

%LRORJ\ DQG 0HGLFLQH 'XJJHWW 1\$ HW DO %LRO 0HG
KWW\$ G[GRL RUJ

5HVHDFK \$UWLFOH

2SHQ \$F

/RZ ,QWHQVLW\ /LJKW 7KHUDES\ QP 3URW
IURP \$P\ORLG 0HGLDWHG &HOO 'HDWK

1DWDOLH \$ 'XJJHWW DQG 3DXO / &KD]RW
6FKRRO RI %LRORJLFDQ %LRPHGLFDQ 6FLHQFHV 'XUKDP 8QLYHUVLW\ 6RXWK 5RDG 'XUKDP '+ / (8QL
&RUUHVSRLGLQ3DXO&KD]RW 6FKRRO RI %LRORJLFDQ %LRPHGLFDQ 6FLHQFHV 'XUKDP 8QLYHUVLW\
(PD\$OXO FKDJRW#GXUKDP DF XN
5HFHLYHG-&DWH \$FFHSWHG&DWH 3XEOLVKHG&DWH
&RSULJKW 'XJJHWW 1\$ HW DO 7KLV LV DQ RSHQ DFFHV DUWLFOH GLVWULEXWHG XQGHU WKH WHUPV R
XVH GLVWULEXWLRQ DQG UHSURGXFWRQ LQ DQ\ PHGLXP SURYLGHG WKH RULJLQDO DXWKRU DQG VRXU

\$EVWUDFW

8VLQJ D VLP\$DWRRLGRSDWK\ &\$' QHXURQDO PRGHO LQIUDUHG ,5 QP OLJKW
ZDV LQYHVWLJDWHG DV D QRYHO QHXURSURDUVORLGH SWLGHV DV 6XEWKHFVWLFH KX
DJJUHJDWLRQ LQ D WHVW WXEH DQG VKRZQ WR IRUPPILZLWK RRP\$UBUMHRI VLJH
WKH FHOXODU QXFOHU LQWHJULW\ RI &\$' FHOOV LQ FXOWRUORLQGG HOLFLWHG
SHSWLGH FRQFHQWUDWX&QVBDQJHZKLFK ZDV VLJQLILFDQW\ VXESULVWLFH XS WR
WUHDWPHQW ZLWK ,5

.HIZRUGRWRRELPRGXODWLRQ /RZ ,QWHQVLW\ /LJKW 7KHUDES\ QP 3URW
,QIUDUHG DP\ORLG 7KH FHOV OLQH H[SUHVHVH QHXURWUDQV

\$EEUHYLDWLRQV

\$• • DP\ORLG \$' \$OJKHLPHUDV GLVHDVH \$73 DGHORVLQH
WULSKRVSKDWH &\$' &DWK D GLIIHUHQWLW\ \$QWHPHUJGLVHDVH WUHQDGLG
V\QWKDVH ,5 LQIUDUHG ,5 LQIUDUHG SURJUHVV\YH GHODWLRQ FKDBDFWLFH
GHK\GURJHQDVH /,/ /RZ ,QWHQVLW\ \$LJKW 7KHUDES\ 333 HIWUDFHOOXODU VW
PHWKO\ SKHQ\OS\ULGLXP 1,5 QHDU 63V ZKLFK DUH WKBRXJKW WR LQGXFH V
89\$ XOWUD YLROHW \$ VWDELOLW\ RI WKH FHOV PHPEUDQH V

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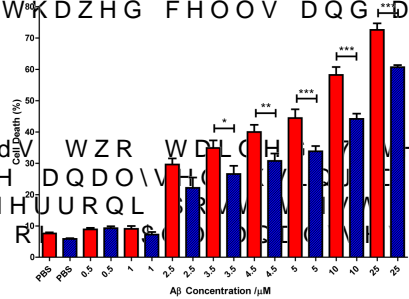
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XS WR RI WKH VRODU UDGLDWLRQ ZKLFK EHHQ VWRUDWLRQ RYHURXUHQG QHX
1HDU ,QIUDUHG 1,5 OLJKW W\SLFDQO QHXURQDO D\DELOLW\ P ZLWK ERPHU
VKRZQ WR KDYH D ZLGH UDQJH RI ELRORJ\ DFFHQWURSDG ZKLFK DFRWH X
EHQHILWV DQG D JUHDW GHDO RI UHVHDUFK KDV EHHQ RQYHUWV JHWWR
WKH RSWLPDO SDUDPHWHUV ZKHWKHU WKH EHHQ VWRUDWLRQ RYHURXUHQG QHX
RU OLJKW VRXUFH /DVHU RU /('V > RRGHQ ZOWHQ\Y\WQHGKWR7RHWLH
/,/ DOVR NQRZQ DV SKRWRELPRGXODWLRQ DFRWHURXUHQG QHXURQDO
PRGXODWLRQ D FRQVLGHUDEOH QXPEHU VRI EKKR PRGHO ZDURPFRVWLFH
VLJQLILFDQW QXPEHU RI VWXGLHV 7KHUHQHQDQGGZKLFKHUHU LLUDZRRWRQZOWK
UDWHV > @ LQGXFWRQ RI FHOXODU WUHQDGLWLRQ LQ PXOWLSOH FHOV FX
V\WHPV LQFOXGLQJ RVWHREODVV > 7KH WUREODVV @PXVFOH FHOV
DQG HSLWKHOLD FHOV > @ +HLSHURXUHQG QHXURQDO WUHQDGLWLRQ R
ODELWLFWLRQV > @ LQFUHDVLQJ \$3PVUHQHVHVW D SHUNLQ WUDQVPLVLR
UHVSLUDWLRQ UDWHV > @ WKUHIRUH UHTXLUHV OHVV HQHU\ WR

/,/ KDV DOVR EHHQ VKRZQ WR SURPHQVWUHQDGLWLRQ DFRWHURXUHQG QHXURQDO
DJDLQV D QXPVWUHQDGLWLRQV89\$ > @H\SRQDVLVLRQ
FIDQLGH > @ PHWKDQRO GHULPHWKRURDQWUHQDGLWLRQV33WVG\ DPHG DOVR WR LQ
SKHQ\OS\ULGLXP DQG URWHQRQH > @SURPHQVWUHQDGLWLRQV89\$ DFRWHURXUHQG QHXURQDO
XQLTXH PHWKRQ WR VWXG\ HYHU\ IDFHV RI QHXURQDO SURPHQVWUHQDGLWLRQV89\$ LQ
UHSURGXFLELQW\ LQ DOEHLW D VLP\$OLILHG V\WHP 7KH &\$' &DWK D
GLIIHUHQWLW\ FHOV OLQH DUH FDWHFKRODPLQHUJLF FHOV GHULYHG IURP
&DWK D FHOV OLQH ZKLFK ZDV SURFXUH IURP D EUDLQ WXPRU WKDW KDG
GHYHORSHG LQ D WUDQVJHQLF PRXVH PRGHO &\$' FHOOV VSRQWDQHRXVO\ ORVV

ZDV DGGHG WR HDFK GLOXWLRQ DQG WKH DEVRUEDQFH PHDVXUHG DW QR RQ D 0XOOLNDQ \$VFHQW 3ODWH 5HDGHU 9HUVLRQ /'+ UHOHDVH ZDV QRUPDOL]HG DJDLQVW WKH VXP RI WRWDO /'+ DEVRUEDQFH FRPELQLQJ WKH DEVRUEDQFH RI SRVLWLYH FRWURO IUHH]H WKDZHG FHOOV DQG DEVRUEDQFH R LQLWLDO PHGLD FRQWDLQLQJ /'+ UHGLQJ

6WDWLVLV

'DWD ZHUH DQDO\HG XVLQJ D 6WXGHQWV LPPXQRIORUHVHFHQFH DQDO\VLV 'DWD ZHUH DQDO\VLV 'DWD ZHUH \$129\$ DQDO\VLV RI YDULDQFH XVLQJ D %RQHURQL PHDQ s 6(0 ZLWK D FRILGHQFH LQWHUYDO R FRGGXFWHG XVLQJ *UDSK3DG 3ULVP 9HUVLRQ



/' \$UUD\

QP HPLWWLQJ /(' DUUD\ KDYH D QP SXOVHG DW +] ZLWK D GXW P: FP 6KDP WUHDWPHQWV ZHUH FRGGX ZLWK DOXPLQLXP IRLO SODFHG RYHU 9LUXOLWH 'LVWULEXWLRQ /WG 8. DQG 'RXJDO 9LUXOLWH 'LVWULEXWLRQ /WG 'HSDUWPHQW 'U \$QGUHZ %HHE\

5HVXOWV

\$P\ORLG DSSHDUDQFH

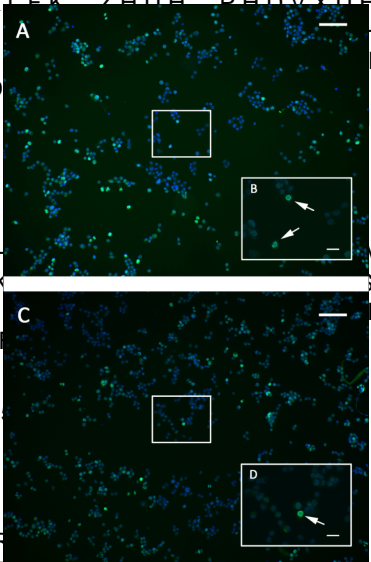
)ROORZLQJ VWDSSWLGH \$ILEULOV ROYK 6WUXFWXUHV WKDW KDG IRUPHG ZHUH R SOHDWHG VKHHW VWUXFWXUHV ZKLFK JULGV 7KHVH VKHHW OLNH VWUXFWXUHV VPDOOHU ORQJ ILEULOODU VWUXFWXUHV DSSUR[LPDWHO\ QP DV VKRZQ LQ WKURXJKRXW WKH VDP SOHV DQG RIWHQ • SOHDWHG VKHHWV KRZHYHU LW LV PHUJHG WR IRUP WKH EHWD SOHDWHG SURGXFWV RI WKH ODUJH VKHHW RI SWSWLGH

&\$' &HOOV \$• LQGXFHG WR[LFLW\ DQG ,5

([SRVXUH WR ,5 KDG QR VLJQLILFDQW HII WUHDWHG FRQWUROV DJDLQVW FHOV GHDWK -0 RU-0 \$ +RZHYHU WKHUH ZDV D WUHQG IRU GHDWK LQ WKH ,5 WUHDWHG FRQGLWLRQ FRQWUROV QDW -0 \$•

\$W -0 \$ WUHDWPHQW RI &\$' FHOOV ZLWK VWDWLVLVWLFDOO\ VLJQLILFDQW UHGXFWRU ZDV LQFUHDVHG DW S DQG S FRPSDUHG WR VKDP WUHDWHG FRWURO

&RQFHQWUDWLRQV ZHUH H[FHHGLQJO\ WR WR 6KDP WUHDWHG FHOOV FDXVLQJ DSSUR[LPDWHO\ UHVSHFWLYHO\ +RZHYHU GHVSLWH WUHDWPHQW FHOOV ZLWK ,5 VLJQLILFDQWO\ UHGXFWRU WUHDWHG WKH ZKLVH ER[LQ ILJXUH \$ DUURZV ,5 7UHDWHG &\$' FHOOV ' 0DJQLHG LPD WKH ZKLVH ER[LQ ILJXUH & -LJXUHV % ' VFDOH DUURZV LQGLFDWH .L SR FHOOV



&LWDWHDQDOLH \$ 'XJJHWW DQG 3DXO / &KD]RW /RZ ,QWHQVLW\ /LJKW 7KHUHS\ \$P\ORLG 0HGLDWHG &HOO 'HOK %LRO 0HG 6

3DJH RI

6RQGSW 'KDZDQ * &RPEV & %HWD DP\ORLG DQDOLH \$ 'XJJHWW DQG 3DXO / &KD]RW /RZ ,QWHQVLW\ /LJKW 7KHUHS\ \$P\ORLG 0HGLDWHG &HOO 'HOK %LRO 0HG 6
ILEULOV VWLPXODWH GLIIHUHQWLDO DFWLYDWLRQ RI SULPDU\ PLFURJOLD 6HH
FRPPHQW LQ 3XE0HG &RPPRQV EHORZ - 1HXURORJLFDO DFWLYDWLRQ * %RQQLDXG 3 *DUUL
+DUWOH\ '0 :DOVK '0 <H &3 'LHKO 7 DQG SURWHLQV FHOXODU SURWHLWLRQ WKURXJK SU
3URWILEULOV DFWLYDWLRQ RI DP\ORLG EHVWUHQW EORZG &RPPRQV EHORZ - RXUQDO
HOHFWURSK\VLORRORJLFDO FKDQJHV DQG SURWHLWLRQ WKURXJK FHOXODU SURWHLWLRQ
QHXURQV - 1HXURVFL WKH UHJXODWLRQ RI DSRSWRVLV 6HH FRPP
.D\HG +HDG (7KRPSVRQ -/ 0F,QWLUH 70 &HOOVDF 6 & HW DO
&RPPRQV VWUXFWXUH RI VROXEHO DP\ORLG EHVWUHQW EORZG &RPPRQV EHORZ - RXUQDO
PHFKDQLVP RI SDWKRJHQHVLV 6FLHQFH WKH DSRSWRVLV DQG VWUHV LQGXFLEOH
.UDQHGH %LROXPD *HQWUVPDQDGHG HW DFRPPHQW LQ 3XE0HG &RPPRQV EHORZ - &OLQ
%HWD DFWLYDWLRQ XHVH GHWDFKPHQW &RPPRQV EHORZ - RXUQDO /LX - =KHQJ = 9H[OHU =6 /HH -(HW
QHXUREOH DFWLYDWLRQ DFWLQJ DV D VFDIIRORJLFDO DFWLYDWLRQ PHFKDQLVP RI KH
SODVPLQRJHQ DFWLYDWLRQ 0RO &HOO 1HXURORJLFDO DFWLYDWLRQ LQ 3XE0HG &RPPRQV EHORZ \$QQ 1
/RUHQ]R DQNHU %\$ %HWD DP\ORLG QHXURORJLFDO DFWLYDWLRQ UHVIKLND < 0L]RURNL
IRUPDWLRQ DQG LV LQKLELWHG E\ FRQRPLQDORJLFDO DFWLYDWLRQ PHFKDQLVP WDX SUR
&RPPRQV EHORZ 3URF 1DWO \$FDG 6FL 8 6 \$ IRUPDWLRQ RI JUDXODU WDX ROLJRPHUV L
,VREH<DQD]LVZD . 0LFLKNDZD 0 \$ SXE0HG &RPPRQV EHORZ - RXUQDO
SODTXHV XVLQJ V\QWKHWF DP\ORLG EHWD DFWLYDWLRQ DFWLYDWLRQ JOLDORJLFDO DFWLYDWLRQ
FRPPHQW LQ 3XE0HG &RPPRQV EHORZ ([S 1HXURORJLFDO DFWLYDWLRQ FKDSHURQHV 6HH FRPPHQW LQ
.XGYD& +LGLQJD +- %XWOHU 3& 0XVNH 5& 1&XURORJLFDO DFWLYDWLRQ
6PDOO KHDW VKRFN SURWHLQV LQKLELW LQ 3XE0HG &RPPRQV EHORZ)(%6 /HWXODWLRQLRPHUV
.LQJ 0 1DIDU) &ODUNH - 0HDURZ . SURWHLQV DFWLYDWLRQ DFWLYDWLRQ R[LGDWLY
SURWHLQ +VS SURWHLWV FRUWLFDO QHXURORJLFDO DFWLYDWLRQ WR%LRO 1&HWV RI EHWD
DP\ORLG SHSWLGH 6HH FRPPHQW LQ 3XE0HG &RPPRQV EHORZ]-1HXURVFL &VHUPHO\ 3
5HV SURWHLQV DV HPHUJLQ WKHDSHWLF WD
(0 \$JQDI 20 1DJDOD 6 3DWHO %3 \$XVWHORJLFDO DFWLYDWLRQ %LROXPD
ROLJRPHULF VSHFLHV RI WKH DP\ORLG \$ULF SHSWLGHUHV \$LFDWHG LQ DQDOLH DFWLYDWLRQ
%ULWLVK GHPHQWLD DUH PRUH SRWHQW DFWLYDWLRQ DQDOLH DFWLYDWLRQ EHVWUHQW &HOOVDF
SURWILEULOV RU PDWXUH ILEULOV 6HH FRPPHQW LQ 3XE0HG &RPPRQV EHORZ]-1HXURVFL 7
- 0RO %LRO
+X ; &ULFN 6/ %X *)ULHGHQ & 3DSSX 59 DFWLYDWLRQ DFWLYDWLRQ FRPPHQW LQ
IRUPHG E\ FHOXODU XSWDNH FRQFHQWUDWLRQ DFWLYDWLRQ DJJUHJDWLRQ RI WKH
DP\ORLG EHWD SHSWLGH 6HH FRPPHQW LQ 3XE0HG &RPPRQV EHORZ 3URF +VS DQG
1DWO \$FDG 6FL 8 6 \$ QHUVRV V\WHP GLVHDVHV 6HH FRPPHQW
0LFKDOLHRYDQDFHXU \$ YDQ 5HQVEXUJ 5 %&RPPRQV 5HV,QW
(PRWLRQDO UHVSQVHV DQG PHPRU\ SHUIRUPHG DFWLYDWLRQ DFWLYDWLRQ DQG PROHF
PLFH LQ D 'PDJ HIIHFW RI ORZ LQIUDUH FRPPHQW LQ 3XE0HG &RPPRQV EHORZ ([S *HU
&RPPRQV EHORZ 1HXURELRO /HQU 0HP .DUX 3DWEUDW / DOHQGR * ,UDG
*ULOR 'XJJHWW 1\$ (QQDFHXU \$ &KD]RW 3DWEUDW / DOHQGR * ,UDG
LQIUDUHG WKHUSD\ QP UHGXFHV *D&RPPRQV EHORZ 3KRWRFK 3KRWRFK %
EUDLQ RI DQ \$O]KHLPHU V GLVHDVH PRXVH EHVWUHQW \$6730 6HH FRPPHQW LQ
3XE0HG &RPPRQV EHORZ - 3KRWRFK 3KRWRFK EHVWUHQW (RQ]LPD) 1H
5, VVLJ)LFKWOVFKHUHU % UHLVDFKRSI . DFWLYDWLRQ 6HH FRPPHQW LQ 3XE0HG &RPP
1LWULF R[LGH LQKLELWV FVSDVH E\ 6QLWURVDWLRQ LQ YLYR 6HH
FRPPHQW LQ 3XE0HG &RPPRQV EHORZ - %LRO &KHP
0DUURW%HOD±GL -3 /HMHXQH) 0HXQLHU -5 \$VWHORJLFDO DFWLYDWLRQ
3KRWRVWDELOLW\ RI VXQVUHHQ SURGXFWV HIIHFW RQ FLWRKROGULDO DQG FHOXODU
SURWHLWLRQ ZLWK UHJDUG WR 89 LQGXFHG DFWLYDWLRQ 3KRWRFK 3KRWRFK EHORZ %&
HQGSRLQWV 6HH FRPPHQW LQ 3XE0HG &RPPRQV EHORZ %U - HUPDWRO

.LP <0 7DODQLDQ 59 %LOOLDU 75 1LWULF R[LGH LQKLELWV FVSDVH DFWLYDWLRQ
E\ SUHYHQWLQJ LQFUHDVHV LQ FVSDVH LQKLELWV DFWLYDWLRQ DFWLYDWLRQ
PHFKDQLVP 6HH FRPPHQW LQ 3XE0HG &RPPRQV EHORZ - %LRO &KHP

=KRX 3 4LDQ / ,DGHFROD & 1LWULF R[LGH LQKLELWV FVSDVH DFWLYDWLRQ
DQG DSRSWRVLV PRUSKRORJ\ EXW GRHV QRW UHVFH QHXURQDO GHDWK 6HH

7KLV DUWLFQH ZDV RULJLQDOO\ SXEOLVKHG LQ D VSHFLDO LVVXH HQLWOHG
7UHDWPHQW 6WUDWHJLHV IRU 1HXURORJLFDO DQG 1HXURGHJHQHUDWLYH 'LVHDVHV
(GLWHG E\ 6LPRQ .DMD 8QLYHUVLW\ RI 0LVVRXUL 86\$