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!"#\$%&'()*

. !/O&'\$%1-#"-2#%3-45'#6/!5-5%-7'&&!\$8#'#9-7'&&!\$8#'#9-24-

:3*; %9-4#<!%/O&-\$1=3#6#<19->,<,\$%-?@A?-

B*>%9-4#<!%/O&-\$1=3#6#<19-; &=&C8&'?-?@D-

E/665C&%%&- ./!O&'\$%19-F56&C9-GH-

I*>%9-.\$1=3#6#<19-B51-?@J-

+, (-!., ' () % / * ! 0 + ! , ! ') \$! -

>\$\$/%\$!%-: '#"\$%\$#'-'-: \$1=3#6#<19-K3&-4#66&<&-#'- E##\$%&'9- E##\$%&'9-GL9-?@AM-N-O'&&\$!%-

>\$\$/%\$!%-: '#"\$%\$#'-'-: \$1=3#6#<19-F%'&-B5'1P\$-4#66&<&-#'-B5'165!+9-F%'&-B5'1P\$-4/19-B ;-

?@AQ-N-?@AM-

:#\$%N+#=#'56-H&\$&5'=3->\$=#/5%&9-R&!%-F%5%&- ./!O&'\$%19-R&!%-GL9-; *-%#3!-; , !6#\$T19->+O/\$#9-?@AUN

?@AQ-

>+V, !=%-W!\$%' ,=%#9-X6#!- ./!O&'\$%19-X6#!9-249-?@A?N?@AU-

7'5+, 5%&-H&\$&5'=3-5!+K&5=3/!<->\$\$/%\$!%-: !/O&'\$%1-#"-2#%3-45'#6/!5-5%-7'&&!\$8#'#9-7'&&!\$8#'#9-24-

; *-%Y/6/-F535T15!9->+O/\$#9-?@AZN?@A?-

Y58-B5!5<&'9- ./!O&'\$%1-#"-G'&<#!9-X, <&!&9-GH9-; *-%B/=35&6->!+&'\$#!9-F, O&'O/\$#9-?@AJN?@AZ-

+ # 1 / '\$ % &' () . -

* designates work completed with College of Wooster undergraduate and ** with graduate students

- 234567*) 8* / 8* [*I&669-7*%\-] ?@A^*-K3&-&'&=&%\$-#'+/O/+&+5%&!%/#!-#!-C&C#1-#'-!#5+-\$/<!\$*-

]U^9-?DU_?MQ [3%OS\\$aa+##/#'<aA@*?JDUMA?U?QN](#)

[BUJ?*S2?Z*U*?DU*](#)

- 234567*) 8* / 89- B , &66&'9-B*Y*\ \9- E 5\$9-4*->%9-H5) \$#!9-R*->%9- [- ; , !6#\$T19-S*]-?@AM^* E 31-+##&\$-/!%&'6&50/!<-

/CO'#0&-C5%3-6&5' !/!<C-K3&-=#!' /8, %/#!\$#'-+/\$=' /C /!5/O&-=#!' %5%5!+-\$/' /8, %&+O'5=/=&*-

[-3%OS\\$aa+##/#'<aA@*UbQDaSAUJ?AN@AMN@MADNJ*-](#)

- 234567*) 8* / 89-H5) \$#!9-R*->%9- [- ; , !6#\$T19-S*]-?@AD^*-F&6"N'&< , 65%&+6&5' !/!<#"-O' /! =/O6&N85\$&+=#!=&O\$*-

; #-\$, +&!%\$-O'&'&') # 'T&+&d5CO6&\$9-"5+&+&d5CO6&\$9-#'-O'#86&C- \$#60/!<C-

-A?JNAUD*-[3%O\\$aa+##/#'<aA@*AZa*6&5' /!/\\$' , =*?@Ab*A@*?*](#)

B # '&3&5+9-R* \ \9- ; , !6#\$T19-S*9- [* - 234567*) 8* / 8]-?@Ab^*- ; #-O&#O6&- , \$&-=5%&<#1-6&5' !/!<-V, +&C&!%\$%-#-

'&< , 65%&-13&/'-6&5' !/!<#"-!5% , '56=5%&<#/'&\$c-

9- 9-A?QUNA?ZM*-

[3%O\\$aa+##/#'<aA@*UbQDaSAUJ?AN@AbN@b?MNM*-](#)

F535T15!9-Y*9- [- - 234567*) 8* / 8]-?@AZ^*-K3&-2&+&'-'-B&5%'<&%%/!<-W!\$/<3%\$-'#C- ; /!&=&%+&-e# '<&%%/!<-W!-

S*- ; , !6#\$T1- [-F*-. *-R*-K5 , 8&']X+*\$*9-

-Gd"#'+ : '\$\$\$-Y#!+#!9-

UJANUQQ*-

- 234567*) 8* / 89- E 5\$9-4*->9- ; , !6#\$T19-S*9- [-W\$5=\$#!9-H* -B *-]?@AZ

-234567*) 8* / 89- ; , !6#ST19-S*9- [-F535T15!9-Y*-]?@AQ^*-W\$-5) 5' &!&\$-\$- %3&-58/6/%1-%#-'# '<&%-]#'- '&C&C8&' ^-
=' /%/=56-'#'-+&C#!\$%'5% /!<-+/'&=%&+-' #'<&%% /!<c- - DDNA@@*-
-
F535T15!9-Y*9- ; &65!&19- : *e*9- -234567*) 8* / 89- [->8, \$35!589- I*-]?@AU^*-Y/\$%NB &%3#+- ; /'&=%&+-e# '<&%% /!<- /!-
4#<! /% /O&-5! +46/! /56-H&\$&5' =3`->-K3&# ' &%/=56-5! +B &%3#+#6#< /56-H&O/ &) *W! - I*-L*-H#\$\$-]X+*9-
-X6\$&O/ &' -W! =->=5+&C/ =- : '\$\$9-AUA_AM@*-
*
-234567*) 8* / 89- [-F535T15!9-Y*-]?@A?^*-B &%5=#<! /% /#! - /!'6, &! =&\$- /%&CNC &%3#+-+ /'&=%&+-' #'<&%% /!<*-
]Q^9-AU@MNAU?J*-
-
-234567*) 8* / 89- [-F535T15!9-Y*-]?@AA^*-K3&- '#6&-#-' #'<&%N=, &-\$56/ &! =&- /! -6/\$%NC &%3#+-+ /'&=%&+-' #'<&%% /!<*-
AA@NAAB*-
-
F535T15!9-Y*9- [- -234567*) 8* / 8-]?@M^*-W! %&! % /# /!56-' #'<&%% /!< -#'-5=% /#! \$`-4#C05' /\$#! -#'-6/\$%NC &%3#+-5! +
/ &%CNC &%3#+-+ /'&=%&+-' #'<&%% /!<*-
9-AUJNAQ?*-
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-
-234567*) 8* / 8*]H&\$, 8C/\$\$/#! -/\$- . !+&' -H&O/ &) -5%* ^*-W! \$% ', =% /#! \$-%#-\$3/'% -&1&\$-+ #! #! - /! = ' &5\$&- /%&CN
C &%3#+-+ /'&=%&+-' #'<&%% /!<*-
*
-234567*) 8* / 89- B , &66&' 9- B *-Y* \ \ 9- ; , !6#ST19-S*9- [-e/! T&! %3569-Y*-]fH&O/\$&-5! +H&\$, 8C/%g-5%- %3&*
^*- E 35%- /\$- %3&- /C05=-#-' /! %&' 6&50/! <-0'5=% /&-5! +-&651/! <-
V, +&C&! %\$-#! -%3&-5==, '5=1-#'' =5%&<# '1-6&5' /! <-V, +&C&! %\$c-
-
-234568*) 8* / 87*

e#\$%'9-2*-Y*9- [-F535T15!9-Y*-]e&8',5'19-?@A?^*-H&3&5'\$/!<-#-"# '<&%`-K3&-/'6,&! =&-#" -C&%5=#<!/%/#!-#!- /%&CNC&%3#+-+/'&=%&+-"# '<&%%/!<*-K56T-</0&!-5%-3&-2#'%3-45'#6/!5-4#<!/%/#!-4#!" '&'! =&-?@A?9-4350&6-L/669-24*-

-
e#\$%'9-2*-Y*9- [-F535T15!9-Y*-]>,<,\$%9-?@AA^*-H&0/\$%/!<-B=7 &#=3-5!+-B = ;#!56+-JAMUA^`-F/C/65'/%1-5!+- '&'#5=%/0&-/%&'&'!&'! =&-D@-1&5'\$-65%&'*-K56T-</0&!-5%-3&-Q%3-W!%&'!5%/#!56-4#!" '&'! =&-#!-B &C# '19-j # 'T9-X!<65!+*-

B ,&66&'9-B * \ \ 9-e#&'9-2*-Y9- [- ; , !6#ST19-S*-]2#0&C8&'9-?@AJ^*- ; #&\$-!%&'6&50/!<-0'5=/%=#"-C5%3&C5%/=\$-0'#86&C\$/C05=/%=-5%&<#'1-6&5'!/!<-V , +<C&!%\$- : #&\$&'0'&\$&!%&+5%-3&-QQ"->!! , 56-B &&%/!<#"-%3&- : \$1=3#!#C/=-F#=#/19-Y#!<-I&5=39-4>*-

e#&\$&'9-2*-Y9- [-F535T15!9-Y*-]2#0&C8&'9-?@A^*-B &&5=#<!/%/#!-/"6 , &!&=\$-/%&CNC&%3#+-+/'&=%&+-'#<&%/!<*- : #&\$&'0'&\$&!%&+5%-3&-QU^S->!! , 56-B &&%/!<#"-%3&- : \$1=3#!#C/=-F#=#/19-B/!!&50#6/\$9-B 2*-

e#&\$&'9-2*-Y9- [-F535T15!9-Y*-]2#0&C8&'9-?@M^*-H&0/\$%/!<-%3&-\$/C/65'/%1-05'5+#d-/'-!&%'#5=%/0&- /!%&'&'&!&=\$- : #&\$&'0'&\$&!%&+5%-3&-Q@%3->!! , 56-B &&%/!<#"-%3&- : \$1=3#!#C/=-F#=#/19-I#&\$#!9-B >*-

e#&\$&'9-2*-Y9- [-F535T15!9-Y*-]B 519-?@M^*-W!%&!%/#!56-'#<&%/!<#"-%5=/%#!\$`-4#C05'/\$#!-#"-6/\$%NC&%3#+-5!+-%/NC&%3#+-+/'&=%&+-'#<&%/!<*- : #&\$&'0'&\$&!%&+5%->\$#=#/5/#!-'#'- : \$1=3#6#</=56-F=/&!&=?A^!>!! , 56-4#!0&!%/#!9-F5!-e'5!&=#9-4>*-

e#&\$&'9-2*-Y9- [-F535T15!9-Y*-]2#0&C8&'9-?@b^*-G!-%3&-!%&!%/#!56/1-#"-+/'&=%&+-'#<&%/!<-W!+/0/+ , 56-+/'&'&!&=\$-/'-#<&%/!<-/\$!' , =/%#!\$*- : #&\$&'0'&\$&!%&+5%-3&-JD%3->!! , 56-B &&%/!<#"-%3&- : \$1=3#!#C/=-F#=#/19-Y#!<-I&5=39-4>*-

e#&\$&'9-2*-Y*-]2#0&C8&'9-?@AD^*-H&C&C8&'!<-%#"#<&%"-B &&5=#<!/%/#!-5!+-%/\$-&65%/#!-%#-!%&!%/#!56-'#<&%/!<-[-#%3&'50&! , &\$-#-/'!k , /'1^*-W!0/%&+-'&\$&5'=3-%56T-5%-K3&-4#66&<&#" - E ##\$&'9- E ##\$&'9-GL*-

e#&\$&'9-2*-Y*-]2#0&C8&'9-?@AD^*- . !+&'\$%5!+!<-C&C#1^*-W!0/%&+6&=# , '&-5%-K3&-4#66&<&#" - E ##\$&'9- E ##\$&'9-GL*-

e#&\$&'9-2*-Y*-]B 5' =39-?@AZ^*->-\$06/%-5' '#) `X-d06#5%/#!-!/\$&'&!+0/%19-&d0&'&!&=9-5!+=#!%&d%*-?@AZ : \$-/43/!+ , =/%#!-R&1!#%&9-F%*-B 5' 1P\$-4#66&<&#" - B 5' 165!+9-F%*-B 5' 1P\$-4/19-B ; *-

e#&\$&'9-2*-Y*-]J5! , 5'19-?@AQ^*-K3&- , !&\$&!-0#) &'#-/'!%&!%/#!56-'#<&%/!<-2&)-'/'!+!<\$-#!-#6+-03&!#C&!5%-W!0/%&+-'&\$&5'=3-%56T-5%-F%*-B 5' 1P\$-4#66&<&#" - B 5' 165!+9-F%*-B 5' 1P\$-4/19-B ; *-

e#&\$&'9-2*-Y*-]B 5' =39-?@AU^*-K3&- '#<&%/!<-05'5+#d-4#!&=0% , 56/h/!<-%3&-C&C#1-\$1\$%&C-81- , !+&'\$%5!+!<-0'#0&'&/\$-#-/'!&+&!%56-'#<&%/!<-5!+-%/!%&!%/#!56-'#<&%/!<-W!0/%&+-'&\$&5'=3-%56T-5%-R&!-F%5%&-! /0&'\$%19-R&!%9-GL*-

e#&\$&'9-2*-Y*-]e&8' , 5'19-?@AU^*-4#<!/%/#!- [-XC#/#!'-K3&-/'!&d%/'=586&-6/!T-8&%) &&!-C&!%56-0'#=&\$&\$-5!+5'''&=#/0&-\$%5&\$9-\$%/C , 6/9-5!+&-C&C#/'&\$*-W!0/%&+6&=# , '&-5%- ; 5&C&!-4#66&<&9->C3&'\$%9-2 j *-

e#&\$&'9-2*-Y*-]J5! , 5'19-?@AU^*-K3&-#00#\$/&#" - '&C&C8&'!<- . !+&'\$%5!+!<-%3&-0'#0&'&/\$-#-/'!%&!%/#!56-'#<&%/!

\$2>6353&:>?@4*:3*+62A53326

%G%, ".*

. 2 4 7 -: \$1=3#6#<1- ; &05%'C&!%F, CC&'-e, !+!<-H&=/O/&!%9- B 51-?@A@-
. 2 4 7 -: \$1=3#6#<1- ; &05%'C&!%F, CC&'-e, !+!<-H&=/O/&!%9- B 51-?@D-
G, %5!+!<-H&\$5'=3&'>) 5'+9- ; &05%'C&!%#"- : \$1=3#6#<19- E /665C&%%&- . !/O&'\$/%1-
L#!#'\$-K3&\$/\$-45!+ /+5%&-
E /665C&%%&-G'&<#!-F=3#65'-
-

, !D'! G') 9

>=%5- : \$1=3#6#<1=5-
>\$&\$&\$C&!%/-!-X+, =5%/#!'-' : !/!=O6&\$9- : #6/=19- [- : '5=%/=&-
4#<!/%/#!-
4#!\$=#, \$!&\$5'+-4#<!/%/#!-
S#, '!56-#"->006/&+H&\$5'=3-!-B &C#'1-5!+-4#<!/%/#!-
S#, '!56-#"-X+, =5%/#!'56- : \$1=3#6#<1-
S#, '!56-#"-Xd0&' /C&!%56- : \$1=3#6#<1'-Y&5' !/!<9- B &C#'19-5!+-4#<!/%/#!-
B &C#'1-
B &C#'1- [-4#<!/%/#!-
: \$1=3#6#<1=56-H&O#'%\$-
: \$1=3#!#C/=- I , 66&%/!- [-H&O/&) -
F=/%!'"/=-H&O#'%\$-