructose-bisphosphate aldolase	6096 // glycolysis // inferred from electronic annotation	---	5515 // protein binding // inferred from physical interaction /// 4332 // fructose-bisphosphate aldolase activity // inferred from electronic annotation /// 8270 // zinc ion binding // inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation --- ---
yjbl yjiQ	hypothetical protein CP4-57 prophage; predicted	---	---	---

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
mltB	protein Membrane-bound lytic murein transglycosylase B precursor	5975 // carbohydrate metabolism // inferred from electronic annotation	---	16787 // hydrolase activity // inferred from electronic annotation /// 16798 // hydrolase activity, acting on glycosyl bonds // inferred from electronic annotation
yhaA	yhaA /// tdcD propionate kinase/acetate kinase C, anaerobic	6082 // organic acid metabolism // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation /// 16310 // phosphorylation // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	8776 // acetate kinase activity // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 16774 // phosphotransferase activity, c
yjeB	yjeB Hypothetical protein yjeB /// predicted DNA-binding transcriptional regulator	6412 // protein biosynthesis // inferred from electronic annotation	---	3677 // DNA binding // inferred from electronic annotation /// 4826 // phenylalanine-tRNA ligase activity // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation
thiF	thiF thiamine biosynthesis protein ThiF	9228 // thiamin biosynthesis // inferred from electronic annotation	---	3824 // catalytic activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 16779 // nucleotidyltransferase activity // inferred from electronic annotation 5506 // iron ion binding // inferred from electronic annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 16728 // oxidoreductase activity, acting on
gcpE	gcpE /// ispG 4-hydroxy-3-methylbut-2-en-1-yl diphosphate synthase /// 4-hydroxy-3-methylbut-2-en-1-yl diphosphate synthase	8299 // isoprenoid biosynthesis // inferred from electronic annotation	---	

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		// terpenoid biosynthesis // inferred from electronic annotation		CH2 groups, disulfide as acceptor // inferred from electronic annotation
mvIN	mvIN	9405 // pathogenesis // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation // 16021 // integral to membrane // inferred from electronic annotation	---
	Virulence factor mvIN homolog /// predicted inner membrane protein			
yihK	yihK /// bipA	6412 // protein biosynthesis // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	5515 // protein binding // inferred from physical interaction /// 166 // nucleotide binding // inferred from electronic annotation /// 5525 // GTP binding // inferred from electronic annotation
	GTP-binding protein typA/BipA /// GTP-binding protein			
ubiG	ubiG	6744 // ubiquinone biosynthesis // inferred from electronic annotation	---	5515 // protein binding // inferred from physical interaction /// 8168 // methyltransferase activity // inferred from electronic annotation /// 8425 // 2-polyprenyl-6-methoxy-1,4-benzoquinone methyltransferase activity // inferred from electronic annotation
	3-demethylubiquinone-9 3-methyltransferase			
yejG	yejG	---	---	---
	Hypothetical protein yejG ///			
304#1	lsrB	---	---	---
	hypothetical protein			
ygfY	ygfY	---	---	---
	AI2 transporter			
	Hypothetical protein ygfY ///			
319#17	ydHZ	---	---	---
	hypothetical protein			
	Hypothetical protein ydhZ ///			
336#6				
430#8	iscR	---	---	---
	Hypothetical protein yfhp ///			

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
DNA-binding transcriptional repressor				
yhfr	yhfr /// frlR	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA- dependent // inferred from electronic annotation /// 45449 // regulation of transcription // inferred from electronic annotation 15716 // phosphonate transport // inferred from electronic annotation /// 19634 // phosphonate metabolism // inferred from electronic annotation ---	5622 // intracellular // inferred from electronic annotation	5515 // protein binding // inferred from physical interaction /// 3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 30528 // transcription regulator activity //
phnG	phnG	PhnG protein /// carbon- phosphorus lyase complex subunit	---	---
ymfE	ymfE	e14 prophage; predicted inner membrane protein	16020 // membrane // inferred from electronic annotation // 16021 // integral to membrane // inferred from electronic annotation 16020 //	---
yejO	yejO	predicted autotransporter outer	7155 // cell	5524 // ATP binding // inferred

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
	membrane protein	adhesion // inferred from electronic annotation	membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic annotation	from electronic annotation
dicC	Qin prophage; DNA-binding transcriptional regulator for DicB	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 7049 // cell cycle // inferred from electronic annotation /// 51301 // cell division // inferred from electronic annotation	---	3677 // DNA binding // inferred from electronic annotation
galR	Galactose operon repressor /// DNA-binding transcriptional repressor	5975 // carbohydrate metabolism // inferred from electronic annotation /// 6012 // galactose metabolism // inferred from electronic annotation /// 6350	5622 // intracellular // inferred from electronic annotation	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation

81 Highly immunogenic proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		// transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA- de		
yphC	yphC	---	---	8270 // zinc ion binding // inferred from electronic annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 46872 // metal ion binding // inferred from electronic annotation
rpIT	50S ribosomal protein L20	27 // ribosomal large subunit assembly and maintenance // inferred from electronic annotation /// 6412 // protein biosynthesis // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation // 5840 // ribosome // inferred from electronic annotation // 30529 // ribonucleoprotein complex // inferred from electronic annotation	3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred from electronic annotation /// 19843 // rRNA binding // inferred from electronic annotation
267#6	paaJ	---	---	8415 // acyltransferase activity // 16740 // transferase activity
selD	selD	---	---	166 // nucleotide binding // inferred from electronic annotation /// 287 // magnesium ion binding // inferred from electronic annotation /// 3824 // catalytic activity // inferred from electronic annotation /// 4756 // selenide, water dikinase activity //

81 Highly immunogenic proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
tdcB	tdcB	threonine dehydratase	6520 // amino acid metabolism // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation	---	3824 // catalytic activity // inferred from electronic annotation /// 4794 // threonine ammonia-lyase activity // inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation
yhfV	yhfV	Phosphotriesterase homology protein	9056 // catabolism // inferred from electronic annotation	---	8270 // zinc ion binding // inferred from electronic annotation /// 16788 // hydrolase activity, acting on ester bonds // inferred from electronic annotation
yjaI	yjaI /// zraP	Zinc resistance-associated protein precursor /// Zn-binding periplasmic protein	---	42597 // periplasmic space // inferred from electronic annotation	8270 // zinc ion binding // inferred from electronic annotation
hycA	hycA	Formate hydrogenlyase Regulatory protein hycA /// regulator of the transcriptional regulator FhlA	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	---	16829 // lyase activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
pbuX	pbuX	hypothetical protein	---	---	---
fabH	fabH	3-oxoacyl-(acyl carrier protein) synthase	6633 // fatty acid biosynthesis // inferred from	---	3824 // catalytic activity // inferred

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		electronic annotation ///		from electronic
		8610 // lipid biosynthesis //		annotation /// 4315
		inferred from electronic		// 3-oxoacyl-[acyl-
		annotation		carrier protein]
				synthase activity //
				inferred from
				electronic
				annotation /// 8415
				// acyltransferase
				activity // inferred
				from electronic
				annotation /// 16740
				/
glpF	glpF	6810 // transport // inferred	16020 // membrane //	287 // magnesium
	Glycerol uptake facilitator protein ///	from electronic annotation	inferred from	ion binding //
	glycerol facilitator		electronic annotation	inferred from
			/// 16021 // integral	electronic
			to membrane //	annotation /// 5215
			inferred from	// transporter
			electronic annotation	activity // inferred
				from electronic
				annotation /// 46872
				// metal ion binding
				// inferred from
				electronic
				annotation
273#6	ycdU	6810 // transport	16020 // membrane	5215 // transporter
	Hypothetical ABC transporter permease		/// 16021 // integral	activity
	protein ycdU /// predicted		to membrane	
ybhR	ybhR	6810 // transport // inferred	16020 // membrane //	5524 // ATP binding
	spermidine/putrescine transporter subunit	from electronic annotation	inferred from	// inferred from
	Hypothetical protein ybhR /// predicted		electronic annotation	electronic
	transporter subunit: membrane component		/// 16021 // integral	annotation /// 42626
	of ABC superfamily		to membrane //	// ATPase activity,
			inferred from	coupled to
			electronic annotation	transmembrane
				movement of
				substances //

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yqcE	Hypothetical protein yqcE /// predicted transporter	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation
flhD	transcriptional activator FlhD	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 9296 // flagellum biogenesis // inferred from electronic annotation /// 45893 // positive regula	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 16563 // transcriptional activator activity // inferred from electronic annotation	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 16563 // transcriptional activator activity // inferred from electronic annotation
trkG	Rac prophage; potassium transporter subunit	6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation annotation /// 6812 // cation transport // inferred from electronic annotation 6813 // potassium ion transport // inferred from electronic annotation 6814 // sodium ion transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	8324 // cation transporter activity // inferred from electronic annotation /// 30955 // potassium ion binding // inferred from electronic annotation
ybdS	Citrate carrier/transporter	6814 // sodium ion transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
bmQ	bmQ	Branched-chain amino acid transport system II carrier protein /// predicted branched chain amino acid transporter (LIV-II)	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	15171 // amino acid transporter activity // inferred from electronic annotation /// 15658 // branched-chain aliphatic amino acid transporter activity // inferred from electronic annotation
ycaD	ycaD	putative MFS family transporter protein	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation
ybhN	ybhN	Hypothetical protein ybhN /// conserved inner membrane protein	---	---
yabK	yabK /// thiP	thiamin ABC transporter membrane component	6810 // transport // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
ycdG	Putative purine permease ycdG /// predicted transporter	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
yojI	Hypothetical ABC transporter ATP- binding protein yojI /// fused predicted multidrug transport subunits of ABC superfamily; membrane component/ATP- binding component	6810 // transport // inferred from electronic annotation /// 15833 // peptide transport // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 15197 // peptide transporter activity // inferred from electronic annotation /// 16887 // ATPase activity // inferred from electronic annotation	
ybaN	Hypothetical protein ybaN /// conserved inner membrane protein	---	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	---
focA	F1C major fimbrial subunit precursor	7155 // cell adhesion // inferred from electronic annotation	9289 // fimbrium // inferred from electronic annotation	---
321#3 yciR	Hypothetical protein yciR	7165 // signal transduction // inferred from electronic annotation	---	4871 // signal transducer activity // inferred from

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
427#1	YfgF Hypothetical protein yfgF /// predicted inner membrane protein	---	16020 // membrane /// 16021 // integral to membrane	electronic annotation ---
celD	celD /// ChbR Cel operon repressor /// DNA-binding transcriptional dual regulator	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 45449 // regulation of transcription // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 43565 // sequence-specific DNA binding // inferred from electronic annotation
uidB	uidB Glucuronide carrier protein /// glucuronide transporter	6810 // transport // inferred from electronic annotation /// 6814 // sodium ion transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 5351 // sugar porter activity // inferred from electronic annotation /// 15293 // symporter activity // inferred from electronic annotation
ydjS	ydjS /// astE succinylglutamate desuccinylase /// succinylglutamate desuccinylase	6525 // arginine metabolism // inferred from electronic annotation /// 6527 // arginine catabolism // inferred from electronic annotation /// 8152 // metabolism // inferred from	---	8270 // zinc ion binding // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		electronic annotation		annotation /// 16788 // hydrolase activity, acting on ester bonds // inferred from electronic annotation /// 46872 // metal ion bin
rocE emrY	hypothetical protein Multidrug resistance protein Y /// predicted multidrug efflux system	--- 6810 // transport // inferred from electronic annotation /// 6306 // DNA methylation // inferred from electronic annotation	--- 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	--- 5215 // transporter activity // inferred from electronic annotation /// 3677 // DNA binding // inferred from electronic annotation
cydC	Transport ATP-binding protein cydC /// fused cysteine transporter subunits of ABC superfamily: membrane component/ATP- binding component	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 16887 // ATPase activity // inferred from electronic annotation /// 17111 // nucleoside- triphosphatase activity // inferred from electronic annotation
yhhS	hypothetical protein /// predicted transporter	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral	5215 // transporter activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
406#7	yfcH	Hypothetical protein yfcH /// conserved protein with NAD(P)-binding Rossmann-fold domain	9225 // nucleotide-sugar metabolism	3824 // catalytic activity /// 51287 // NAD binding
atoE	atoE	Short-chain fatty acids transporter /// short chain fatty acid transporter	6810 // transport // inferred from electronic annotation /// 15912 // short-chain fatty acid transport // inferred from electronic annotation	15635 // short-chain fatty acid transporter activity // inferred from electronic annotation
ybgE	ybgE	Protein ybgE /// conserved inner membrane protein	---	---
JW0438	mdlA	Multidrug resistance-like ATP-binding protein mdlA	6810 // transport	166 // nucleotide binding /// 5524 // ATP binding /// 16887 // ATPase activity /// 17111 // nucleoside-triphosphatase activity /// 42626 // ATPase activity, coupled to transmembrane movement of substances
(yhhT)	yhhT	Hypothetical protein yhhT /// predicted inner membrane protein	---	---
ybhM yicO	ybhM yicO	Hypothetical protein ybhM Hypothetical protein yicO /// predicted xanthine/uracil permease	6810 // transport // inferred from electronic annotation	5215 // transporter activity // inferred

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
ybhL	ybhL Hypothetical protein ybhL /// predicted inner membrane protein	---	electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	from electronic annotation ---
yhiQ ydaA	yhiQ ydaA /// uspE Hypothetical protein yhiQ Protein ydaA /// stress-induced protein	---	6950 // response to stress // inferred from electronic annotation	---
ydjZ	ydjZ Hypothetical protein ydjZ /// conserved inner membrane protein	---	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 5622 // intracellular // inferred from electronic annotation	---
dnaQ	dnaQ DNA polymerase III subunit epsilon	6260 // DNA replication // inferred from electronic annotation	287 // magnesium ion binding // inferred from electronic annotation /// 3677 // DNA binding // inferred from electronic annotation /// 3887 // DNA-directed DNA polymerase activity // inferred from electronic annotation /// 4518 // nuclease activity	

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
ydY	Hypothetical transport protein ydY /// multidrug efflux system protein	6810 // transport // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	// inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation
211#11 dgkA	Diglycerol kinase	8654 // phospholipid biosynthesis // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	4143 // diacylglycerol kinase activity // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation
secF	protein export protein SecF	6605 // protein targeting // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 6886 // intracellular protein transport // inferred from electronic annotation /// 15031 // protein transport // inferred from electronic annotation	9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 15627 // type II protein secretion system complex // inferred from electronic annotation /// 16020 // membrane // inferred from electronic	8565 // protein transporter activity // inferred from electronic annotation /// 15450 // protein translocase activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
ybbC fadA	ybbC fadA	hypothetical protein acetyl-CoA acetyltransferase	--- 6629 // lipid metabolism // inferred from electronic annotation /// 6631 // fatty acid metabolism // inferred from electronic annotation /// 16042 // lipid catabolism // inferred from electronic annotation	--- --- ---	--- 3988 // acetyl-CoA C-acyltransferase activity // inferred from electronic annotation /// 8415 // acyltransferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation 5506 // iron ion binding // inferred from electronic annotation /// 46872 // metal ion binding // inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation /// 5351 // sugar porter activity // inferred from electronic annotation /// 15542 // sugar efflux
fepD	fepD	Ferric enterobactin transport system permease protein fepD	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation	
sdhD	sdhD	succinate dehydrogenase cytochrome b556 small membrane subunit	6099 // tricarboxylic acid cycle // inferred from electronic annotation /// 6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation 6810 // transport // inferred from electronic annotation /// 8643 // carbohydrate transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	
yeiO	yeiO /// setB	Sugar efflux transporter B /// lactose/glucose efflux system			

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yhfu	Hypothetical protein yhfU /// hypothetical protein	---	---	transporter activity // inferred from electronic annotation ---
(yeeF)	Hypothetical transport protein yeeF /// predicted amino-acid transporter	6810 // transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5279 // amino acid- polyamine transporter activity // inferred from electronic annotation /// 15171 // amino acid transporter activity // inferred from electronic annotation ---
yaeG	yaeG /// cdaR	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	---	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation 166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from
nac	Nitrogen assimilation Regulatory protein nac /// DNA-binding transcriptional dual regulator of nitrogen assimilation	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 42128 // nitrate assimilation // inferred from electronic annotation	---	9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 16020 //
msbA	msbA	Probable transport ATP-binding protein msbA /// fused lipid transporter subunits of ABC superfamily; membrane component/ATP-binding component	9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 16020 //	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
narI	Respiratory nitrate reductase 1 gamma chain /// nitrate reductase 1, gamma (cytochrome b(NR)) subunit	6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 42128 // nitrate assimilation // inferred from electronic annotation	9325 // nitrate reductase complex // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	electronic annotation /// 16887 // ATPase activity // inferred from electronic annotation /// 17111 // nucleoside-triphosphatase activity // inferred from electronic annotation 5506 // iron ion binding // inferred from electronic annotation /// 8940 // nitrate reductase activity // inferred from electronic annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 46872 // metal ion binding // inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation /// 15198 // oligopeptide transporter activity // inferred from electronic annotation ---
oppC	Oligopeptide transport system permease protein oppC /// oligopeptide transporter subunit	6810 // transport // inferred from electronic annotation /// 6857 // oligopeptide transport // inferred from electronic annotation /// 15031 // protein transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	electronic annotation 5215 // transporter activity // inferred from electronic annotation /// 15198 // oligopeptide transporter activity // inferred from electronic annotation ---
yibQ	Hypothetical protein yibQ precursor /// predicted polysaccharide deacetylase	---	---	---

192 Highly immunogenic response proteins in HC					
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF	
pheP	Phenylalanine-specific permease /// phenylalanine transporter	6810 // transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5279 // amino acid- polyamine transporter activity // inferred from electronic annotation /// 15171 // amino acid transporter activity // inferred from electronic annotation	
16-3B0 emrD	Multidrug resistance protein D /// multidrug efflux system protein	6810 // transport // inferred from electronic annotation /// 15893 // drug transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 15238 // drug transporter activity // inferred from electronic annotation	
ydeZ ydeZ /// lsrD	AI2 transporter	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation	
280#1 ddpX	D-ala-D-ala dipeptidase, Zn-dependent	6508 // proteolysis	5618 // cell wall	8233 // peptidase activity /// 8237 // metalloproteinase activity /// 16787 // hydrolase activity /// 16805 // dipeptidase activity	
ybfC ydcD ygiR	hypothetical protein hypothetical protein Hypothetical oxidoreductase ygiR /// predicted NAD(P)-binding dehydrogenase	--- --- 6118 // electron transport // inferred from electronic annotation	--- --- 16020 // membrane // inferred from	--- --- 16491 // oxidoreductase	

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yehY	yehY	annotation /// 8152 // metabolism // inferred from electronic annotation	electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation	activity // inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation
ppx	Hypothetical ABC transporter permease protein yehY /// predicted transporter subunit: membrane component of ABC superfamily	6810 // transport // inferred from electronic annotation	---	287 // magnesium ion binding // inferred from electronic annotation /// 4309 // exopolyphosphatase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation
nagE	PTS system, N-acetylglucosamine-specific IIABC component	6810 // transport // inferred from electronic annotation /// 9401 // phosphoenolpyruvate-dependent sugar phosphotransferase system // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation /// 19866 // organelle inner membrane // inferred from electronic annotation	5351 // sugar porter activity // inferred from electronic annotation /// 8982 // protein-N(P1)-phosphohistidine-sugar phosphotransferase activity // inferred from electronic annotation
kch	Putative potassium channel protein ///	6810 // transport // inferred	16020 // membrane // inferred from electronic annotation	5216 // ion channel

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
	voltage-gated potassium channel	from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6813 // potassium ion transport // inferred from electronic annotation	inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	activity // inferred from electronic annotation
yjeM	Hypothetical transporter yjeM /// predicted transporter	6810 // transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5279 // amino acid- polyamine transporter activity // inferred from electronic annotation
ybfB	predicted inner membrane protein	---	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	---
279#6	D-ala-D-ala transporter subunit	6810 // transport	electronic annotation 16020 // membrane /// 16021 // integral to membrane inferred from electronic annotation	5215 // transporter activity
aqpZ	aquaporin Z	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 15250 // water channel activity // inferred from electronic annotation
yhjX	Hypothetical protein yhjX	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 15297 // antiporter activity // inferred from

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
malX	PTS system, maltose and glucose-specific IIABC component /// fused maltose and glucose-specific PTS enzymes: IIB component -I IIC component	6810 // transport // inferred from electronic annotation /// 9401 // phosphoenolpyruvate- dependent sugar phosphotransferase system // inferred from electronic annotation	electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	electronic annotation 5351 // sugar porter activity // inferred from electronic annotation /// 8982 // protein-N(P1)- phosphohistidine- sugar phosphotransferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotati
ycbM	Putative aliphatic sulfonates transport permease protein ssuC /// alkanesulfonate transporter subunit	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
narU	Nitrite extrusion protein 2 /// nitrate/nitrite transporter	6810 // transport // inferred from electronic annotation /// 15698 // inorganic anion transport // inferred from electronic annotation /// 42128 // nitrate assimilation // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	15103 // inorganic anion transporter activity // inferred from electronic annotation
lpxC	UDP-3-O-[3-hydroxymyristoyl] N- acetylglucosamine deacetylase	8610 // lipid biosynthesis // inferred from electronic annotation /// 9245 // lipid A biosynthesis // inferred from electronic annotation	---	8759 // UDP-3-O- [3- hydroxymyristoyl] N- acetylglucosamine deacetylase activity

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
secY/prlA	secY /// prlA	6605 // protein targeting // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 9306 // protein secretion // inferred from electronic annotation /// 15031 // protein transport // inferred from electronic annotation 6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	// inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation 15450 // protein translocase activity // inferred from electronic annotation
(yhcP)	yhcP	Hypothetical protein yhcP /// p- hydroxybenzoic acid efflux system component	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	---
phsE	phsE /// dacD	Penicillin-binding protein 6B precursor /// D-alanyl-D-alanine carboxypeptidase (penicillin-binding protein 6b)	6508 // proteolysis // inferred from electronic annotation /// 8360 // regulation of cell shape // inferred from electronic annotation /// 9252 // peptidoglycan biosynthesis // inferred from electronic annotation	4180 // carboxypeptidase activity // inferred from electronic annotation /// 8233 // peptidase activity // inferred from electronic annotation /// 9002 // serine-type D- Ala-D-Ala carboxypeptidase activity // inferred from electronic

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
hemY	hemY	predicted protoheme IX synthesis protein	6779 // porphyrin biosynthesis // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation // 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation // 16021 // integral to membrane // inferred from electronic annotation 3824 // catalytic activity // inferred from electronic annotation // 4558 // alpha-glucosidase activity // inferred from electronic annotation // 16787 // hydrolase activity // inferred from electronic annotation // 16798 // hydrolase activity, acting
yciS	yciS	Hypothetical protein yciS /// conserved inner membrane protein	---	8415 // acyltransferase activity // inferred from electronic annotation // 16740 // transferase activity // inferred
malZ	malZ	Maltodextrin glucosidase	5975 // carbohydrate metabolism // inferred from electronic annotation	---
ymdD	ymdD /// mdoC	glucans biosynthesis protein	9250 // glucan biosynthesis // inferred from electronic annotation	---

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
316#4 rfbB	hypothetical protein UDP-D- galactose:(glucosyl)lipopolysaccharide- 1,6-D-galactosyltransferase	--- 9058 // biosynthesis // inferred from electronic annotation /// 9103 // lipopolysaccharide biosynthesis // inferred from electronic annotation	--- ---	from electronic annotation /// 16741 // transferase activity, transferring one-carbon groups // inferred from electronic annotation /// 1 --- 16740 // transferase activity // inferred from electronic annotation /// 16757 // transferase activity, transferring glycosyl groups // inferred from electronic annotation
emrB	multidrug efflux system protein	6810 // transport // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
356#7 fsr	hypothetical protein Fosmidomycin resistance protein /// predicted fosmidomycin efflux system	--- 6810 // transport // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	--- 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	--- 5215 // transporter activity // inferred from electronic annotation
yigF 233#6	conserved inner membrane protein Cytochrome b561 homolog 2 /// predicted cytochrome b561	--- 6118 // electron transport /// 6810 // transport	--- 16020 // membrane /// 16021 // integral to membrane	--- 5506 // iron ion binding /// 46872 // metal ion binding

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
331#2	yeaE Hypothetical protein yeaE	---	---	16491 // oxidoreductase activity ---
mrdB	Rod shape-determining protein rodA	7049 // cell cycle // inferred from electronic annotation /// 8360 // regulation of cell shape // inferred from electronic annotation	9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation ---	---
thiL	thiamine monophosphate kinase	9228 // thiamin biosynthesis // inferred from electronic annotation	---	9030 // thiamin phosphate kinase activity // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation
yphD	predicted sugar transporter subunit: membrane component of ABC superfamily	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
fabZ	(3R)-hydroxymyristoyl ACP dehydratase	6633 // fatty acid biosynthesis // inferred from electronic annotation /// 8610 // lipid biosynthesis // inferred from electronic annotation /// 9245 // lipid A annotation	5737 // cytoplasm // inferred from electronic annotation	16829 // lyase activity // inferred from electronic annotation /// 16836 // hydro-lyase activity // inferred

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yoaA	conserved protein with nucleoside triphosphate hydrolase domain	biosynthesis // inferred from electronic annotation 6139 // nucleobase, nucleoside, nucleotide and nucleic acid metabolism // inferred from electronic annotation	---	from electronic annotation 166 // nucleotide binding // inferred from electronic annotation /// 3676 // nucleic acid binding // inferred from electronic annotation /// 3677 // DNA binding // inferred from electronic annotation /// 4386 // helicase activity // inferred from electronic annotation
yfjY	CP4-57 prophage; predicted DNA repair protein	6281 // DNA repair // inferred from electronic annotation	---	---
nrfe	heme lyase (NrfeFG) for insertion of heme into c552, subunit Nrfe	6461 // protein complex assembly // inferred from electronic annotation /// 8535 // cytochrome c oxidase complex assembly // inferred from electronic annotation /// 15886 // heme transport // inferred from electronic annotation /// 17004 // cytochrome com 8655 // pyrimidine salvage // inferred from electronic annotation /// 9058 // biosynthesis // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	15232 // heme transporter activity // inferred from electronic annotation
udk	uridine kinase		---	166 // nucleotide binding // inferred from electronic annotation /// 4849 // uridine kinase activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yhhL	Hypothetical protein yhhL /// conserved inner membrane protein	---	---	annotation /// 5524 // ATP binding // inferred from electronic
JW1949 sucB	yedS_3 sucB Pseudo dihydrolipoamide acetyltransferase	---	---	annotation /// 16301 // kinase activity // inferred from electronic annotation ---
		6099 // tricarboxylic acid cycle // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation	45252 // oxoglutarate dehydrogenase complex // inferred from electronic annotation	4149 // dihydrolipoyllysine- residue succinyltransferase activity // inferred from electronic annotation /// 5515 // protein binding // inferred from electronic annotation /// 8415 // acyltransferase activity // inferred from electronic annotation /// 1674 5515 // protein binding // inferred from physical interaction /// 4742 // dihydrolipoyllysine- residue acetyltransferase activity // inferred from electronic annotation /// 5515
aceF	aceF dihydrolipoamide acetyltransferase	6096 // glycolysis // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation	45254 // pyruvate dehydrogenase complex // inferred from electronic annotation	

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yaiV	Hypothetical protein yaiV /// predicted DNA-binding transcriptional regulator	6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	3700 // transcription factor activity // inferred from electronic annotation /// 8415 // acyltran
yccY	yccY /// etp phosphotyrosine-protein phosphatase	6470 // protein amino acid dephosphorylation // inferred from electronic annotation	---	4721 // phosphoprotein phosphatase activity // inferred from electronic annotation /// 4725 // protein tyrosine phosphatase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation
yhaO	predicted transporter	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
yhiP	Hypothetical transporter yhiP /// predicted transporter	6810 // transport // inferred from electronic annotation /// 6857 // oligopeptide transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane //	5215 // transporter activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yaaH	Hypothetical protein yaaH /// conserved inner membrane protein associated with acetate transport	---	inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation	--- 166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 15197 // peptide transporter activity // inferred from electronic annotation /// 15198 // oligopeptide transporter activity ---
oppF	Oligopeptide transport ATP-binding protein oppF /// oligopeptide transporter subunit	6810 // transport // inferred from electronic annotation /// 6857 // oligopeptide transport // inferred from electronic annotation // 15031 // protein transport // inferred from electronic annotation /// 15833 // peptide transport // inferred from electronic annotation		
pnuC	Protein pnuC /// predicted nicotinamide mononucleotide transporter	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	
ansP	L-asparagine permease /// L-asparagine transporter	6810 // transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation		5279 // amino acid-polyamine transporter activity // inferred from electronic annotation /// 15171 // amino acid

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
cybB	Cytochrome b561	6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	transporter activity // inferred from electronic annotation 5506 // iron ion binding // inferred from electronic annotation /// 46872 // metal ion binding // inferred from electronic annotation 16491 // oxidoreductase activity // inferred from electronic annotation 3677 // DNA binding // inferred from electronic annotation --- ---
yddH	Hypothetical protein yddH	6118 // electron transport // inferred from electronic annotation	---	---
sfsA	sugar fermentation stimulation protein /// sugar fermentation stimulation protein A	---	---	---
slyX dinI	hypothetical protein DNA-damage-inducible protein I /// DNA damage-inducible protein I	--- 6281 // DNA repair // inferred from electronic annotation /// 6974 // response to DNA damage stimulus // inferred from electronic annotation // 9432 // SOS response // inferred from electronic annotation 6810 // transport // inferred from electronic annotation	--- ---	---
ynjC	fused transporter subunits of ABC superfamily: membrane components	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
411#1	yfdG	CPS-53 (KpLE1) prophage; bactoprenol-linked glucose translocase (flippase)	271 // polysaccharide biosynthesis // 6810 // transport	16020 // membrane // 16021 // integral to membrane	---
yigT	yigT /// idnT	Gnt-II system L-idonate transporter /// L-idonate and D-gluconate transporter	6810 // transport // inferred from electronic annotation /// 15725 // gluconate transport // inferred from electronic annotation /// 19521 // D-gluconate metabolism // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5351 // sugar porter activity // inferred from electronic annotation /// 15128 // gluconate transporter activity // inferred from electronic annotation
yheG	yheG	Probable general secretion pathway protein E	6810 // transport // inferred from electronic annotation /// 15628 // type II protein secretion system // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation /// 15627 // type II protein secretion system complex // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 8565 // protein transporter activity // inferred from electronic annotation /// 17111 // nucleoside-triphosphatase activity
dgt	dgt	deoxyguanosinetriphosphate triphosphohydrolase	46039 // GTP metabolism // inferred from electronic annotation	---	287 // magnesium ion binding // inferred from electronic annotation /// 3824 // catalytic activity // inferred from electronic annotation /// 8832 // dGTPase activity // inferred from

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
folK	2-amino-4-hydroxy-6-hydroxymethylidihydropteridine pyrophosphokinase	9396 // folic acid and derivative biosynthesis // inferred from electronic annotation	---	electronic annotation /// 16787 // hydrolase activity // inferred from 3848 // 2-amino-4-hydroxy-6-hydroxymethylidihydropteridine diphosphokinase activity // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 8894 // guanosine-5'-triphosphate,3'-diphosphate diphosphatase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation 3824 // catalytic activity // inferred from electronic annotation /// 8773 // [protein-PII] uridylyltransferase activity // inferred
gppA	gppA /// gpp	Guanosine-5'-triphosphate,3'-diphosphate pyrophosphatase /// guanosine pentaphosphatase/exopolyphosphatase	---	electronic annotation 8894 // guanosine-5'-triphosphate,3'-diphosphate diphosphatase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation 3824 // catalytic activity // inferred from electronic annotation /// 8773 // [protein-PII] uridylyltransferase activity // inferred
glnD	glnD	PII uridylyl-transferase	6807 // nitrogen compound metabolism // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation /// 9399 // nitrogen fixation // inferred	---

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		from electronic annotation		from electronic annotation /// 16597 // amino acid binding // inferred from electronic annotation /// 16740 // transferase
yhbX	yhbX	8152 // metabolism // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	8484 // sulfuric ester hydrolase activity // inferred from electronic annotation
ygiQ	Hypothetical protein ygiQ	---	---	---
323#1	Hypothetical protein ydiV /// hypothetical protein	---	---	---
cydB	Cytochrome D ubiquinol oxidase subunit II /// cytochrome d terminal oxidase, subunit II	6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5506 // iron ion binding // inferred from electronic annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 46872 // metal ion binding // inferred from electronic annotation
ybhA	ybhA	6812 // cation transport // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation	287 // magnesium ion binding // inferred from electronic annotation /// 3824 // catalytic activity // inferred from electronic annotation /// 5524

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yibL	hypothetical protein	---	---	// ATP binding // inferred from electronic annotation /// 15662
yifE	Protein yifE /// hypothetical protein	---	---	// ATPase activity, coupled to transmembrane ---
ygff	predicted NAD(P)-binding oxidoreductase with NAD(P)-binding Rossmann-fold domain	8152 // metabolism // inferred from electronic annotation	---	5515 // protein binding // inferred from physical interaction /// 16491 // oxidoreductase activity // inferred from electronic annotation 3824 // catalytic activity // inferred from electronic annotation /// 8460 // dTDP-glucose 4,6-dehydratase activity // inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation /// 50662 // coenzyme binding //
rffG	dTDP-glucose 4,6-dehydratase	9103 // lipopolysaccharide biosynthesis // inferred from electronic annotation /// 9225 // nucleotide-sugar metabolism // inferred from electronic annotation /// 44237 // cellular metabolism // inferred from electronic annotation	---	5293 // lysine permease activity // inferred from electronic annotation
yeaS	Hypothetical protein yeaS /// neutral amino-acid efflux system	6865 // amino acid transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from	

192 Highly immunogenic response proteins in HC						
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF		
yaiM	yaiM /// frmB Hypothetical protein yaiM /// predicted esterase	---	electronic annotation ---	4759 // serine esterase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation /// 4091 // carboxylesterase activity // inferred from electronic annotation ---		
ygeD	ygeD Hypothetical protein ygeD /// predicted inner membrane protein	---	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation		
yjhB	yjhB KpLE2 phage-like element; predicted transporter	6810 // transport // inferred from electronic annotation				
codB	codB Cytosine permease /// cytosine transporter	6810 // transport // inferred from electronic annotation /// 15931 // nucleobase, nucleoside, nucleotide and nucleic acid transport // inferred from electronic annotation /// 19858 // cytosine metabolism // inferred from electronic annotation	electronc annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	15205 // nucleobase transporter activity // inferred from electronic annotation		

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
rfaL	O-antigen ligase	9103 // lipopolysaccharide biosynthesis // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	16874 // ligase activity // inferred from electronic annotation
viaQ	Probable hexulose-6-phosphate synthase /// 3-keto-L-gulonate 6-phosphate decarboxylase	5975 // carbohydrate metabolism // inferred from electronic annotation /// 6207 // 'de novo' pyrimidine base biosynthesis // inferred from electronic annotation	---	5515 // protein binding // inferred from physical interaction /// 287 // magnesium ion binding // inferred from electronic annotation /// 4590 // orotidine-5'-phosphate decarboxylase activity // inferred from electronic annotation /// 16829 // lyase activ
potC	spermidine/putrescine ABC transporter membrane component /// spermidine/putrescine ABC transporter membrane protein	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
secB	export protein SecB	6457 // protein folding // inferred from electronic annotation /// 6605 // protein targeting // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 15031 // protein transport	---	51082 // unfolded protein binding // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
murG	murG	// inferred from electronic annotation 5975 // carbohydrate metabolism // inferred from electronic annotation /// 7049 // cell cycle // inferred from electronic annotation /// // 8360 // regulation of cell shape // inferred from electronic annotation /// 9252 // peptidoglycan biosynthesis // inferred from electronic annotation	5618 // cell wall // inferred from electronic annotation /// 9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation	16740 // transferase activity // inferred from electronic annotation /// 16757 // transferase activity, transferring glycosyl groups // inferred from electronic annotation /// 16758 // transferase activity, transferring hexosyl groups // inferred from electronic annotation 16491 // oxidoreductase activity // inferred from electronic annotation /// 16730 // oxidoreductase activity, acting on iron-sulfur proteins as donors // inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation /// 5298 // proline:sodium symporter activity // inferred from electronic annotation /// 15171
ydhV	Hypothetical protein ydhV /// predicted oxidoreductase		---	
putP	Sodium/proline symporter /// proline:sodium symporter		16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	
		6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6814 // sodium ion transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation		

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		annotation		// amino acid transporter activity // inferred from electronic annotation /// 15293 // sympo
viaL queA	Hypothetical protein viaL S-adenosylmethionine:tRNA ribosyltransferase-isomerase	--- 8616 // queuosine biosynthesis // inferred from electronic annotation	--- ---	--- 3824 // catalytic activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 16853 // isomerase activity // inferred from electronic annotation
yhaH	Hypothetical protein yhaH /// predicted inner membrane protein	---	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	---
cobU	adenosylcobinamide kinase /// adenosylcobinamide kinase/adenosylcobinamide-phosphate guanylyltransferase	6779 // porphyrin biosynthesis // inferred from electronic annotation /// 9236 // cobalamin biosynthesis // inferred from electronic annotation	---	166 // nucleotide binding // inferred from electronic annotation /// 3824 // catalytic activity // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
23-12A0 yadQ	chloride channel protein	6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6821 // chloride transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	annotation /// 5525 // GTP binding // inferred from electronic annotation 5247 // voltage-gated chloride channel activity // inferred from electronic annotation annotation /// 15297 // antiporter activity // inferred from electronic annotation annotation /// 31404 // chloride ion binding // inferred from electronic annotation --- 166 // nucleotide binding // inferred from electronic annotation annotation /// 5524 // ATP binding // inferred from electronic annotation annotation /// 15411 // taurine-transporting ATPase activity // inferred from electronic annotation annotation /// 16787 // hydrolase activity // inferred from electronic annotation
yciQ tauB	predicted inner membrane protein Taurine transport ATP-binding protein tauB /// taurine transporter subunit	--- 6810 // transport // inferred from electronic annotation	--- 16020 // membrane // inferred from electronic annotation	--- 166 // nucleotide binding // inferred from electronic annotation annotation /// 5524 // ATP binding // inferred from electronic annotation annotation /// 15411 // taurine-transporting ATPase activity // inferred from electronic annotation annotation /// 16787 // hydrolase activity // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yagG	CP4-6 prophage; predicted sugar transporter	6810 // transport // inferred from electronic annotation /// 6814 // sodium ion transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 15293 // symporter activity // inferred from electronic annotation 3824 // catalytic activity // inferred from electronic annotation /// 5506 // iron ion binding // inferred from electronic annotation annotation /// 16740 // transferase activity // inferred from electronic annotation annotation /// 16783 // sulfotransferase activity // inferred from electronic annotation annotation ---
lipA	lipoyl synthase	9107 // lipolate biosynthesis // inferred from electronic annotation	---	---
yhcO	Hypothetical protein yhcO /// predicted barnase inhibitor	---	---	---
maoC	fused aldehyde dehydrogenase/enoyl-CoA hydratase	8152 // metabolism // inferred from electronic annotation	---	16491 // oxidoreductase activity // inferred from electronic annotation
nfrB	Bacteriophage N4 adsorption protein B /// bacteriophage N4 receptor, inner membrane subunit	6810 // transport // inferred from electronic annotation /// 9597 // detection of virus // inferred from electronic annotation /// 46718 // entry of virus into host cell // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5524 // ATP binding // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yajR	Hypothetical transport protein yajR /// predicted transporter	annotation 6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
trkH	Trk system potassium uptake protein trkH /// potassium transporter	6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6812 // cation transport // inferred from electronic annotation /// 6813 // potassium ion transport // inferred from electronic a	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	8324 // cation transporter activity // inferred from electronic annotation /// 30955 // potassium ion binding // inferred from electronic annotation
exuR	Exu regulon transcriptional regulator /// DNA-binding transcriptional repressor	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation
glnQ	glutamine ABC transporter ATP-binding component /// glutamine ABC transporter ATP-binding protein	6810 // transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 15171 // amino acid transporter activity // inferred from

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yaJ	Hypothetical protein yaJ /// predicted amidotransferase	8152 // metabolism // inferred from electronic annotation	---	electronic annotation /// 16887 // ATPase activity // inferred from electronic annotation r
ydeF	Hypothetical protein ydeE /// predicted transporter	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
yefF	Hypothetical ABC transporter ATP-binding protein yefF /// fused predicted oligopeptide transporter subunits of ABC superfamily: ATP-binding components	6810 // transport // inferred from electronic annotation /// 6857 // oligopeptide transport // inferred from electronic annotation /// 15031 // protein transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 16887 // ATPase activity // inferred from electronic annotation /// 17111 // nucleoside-triphosphatase activity // inferred from electronic annotation
yheU greA	hypothetical protein transcription elongation factor GreA	6350 // transcription // inferred from electronic annotation /// 6355 //	---	3677 // DNA binding // inferred from electronic annotation

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		regulation of transcription, DNA-dependent // inferred from electronic annotation		annotation /// 3711 // transcriptional elongation regulator activity // inferred from electronic annotation
yagM allP	CP4-6 prophage; predicted protein Putative allantoin permease /// predicted allantoin transporter	---	---	---
	yagM allP /// ybbW	6144 // purine base metabolism // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 15931 // nucleobase, nucleoside, nucleotide and nucleic acid transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	15205 // nucleobase transporter activity // inferred from electronic annotation
yghK	Glycolate permease glcA /// glycolate transporter	6810 // transport // inferred from electronic annotation /// 15727 // lactate transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	15129 // lactate transporter activity // inferred from electronic annotation
yjFP	Hypothetical protein yjFP /// predicted hydrolase	---	---	16787 // hydrolase activity // inferred from electronic annotation
409#5	Hypothetical fimbrial-like protein yfcP precursor	7155 // cell adhesion	9289 // fimbrium	---
yefI	lipopolysaccharide biosynthesis protein wbbK	9058 // biosynthesis // inferred from electronic annotation /// 9103 // lipopolysaccharide biosynthesis // inferred from electronic annotation	---	16740 // transferase activity // inferred from electronic annotation
ydbD 214#3	hypothetical protein	---	---	---

192 Highly immunogenic response proteins in HC						
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF	
yhiN	yhiN	Hypothetical protein yhiN /// predicted oxidoreductase with FAD/NAD(P)-binding domain	6118 // electron transport // inferred from electronic annotation	---	16491 // oxidoreductase activity // inferred from electronic annotation	
mutT	mutT	Mutator mutT protein /// nucleoside triphosphate pyrophosphohydrolase, marked preference for dGTP	6260 // DNA replication // inferred from electronic annotation /// 6281 // DNA repair // inferred from electronic annotation /// 6974 // response to DNA damage stimulus // inferred from electronic annotation /// 8299 // isoprenoid biosynthesis // inferred from electronic annotation	---	287 // magnesium ion binding // inferred from electronic annotation /// 4452 // isopenentenyl-diphosphate delta-isomerase activity // inferred from electronic annotation /// 8413 // 8-oxo-7,8-dihydroguanine triphosphatase activity // inferred from electronic annotation	
virK ompC	virK ompC	hypothetical protein Outer membrane protein C precursor	---	6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 9597 // detection of virus // inferred from electronic annotation /// 46718 // entry of virus into host cell // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation /// 15288 // porin activity // inferred from electronic annotation
yghT	yghT	Hypothetical ATP-binding protein yghT /// predicted protein with nucleoside triphosphate hydrolase domain	---	---	166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding //	

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yohG	Putative channel/filament proteins /// predicted outer membrane protein	6810 // transport // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic annotation	inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation /// 8289 // lipid binding // inferred from electronic annotation
ebgA	Evolved beta-galactosidase alpha-subunit	5975 // carbohydrate metabolism // inferred from electronic annotation	9341 // beta-galactosidase complex // inferred from electronic annotation	3824 // catalytic activity // inferred from electronic annotation /// 4553 // hydrolase activity, hydrolyzing O-glycosyl compounds // inferred from electronic annotation /// 4565 // beta-galactosidase activity // inferred from electronic annotation /// 16 5215 // transporter activity // inferred from electronic annotation
yjff	Hypothetical ABC transporter permease protein yjff	6810 // transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation	---
452#13 yphG	hypothetical protein Hypothetical protein yphG	---	---	5488 // binding // inferred from electronic annotation
ynaJ	Hypothetical protein ynaJ /// predicted inner membrane protein	---	16020 // membrane // inferred from electronic annotation /// 16021 // integral	---

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
sucD	succinyl-CoA synthetase alpha subunit /// succinyl-CoA synthetase subunit alpha	6099 // tricarboxylic acid cycle // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation	to membrane // inferred from electronic annotation ---	166 // nucleotide binding // inferred from electronic annotation /// 3824 // catalytic activity // inferred from electronic annotation /// 4775 // succinate-CoA ligase (ADP- forming) activity // inferred from electronic annotation /// 5524 // ATP binding / --- ---
prtC yhdT	hypothetical protein Hypothetical protein yhdT /// conserved inner membrane protein	--- ---	--- 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 5622 // intracellular // inferred from electronic annotation	--- ---
(yhiW)	Hypothetical transcriptional regulator yhiW	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 45449 // regulation of transcription // inferred from electronic annotation	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 43565 // sequence-specific DNA binding // inferred from	

192 Highly immunogenic response proteins in HC				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
610#6.1				electronic annotation

Table 3. SAM ANALYSIS OF CROHN'S DISEASE (CD) VERSUS ULCERATIVE COLITIS (UC) (see Fig. 3B)

51 Highly immunogenic proteins in UC			
SPOT	PROTEIN NAME	GO BP	GO CC
			GO MF
			9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 15627 // type II protein secretion system complex // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane
secF	secF	6605 // protein targeting // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 6886 // intracellular protein transport // inferred from electronic annotation /// 15031 // protein transport // inferred from electronic annotation	8565 // protein transporter activity // inferred from electronic annotation /// 15450 // protein translocase activity // inferred from electronic annotation
427#1	Hypothetical protein yfgF /// predicted inner membrane protein	---	---
			166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 15197 // peptide transporter activity // inferred from electronic annotation /// 16887 // ATPase activity // inferred
yojI	yojI	6810 // transport // inferred from electronic annotation /// 15833 // peptide transport // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation
	Hypothetical ABC transporter ATP-binding protein yojI /// fused predicted multidrug transport subunits of ABC superfamily: membrane component/ATP-binding component		

51 Highly immunogenic proteins in UC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
emrY	emrY	Multidrug resistance protein Y /// predicted multidrug efflux system	6810 // transport // inferred from electronic annotation /// 6306 // DNA methylation // inferred from electronic annotation 6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6812 // cation transport // inferred from electronic annotation /// 6813 // potassium ion transport // inferred from electronic a	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	from 5215 // transporter activity // inferred from electronic annotation /// 3677 // DNA binding // inferred from electronic annotation 8324 // cation transporter activity // inferred from electronic annotation /// 30955 // potassium ion binding // inferred from electronic annotation 16491 // oxidoreductase activity // inferred from electronic annotation
trkG	trkG	Rac prophage; potassium transporter subunit			
yhiN 23-12A0	yhiN	Hypothetical protein yhiN /// predicted oxidoreductase with FAD/NAD(P)- binding domain	6118 // electron transport // inferred from electronic annotation	---	
ydaA	ydaA /// uspE	Protein ydaA /// stress-induced protein	6950 // response to stress // inferred from electronic annotation	---	---
nagE	nagE	PTS system, N-acetylglucosamine- specific IIABC component	6810 // transport // inferred from electronic annotation /// 9401 // phosphoenolpyruvate- dependent sugar phosphotransferase system // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation ///	5351 // sugar porter activity // inferred from electronic annotation /// 8982 // protein-N(PI)- phosphohistidine- sugar phosphotransferase activity // inferred

51 Highly immunogenic proteins in UC				
SPOT	PROTEIN	NAME	GO BP	GO CC
				GO MF
				19866 // organelle inner membrane // inferred from electronic annotation
				16491 // oxidoreductase activity // inferred from electronic annotation /// 16730 // oxidoreductase activity, acting on iron-sulfur proteins as donors // inferred from electronic annotation 16491 //
ydhV	ydhV	Hypothetical protein ydhV /// predicted oxidoreductase	6118 // electron transport // inferred from electronic annotation	
maoC	maoC	fused aldehyde dehydrogenase/enoyl-CoA hydratase	8152 // metabolism // inferred from electronic annotation	oxidoreductase activity // inferred from electronic annotation 4759 // serine esterase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation /// 4091 // carboxylesterase activity // inferred from electronic annotation
yaiM	yaiM /// frmB	Hypothetical protein yaiM /// predicted esterase	---	5215 // transporter activity // inferred from electronic annotation /// 5351 // sugar porter activity
yeiO	yeiO /// setB	Sugar efflux transporter B /// lactose/glucose efflux system	6810 // transport // inferred from electronic annotation /// 8643 // carbohydrate transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation // 16021 // integral to

51 Highly immunogenic proteins in UC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
				membrane // inferred from electronic annotation	// inferred from electronic annotation /// 15542 // sugar efflux transporter activity // inferred from electronic annotation
				16020 // membrane // inferred from electronic annotation ///	
				16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
ypbD	ypbD	predicted sugar transporter subunit: membrane component of ABC superfamily	6810 // transport // inferred from electronic annotation	9325 // nitrate reductase complex // inferred from electronic annotation ///	5506 // iron ion binding // inferred from electronic annotation /// 8940 // nitrate reductase activity // inferred from electronic annotation
				6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation ///	from electron annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 46872 // metal ion binding // inf
narI	narI	Respiratory nitrate reductase 1 gamma chain /// nitrate reductase 1, gamma (cytochrome b(NR)) subunit	42128 // nitrate assimilation // inferred from electronic annotation	16021 // integral to membrane // inferred from electronic annotation	
				16020 // membrane // inferred from electronic annotation ///	
				16021 // integral to membrane // inferred from electronic annotation	5215 // transporter activity // inferred from electronic annotation
ycbM	ycbM	Putative aliphatic sulfonates transport permease protein ssuC /// alkanesulfonate transporter subunit	6810 // transport // inferred from electronic annotation	inferred from electronic annotation	from electron annotation

51 Highly immunogenic proteins in UC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
yafJ		Hypothetical protein yafJ /// predicted	8152 // metabolism // inferred from electronic annotation	16740 // transferase activity // inferred from electronic annotation	
lueO	yafJ	amidotransferase	---	---	---
ybbC	lueO	hypothetical protein	---	---	---
	ybbC	hypothetical protein	---	---	---
			5279 // amino acid-polyamine transporter activity // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation	5279 // amino acid-polyamine transporter activity // inferred from electronic annotation
			16021 // integral to membrane // inferred from electronic annotation	16021 // integral to membrane // inferred from electronic annotation	/// 15171 // amino acid transporter activity // inferred from electronic annotation
(yeeF)	yeeF	Hypothetical transport protein yeeF /// predicted amino-acid transporter	6810 // transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation	16021 // integral to membrane // inferred from electronic annotation	8774 // acetaldehyde dehydrogenase (acetylating) activity // inferred from electronic annotation
			6520 // amino acid metabolism // inferred from electronic annotation	16491 // oxidoreductase activity // inferred from electronic annotation	/// 16491 // oxidoreductase activity // inferred from electronic annotation
			/// 15976 // carbon utilization // inferred from electronic annotation	5737 // cytoplasm // inferred from electronic annotation	/// 16620 // oxidoreductase activity, acting on the aldehyde or oxo group of donor
mhpF	mhpF	acetaldehyde dehydrogenase	19439 // aromatic compound catabolism // inferred from electronic annotation	16740 // transferase activity // inferred from electronic annotation	16740 // transferase activity // inferred from electronic annotation
			9058 // biosynthesis // inferred from electronic annotation	9103 // lipopolysaccharide biosynthesis // inferred from electronic annotation	/// 16757 // transferase activity, transferring glycosyl groups // inferred
rfaB	rfaB	UDP-D-galactose:(glucosyl)lipopolysaccharide-1,6-D-galactosyltransferase			

S1 Highly immunogenic proteins in UC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
yciD	yciD /// ompW	Outer membrane protein W precursor /// outer membrane protein W	--- 6281 // DNA repair // inferred from electronic annotation /// 6974 // response to DNA damage stimulus // inferred from electronic annotation // 9432 // SOS response // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation // 19867 // outer membrane // inferred from electronic annotation	from electronic annotation ---
dinI	dinI	DNA-damage-inducible protein I /// DNA damage-inducible protein I	6810 // transport // inferred from electronic annotation /// 15725 // gluconate transport // inferred from electronic annotation // 19521 // D-gluconate metabolism // inferred from electronic annotation	--- 16020 // membrane // inferred from electronic annotation // 16021 // integral to membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation // 16021 // integral to membrane // inferred from electronic annotation	--- 5351 // sugar porter activity // inferred from electronic annotation /// 15128 // gluconate transporter activity // inferred from electronic annotation
yjiT	yjiT /// idnT	Gnt-II system L-idonate transporter /// L- idonate and D-gluconate transporter			
yjiJ	yjiJ	Hypothetical protein yjiJ /// predicted inner membrane protein	---		---

51 Highly immunogenic proteins in UC			
SPOT	PROTEIN	NAME	
		GO BP	GO CC
			GO MF
fsr	fsr	Fosmidomycin resistance protein /// predicted fosmidomycin efflux system	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation 3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation
nac	nac	Nitrogen assimilation Regulatory protein nac /// DNA-binding transcriptional dual regulator of nitrogen assimilation	--- 9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation /// 16887 // ATPase activity // inferred from electronic annotation /// 17111 // nucleoside- triphosphatase activity // inferred 166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding //
msbA	msbA	Probable transport ATP-binding protein msbA /// fused lipid transporter subunits of ABC superfamily: membrane component/ATP-binding component	6810 // transport // inferred from electronic annotation /// 6869 // lipid transport // inferred from electronic annotation 6810 // transport // inferred from electronic annotation /// 15689 // molybdate ion transport // inferred from electronic annotation
modC	modC	Molybdenum transport ATP-binding protein modC /// molybdate transporter subunit	9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation

51 Highly immunogenic proteins in UC			
SPOT	PROTEIN	NAME	
		GO BP	GO CC
		GO MF	
		inferred from electronic annotation /// 15098 // molybdate ion transporter activity // inferred from electronic annotation /// 15412 // molybdate- transporting ATPa	annotation /// 16020 // membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation ---
		6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6813 // potassium ion transport // inferred from electronic annotation ---	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation ---
kch prtC	kch prtC	Putative potassium channel protein // voltage-gated potassium channel hypothetical protein	5216 // ion channel activity // inferred from electronic annotation --- 3723 // RNA binding // inferred from electronic annotation /// 8168 // methyltransferase activity // inferred from electronic annotation /// 8173 // RNA methyltransferase activity // inferred from electronic annotation /// 16740 // transferase activity // 3824 // catalytic activity // inferred from electronic
yjfh	yjfh /// rlmB	Hypothetical rRNA/rRNA methyltransferase yjfh /// 23S rRNA (Gm2251)-methyltransferase	6364 // rRNA processing // inferred from electronic annotation /// 6396 // RNA processing // inferred from electronic annotation // 9451 // RNA modification // inferred from electronic annotation 6807 // nitrogen compound metabolism // inferred from electronic annotation ---
glnD	glnD	PII uridylyl-transferase	---

51 Highly immunogenic proteins in UC			
SPOT	PROTEIN	NAME	
GO BP	GO CC	GO MF	
yhjC	Hypothetical transcriptional regulator yhjC /// predicted DNA-binding transcriptional regulator	/// 8152 // metabolism // inferred from electronic annotation /// 9399 // nitrogen fixation // inferred from electronic annotation 6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	annotation /// 8773 // [protein-PII] uridylyltransferase activity // inferred from electronic annotation /// 16597 // amino acid binding // inferred from electronic annotation /// 16740 // transferase 3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation 3824 // catalytic activity // inferred from electronic annotation /// 16874 // ligase activity // inferred from electronic annotation /// 50218 // propionate-CoA ligase activity // inferred from electronic annotation
prpE	predicted propionyl-CoA synthetase with ATPase domain	8152 // metabolism // inferred from electronic annotation /// 19629 // propionate catabolism, 2- methylcitrate cycle // inferred from electronic annotation	--- 16020 // membrane /// 16021 // integral to membrane 16020 // membrane // inferred from electronic annotation ///
279#6	D-ala-D-ala transporter subunit	6810 // transport 6118 // electron transport // inferred from electronic annotation /// 8152 // metabolism // inferred	5215 // transporter activity 16491 // oxidoreductase activity // inferred from electronic
ygjR	Hypothetical oxidoreductase ygjR /// predicted NAD(P)-binding dehydrogenase	ygjR	

51 Highly immunogenic proteins in UC			
SPOT	PROTEIN NAME	GO BP	GO CC
		from electronic annotation	16021 // integral to membrane // inferred from electronic annotation
			287 // magnesium ion binding // inferred from electronic annotation /// 4309 // exopolyphosphatase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation
ppx	ppx	Exopolyphosphatase	16020 // membrane // inferred from electronic annotation
		---	---
		9058 // biosynthesis // inferred from electronic annotation /// 9103 // lipopolysaccharide biosynthesis // inferred from electronic annotation	---
yefl	yefl /// wbbK	lipopolysaccharide biosynthesis protein	16740 // transferase activity // inferred from electronic annotation
			166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 16874 // ligase activity // inferred from electronic annotation /// 16879 // ligase activity, forming carbon-nitrogen bonds 15450 // protein translocase activity //
mesJ	mesJ	Putative cell cycle protein mesJ	8033 // tRNA processing // inferred from electronic annotation /// 16549 // tRNA editing // inferred from electronic annotation
secY/prlA	secY /// prlA	preprotein translocase SecY /// protein translocase subunit SecY	6605 // protein targeting // inferred from electronic annotation
			16020 // membrane // inferred from

51 Highly immunogenic proteins in UC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
yejA	yejA	Hypothetical protein yejA precursor /// predicted oligopeptide transporter subunit	annotation /// 6810 // transport // inferred from electronic annotation /// 9306 // protein secretion // inferred from electronic annotation /// 15031 // protein transport // inferred from electronic annotation	electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	inferred from electronic annotation 5215 // transporter activity // inferred from electronic annotation 4143 // diacylglycerol kinase activity // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 16301 // kinase activity // inferred from electronic annotation
dgkA	dgkA	Diacylglycerol kinase	8654 // phospholipid biosynthesis // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	
ygce	ygce	Hypothetical sugar kinase ygce	5975 // carbohydrate metabolism // inferred from electronic annotation	9289 // fimbrium // inferred from electronic annotation --- ---	
focA (rtn) ydbD 211#11	focA rtn ydbD	F1C major fimbrial subunit precursor Rtn protein hypothetical protein	7155 // cell adhesion // inferred from electronic annotation --- ---	16020 // membrane // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation /// 5215 //
ygfQ	ygfQ	predicted transporter	6810 // transport // inferred from electronic annotation		

51 Highly immunogenic proteins in UC			
SPOT	PROTEIN NAME	GO BP	GO CC
			GO MF
			transporter activity // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation 3848 // 2-amino-4- hydroxy-6- hydroxymethylhydr opterin diphosphokinase activity // inferred from electronic annotation // 16301 // kinase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic ann
folK	2-amino-4-hydroxy-6- hydroxymethylhydropteridine pyrophosphokinase	9396 // folic acid and derivative biosynthesis // inferred from electronic annotation	---

137 Highly immunogenic response proteins in CD			
SPOT	PROTEIN NAME	GO BP	GO CC
			GO MF
			16787 // hydrolase activity // inferred from electronic annotation
frvX	predicted endo-1,4-beta- glucanase	---	---
LDR-D 416#1			
sugE	SugE protein	6810 // transport // inferred from	16020 // membrane // inferred

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
dinD	dinD	DNA-damage-inducible protein	---	---
		6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6826 // iron ion transport // inferred from electronic annotation /// 6827 // high affinity iron ion transport // inferred from electronic annotation	from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation ---	5381 // iron ion transporter activity // inferred from electronic annotation /// 5506 // iron ion binding // inferred from electronic annotation 3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 3899 // DNA- directed RNA polymerase activity // inferred from electronic annotation /// 16740 // transferase ac 5351 // sugar
fecB	fecB	KpLE2 phage-like element; iron-dicitrate transporter subunit	6350 // transcription // inferred from electronic annotation /// 6352 // transcription initiation // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation 6810 // transport // inferred from	42597 // periplasmic space // inferred from electronic annotation
fliA	fliA	flagellar biosynthesis sigma factor FliA /// flagellar biosynthesis sigma factor	6350 // transcription // inferred from electronic annotation /// 6352 // transcription initiation // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	3899 // DNA- directed RNA polymerase activity // inferred from electronic annotation /// 16740 // transferase ac
yjhA	yjhA	Hypothetical protein yjhA	6810 // transport // inferred from	16020 // membrane // inferred

137 Highly immunogenic response proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
		precursor /// N-acetylneuraminic acid outer membrane channel protein	electronic annotation /// 6811 // ion transport // inferred from electronic annotation	from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic annotation	porter activity // inferred from electronic annotation /// 15288 // porin activity // inferred from electronic annotation
(thiS)	thiS	sulfur carrier protein ThiS	6790 // sulfur metabolism // inferred from electronic annotation	---	---
mcrD	mcrD /// yjiV	hypothetical protein	---	---	---
ygbA	ygbA	Hypothetical protein ygbA ///	---	---	---
LDR-ABC		hypothetical protein			5515 // protein binding // inferred from physical interaction /// 3755 // peptidyl-prolyl cis-trans isomerase activity // inferred from electronic annotation /// 5507 // copper ion binding // inferred from electronic annotation /// 8270 // zinc ion bindin

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				3824 // catalytic activity // inferred from electronic annotation /// 5506 // iron ion binding // inferred from electronic annotation /// 46872 // metal ion binding // inferred from electronic annotation /// 51536 // iron-sulfur cluster binding // inferred from catalytic activity // inferred from electronic annotation
yliG	Hypothetical protein yliG // predicted SAM-dependent methyltransferase	---	---	---
yfiD	Protein yfiD /// pyruvate formate lyase subunit	8152 // metabolism // inferred from electronic annotation	---	---
ycfF	HIT-like protein ycfF /// purine nucleoside phosphoramidase	---	---	---
metJ	transcriptional repressor protein MetJ	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 6555 // methionine metabolism // inferred from electronic annotation /// 8652 // amino acid bios	---	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yicC	Protein yicC	--- 6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 6826 // iron ion transport // inferred from electronic annotation /// 50896 // response to stimulus // inferred from electronic a	---	electronic annotation /// 16564 // transcriptional repressor activity // inferred from electronic annotation ---
fecR	KpLE2 phage-like element; transmembrane signal transducer for ferric citrate transport		42597 // periplasmic space // inferred from electronic annotation	5506 // iron ion binding // inferred from electronic annotation 3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred from electronic annotation /// 19843 // rRNA binding // inferred from electronic annotation ---
rpsR ycgN 448#2	30S ribosomal protein S18 hypothetical protein pseudo /// anaerobic nitric oxide	6412 // protein biosynthesis // inferred from electronic annotation --- 6118 // electron transport /// 6810	5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation // 30529 // ribonucleoprotein complex // inferred from electronic annotation ---	5506 // iron

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
	reductase flavorubredoxin	// transport		ion binding /// 10181 // FMN binding /// 16491 // oxidoreductas e activity /// 46872 // metal ion binding 5351 // sugar porter activity // inferred from electronic annotation /// 15407 // monosacchari de- transporting ATPase activity // inferred from electronic annotation /// 16787 // hydrolase activity // inferred from electronic annotation 166 // nucleotide binding // inferred from electronic annotation /// 3991 // acetylglutama te kinase
rbsB	D-ribose-binding periplasmic protein precursor /// D-ribose transporter subunit	6810 // transport // inferred from electronic annotation /// 6935 // chemotaxis // inferred from electronic annotation	42597 // periplasmic space // inferred from electronic annotation	
argB	acetylglutamate kinase	6526 // arginine biosynthesis // inferred from electronic annotation /// 8652 // amino acid biosynthesis // inferred from electronic annotation /// 9085 // lysine biosynthesis // inferred from electronic annotation	5737 // cytoplasm // inferred from electronic annotation	

137 Highly immunogenic response proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
					activity // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 16301 // kinase activity // inferred fro --- 5215 // transporter activity // inferred from electronic annotation --- 3824 // catalytic activity // inferred from electronic annotation /// 3857 // 3- hydroxyacyl- CoA dehydrogenas e activity // inferred from electronic annotation /// 4165 // dodecenoyl- CoA delta- isomerase
hoxK	hoxK	hypothetical protein	---	---	
yfhD yigF	yfhD yigF	Hypothetical protein yfhD /// predicted transglycosylase Protein yigF	6810 // transport // inferred from electronic annotation ---	30288 // periplasmic space (sensu Proteobacteria) // inferred from electronic annotation ---	
fadB	fadB	3-hydroxyacyl-CoA dehydrogenase /// fused 3- hydroxybutyryl-CoA epimerase/delta(3)-cis-delta(2)- trans-enoyl-CoA isomerase/enoyl-CoA hydratase/3-hydroxyacyl-CoA dehydrogenase	6629 // lipid metabolism // inferred from electronic annotation /// 6631 // fatty acid metabolism // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation /// 9062 // fatty acid catabolism // inferred from elect	16507 // fatty acid beta- oxidation multienzyme complex // inferred from electronic annotation	

137 Highly immunogenic response proteins in CD			
SPOT	PROTEIN NAME	GO BP	GO CC
			GO MF
			activity // inferred from electronic annotation /// 43 5215 // transporter activity // inferred from electronic annotation /// 15604 // phosphonate transporter activity // inferred from electronic annotation /// 16020 // membrane // phosphonate transporter activity // inferred from electronic annotation /// 16021 // integral to membrane // phosphonate transporter activity // inferred from electronic annotation /// 16491 // oxidoreductas e activity // inferred from electronic annotation /// 16620 // oxidoreductas e activity, acting on the aldehyde or
		5887 // integral to plasma membrane // inferred from electronic annotation /// 16020 // membrane // phosphonate transporter activity // inferred from electronic annotation /// 16021 // integral to membrane // phosphonate transporter activity // inferred from electronic annotation	
(phnE)	phnE membrane channel protein component of Pn transporter	6810 // transport // inferred from electronic annotation /// 15716 // phosphonate transport // inferred from electronic annotation	
			8152 // metabolism // inferred from electronic annotation
	Succinate-semialdehyde dehydrogenase [NADP+] /// succinate-semialdehyde dehydrogenase I, NADP- dependent		---
gabD	gabD		

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
rbfA	rbfA	6364 // rRNA processing // inferred from electronic annotation	---	oxo group of --- 49 // rRNA binding // inferred from electronic annotation // 3676 // nucleic acid binding // inferred from electronic annotation // 3723 // RNA binding // inferred from electronic annotation // 3735 // structural constituent of ribosome // inferred fro ---
rpSL yjbL	30S ribosomal protein S12 hypothetical protein	6412 // protein biosynthesis // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation ---	5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation // 15935 // small ribosomal subunit // inferred from electronic annotation // 30529 // ribonucleoprotein complex // inferred from electronic annotation ---	---
nuoE	ATP synthase subunit E /// NADH dehydrogenase subunit E	6120 // mitochondrial electron transport, NADH to ubiquinone // inferred from electronic annotation	---	5506 // iron ion binding // inferred from electronic annotation // 8137 // NADH dehydrogenas e (ubiquinone) activity // inferred from electronic annotation // ---

137 Highly immunogenic response proteins in CD			
SPOT	PROTEIN NAME	GO BP	GO CC
			GO MF
			16491 // oxidoreductase activity // inferred from electronic annotation /// 46872 // metal ion 5351 // sugar porter activity // inferred from electronic annotation /// 15128 // gluconate transporter activity // inferred from electronic annotation 49 // tRNA binding // inferred from electronic annotation /// 3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred from electronic annotation ///
		6810 // transport // inferred from electronic annotation /// 15725 // gluconate transport // inferred from electronic annotation /// 19521 // D-gluconate metabolism // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation
(gntU)	Low-affinity gluconate transport permease protein, interrupted /// gluconate transporter, low affinity GNT 1 system		
			5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation /// 30529 // ribonucleoprotein complex // inferred from electronic annotation
rpIP	50S ribosomal protein L16	6412 // protein biosynthesis // inferred from electronic annotation	
rpIP			

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				19843 // rRNA binding // inferred from elect 5515 // protein binding // inferred from physical interaction /// 8168 // methyltransfer ase activity // inferred from electronic annotation /// 8425 // 2- polyprenyl-6- methoxy-1,4- benzoquinone methyltransfer ase activity // inferred from electronic annotati
ubiG	3-demethylubiquinone-9 3- methyltransferase	6744 // ubiquinone biosynthesis // inferred from electronic annotation 15716 // phosphonate transport // inferred from electronic annotation /// 19634 // phosphonate metabolism // inferred from electronic annotation	---	
phnG	PhnG protein /// carbon- phosphorus lyase complex subunit		---	
	Virulence factor mviN homolog /// predicted inner membrane protein	9405 // pathogenesis // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation // 16021 // integral to membrane // inferred from electronic annotation	---
mviN	Hypothetical protein ydfB // Hypothetical protein ydfA //			---
ydfA	Qin prophage; predicted protein	---	---	---

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
rpmJ	50S ribosomal protein L36		5622 // intracellular // inferred from electronic annotation /// 5840 //	3735 // structural constituent of ribosome //
yihD	Protein yihD /// hypothetical protein	6412 // protein biosynthesis // inferred from electronic annotation	ribosome // inferred from electronic annotation ///	inferred from electronic annotation
ydfr	Hypothetical protein ydfr	---	30529 // ribonucleoprotein complex // inferred from electronic annotation	---
baiF	hypothetical protein	---	---	---
			4730 //	4730 // pseudouridylate synthase activity //
				inferred from electronic annotation ///
				16439 //
				tRNA- pseudouridine synthase activity //
				inferred from electronic annotation ///
				16853 //
				isomerase activity //
				inferred from electronic annotation
ygbO	tRNA pseudouridine synthase D Hypothetical protein yfeC ///	8033 // tRNA processing // inferred from electronic annotation /// 31119 // tRNA pseudouridine synthesis // inferred from electronic annotation	---	
yfeC	predicted DNA-binding transcriptional regulator	---		---
basS	Sensor protein basS/pmrB ///	160 // two-component signal transduction system	16020 // membrane // inferred from electronic annotation ///	155 // two- component

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
	component regulatory system with BasR	(phosphorelay) // inferred from electronic annotation /// 6468 // protein amino acid phosphorylation // inferred from electronic annotation /// 7165 // signal transduction // inferred from electronic annotation	16021 // integral to membrane // inferred from electronic annotation	sensor activity // inferred from electronic annotation /// 4871 // signal transducer activity // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation /// 166 // nucleotide binding // inferred from electronic annotation /// 4812 // aminoacyl-tRNA ligase activity // inferred from electronic annotation /// 4821 // histidine-tRNA ligase activity // inferred from electronic annotation
hisS	hisS histidyl-tRNA synthetase	6412 // protein biosynthesis // inferred from electronic annotation /// 6418 // tRNA aminoacylation for protein translation // inferred from electronic annotation /// 6427 // histidyl-tRNA aminoacylation // inferred from electronic annotation	5737 // cytoplasm // inferred from electronic annotation	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				annotation /// 5524 // ATP binding // 5515 // protein binding // inferred from physical interaction /// 4751 // ribose- 5-phosphate isomerase activity // inferred from electronic annotation /// 16853 // isomerase activity // inferred from electronic annotation 5515 // protein binding // inferred from physical interaction /// 16853 // isomerase activity // inferred from electronic annotation /// 16857 // racemase and epimerase activity,
rpiB		5975 // carbohydrate metabolism // inferred from electronic annotation /// 6098 // pentose-phosphate shunt // inferred from electronic annotation	---	
	ribose-5-phosphate isomerase B			
rpiB				
		5975 // carbohydrate metabolism // inferred from electronic annotation /// 6051 // N-acetylmannosamine metabolism // inferred from electronic annotation	---	
	Hypothetical protein yhcJ /// predicted N- acetylmannosamine-6-P epimerase			
yhcJ	yhcJ /// nanE			

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				acting on carbohydrates and derivatives // inferred from electronic annotation // 15078 // hydrogen ion transporter activity // inferred from electronic annotation /// 16820 // hydrolase activity, acting on acid anhydrides, catalyzing transmembrane movement of substances // inferred from electronic annotation /// 16787 // hydrolase act
			16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation /// 16469 // proton-transporting two-sector ATPase complex // inferred from electronic annotation /// 45263 // proton-transpo	
atpB	ATP synthase subunit A /// F0F1 ATP synthase subunit A	6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation /// 15992 // proton transport // inferred from electronic annotation		
yijF	Hypothetical protein yijF precursor /// hypothetical protein	---		---
		6457 // protein folding // inferred from electronic annotation /// 15031 // protein transport // inferred from electronic annotation /// 19538 // protein metabolism // inferred from electronic annotation		166 // nucleotide binding // inferred from electronic annotation ///
clpX	ATP-dependent protease ATP-binding subunit		---	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		/// 6986 // response to unfolded protein // inferre		5515 // protein binding // inferred from electronic annotation /// 5524 // ATP binding // inferred from electronic annotation /// 8270 // zinc ion binding // inferred from electronic ann 5515 // protein binding // inferred from physical interaction /// 3824 // catalytic activity // inferred from electronic annotation /// 8797 // aspartate ammonia-lyase activity // inferred from electronic annotation /// 16829 // lyase activity // inferred
aspA	Aspartate ammonia-lyase	6531 // aspartate metabolism // inferred from electronic annotation	---	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yigK	Homoserine/homoserine lactone efflux protein /// neutral amino-acid efflux system yigK /// rhtB	6810 // transport // inferred from electronic annotation /// 6865 // amino acid transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5293 // lysine permease activity // inferred from electronic annotation 16787 // hydrolase activity // inferred from electronic annotation 4781 // sulfate adenylyltransferase (ATP) activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 16779 // nucleotidyltransferase activity // inferred from electronic annotation
yjhO	KpLE2 phage-like element; predicted endoglucanase with Zn-dependent exopeptidase domain yjhO /// sgcX	---	---	---
cysD	sulfate adenylyltransferase subunit 2	103 // sulfate assimilation // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation /// 8652 // amino acid biosynthesis // inferred from electronic annotation /// 19344 // cysteine biosynthesis // inferred from electronic annotation	---	---
yjbR	Protein yjbR /// hypothetical protein	---	---	---
yjiF	hypothetical protein	---	---	---
cysW	sulfate/thiosulfate transporter subunit	6810 // transport // inferred from electronic annotation /// 8272 // sulfate transport // inferred from	9276 // cell wall (sensu Proteobacteria) // inferred from electronic annotation ///	5215 // transporter activity //

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
221#15		electronic annotation	16020 // membrane // inferred from electronic annotation ///	inferred from electronic annotation ///
			16021 // integral to membrane // inferred from electronic annotation	15116 // sulfate transporter activity // inferred from electronic annotation // 15563 // uptake permease activity // inferred from electronic annotation
rpsG	30S ribosomal protein S7	6412 // protein biosynthesis // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation // 5840 // ribosome // inferred from electronic annotation // 15935 // small ribosomal subunit // inferred from electronic annotation // 30529 // ribonucleoprotein complex // inferred from electronic annotation	49 // tRNA binding // inferred from electronic annotation // 3723 // RNA binding // inferred from electronic annotation // 3735 // structural constituent of ribosome // inferred from electronic annotation // 19843 // rRNA binding // inferred

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				from elect 5515 // protein binding // inferred from physical interaction /// 3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 30528 // transcription regulator activity // --- 9024 // tagatose-6- phosphate kinase activity // inferred from electronic annotation /// 16301 // kinase activity // inferred from electronic annotation ///
		6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 45449 // regulation of transcription // inferred from electronic annotation ---	5622 // intracellular // inferred from electronic annotation ---	
yhfr flxA	yhfr /// frlR flxA	predicted DNA-binding transcriptional regulator Qin prophage; predicted protein		
agaZ	agaZ /// kbaZ subunit	Putative tagatose 6-phosphate kinase agaZ /// tagatose 6- phosphate aldolase 1, kbaZ	19402 // galactitol metabolism // inferred from electronic annotation ---	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
(ycfA)	e14 prophage; predicted tail fiber assembly protein	---	---	16740 // transferase activity // inferred from electronic annotation
	tfaE	---	---	8270 // zinc ion binding // inferred from electronic annotation /// 16788 // hydrolase activity, acting on ester bonds // inferred from electronic annotation
yhfV	Phosphotriesterase homology protein	9056 // catabolism // inferred from electronic annotation	---	---
yieJ	hypothetical protein yieJ /// cbrC	---	---	---
yibQ	Hypothetical protein yibQ /// hypothetical protein	---	---	---
		---	---	5351 // sugar porter activity // inferred from electronic annotation /// 8982 // protein-N(PD)-phosphohistidine-sugar phosphotransferase activity // inferred from
ptsN	Nitrogen regulatory IIA protein /// sugar-specific enzyme IIA component of PTS	6810 // transport // inferred from electronic annotation /// 9401 // phosphoenolpyruvate-dependent sugar phosphotransferase system // inferred from electronic annotation	---	---
ptsN				

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				electronic annotation /// 16740 // transferase activity // inferred from electronic annotati 15036 // disulfide oxidoreductas e activity // inferred from electronic annotation /// 16491 // oxidoreductas e activity // inferred from electronic annotation /// 16731 // oxidoreductas e activity, acting on iron-sulfur proteins as donors, NAD or NADP as ac
ygbD	nitric oxide reductase	6118 // electron transport // inferred from electronic annotation 6310 // DNA recombination // inferred from electronic annotation /// 6313 // transposition, DNA- mediated // inferred from electronic annotation /// 6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-d	---	3677 // DNA binding // inferred from electronic annotation
fimB	Type 1 fimbriae Regulatory protein fimB /// tyrosine recombinase/inversion of on/off regulator of fimA		9289 // fimbrium // inferred from electronic annotation	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				3723 // RNA binding // inferred from electronic annotation /// 8168 // methyltransferase activity // inferred from electronic annotation /// 8173 // RNA methyltransferase activity // inferred from electronic annotation /// 16740 // transferase activity //
lasT	Hypothetical tRNA/rRNA methyltransferase lasT /// predicted rRNA methyltransferase	6396 // RNA processing // inferred from electronic annotation 8652 // amino acid biosynthesis // inferred from electronic annotation /// 9082 // branched chain family amino acid biosynthesis // inferred from electronic annotation	---	
ivbL	IlvBN operon leader peptide /// ilvB operon leader peptide		---	---
				4364 // glutathione transferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic
gst	Glutathione S-transferase /// glutathionine S-transferase	---	---	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
phbA	phbA	hypothetical protein	---	annotation --- 16787 // hydrolase activity // inferred from electronic annotation
phnM	phnM	PhnM protein	---	---
yhgl	yhgl /// gntY Protein yhgl /// predicted gluconate transport associated protein	---	---	3723 // RNA binding // inferred from electronic annotation /// 8168 // methyltransfer ase activity // inferred from electronic annotation /// 8175 // tRNA methyltransfer ase activity // inferred from electronic annotation /// 9019 // tRNA (guanine-N1-)-meth 5515 // protein binding // inferred from physical interaction /// 9055 //
trmD	trmD	tRNA (guanine-N(1)- methyltransferase	6400 // tRNA modification // inferred from electronic annotation /// 8033 // tRNA processing // inferred from electronic annotation 6118 // electron transport // inferred from electronic annotation /// 6810 // transport // inferred from electronic annotation /// 9263 // deoxyribonucleotide biosynthesis // inferred from electronic annotation /// 45454 //	---
grxA	grxA	Glutaredoxin 1 /// glutaredoxin 1, redox coenzyme for ribonucleotide reductase (RNR1a)	---	---

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		cell redox homeostasis // infer		electron carrier activity // inferred from electronic annotation /// 15035 // protein disulfide oxidoreductase activity // inferred from electronic annotation 5506 // iron ion binding // inferred from electronic annotation /// 16491 // oxidoreductase activity // inferred from electronic annotation /// 16728 // oxidoreductase activity, acting on CH2 groups, disulfide as acceptor // inferred from electronic annotation --- 8168 // methyltransfer
gcpE	4-hydroxy-3-methylbut-2-en-1-yl diphosphate synthase /// 4-hydroxy-3-methylbut-2-en-1-yl diphosphate synthase	8299 // isoprenoid biosynthesis // inferred from electronic annotation /// 16114 // terpenoid biosynthesis // inferred from electronic annotation		
ycdB	gcpE /// ispG			
yfiC	hypothetical protein yfiC /// predicted S-adenosyl-L-	---	---	

137 Highly immunogenic response proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
		methionine-dependent methyltransferase			ase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 155 // two-component sensor activity // inferred from electronic annotation /// 156 // two-component response regulator activity // inferred from electronic annotation /// 4871 // signal transducer activity // inferred from electronic annotation /// 5524
			160 // two-component signal transduction system (phosphorelay) // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 6468 // protein amino acid phosphorylation // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation /// 30113 // capsule (sensu Bacteria) // inferred from electronic annotation	
		Sensor protein rcsC /// hybrid sensory kinase in two-component regulatory system with RcsB and YojN			
(rcsC)	rcsC	Hypothetical protein yedF ///			
yedF	yedF	hypothetical protein CP4-57 prophage; predicted protein			
yfjI	yfjI	Hypothetical protein yhdN ///			
yhdN	yhdN	hypothetical protein			

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
phnB	phnB protein	---	---	---
	PhnB protein /// hypothetical protein			15105 // arsenite transporter activity // inferred from electronic annotation
(yjfV)	CP4-57 prophage; predicted protein	46685 // response to arsenic // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	
ydhL	Hypothetical protein ydhL precursor	---	---	---
	hypothetical protein /// hypothetical protein		16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	
yhaN	yhaN	---	---	---
				3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation
slyA	transcriptional regulator SlyA	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 9405 // pathogenesis // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	
411#4	Hypothetical protein yfdK	---	---	---
633#5				4156 // dihydropteroate synthase activity // inferred from electronic annotation /// 16740 //
folP	Dihydropteroate synthase /// 7,8-dihydropteroate synthase	9396 // folic acid and derivative biosynthesis // inferred from electronic annotation /// 46656 // folic acid biosynthesis // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	---	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
336#6				transferase activity // inferred from electronic annotation 5351 // sugar porter activity // inferred from electronic annotation /// 8982 // protein-N(P)-phosphohistidine-sugar phosphotransferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 166 // nucleotide binding // inferred from electronic annotation /// 5525 // GTP binding // inferred from electronic annotation
glvB	glvB	6810 // transport // inferred from electronic annotation /// 9401 // phosphoenolpyruvate-dependent sugar phosphotransferase system // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	
glvB	glvB	arbutin specific enzyme IIB component of PTS		
hfX	hfX	7264 // small GTPase mediated signal transduction // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	
hfX	hfX	GTP-binding protein hfX /// predicted GTPase		

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				annotation /// 8233 // peptidase activity // inferred from electronic annotation 4851 // uroporphyrin- III C- methyltransfer ase activity // inferred from electronic annotation /// 8168 // methyltransfer ase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation
			16020 // membrane // inferred from electronic annotation ///	---
			16021 // integral to membrane // inferred from electronic annotation	---
		6779 // porphyrin biosynthesis // inferred from electronic annotation	---	3874 // 6- pyruvoyltetra hydropterin synthase activity // inferred from electronic annotation /// 8270 // zinc
hemX	Putative uroporphyrin-III C- methyltransferase /// predicted uroporphyrinogen III methylase			
yceD	Hypothetical protein yceD /// hypothetical protein			
ptpS	Putative 6-pyruvoyl tetrahydrobiopterin synthase /// 6-pyruvoyl tetrahydrobiopterin synthase (PTPS)	6729 // tetrahydrobiopterin biosynthesis // inferred from electronic annotation	---	
	ptpS /// ygcM			

137 Highly immunogenic response proteins in CD			
SPOT	PROTEIN NAME	GO BP	GO CC
			GO MF
			ion binding // inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation /// 46872 // metal ion bindi 5515 // protein binding // inferred from physical interaction /// 51082 // unfolded protein binding // inferred from electronic annotation
		6457 // protein folding // inferred from electronic annotation /// 6986 // response to unfolded protein // inferred from electronic annotation /// 50821 // protein stabilization // inferred from electronic annotation	
ibpB	16 kDa heat shock protein B /// heat shock chaperone Putative toxin of osmotically regulated toxin-antitoxin system associated with programmed cell death /// entericidin B membrane lipoprotein		---
ecnB		9636 // response to toxin // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation
aceB	malate synthase	6097 // glyoxylate cycle // inferred from electronic annotation /// 6099 // tricarboxylic acid cycle // inferred from electronic annotation	---
			4474 // malate synthase activity // inferred from electronic annotation /// 16829 // lyase activity // inferred from

137 Highly immunogenic response proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
yehR	yehR	Hypothetical lipoprotein yehR precursor /// hypothetical protein	---	16020 // membrane // inferred from electronic annotation	electronic annotation --- 5515 // protein binding // inferred from physical interaction /// 3677 // DNA binding // inferred from electronic annotation /// 8168 // methyltransferase activity // inferred from electronic annotation /// 8170 // N-methyltransferase activity // inferred
hsdM	hsdM	DNA methylase M	6306 // DNA methylation // inferred from electronic annotation /// 9307 // DNA restriction-modification system // inferred from electronic annotation	---	---
yrbB	yrbB	Hypothetical protein yrbB /// hypothetical protein	---	---	---
hypC	hypC	Hydrogenase isoenzyme formation protein hypC /// protein required for maturation of hydrogenases 1 and 3	---	---	3676 // nucleic acid binding // inferred from electronic annotation
vacJ	vacJ	VacJ lipoprotein precursor /// predicted lipoprotein	---	16020 // membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic	---

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
405#2 ydfD	Hypothetical protein ydfD	---	annotation ---	--- 3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred from electronic annotation /// 19843 // rRNA binding // inferred from electronic annotation 16491 // oxidoreductase activity // inferred from electronic annotation
rpsK	30S ribosomal protein S11	6412 // protein biosynthesis // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation /// 30529 // ribonucleoprotein complex // inferred from electronic annotation	
yieF	Hypothetical protein yieF /// chromate reductase, Class I, flavoprotein	---	---	16020 // membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic annotation 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation 9288 // flagellum (sensu
sixA	Outer membrane protein slp precursor /// outer membrane lipoprotein	---	---	---
yjyD fliS	Hypothetical protein yjyD /// conserved inner membrane protein flagellar protein FliS	---	9296 // flagellum biogenesis //	---

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
		inferred from electronic annotation	Bacteria) // inferred from electronic annotation ///	
		6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	19861 // flagellum // inferred from electronic annotation	16829 // lyase activity // inferred from electronic annotation
hycA	Formate hydrogenlyase Regulatory protein hycA /// regulator of the transcriptional regulator FhlA	hycA	---	16740 // transferase activity // inferred from electronic annotation
wcaA yhaC 348#4	Putative colanic acid biosynthesis glycosyl transferase wcaA /// predicted glycosyl transferase hypothetical protein hypothetical protein	9103 // lipopolysaccharide biosynthesis // inferred from electronic annotation --- ---	---	15128 // gluconate transporter activity // inferred from electronic annotation
yjhF	KpLE2 phage-like element; predicted transporter	6810 // transport // inferred from electronic annotation /// 15725 // gluconate transport // inferred from electronic annotation	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	5515 // protein binding // inferred from physical interaction /// 166 // nucleotide binding // inferred from electronic annotation /// 5524 // ATP binding //
recN	DNA repair protein recN /// recombination and repair protein	6281 // DNA repair // inferred from electronic annotation /// 6310 // DNA recombination // inferred from electronic annotation /// 6974 // response to DNA damage stimulus // inferred from electronic annotation /// 51276 // chromosome organization and biog	5694 // chromosome // inferred from electronic annotation /// 16020 // membrane // inferred from electronic annotation	

137 Highly immunogenic response proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
			6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	inferred from electronic annotation 3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation 166 // nucleotide binding // inferred from electronic annotation 5525 // GTP binding // inferred from electronic annotation 5622 // intracellular // inferred from electronic annotation
		Putative L-lactate dehydrogenase operon			
		Regulatory protein			
lldR	lldR				
yiiA	yiiA	GTP-binding protein	917 // barrier septum formation // inferred from electronic annotation /// 7049 // cell cycle // inferred from electronic annotation /// 51301 // cell division // inferred from electronic annotation		
ydiL	ydiL	Hypothetical protein ydiL /// hypothetical protein			
tdcB	tdcB	threonine dehydratase	6520 // amino acid metabolism // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation		3824 // catalytic activity // inferred from electronic annotation /// 4794 // threonine ammonia-lyase activity

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				// inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation 3677 // DNA binding // inferred from electronic annotation /// 4252 // serine-type endopeptidase activity // inferred from electronic annotation /// 8233 // peptidase activity // inferred from electronic annotation /// 8236 // serine-type peptidase activity
		6280 // mutagenesis // inferred from electronic annotation /// 6281 // DNA repair // inferred from electronic annotation /// 6508 // proteolysis // inferred from electronic annotation /// 6974 // response to DNA damage stimulus // inferred from electronic annotation	---	5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation /// 30529 // ribonucleoprotein complex // inferred from electronic annotation
umuD	UmuD protein /// DNA polymerase V, subunit D			
umuD	umuD			
rpIQ	50S ribosomal protein L17	6412 // protein biosynthesis // inferred from electronic annotation		
rpIQ	rpIQ			

137 Highly immunogenic response proteins in CD					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
yjbl	yjbl	hypothetical protein	---	---	---
			6412 // protein biosynthesis // inferred from electronic annotation /// 6413 // translational initiation // inferred from electronic annotation /// 6417 // regulation of protein biosynthesis // inferred from electronic annotation /// 6445 // regulation of		3743 // translation initiation factor activity // inferred from electronic annotation /// 3723 // RNA binding // inferred from electronic annotation 3849 // 3- deoxy-7- phosphoheptu lonate synthase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation 166 // nucleotide binding // inferred from
infC	infC	Translation initiation factor IF-3		---	
			8652 // amino acid biosynthesis // inferred from electronic annotation /// 9058 // biosynthesis // inferred from electronic annotation /// 9073 // aromatic amino acid family biosynthesis // inferred from electronic annotation		
aroF	aroF	3-deoxy-7-phosphoheptulonate synthase /// 3-deoxy-D-arabino- heptulosonate-7-phosphate synthase, tyrosine-repressible			
yjiA	yjiA	Hypothetical protein yjiA /// predicted GTPase	---	---	

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
yohL	Hypothetical protein yohL ///	---	---	electronic annotation ///
	hypothetical protein	---	---	5525 // GTP binding // inferred from electronic annotation

				4322 //
				ferroxidase activity // inferred from electronic annotation ///
				5488 //
				binding // inferred from electronic annotation ///
				5506 // iron ion binding // inferred from electronic annotation ///
				8199 // ferric iron binding // inferred from electronic annotation ///
				3824 //
				catalytic activity // inferred from electronic annotation ///
				4124 //
				cysteine synthase
ftn	Ferritin 1 /// ferritin iron storage protein (cytoplasmic)	6826 // iron ion transport // inferred from electronic annotation /// 6879 // iron ion homeostasis // inferred from electronic annotation	---	
		6535 // cysteine biosynthesis from serine // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation /// 8652 // amino acid biosynthesis // inferred from electronic annotation /// 19344 //	---	
cysM	Cysteine synthase B /// cysteine synthase B (O-acetylserine sulphydrolase B)	cysine biosynthesis //	---	

[illegible]

137 Highly immunogenic response proteins in CD				
SPOT	PROTEIN NAME	GO BP	GO CC	GO MF
				inferred from electronic annotation /// 4634 // phosphopyruv ate hydratase activity // inferred from electronic annotation /// 16829 // lyase activity // inferred from electronic annotation /// 46872 // metal ion binding //

Table 4. SAM ANALYSIS OF HEALTHY CONTROLS (HC) VERSUS ULCERATIVE COLITIS (UC) (see Fig. 3C)

6 Highly immunogenic proteins in UC			
SPOT	PROTEIN NAME	GO BP	GO CC
era	GTP-binding protein Era	50875 // cellular physiological process // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation // 16020 // membrane // inferred from electronic annotation
era		6164 // purine nucleotide biosynthesis // inferred from electronic annotation // 6189 // de novo IMP biosynthesis // inferred from electronic annotation	166 // nucleotide binding // inferred from electronic annotation // 3676 // nucleic acid binding // inferred from electronic annotation // 3723 // RNA binding // inferred from electronic annotation // 5525 // GTP binding // inferred from electronic annotation
purK	phosphoribosylaminoimidazole carboxylase		166 // nucleotide binding // inferred from electronic annotation // 3824 // catalytic activity // inferred from electronic annotation // 4638 // phosphoribosylaminoimidazole carboxylase activity // inferred from electronic annotation // 5524 // ATP bin
cadA	Lysine decarboxylase, inducible // lysine decarboxylase 1	6520 // amino acid metabolism // inferred from electronic annotation	5515 // protein binding // inferred from physical interaction // 3824 // catalytic activity // inferred from electronic annotation // 8923 // lysine decarboxylase activity // inferred from electronic annotation // 16829 // lyase activity // inferred from electronic annotation
nrff	Formate-dependent nitrite reductase complex nrff subunit precursor // heme lyase (NrFEG) for insertion of heme into c552, subunit Nrff	---	5506 // iron ion binding // inferred from electronic annotation // 46872 // metal ion binding // inferred from electronic annotation
murA	UDP-N-acetylglucosamine 1-carboxyvinyltransferase	7049 // cell cycle // inferred from electronic annotation // 8360 // regulation of cell shape // inferred from electronic annotation // 9252 //	8760 // UDP-N-acetylglucosamine 1-carboxyvinyltransferase activity // inferred from electronic annotation // 16740 // transferase activity // inferred from electronic annotation

6 Highly immunogenic proteins in UC			
SPOT	PROTEIN NAME	GO BP	GO CC
		GO MF	
		peptidoglycan	
		biosynthesis // inferred	
		from electronic	
		annotation /// 19277 //	
		UDP-N-	
		acetyl/galactosamine bios	
		6094 // gluconeogenesis	
		// inferred from electronic	
		annotation /// 6096 //	
		glycolysis // inferred	
		from electronic	
		annotation /// 6098 //	
		pentose-phosphate shunt	
		// inferred from electronic	
		annotation /// 6633 //	
		fatty acid biosynthesis //	
		inferred from electronic	
		annotation	---
tpiA	tpiA	triosephosphate isomerase	
		4807 // triose-phosphate isomerase	
		activity // inferred from electronic	
		annotation /// 16853 // isomerase	
		activity // inferred from electronic	
		annotation	

27 Highly immunogenic proteins in HC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
yphA	yphA	Hypothetical protein yphA /// predicted inner membrane protein	---	16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation	---
			6350 // transcription // inferred from electronic annotation // 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation /// 45892 // negative regulation of transcription, DNA-dependent // inferred from electronic annotat		3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation
pssR	pssR	transcriptional regulator HdfR /// transcriptional regulator Hdfr	---	---	---
yhdN	yhdN	Hypothetical protein yhdN /// hypothetical protein	---	5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation // 15934 // large ribosomal subunit // inferred from electronic annotation // 30529 // ribonucleoprotein complex // inferred from electronic annotation	3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred from electronic annotation // 19843 // rRNA binding // inferred from electronic annotation 8080 // N-acetyltransferase activity /// 8415 // acyltransferase activity // 16740 // transferase activity /// 16747 // transferase activity, transferring groups other than amino-acyl groups other --- 8415 // acyltransferase activity // inferred from
rp10	rp10	50S ribosomal protein L15	6412 // protein biosynthesis // inferred from electronic annotation		
420#7	yphA	putative acetyltransferase	---	---	---
yehK	yehK	hypothetical protein	---	---	---
yihG	yihG	Hypothetical protein yihG /// predicted endonuclease	8152 // metabolism // inferred from electronic annotation	16020 // membrane // inferred from electronic	

27 Highly immunogenic proteins in HC

SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
				annotation /// 16021 // integral to membrane // inferred from electronic annotation	electronic annotation /// 16740 // transferase activity // inferred from electronic annotation /// 4519 // endonuclease activity // inferred from electronic annotation 4149 // dihydrolipooyllysine- residue succinyltransferase activity // inferred from electronic annotation /// 5515 // protein binding // inferred from electronic annotation /// 8415 // acyltransferase activity // inferred from electronic annotation /// 1674 8168 // methyltransferase activity // inferred from electronic annotation /// 8176 // tRNA (guanine-N7)- methyltransferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation 3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred from electronic annotation /// 19843 // rRNA binding // inferred from electronic annotation 3988 // acetyl-CoA C- acyltransferase activity // inferred from electronic annotation /// 8415 //
sucB	sucB	dihydrolipoamide acetyltransferase	6099 // tricarboxylic acid cycle // inferred from electronic annotation /// 8152 // metabolism // inferred from electronic annotation	45252 // oxoglutarate dehydrogenase complex // inferred from electronic annotation	
yggH	yggH	tRNA (guanine-N(7))- methyltransferase // tRNA(m7G46)- methyltransferase	6400 // tRNA modification // inferred from electronic annotation /// 8033 // tRNA processing // inferred from electronic annotation		
rpsK	rpsK	30S ribosomal protein S11	6412 // protein biosynthesis // inferred from electronic annotation 6629 // lipid metabolism // inferred from electronic annotation /// 6631 // fatty acid metabolism // inferred from	5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation /// 30529 // ribonucleoprotein complex // inferred from electronic annotation	
fadA	fadA	acetyl-CoA acetyltransferase		---	

27 Highly immunogenic proteins in HC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
			electronic annotation /// 16042 // lipid catabolism // inferred from electronic annotation		acyltransferase activity // inferred from electronic annotation /// 16740 // transferase activity // inferred from electronic annotation
ydfo	ydfo	Hypothetical protein ydfo /// Qin prophage; predicted protein	---	--- 16020 // membrane // inferred from electronic annotation /// 16021 // integral to membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic annotation	--- 5351 // sugar porter activity // inferred from electronic annotation /// 15288 // porin activity // inferred from electronic annotation
yjha	yjha	Hypothetical protein yjha precursor /// N- acetylauraminic acid outer membrane channel protein	6810 // transport // inferred from electronic annotation /// 6811 // ion transport // inferred from electronic annotation	---	---
yheU	yheU	hypothetical protein	---	5622 // intracellular // inferred from electronic annotation /// 5840 // ribosome // inferred from electronic annotation ///	49 // rRNA binding // inferred from electronic annotation // 3676 // nucleic acid binding // inferred from electronic annotation /// 3723 // RNA binding // inferred from electronic annotation /// 3735 // structural constituent of ribosome // inferred fro
rpsL	rpsL	30S ribosomal protein S12	6412 // protein biosynthesis // inferred from electronic annotation /// 46677 // response to antibiotic // inferred from electronic annotation	---	---
yibQ	yibQ	Hypothetical protein yibQ precursor /// predicted polysaccharide deacetylase HIT-like protein ycff ///	---	---	---
ycfF	ycfF /// hinT	purine nucleoside phosphoramidase	---	---	---
yzgL	yzgL	hypothetical protein	---	---	---
yjFY	yjFY	hypothetical protein	---	---	---
316#4	rsxA	hypothetical protein	---	---	---
yneC	yneC	hypothetical protein	---	---	---
yneG	yneG	Hypothetical protein yneG	---	---	---

27 Highly immunogenic proteins in HC					
SPOT	PROTEIN	NAME	GO BP	GO CC	GO MF
		/// hypothetical protein			
fabH	fabH	3-oxoacyl-(acyl carrier protein) synthase	6633 // fatty acid biosynthesis // inferred from electronic annotation /// 8610 // lipid biosynthesis // inferred from electronic annotation	---	3824 // catalytic activity // inferred from electronic annotation /// 4315 // 3-oxoacyl-[acyl-carrier protein] synthase activity // inferred from electronic annotation /// 8415 // acyltransferase activity // inferred from electronic annotation /// 16740 /
menG	menG	ribonuclease activity regulator protein RraA	---	---	---
sixA	slp	Outer membrane protein slp precursor /// outer membrane lipoprotein	---	16020 // membrane // inferred from electronic annotation /// 19867 // outer membrane // inferred from electronic annotation	---
yhdM	yhdM /// zntR	zinc-responsive transcriptional regulator	6350 // transcription // inferred from electronic annotation /// 6355 // regulation of transcription, DNA-dependent // inferred from electronic annotation	5622 // intracellular // inferred from electronic annotation	3677 // DNA binding // inferred from electronic annotation /// 3700 // transcription factor activity // inferred from electronic annotation /// 8270 // zinc ion binding // inferred from electronic annotation /// 46872 // metal ion binding // inferred from
ptsH	ptsH	Phosphocarrier protein HPr /// phosphohistidinoprotein-hexose phosphotransferase component of PTS system (Hpr)	6810 // transport // inferred from electronic annotation /// 9401 // phosphoenolpyruvate-dependent sugar phosphotransferase system // inferred from electronic annotation	---	5515 // protein binding // inferred from physical interaction /// 5351 // sugar porter activity // inferred from electronic annotation

As shown in the Venn diagram in Figure 3D, the immunogenic responses to 417 proteins were found to be different between healthy control and Crohn's Disease or ulcerative colitis. Of these 417 proteins, 169 proteins were identified as highly immunogenic in healthy control, 186 proteins are highly immunogenic in Crohn's Disease and only 19 in ulcerative colitis. 44 proteins were highly immunogenic in both healthy control and inflammatory bowel disease (Crohn's Disease or ulcerative colitis). Among these 44 proteins, six overlap between healthy control and Crohn's Disease and 38 overlap between healthy control and ulcerative colitis. A full list of the immunogenic *E. coli* proteins in Figure 3D can be found in Table 5.

Table 5. List of differentially immunogenic proteins among Healthy Control (HC), Crohn's Disease (CD) and ulcerative colitis (UC), as illustrated in Fig. 3A

PROTEIN SPOT	HC	CD	UC	Legend
rpsK				Highly immunogenic
rpsL				
sixA				
ycfF				
yhdN				
yjhA				
era				
(yeeF)				
211#11				
23-12A0				
279#6				
427#1				
dgkA				
dinI				
emrY				
focA				
folK				
fsr				
glnD				
kch				
maoC				
msbA				
nac				
nagE				

narI		
ppx		
priC		
rfaB		
secF		
secY/priA		
trkG		
yafJ		
yaiM		
ybbC		
ycbM		
ydaA		
ydbD		
ydhV		
yefI		
yeiO		
ygjR		
yhiN		
yjgT		
yojI		
yphD		
(yhcP)		
(yhhT)		
(yhiW)		
16-3B0		
214#3		
233#6		
273#6		
280#1		
316#4		
321#3		
323#1		
331#2		
356#7		
406#7		
409#5		
411#1		
420#7		
452#13		
610#6.1		
aceF		
allP		
ansP		

aqpZ		
atoE		
brnQ		
celD		
cobU		
codB		
cybB		
cydB		
cydC		
dgt		
dnaQ		
ebgA		
emrB		
emrD		
exuR		
fabH		
fabZ		
fadA		
fepD		
flhD		
glnQ		
glpF		
gppA		
greA		
hemY		
JW0438		
JW1949		
lipA		
lpxC		
malX		
malZ		
menG		
mrdB		
murG		
mutT		
narU		
nfrB		
nrfE		
ompC		
oppC		
oppF		
pbuX		
pheP		

phsE
pnuC
potC
pssR
ptsH
putP
queA
rfaL
rffG
rocE
rplO
sdhD
secB
sfsA
slyX
sucB
sucD
tauB
thiL
trkH
udk
uidB
virK
yaaH
yabK
yadQ
yaeG
yagG
yagM
yaiV
yajR
ybaN
ybdS
ybfB
ybfC
ybgE
ybhA
ybhL
ybhM
ybhN
ybhR
ycaD
yccY

ycdG			
yciQ			
yciR			
yciS			
ydcD			
yddH			
ydeF			
ydeZ			
ydfO			
ydjS			
ydjZ			
yeaS			
yehK			
yehY			
yejF			
yfjY			
ygeD			
ygfF			
yggH			
yghK			
yghT			
ygjQ			
yhaH			
yhaO			
yhbX			
yhcO			
yhdM			
yhdT			
yheG			
yheU			
yhfU			
yhhL			
yhhS			
yhiP			
yhiQ			
yhjX			
yiaL			
yiaQ			
yibL			
yibQ			
yicO			
yidY			
yifE			

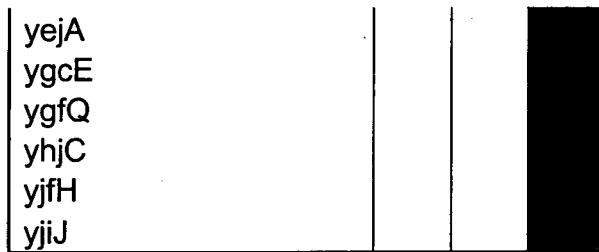
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yjeM		
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yneG		
ynjC		
yoaA		
yohG		
yphA		
yphG		
yqcE		
yzgL		
(gntU)		
(phnE)		
(rcsC)		
(thiS)		
(ycfA)		
(yfiV)		
221#15		
267#6		
304#1		
319#17		
336#6		
348#4		
405#2		
411#4		
416#1		
430#8		
445#15		
448#2		
633#5		
aceB		
agaZ		
aidA		
argB		
argC		
aroF		

aroK		
aspA		
atpB		
baiF		
basS		
cedA		
citB		
citG		
clpX		
cysD		
cysJ		
cysM		
cysW		
dgxA		
dicC		
dinD		
ecnB		
eno		
fadB		
fba		
fdhE		
fecB		
fecR		
fimB		
fimC		
fliA		
fliS		
flxA		
folP		
frvX		
ftn		
fumB		
gabD		
galR		
gcpE		
glvB		
grxA		
grxC		
gst		
hemX		
hflX		
hisS		
hofH		

hoxK	
hsdM	
hycA	
hycF	
hypC	
ibpB	
infC	
ivbL	
lasT	
LDR-ABC	
LDR-D	
lldR	
mcrD	
metB	
metJ	
mltB	
mviN	
narY	
nuoE	
phbA	
phnB	
phnG	
phnM	
ppdB	
ptpS	
ptsN	
purM	
radC	
rbfA	
rbsB	
recN	
rffD	
rpiB	
rplP	
rplQ	
rplT	
rpmJ	
rpsG	
rpsR	
selD	
slyA	
slyD	
ssi6	

sugE	
tdcB	
thiF	
torA	
trmD	
ubiG	
umuD	
vacJ	
wcaA	
ybbA	
ybbQ	
ycbF	
ycdB	
yceD	
ycgN	
ydfA	
ydfD	
ydfR	
ydhL	
ydiL	
yedF	
yehR	
yejG	
yejO	
yfeC	
yfhD	
yfiC	
yfiD	
yfiJ	
yfiQ	
ygbA	
ygbD	
ygbO	
ygcQ	
ygeW	
ygfY	
yhaA	
yhaC	
yhaN	
yhcl	
yhcJ	
yhfR	
yhfV	

yhgH			
yhgl			
yicC			
yeF			
yeJ			
yigK			
yihA			
yihD			
yihK			
yiiF			
yijD			
yijF			
yjaI			
yjbl			
yjbL			
yjbQ			
yjbR			
yjcS			
yjeB			
yjeJ			
yjgF			
yjhC			
yjhE			
yjhF			
yjhO			
yjiA			
yliG			
ymfE			
yohL			
yphC			
yrbB			
(rtn)			
cadA			
lueO			
mesJ			
mhpF			
modC			
murA			
nrfF			
prpE			
purK			
tpiA			
yciD			



This demonstrates that ulcerative colitis and healthy control subjects share more common immunogenic profiles than Crohn's Disease and healthy control. In general, these results indicate that much of the global immunogenic profiles of sera samples were systematically correlated with either healthy controls or IBD phenotypes and that sample class can be distinguished based on the sample's immunogenic profile.

Example 3: Protein Functional Enrichment Analysis.

To delineate the immunogenic signatures of the healthy controls and IBD subtypes the differentially immunogenic proteins were assigned to functional groups based on classification by Gene Ontology (www.geneontology.org). Functional grouping of the 417 proteins were assigned by querying EcoCyc (<http://ecocyc.org/>) and KEGG (www.genome.ad.jp/kegg) databases, as well as cross-checked with Affymetrix *E. coli* Genome Array annotation file (www.affymetrix.com). 338 of these 417 proteins were assigned to at least one gene ontology (GO) term, and 78 hypothetical proteins have unknown annotations. The enrichment analysis was focussed on five GO cellular component terms (membrane, cell wall, intracellular, macromolecular complex, periplasmic space and cell projection). To assess whether the selected differentially immunogenic proteins were enriched in one of the GO terms, the hypergeometric statistical test was used to compute the probability of the number of proteins in each cellular component appearing by chance within the proteins highly immunogenic in healthy control (169), Crohn's Disease (185) and ulcerative colitis (18). Figure 4 summarizes the enrichment analysis of these proteins that are immunogenic in healthy control and Crohn's Disease or ulcerative colitis. Antibodies against membrane proteins are highly enriched in healthy control samples ($p < 0.0001$). Interestingly, antibodies against intracellular and macromolecular complex proteins are highly enriched in Crohn's Disease samples ($p < 0.05$), while those against cell wall proteins are highly enriched in ulcerative colitis samples ($p < 0.05$). Although 12% proteins that were found to be highly immunogenic in Crohn's Disease samples were located in periplasmic

space, their enrichment was not statistically significant ($p = 0.064$) for this IBD subtype. Proteins located in cell projection term are not enriched in either healthy controls or IBD subtypes.

5 **Example 4: Machine Learning Analysis.**

Next, optimal classifiers were constructed from the immunogenic response profiles to differentiate healthy control from the IBD subtypes (Crohn's Disease and ulcerative colitis), as well as to differentiate Crohn's Disease from ulcerative colitis. Upon successful construction of these classifiers, the classification rules may result in the discovery of new robust biomarkers. k-TSP, a novel machine learning method was employed to discover simple decision rules classifiers from the immunogenic response profiles. The three top scoring pairs were identified as classifiers to differentiate healthy control samples from Crohn's Disease samples as follows:

1. If a subject sample shows greater immunogenic reactivity to era than to ybaN then the subject is identified as likely having Crohn's Disease, or else as UC.

2. If a subject sample shows greater immunogenic reactivity to yhgN than to focA then the subject is identified as as likely having Crohn's Disease or as a healthy control; and

3. If a subject sample shows greater immunogenic reactivity to gabT than ycdG then the subject is identified as likely having Crohn's Disease (see representative examples of actual images of immuno-reactive protein spots in Figure 2). If all three pairs identify the subject as having Crohn's disease then the sample is classified as a Crohn's Disease sample. Figure 5A depicts the protein spot ratios for this classifier that separate the data between the two phenotypes where yellow represents a vote for Crohn's Disease and blue represents a vote for healthy control. Using the k-TSP classifier, 36 out of 39 healthy control and 62 out of 64 Crohn's Disease samples are correctly classified, with an estimated ten-fold cross-validation accuracy of $86 \pm 4\%$ ($p < 0.01$).

For distinguishing healthy control from ulcerative colitis samples, the k-TSP algorithm identifies eleven feature pairs (Figure 5B) with an estimated ten-fold crossvalidation accuracy of $66 \pm 5\%$ ($p < 0.04$). A single feature pair of k-TSP classifier was identified for differentiating Crohn's disease from ulcerative colitis: If the sample has greater immunogenic reactivity to frvX than to yidX then the subject is identified as having ulcerative colitis as illustrated in Figure 5C (see representative examples of actual images of immuno-reactive protein spots in Figure 5D). This classifier has an estimated ten-fold cross-validation accuracy of $80 \pm 2\%$ ($p < 0.1$).

The performance of k-TSP was also compared with SVM and kNN, two other commonly used learning algorithms, for each of the classification problems based on five runs of ten-fold crossvalidation. Table 6 displays the results of ten-fold cross-validation for each of the three classifiers.

Table 6. Estimated ten-fold cross-validation classification rates of IBD using the three described classification methods. The reported rates are given in percentages and are the mean performance on all five runs of ten-fold cross validation $\pm$ the standard deviation. In parenthesis are the numbers of samples in each subtype used for classification. Sp = specificity, Sn = sensitivity, PPV= positive predictive value, NPV= negative predictive value.

Healthy control (HC) (39) vs CD (66)					
Method	Accuracy (%)	Sp (HC) (%)	Sn (CD) (%)	PPV (CD) (%)	NPV (HC) (%)
k-TSP	86 $\pm$ 4	81 $\pm$ 5	89 $\pm$ 3	89	81
SVM	70 $\pm$ 2	66 $\pm$ 1	73 $\pm$ 2	79	59
kNN	63 $\pm$ 3	47 $\pm$ 7	73 $\pm$ 6	70	50
Healthy control (HC) (39) vs UC (29)					
Method	Accuracy (%)	Sp (HC) (%)	Sn (UC) (%)	PPV (UC) (%)	NPV (HC) (%)
k-TSP	66 $\pm$ 5	69 $\pm$ 5	61 $\pm$ 7	59	70
SVM	62 $\pm$ 5	58 $\pm$ 1	68 $\pm$ 12	55	71
kNN	60 $\pm$ 6	57 $\pm$ 2	64 $\pm$ 12	53	68
CD (66) vs UC (29)					
Method	Accuracy (%)	Sp (CD) (%)	Sn (UC) (%)	PPV (CD) (%)	PPV (UC) (%)
k-TSP	80 $\pm$ 2	84 $\pm$ 1	70 $\pm$ 6	86	66
SVM	78 $\pm$ 3	82 $\pm$ 2	69 $\pm$ 9	86	63
kNN	78 $\pm$ 3	78 $\pm$ 4	61 $\pm$ 2	82	55

As demonstrated in Table 6, based on cross-validation, k-TSP performance meets or exceeds the performance of kNN and SVM for these classification problems. Because the cross-validation structure allowed each classifier to test the same subsets of data as described in the methods section, the performance of the three classifiers can be directly compared and tested for statistical significance by a simple student's t-test. The healthy control vs. CD k-TSP classifier outperformed the other methods in total classification performance ($p < 0.001$). For the remaining two classification problems, the k-TSP classifiers achieved nominally better, but not statistically significant in classification accuracy when compared to SVM and kNN classifiers. From this study, k-TSP was found to perform much better than SVM and kNN in separating healthy control from Crohn's Disease. In addition, the ordering of the expression values within profiles were utilized in the k-TSP decision rules, therefore, the classifier is invariant to data pre-processing (28). Figures 6A and 6B show that on their own, the immunogenic responses to era

and ybaN (the top scoring pair in the healthy control vs CD k-TSP classifier) do not allow for class separation of the data; no threshold level would clearly separate healthy control from Crohn's Disease. However, the ratio of the two features (top-scoring pair ratio) results in clear separation in the data lending well to classification (Figure 6C). Similar results are true when scatter plot analysis was done for the other two TSP pairs from the healthy control vs Crohn's Disease classifier (yhgN vs focA and gabT vs ycdG, respectively). This represents an advantage of k-TSP over other learning methods where interpreting the decision rules are easy and can facilitate follow-up study. It is important to note that SAM identified era as the second best individual marker for up regulation in CD, thus it appears that individual markers will not work well for classification and explains why KNN and SVM fail to match the performance of k-TSP as the relative feature levels within samples appear to be much more robust than the absolute feature levels across samples

Example 5: Robustness of the k-TSP classifiers.

To determine that class imbalance did not greatly affect the classification results, an additional analysis was performed where samples were randomly discarded from a class with greater total number of samples in order to equalize the class sizes. 10-fold cross validation was performed as described. The process was then repeated by discarding a different random set of samples.

Table 7 (below) shows the performance of each classifier given class balance in the training set.

Table 7. Permutation statistics for each pair of biomarkers. Top scoring pairs used for each classifier and the percentage of surrogate classifiers in which those pairs appear during 10-fold cross validation (mean $\pm$ standard deviation, p-value).

k-TSP Classifier	Accuracy (%)		Estimated p-value	Features in k-TSP classifier	% feature appearance
	10-fold CV	10-fold CV Permutation			
HC vs. CD	86 $\pm$ 3	50 $\pm$ 8	p < 0.01	era > ybaN = CD yhgN > focA = CD gabT > ycdG = CD	90 84 64
HC vs. UC	66 $\pm$ 5	51 $\pm$ 9	p < 0.05	relE > cysE/wcaB = UC pyrI > yjgK = UC Int > ybiO = UC ftsE > pssR = UC yhgN > yhfG = UC yafN > dsbB = UC yihI > yabK = UC 421#15 > yhdN = UC hisP > rplO = UC cml > nuoM = UC yieC > nuol = UC	80 42 36 36 20 20 26 24 16 14 12
UC vs. CD	80 $\pm$ 2	52 $\pm$ 6	p < 0.01	yidX > frvX = UC	88

These results demonstrate that k-TSP outperforms SVM and kNN in most instances whether or not the class size is balanced, further supporting the data presented in Table 5.

Next, to determine the significance of each classifier, a permutation test was performed by randomly shuffling the class labels while maintaining the same number of samples in each class. 10-fold cross validation is carried out to yield a classification rate for the permutation set. 100 permutations were performed in order to get a null distribution of expected classification rates by chance. The classification rate from the un-permuted data is then compared to the null distribution to determine significance. Table 7 shows the permutation test results for all the classification problems. For the k-TSP classifiers trained to differentiate between healthy control and Crohn's Disease samples as well as Crohn's Disease and ulcerative colitis samples, no permuted set achieved classification rates equal or superior to the original data out of 100 permutations. Thus, these classifiers were estimated to be significant at the p < 0.01 level. The k-TSP classifier built to differentiate healthy control and ulcerative colitis had 4/100 permutations achieve rates that matched or exceeded the original classifier, thus this classifier is near the typical significance threshold at p < 0.05.

Finally, to gauge the robustness of the classification rules discovered by the k-TSP method, the surrogate classifiers created during the ten-fold cross validation procedure were inspected. Every loop of cross validation creates a separate classifier used to predict the left out sample classes, these are called surrogate classifiers. Thus, for each problem of interest that was performed ten fold cross-validation in Table 7, there were 50 classifiers to inspect (10 for each of the 5 runs). The percentage of the time that the rule from the final k-TSP classifier showed up in the 50 surrogate classifiers was an indicator of the robustness of that rule. Table 7 shows that the pairs that show up in the healthy control vs. Crohn's Disease classifier as well as the ulcerative colitis vs. Crohn's Disease classifier are fairly robust while the pairs in the healthy control vs. ulcerative colitis classifier are not. Along with the permutation testing, this indicates that the healthy control vs. Crohn's Disease and ulcerative colitis vs. Crohn's Disease classifier should perform well in independent testing while the healthy control vs. ulcerative colitis classifier may not.

Example 6: Stratifying Crohn's Disease subtypes and risk for surgery.

Certain antibody-based serological biomarkers (such as pANCA and ASCA) have shown promise in risk stratifying patients prior to instituting medical therapy or embarking on surgery. As an example, the presence of pANCA has been associated with the development of acute and chronic pouchitis after colectomy with ileal pouchanal anastomosis. Similarly, the presence of high titers of ASCA has been found to predict the occurrence of pouch complications and a more complicated disease course in Crohn's disease. To evaluate whether the new biomarkers identified can be used to stratify Crohn's Disease and ulcerative colitis subtypes or risk for surgery, the Vienna classification was used to subtype patients with Crohn's Disease into the following behavior subtypes (Table 1): penetrating/fistulizing, stricturing, penetrating/structuring and non-penetrating non-stricturing. Patients with ulcerative colitis were divided into those with left sided disease (inflammation extending no further than the splenic flexure). Pancolitis was considered to be continuous inflammation from the rectum extending beyond the splenic flexure. Due to the small sample sizes for each disease type, k-TSP analysis using the newly identified biomarkers was unable to stratify subtypes of Crohn's Disease or ulcerative colitis, or risk for surgery. When larger sample sizes are available, it is expected that at least those biomarkers listed herein will be useful for identifying subjects in need of surgery.

In particular, pairs and sets of biomarkers delineated in Tables 2-5, 7, and Figure 5 are useful alone or in combination with existing biomarkers to identify subjects that could benefit from surgery.

5 **Example 7: OmpC and fliC, two of the known serological markers, performed poorly.**

Although anti-OmpC and anti-Cbir (fliC) have been recently considered two new IBD serological biomarkers, these markers were not identified in our screening of the *E. coli* K12 proteome. Scatter plot (Figure 7) analysis of *E. coli* ompC and fliC demonstrates that neither allows for class separation between control vs Crohn's Disease vs ulcerative colitis; no threshold
10 level would clearly separate the data.

Protein microarrays have been demonstrated to be a powerful tool to identify biomarkers. The results reported herein provide the first study to identify serological biomarkers in human autoimmune diseases using a protein chip of whole prokaryotic proteome. The significance of this study is three-fold: First, it presents here the first proof of principle for the feasibility of
15 application of high density protein microarray/chip technology in the discovery of novel serological IBD biomarkers. This study can serve as an example of similar proteomic approaches for hunting serological biomarkers for other immune-related diseases, such as autoimmune disorders. Second, this is the first examination of human immune responses to the entire proteome of a microbial species under normal or any disease condition. It is surprising to
20 learn that human circulating antibodies can recognize more than 400 *E. coli* proteins (Figure 3D). Since it has been demonstrated that defective intestinal barrier function plays a central role in the pathogenesis of Crohn's Disease, it is conceivable that in patients with Crohn's Disease commensal bacteria or their products could more readily penetrate intestinal epithelia. Therefore, it is less surprising that 185 of the *E. coli* proteins were recognized by sera from
25 Crohn's Disease patients (Fig. 3D). However, it remains a mystery why there are a large number (185) of immunogenic *E. coli* proteins that are specific in healthy controls while only 18 immunogenic proteins are found to be specific to ulcerative colitis. Third, this study identified a set of novel serological biomarkers that have >80% overall accuracy and sensitivity in differentiating CD from healthy control or ulcerative colitis.

30 An intriguing observation in this study is the difference in the immunogenicity of surface/membrane vs intracellular proteins in healthy control vs CD patients. Approximately

85% of the highly immunogenic proteins were either cell wall proteins or membrane proteins in healthy control, compared to only ~37% of the top immunogenic proteins in Crohn's Disease patients (Figure 4, Figure 5 and Tables 2-5, and 7). Conversely, ~30% of top immunogenic proteins in Crohn's Disease patients are intracellular proteins compared to only ~7% in healthy control (Figure 4, Figure 5 and Tables 2-5, and 7). Furthermore, there is no overlap among the top immunogenic *E. coli* surface/membrane proteins among the three distinct populations (healthy control, Crohn's Disease and ulcerative colitis, see Figure 3D). This suggests that the host immunological response to *E. coli* is drastically different between healthy control and CD patients. The mechanism of having these immunogenic differences is not clear at this moment. It is likely that in immunologically healthy hosts where *E. coli* are largely confined to the luminal side of the gut due to intestinal epithelial barrier, surface and membrane proteins of *E. coli* might be the primary antigens that are more accessible to the immune system, compared to intracellular proteins. In this case, immune system has adapted to the presence of luminal *E. coli*. In contrast, in Crohn's Disease patients, a disrupted or compromised intestinal barrier may lead to the bacterium or its products crossing the gut luminal barrier. If the whole *E. coli* invades into the lamina propria, it will mostly likely be lysed by host immune system. Subsequently, *E. coli* components such as intracellular proteins that would otherwise not be seen by the intestinal immune system in the lamina propria are presented by antigen-presenting cells (such as macrophages or dendritic cells).

This may dramatically alter the previously adapted immune system that is only used to the lumenally exposed *E. coli*, resulting in an overwhelming production of antibodies against these intracellular *E. coli* proteins. The consequences of these immune responses include recruitment of various inflammatory immune cells such as neutrophils, dendritic cells, and lymphocytes to lamina propria or between colonic epithelial cells, leading to dysregulated mucosal inflammation. This may also explain why there are only 6 overlapping proteins among 354 top immunogenic proteins recognized by healthy control and Crohn's Disease patients (Fig. 3D).

None of the serum antibody biomarkers that are identified here for discriminating Crohn's Disease from healthy control or ulcerative colitis have been previously described.

Although most of the antigens (*E. coli* proteins) responsible for generation of these marker antibodies have not been well characterized, their identity and function can be predicted based on

their sequence information. Among the proteins in the k-TSP classifier – era, ybaN, yhgN, focA, gabT and ycdG (Figure 5A)– for discriminating CD from healthy control, era is a GTP binding protein that involves in the binding of GTP and nucleotide of cell cycle and can be found in intracellular membrane. In this study, an increased immunogenic response to era is associated with Crohn's Disease, identified by both SAM and k-TSP analyses. YbaN is predicted as a conserved inner membrane protein with unknown function. YhgN is predicted as an inner six transmembrane domains protein where the C-terminus is located in the periplasm (36). YcdG (also called rutG) is another predicted transmembrane with eleven helices; the C-terminus of the protein is located on the cytoplasmic side of the inner membrane (36). This protein is predicted to be involved in the pyrimidine utilization in *E. coli* where it may function as a proton-driven uracil uptake system (37). FocA, an inner membrane protein, is a putative formate transporter that may involve in both formate uptake and efflux. Disruption of the focA gene confers resistance to hypophosphite, a toxic formate analogue (38). GabT, 4-aminobutyrate aminotransferase, is a well characterized protein and acts as the initial enzyme of the 4-aminobutyrate (GABA) degradation pathway in *E. coli* (39). Among the pair of proteins (frvX and yidX) that were identified to be discriminatory between CD and ulcerative colitis, frvX is a important protein in fructose-specific PEP-dependent sugar phosphotransferase system (40); and yidX is a predicted lipoprotein, the function of which is currently unknown.

Like all previously identified serological (antibody) biomarkers, including p-ANCA, ASCA, anti-OmpC, and anti-I2 and anti-Cbir, the pathological or functional consequences of having these newly identified circulating antibodies is unclear.

The newly identified biomarkers by k-TSP analysis have a particular impressive ~86% accuracy in differentiating CD from healthy control, with a specificity of ~81% and a sensitivity of ~89% (Table 6). In addition, k-TSP analysis yields an accuracy of ~80% in differentiating CD and ulcerative colitis, with a sensitivity of ~84% and specificity of ~70% (Table 6). These demonstrate that the sensitivity and specificity of these novel serological markers are comparable to those of combination of the multiple best-characterized IBD biomarkers (ASCA, pANCA, anti-OmpC, and anti-Cbir) (41, 42). More importantly, an identical performance can be achieved by using only the top 3 pairs of *E. coli* proteins for discriminating healthy controls vs CD, and one top pair of proteins for differentiating CD vs ulcerative colitis (Figs. 2 & 5 and Tables 2 & 3).

These data provide a critical feasibility for 1) validation study using additional larger cohorts of IBD patients and controls and 2) future development of novel assay kits for diagnosis of CD and ulcerative colitis. However, it is necessary to point out that our current approach screening *E. coli* protein array is not suitable for identifying serological biomarkers in differentiating ulcerative colitis from healthy control (only ~66% accuracy) (Tables 5 and 6). Importantly, OmpC, an *E. coli* antigen for one of the widely studied current serological biomarker (anti-OmpC), was not picked up in our screen (Figure 7A). Similarly, fliC, an *E. coli* flagellin protein equivalent the *Salmonella* flagellin (which is the antigen for anti-Cbir, another widely studied anti-bacterial antibody) did not show up in our analysis (Figure 7A). These data would suggest that anti-OmpC and at least the antibody against *E. coli* fliC are not robust serological biomarkers for IBD. In conclusion, we have presented here the first demonstration that using protein array to screen circulating disease-specific antibodies is a robust, effective and high throughput approach for discovery of novel biomarkers of IBD. This approach can be readily applied to screen serological biomarkers of various autoimmune diseases and/or even infectious diseases.

The results reported above were obtained using the following methods and materials.

Patients and serum acquisition.

Serum was obtained from 134 subjects in accordance with the policy of the Johns Hopkins Hospital Institutional Review Board. Sixty six patients had the diagnosis of Crohn's disease (CD), 29 patients were diagnosed with ulcerative colitis (UC), and 39 subjects were non-IBD healthy controls (HC). The healthy controls and IBD patients were similar in age and sex distribution. The demographic and clinical characteristics of the patients are summarized in **Table 1**. Clinical information was abstracted from the written and electronic medical records. The diagnosis of CD and ulcerative colitis was established by standard clinical, radiographic, endoscopic and histological criteria. Patients were classified as having CD based on the typical findings of skip lesions, deep linear or serpiginous ulcerations, cobblestoning, multiple noncaseating granulomas, transmural inflammation, small bowel involvement, structuring disease or presence of fistulizing disease. The diagnosis of ulcerative colitis was considered if the colonic inflammation involved the rectum with or without proximal extension. The inflammation had to be continuous and be limited to the mucosa. There were no patients with

proctitis enrolled in this study. The healthy controls consisted of individual undergone colon cancer screening or other non-IBD GI diseases or any other immune diseases. The serum samples were obtained at the time of initial outpatient encounter, at the time of an endoscopy or during hospitalization. The blood was collected into a serum separator tube (Red top tube, BD Vacutainer) and spun down within 60 minutes of collection. Serum was removed, aliquoted, and stored in multiple at -80°C until assayed.

Fabrication of *E. coli* proteome chips.

To facilitate the analysis of protein function in the bacterial proteomes, we have constructed a protein chip that essentially covers the entire proteome of the *E. coli* K 12 strain (Chen (2008) Nat. Methods 5, 69-74). Briefly, 4,256 *E. coli* proteins were first purified using an ORF collection kindly provided by Dr. Mori and colleagues (26). *E. coli* cells first were grown overnight at 37 °C in 2x LB media containing 30 µg/ml chloramphenicol in a 96-well format and allowed to grow for overnight. The overnight cultures were diluted to a final OD600 of ~0.1. After the cells were grown for ~3 hrs at 37 °C, and protein expression were induced with 1 mM isopropyl β-D-thiogalactoside (IPTG) for ~3.5 hrs. The liquid cultures were then harvested by centrifuge of 3500 rpm for 5 min at 4°C. The pellets were stored at -80°C for future protein purification.

To purify the fusion proteins, the frozen cell pellets were re-suspended in phosphate lysis buffer, containing 300 mM NaCl, 20 mM imidazole, CelLytic B, Lysozyme (1 mg/mL), Benzonase (50 units/ml), proteinase inhibitor cocktail, and PMSF (1 mM). Along with Ni-NTA beads, the mixtures were incubated for 1.5 h at 4°C. After mixing, the resin-protein complexes were washed 3 times with Wash buffer I (50 mM NaH₂PO₄ with 300 mM NaCl, 10% glycerol, 20 mM imidazole, 0.01% Triton X-100, at pH 8) and 3 times with Wash buffer II (50 mM NaH₂PO₄ with 150 mM NaCl, 25% glycerol, 20 mM imidazole, 0.01% Triton X-100, at pH 8). Finally, the fusion protein was eluted with elution buffer (50 mM NaH₂PO₄/150 mM NaCl/25% glycerol/250 mM imidazole/0.01% Triton X-100, pH 7.5). All purified proteins were printed in duplicate onto FullMoon slides using a ChipWriter Pro (Bio-Rad) in a humidity-controlled chamber in a cold room (25).

Screen of *E. coli* Proteome Chip for anti-*E. coli* antibodies.

The entire screening process, except for the washing steps as specified, was done at room temperature. *E. coli* protein chips stored at -80 °C were thawed at room temperature (22 °C) and blocked in Superblock Blocking Buffer (Pierce) for one hour. The patient's serum was diluted (1:1000) with blocking buffer in a total volume of 3 ml. The diluted serum was then applied to the chip entirely covering the surface. After 1 hour incubation with gentle shaking on a rocker, the chip was rinsed once with 4 ml of Tris-buffered saline (TBS) with 0.05% Tween 20 (TBS-T). The chip was then soaked in 4 ml TBS-T, placed in a water bath and washed for 10 min at 50 °C with gentle horizontal agitation. This washing step was repeated twice. The chip was then cooled to room temperature. After removal of TBS-T, the chip was incubated for 1 h with the secondary antibody, a Cy3-labeled donkey anti-human IgA, G, and M (Jackson ImmunoLab) diluted at 1:400 in 3 mL Superblock Blocking Buffer. The chip was then washed at 50 °C in the same fashion as previously stated. After the final wash, the chip was rinsed in sterile water briefly, and quickly spun at 2000 rpm until dry prior to scanning. The chips were scanned with a GenePix array scanner (GenePix Pro 6.0 or GenePix 4200AL, Molecular Devices, PA) at wavelength of 536 nm. To achieve the best signal-to-noise ratio, many washing conditions with different stringencies had been tested, including increase of salt (0.5 or 1 M NaCl), addition of SDS (0.05 or 0.1%), change of washing temperature (22, 37, 40, or 50 °C), and/or various combination of conditions described above. The washing condition described here gave best results among all conditions tested.

Protein Array Data preprocessing.

Each quantified sample array image was exported from Genepix (Molecular Devices, CA) as a text file for preprocessing. The goal of preprocessing is to yield a feature of interest from each protein spot in the array that minimizes technical variability and maximizes the signal of interest. The ratio of the mean signal over the mean background signal for each protein spot was determined to be the best method of preprocessing. This method has the advantage that all features are normalized to their background signals. Thus, if a protein spot signal is artificially high due to an artifact on the slide the ratio will account for it. Furthermore this preprocessing method also normalizes the features across all arrays, as the ratio is a standardized metric. The

ratio represents the fold change of the signal above background and can be interpreted as the degree of host serum reactivity to each spotted protein.

Univariate Significance Testing.

5 Significance Analysis for Microarrays (SAM) (27) was used to determine proteins to which healthy control, CD, and ulcerative colitis groups of samples show a statistically significant immunogenic response. We used stringent criteria in the SAM analysis and only called a protein as significant with at least 1.5 fold change differences between two phenotypes at 0% False Discovery Rate in 500 permutations.

Supervised learning algorithms.

10 To construct the classifier in this study, we employed three supervised learning methods. The algorithms implemented were k-Nearest Neighbors (kNN) (27), Support Vector Machines (SVM), and the k-Top Scoring Pairs Algorithm (k-TSP) (28). The k-TSP was implemented using
15 a publicly available executable program (www.ccbm.jhu.edu/aboutus/news-ktsp.php) developed at the Institute for Computational Medicine of Johns Hopkins University (Tan (2005) Bioinformatics. 21, 3896-3904). SVM and kNN were implemented using the R statistical programming language (www.r-project.org), packages: e1071 and class for SVM and kNN, respectively.

Feature Selection.

20 For kNN and SVM learning methods, SAM was applied to the training set for feature selection before the classifiers were trained on that data. The features selected in SAM were those that were found to be significant with a false discovery rate of zero. The k-TSP algorithm
25 does not require feature reduction as it intrinsically selects the top scoring features. Parameters such as the number of nearest neighbors for kNN and the number of top scoring pairs for k-TSP were selected based on leave one out cross-validation performance on the training set. A script was written in Matlab to perform the cross-validation scheme and call executables for the learning algorithms.

Statistical Analyses.

We used the open source statistical software R (www.r-project.org/) to perform the statistical analyses in this study. P-value < 0.05 was regarded as significant.

5 Other Embodiments

From the foregoing description, it will be apparent that variations and modifications may be made to the invention described herein to adopt it to various usages and conditions. Such embodiments are also within the scope of the following claims.

10 The recitation of a listing of elements in any definition of a variable herein includes definitions of that variable as any single element or combination (or subcombination) of listed elements. The recitation of an embodiment herein includes that embodiment as any single embodiment or in combination with any other embodiments or portions thereof.

15 All patents and publications mentioned in this specification are herein incorporated by reference to the same extent as if each independent patent and publication was specifically and individually indicated to be incorporated by reference.

What is claimed is:

1. A microchip comprising at least about 85, 90, 95 or 100% of the *E. coli* proteome.
2. A microchip comprising a set of biomarkers for characterizing an inflammatory bowel disease (IBD) in a subject, wherein the set is selected from the group consisting of *E. coli* polypeptides (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, 10 punC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yefF, yefY, ygeD, ygfF, yggH, yghK, yghT, ygiQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, 15 yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjff, yjfp, yjfy, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, yzgL, rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, 20 dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, 25 rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yefG, yefO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, 30 yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, yrbB, (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yefA, ygcE, ygfQ, yhjC, yjfh, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE,

narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygjR, yhiN, yjgT, yojI, and yphD, or fragments thereof.

2. A microchip comprising a set of biomarkers for characterizing Crohn's disease in a subject, wherein the set is selected from the group consisting of *E. coli* polypeptides rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, yrbB, (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pneC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yejF, yfjY, ygeD, ygff, yggH, yghK, yghT, ygjQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjff, yjfp, yjfy, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and yzgL, or fragments thereof.

3. The microchip of claim 2, wherein the set is selected from the group consisting of *E. coli* polypeptides rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, 5 cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, 10 ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgl, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, and yrbB, or fragments 15 thereof.

4. A microchip comprising a set of biomarkers for distinguishing Crohn's Disease from ulcerative colitis, the set comprising *E. coli* polypeptides era, ybaN, yhgN, focA, ga bT and ycdG, or fragments thereof.

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5. A microchip comprising a set of biomarkers for diagnosing ulcerative colitis, wherein the set is selected from the group consisting of *E. coli* polypeptides (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrff, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, 25 narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygjR, yhiN, yjgT, yojI, yphD, (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, 30 JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pnuC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD,

secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yefF, yefY, ygeD, ygfF, yggH, yghK, yghT, ygiQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjfF, yjfP, yjfY, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and yzgL, or fragments thereof.

6. The microchip of claim 5, wherein the set of biomarkers is selected from the group consisting of (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygiR, yhiN, yjgT, yojI, and yphD, or fragments thereof.

7. A microchip comprising a set of biomarkers for distinguishing Crohn's disease from ulcerative colitis, the chip comprising a set of biomarkers selected from the group consisting of rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, yrbB, (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF),

211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygjR, yhiN, yjgT, yojI, and yphD, or fragments thereof.

- 5 8. The microchip of any of claims 1-7, further comprising one or more biomarkers selected from the group consisting of antibodies that specifically bind chitobioside IgA (ACCA), laminaribioside IgG (ALCA), manobioside IgG (AMCA), Man α -1,3 Man α -1,2 Man (Σ Man3), Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) pANCA, antineutrophil cytoplasmic antibody, yeast oligomanna, *Saccharomyces cerevisiae*, ASCA, bacterial outer membrane porin C
 10 (OmpC), *Pseudomonas fluorescens* bacterial sequence I2, and bacterial flagellin (Cbir).
9. The microchip of any of claim 1-7, wherein the *E. coli* polypeptides induce an immune response when injected into a subject.
- 15 10. A microchip comprising a polypeptide, polypeptide set, or polypeptide pair delineated in Tables 2-5, 7, or Figure 5.
11. A method for characterizing a condition associated with a dysregulated immune response to a polypeptide in a subject, the method comprising
 20 (a) contacting a microarray comprising a set of polypeptides with sera derived from the subject,
 (b) detecting differential antibody binding to a polypeptide on the microarray in the subject sera relative to a control, wherein detection of differential antibody binding identifies the subject as having a condition associated with a dysregulated immune response to a .
 25
12. The method of claim 11, wherein the control is a healthy subject, a subject with Crohn's disease, or a subject with ulcerative colitis.
13. The method of claim 11, wherein the detecting is of differential binding of a pair of
 30 antibodies to a pair of polypeptides on the array.

14. The method of claim 11, wherein the array comprises cell wall polypeptides, intracellular polypeptides, and macromolecular complex polypeptides.

15. The method of claim 11, wherein an increase in subject antibody binding to a polypeptide relative to healthy control antibody binding identifies the polypeptide as immunogenic in subjects having a dysregulated immune response to the polypeptide.

16. The method of claim 11, wherein the condition is selected from the group consisting of inflammatory bowel disease, Crohn's disease, ulcerative colitis, and indeterminate colitis.

17. A method for diagnosing a subject as having or having a propensity to develop inflammatory bowel disease, the method comprising

(a) contacting an array comprising a set of *E. coli* polypeptides with sera derived from the subject,

(b) detecting differential antibody binding to the polypeptide on the array in the subject sera relative to a healthy control, thereby characterizing inflammatory bowel disease in the subject.

18. The method of claim 17, wherein the array comprises at least about 85, 90, 95, or 100% of the *E. coli* proteome.

19. The method of claim 17, wherein the microarray comprises a membrane protein, cell wall protein, intracellular protein, and/or macromolecular complex protein.

20. The method of claim 17, wherein the polypeptides are differentially immunogenic in healthy controls, Crohn's disease, and/or ulcerative colitis.

21. The method of claim 20, wherein antibodies that bind an *E. coli* polypeptide are selected from the group consisting of (yhcP), (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA,

lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pneC, potC, pssR, ptsH, putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yefF, yefY, ygeD, ygfF, yggH, yghK, yghT, ygiQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ, yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjff, yjfp, yjfY, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and yzgL.

22. The method of claim 17, wherein antibodies that bind an *E. coli* polypeptide are selected from the group consisting of rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yefG, yefO, yfeC, yfhD, yfiC, yfiD, yfjI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbl, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, and yrbB.

23. The method of claim 17, wherein antibodies that bind an *E. coli* polypeptide are selected from the group consisting of (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yefA, ygeE, ygfQ, yhjC, yjfh, yjiJ, (yefF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD, kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafJ, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygjR, yhiN, yjgT, yojI, and yphD.

24. The method of any of claims 17-23, further comprising detecting an antibody that specifically binds any one or more of chitobioside IgA (ACCA), laminaribioside IgG (ALCA), manobioside IgG (AMCA), Man α -1,3 Man α -1,2 Man (Σ Man3), Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) pANCA, antineutrophil cytoplasmic antibody, yeast oligomanna, *Saccharomyces cerevisiae*, ASCA, bacterial outer membrane porin C (OmpC), *Pseudomonas fluorescens* bacterial sequence I2, and bacterial flagellin.

25. The method of any of claims 16-19, further comprising stool sample analysis, colonoscopy, sigmoidoscopy, barium x-ray, computerized axial tomography, and/or capsule endoscopy.

26. The method of any of claims 16-19, wherein an increase in levels of antibodies that specifically bind one or more *E. coli* polypeptides selected from the group consisting of rpsK, rpsL, sixA, ycfF, yhdN, yjhA, (gntU), (phnE), (rcsC), (thiS), (ycfA), (yjfV), 221#15, 267#6, 304#1, 319#17, 336#6, 348#4, 405#2, 411#4, 416#1, 430#8, 445#15, 448#2, 633#5, aceB, agaZ, aidA, argB, argC, aroF, aroK, aspA, atpB, baiF, basS, cedA, citB, citG, clpX, cysD, cysJ, cysM, cysW, dgxA, dicC, dinD, ecnB, eno, fadB, fba, fdhE, fecB, fecR, fimB, fimC, fliA, fliS, flxA, folP, frvX, ftn, fumB, gabD, galR, gcpE, glvB, grxA, grxC, gst, hemX, hflX, hisS, hofH, hoxK, hsdM, hycA, hycF, hypC, ibpB, infC, ivbL, lasT, LDR-ABC, LDR-D, lldR, mcrD, metB, metJ, mltB, mviN, narY, nuoE, phbA, phnB, phnG, phnM, ppdB, ptpS, ptsN, purM, radC, rbfA, rbsB, recN, rffD, rpiB, rplP, rplQ, rplT, rpmJ, rpsG, rpsR, selD, slyA, slyD, ssi6, sugE, tdcB, thiF, torA, trmD, ubiG, umuD, vacJ, wcaA, ybbA, ybbQ, ycbF, ycdB, yceD, ycgN, ydfA, ydfD, ydfR, ydhL, ydiL, yedF, yehR, yejG, yejO, yfeC, yfhD, yfiC, yfiD, yfiI, yfjQ, ygbA, ygbD, ygbO, ygcQ, ygeW, ygfY, yhaA, yhaC, yhaN, yhcI, yhcJ, yhfR, yhfV, yhgH, yhgI, yicC, yieF, yieJ, yigK, yihA, yihD, yihK, yiiF, yijD, yijF, yjaI, yjbI, yjbL, yjbQ, yjbR, yjcS, yjeB, yjeJ, yjgF, yjhC, yjhE, yjhF, yjhO, yjiA, yliG, ymfE, yohL, yphC, and yrbB identifies the subject as having Crohn's disease.

27. The method of any of claims 16-19, wherein an increase in levels of antibodies that specifically bind one or more *E. coli* polypeptides selected from the group consisting of (rtn), cadA, lueO, mesJ, mhpF, modC, murA, nrfF, prpE, purK, tpiA, yciD, yejA, ygcE, ygfQ, yhjC, yjfH, yjiJ, (yeeF), 211#11, 23-12A0, 279#6, 427#1, dgkA, dinI, emrY, focA, folK, fsr, glnD,

kch, maoC, msbA, nac, nagE, narI, ppx, prtC, rfaB, secF, secY/prlA, trkG, yafI, yaiM, ybbC, ycbM, ydaA, ydbD, ydhV, yefI, yeiO, ygiR, yhiN, yjgT, yojI, and yphD identifies the subject as having ulcerative colitis.

5 28. The method of claim 17-27, wherein the method identifies the subject as a healthy control or as not having Crohn's disease or ulcerative colitis.

29. The method of any of claims 17-28, wherein an increase in levels of antibodies that specifically bind one or more *E. coli* polypeptides selected from the group consisting of (yhcP),
 10 (yhhT), (yhiW), 16-3B0, 214#3, 233#6, 273#6, 280#1, 316#4, 321#3, 323#1, 331#2, 356#7, 406#7, 409#5, 411#1, 420#7, 452#13, 610#6.1, aceF, allP, ansP, aqpZ, atoE, brnQ, celD, cobU, codB, cybB, cydB, cydC, dgt, dnaQ, ebgA, emrB, emrD, exuR, fabH, fabZ, fadA, fepD, flhD, glnQ, glpF, gppA, greA, hemY, JW0438, JW1949, lipA, lpxC, malX, malZ, menG, mrdB, murG, mutT, narU, nfrB, nrfE, ompC, oppC, oppF, pbuX, pheP, phsE, pneC, potC, pssR, ptsH,
 15 putP, queA, rfaL, rffG, rocE, rplO, sdhD, secB, sfsA, slyX, sucB, sucD, tauB, thiL, trkH, udk, uidB, virK, yaaH, yabK, yadQ, yaeG, yagG, yagM, yaiV, yajR, ybaN, ybdS, ybfB, ybfC, ybgE, ybhA, ybhL, ybhM, ybhN, ybhR, ycaD, yccY, ycdG, yciQ, yciR, yciS, ydcD, yddH, ydeF, ydeZ, ydfO, ydjS, ydjZ, yeaS, yehK, yehY, yejF, yfjY, ygeD, ygfF, yggH, yghK, yghT, ygjQ, yhaH, yhaO, yhbX, yhcO, yhdM, yhdT, yheG, yheU, yhfU, yhhL, yhhS, yhiP, yhiQ, yhjX, yiaL, yiaQ,
 20 yibL, yibQ, yicO, yidY, yifE, yigF, yihG, yjeM, yjff, yjfp, yjfY, yjhB, ymdD, ynaJ, yneC, yneG, ynjC, yoaA, yohG, yphA, yphG, yqcE, and yzgL identifies the subject as a healthy control.

30. A method for diagnosing Crohn's disease, the method comprising
 (a) contacting an array comprising a set of *E. coli* polypeptides with sera derived from the
 25 subject,
 (b) detecting in said subject's sera greater immunogenic reactivity to era than to ybaN, greater immunogenic reactivity to yhgN than to focA, and/or greater immunogenic reactivity to gabT than to ycdG, thereby identifying the subject as having Crohn's Disease.

30- 31. A method for diagnosing ulcerative colitis in a subject, the method comprising

(a) contacting an array comprising a set of *E. coli* polypeptides with sera derived from the subject,

(b) detecting in said subject's sera greater immunogenic reactivity to relE > cysE/wcaB, pyrI > yjgK, lnt > ybiO, ftsE > pssR, yhgN > yhfG, yafN > dsbB, yihI > yabK, 421#15 > yhdN, hisP > rplO, cml > nuoM, yieC > nuoI, thereby identifying the subject as having ulcerative colitis.

32. A method for diagnosing ulcerative colitis, the method comprising

(a) contacting an array comprising a set of *E. coli* polypeptides with sera derived from the subject,

(b) detecting in said subject's sera greater immunogenic reactivity to frvX than to yidX identifies a subject as having ulcerative colitis.

33. A method for selecting an appropriate treatment for a subject, the method comprising

contacting a microarray of any of claims 1-11 with subject sera and detecting binding to a polypeptide that identifies the subject as having inflammatory bowel disease, thereby indicating that inflammatory bowel disease therapy is appropriate for said subject.

34. The method of claim 24, wherein the subject is identified as having Crohn's disease or ulcerative colitis.

35. A method for selecting surgery for a subject, the method comprising contacting a microarray of any of claims 1-11 with subject sera and detecting binding to a polypeptide that identifies the subject as having inflammatory bowel disease, thereby indicating that surgery is appropriate for said subject.

36. The method of any of claims 33-35, wherein the method detects greater immunogenic reactivity to era than to ybaN, greater immunogenic reactivity to yhgN than to focA, and/or greater immunogenic reactivity to gabT than to ycdG.

37. The method of any of claims 33-35, wherein the method detects *relE* > *cysE/wcaB*, *pyrI* > *yjgK*, *lnt* > *ybiO*, *ftsE* > *pssR*, *yhgN* > *yhfG*, *yafN* > *dsbB*, *yihI* > *yabK*, 421#15 > *yhdN*, *hisP* > *rplO*, *cml* > *nuoM*, and/or *yieC* > *nuoI*.

5 38. The method of any of claims 33-35, wherein the method further comprises detecting an antibody that specifically binds any one or more of chitobioside IgA (ACCA), laminaribioside IgG (ALCA), manobioside IgG (AMCA), Man α -1,3 Man α -1,2 Man (Σ Man3), Man α -1,3 Man α -1,2 Man α -1,2 Man (Σ Man4) pANCA, antineutrophil cytoplasmic antibody, yeast oligomanna, *Saccharomyces cerevisiae*, ASCA, bacterial outer membrane porin C (OmpC), *Pseudomonas*
10 *fluorescens* bacterial sequence I2, and bacterial flagellin.

39. A method for selecting an appropriate treatment method for a subject, the method comprising contacting a microarray of any of claims 1-11 with subject sera and detecting binding to a polypeptide that identifies the subject as not having inflammatory bowel disease, thereby
15 indicating that inflammatory bowel disease therapy is not appropriate for said subject.

40. A method for monitoring the condition of a subject having Crohn's disease, the method comprising

(a) contacting an array comprising a set of *E. coli* polypeptides with sera derived from the
20 subject,

(b) detecting in said subject's sera immunogenic reactivity to *era* relative to *ybaN*, immunogenic reactivity to *yhgN* relative to *focA*, and immunogenic reactivity to *gabT* relative to *ycdG*, wherein a reduction in said immunogenic reactivity identifies an improvement in the subject's condition, and an increase in said immunogenic reactivity identifies a worsening in the
25 subject's condition.

41. A method for monitoring the condition of a subject having ulcerative colitis, the method comprising

(a) contacting an array comprising a set of *E. coli* polypeptides with sera derived from the
30 subject,

(b) detecting in said subject's sera immunogenic reactivity to frvX relative to yidX, wherein a reduction in said immunogenic reactivity identifies an improvement in the subject's condition, and an increase in said immunogenic reactivity identifies a worsening in the subject's condition.

5

42. A method for determining whether a therapy is efficacious for a subject, the method comprising

(a) contacting a microarray of any of claims 1-11 with subject sera collected at a first time and detecting binding to a polypeptide that identifies the subject as having inflammatory
10 bowel disease,

(b) contacting a microarray of any of claims 1-11 with subject sera collected at a second time and detecting binding to a polypeptide that identifies the subject as having inflammatory bowel disease, wherein detection of a reduction in binding at the second time relative to the first indicates that said therapy is efficacious and a failure to detect a reduction in binding indicates
15 that said therapy is not efficacious.

43. The method of any of claim 12-42, wherein binding is detected in an immunoassay.

44. The method of any of claim 12-42, wherein binding is detected by ELISA.

20

45. A kit comprising a microarray of any of claims 1-11, and instructions for use of the array in diagnosing inflammatory bowel disease, Crohn's disease, or ulcerative colitis.

Figure 1

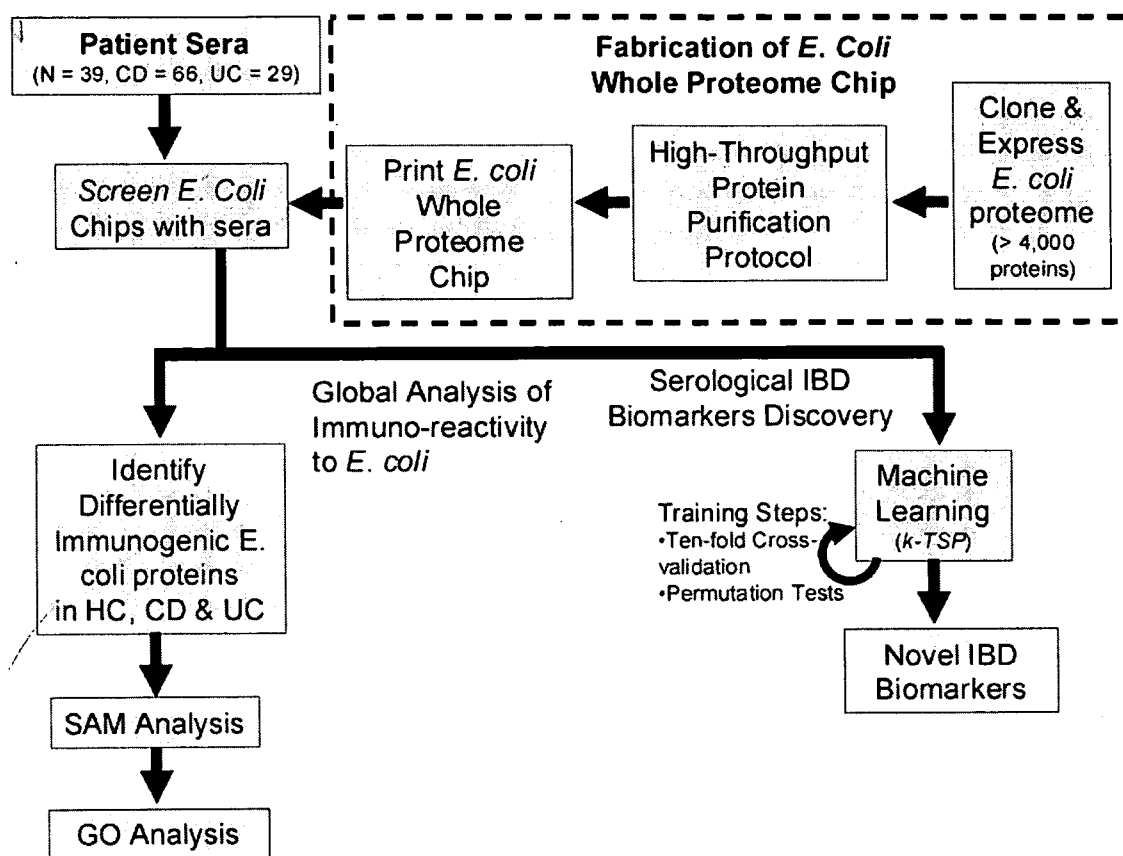
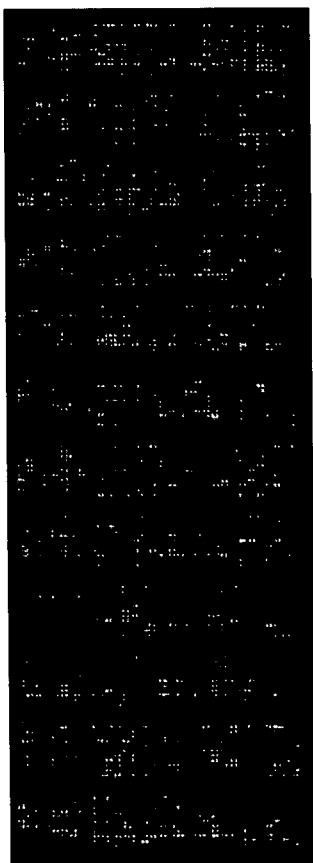


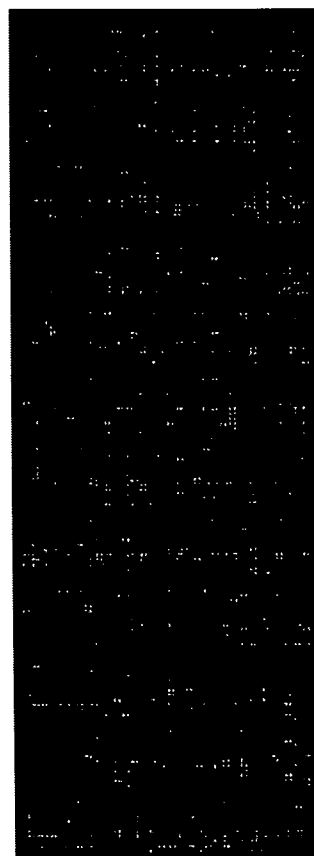
Fig. 1

Figure 2A

Crohn's Disease (CD)
(whole *E. coli* chip)



Healthy Controls (HC)
(whole *E. coli* chip)



**Representative
immunogenic spots**

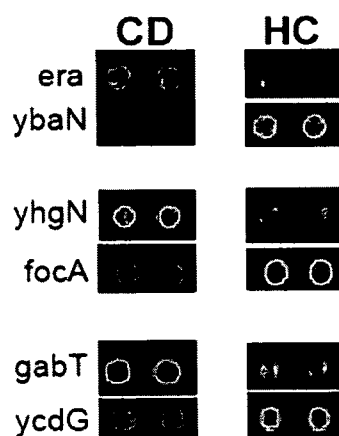


Figure 2B

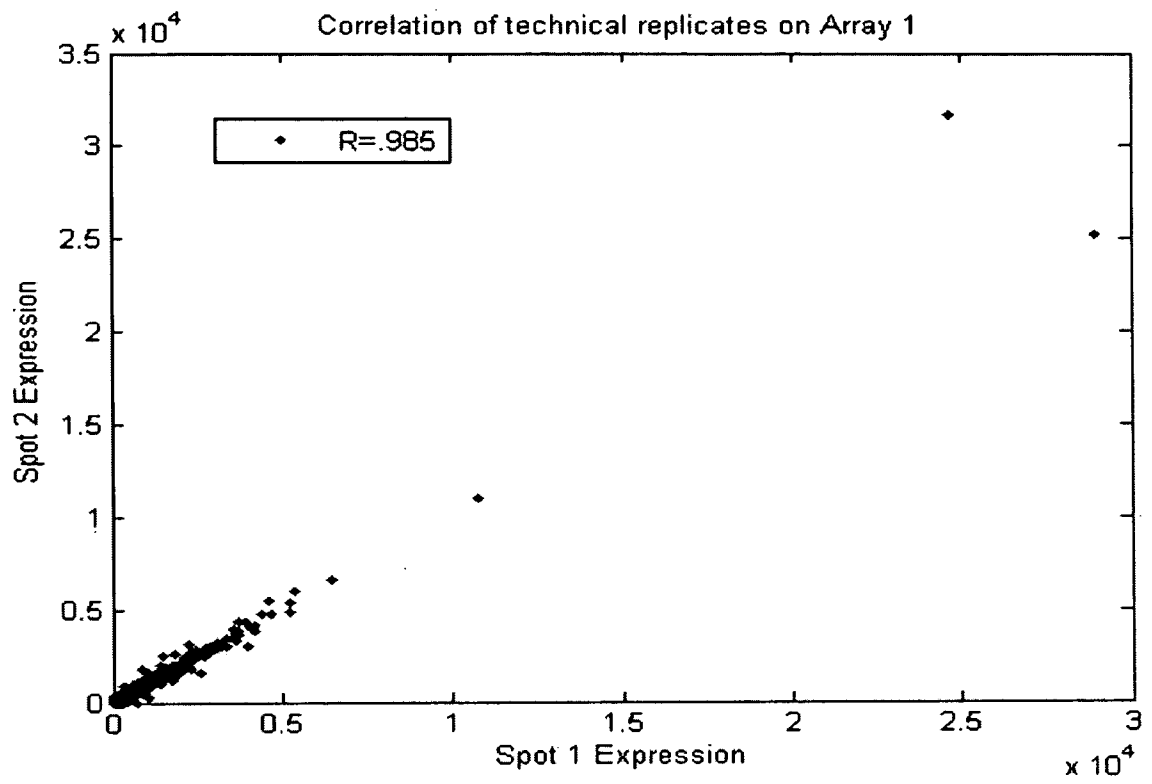


Figure 3

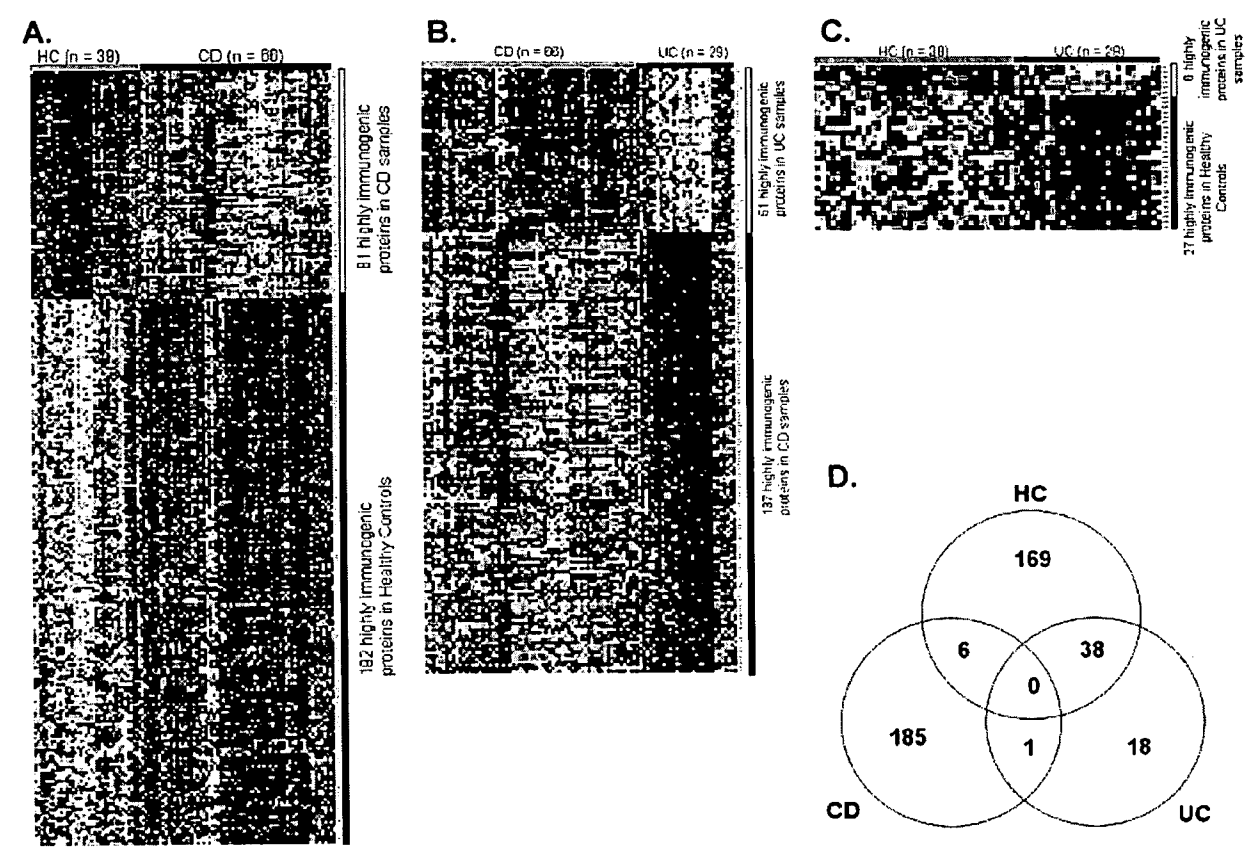


Fig. 3

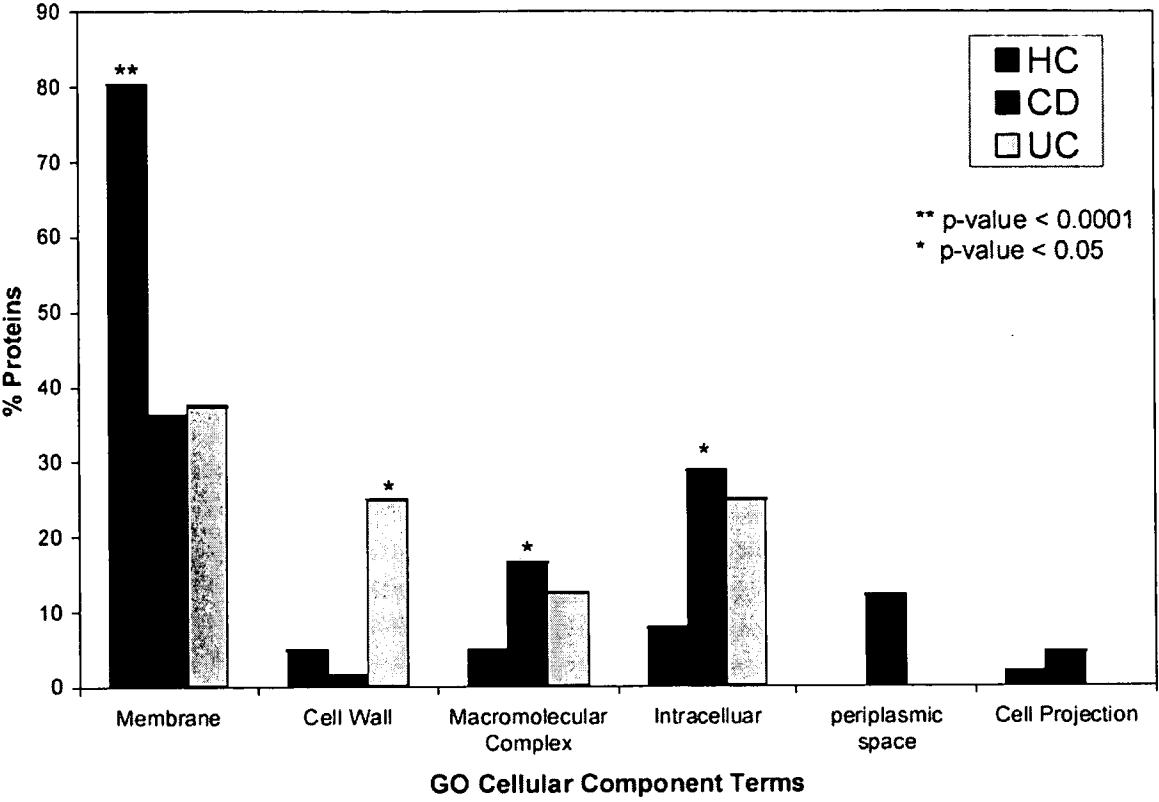


Fig. 4

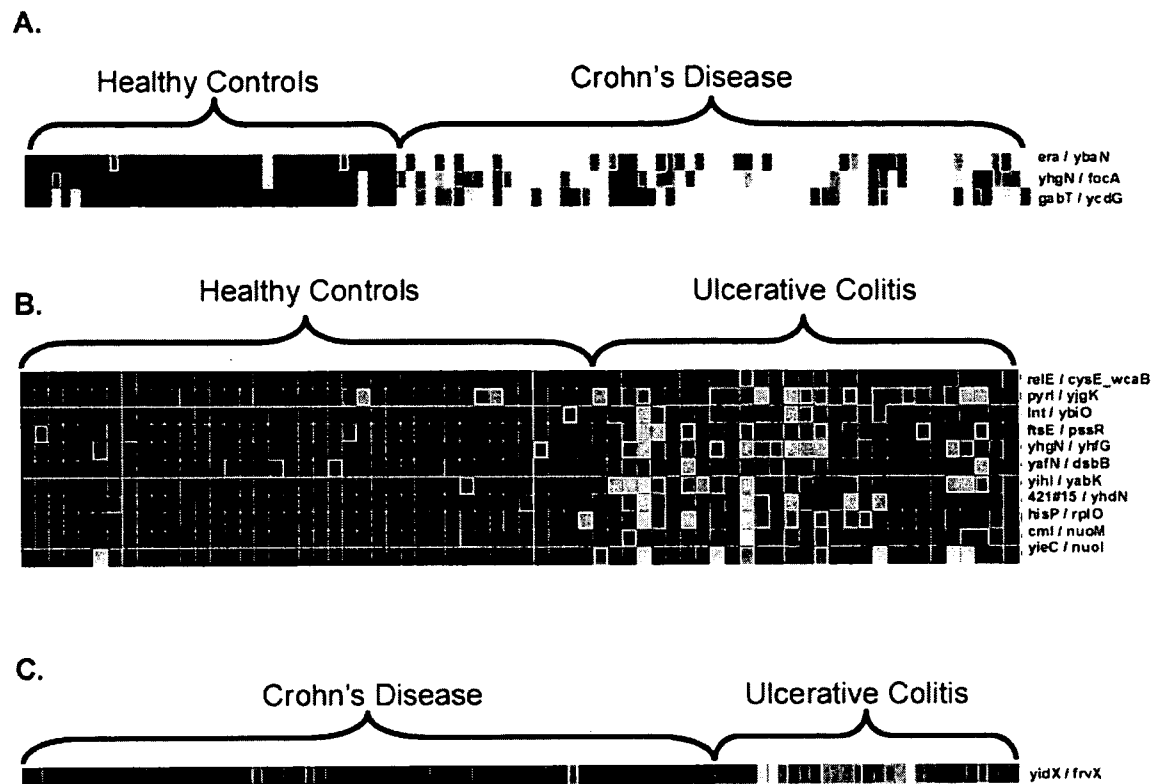


Fig. 5.

Figure 5D

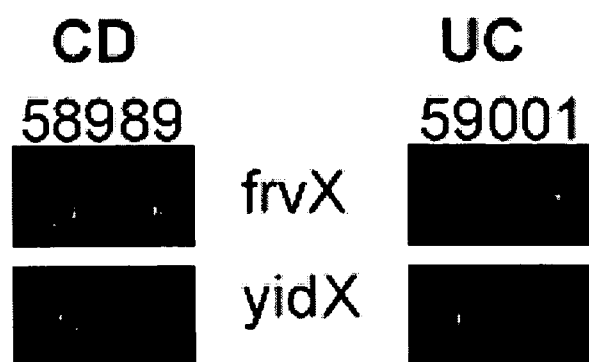


Figure 6

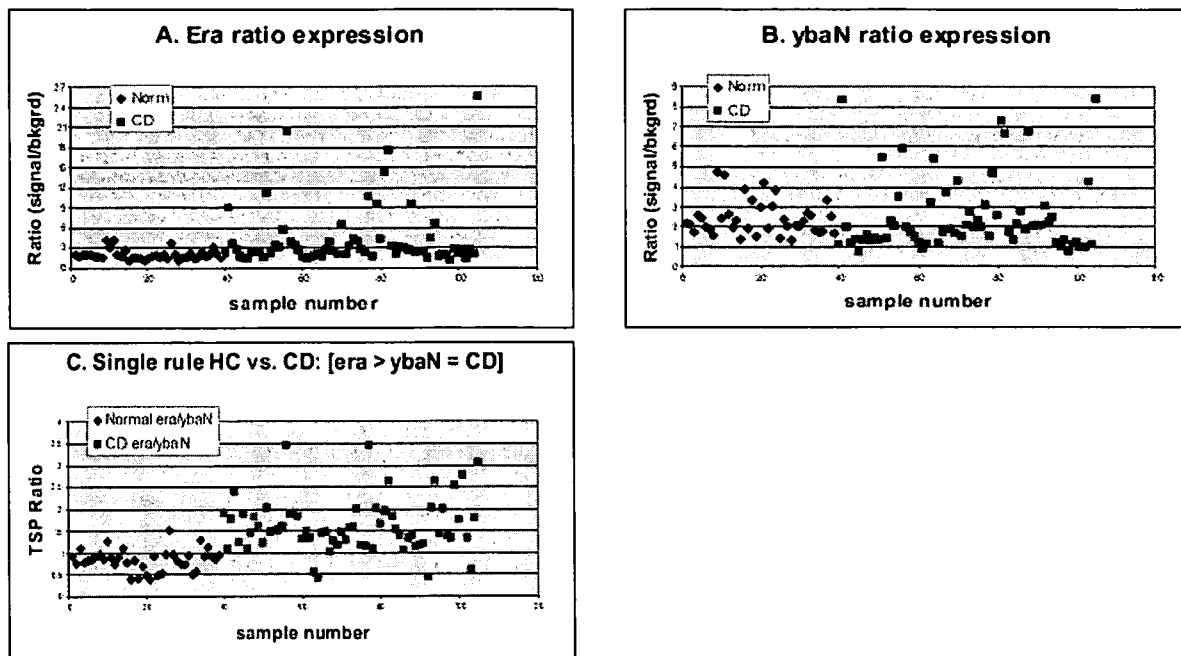
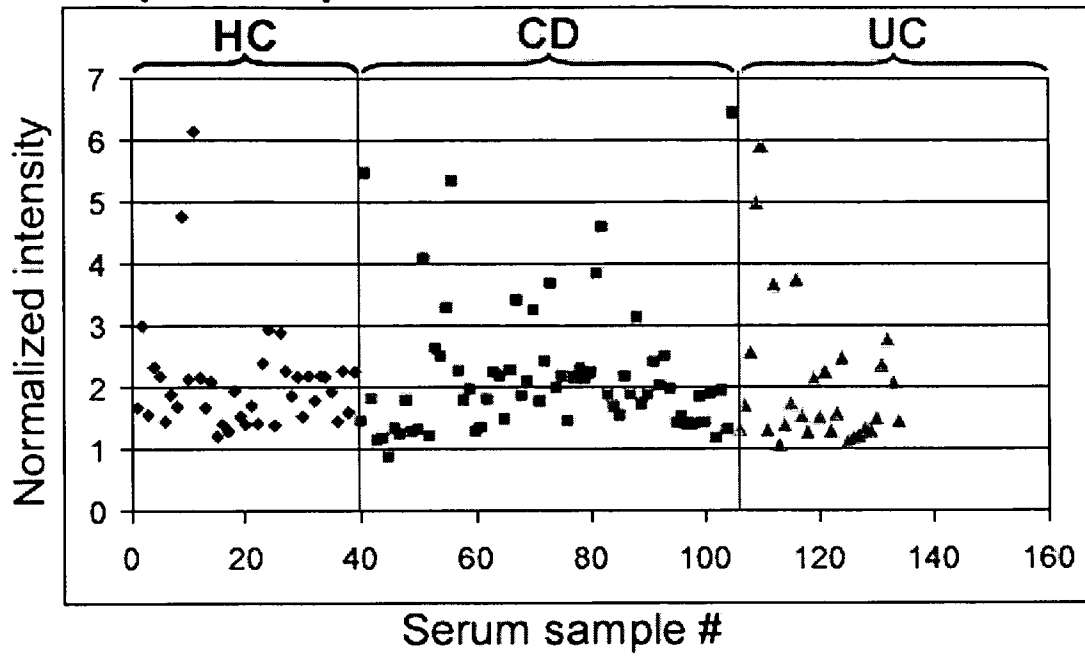


Figure 7

A. ompC ratio plot**B. fliC ratio plot**