

CRIM1010

7 f]a]bc`c[m˙5b˙±bfcXi W•]cb

HYfa 'H\fYY''##'&\$%-

7ci fgY[·]Cj Yfj]Yk

GHJZZ:7cbHJWh:8YHJ]`g`

7cbj Ybcfg

B Ua Y	9a U]`	5j U]`UV]`] m	@cWUh]cb	D\cbY
; Ycf[Y [·] fPYjŁ 8YfHUX]Ub	_"XYffUX]Ub4 i bgk "YXi "Ui	6m'Uddc]bha Ybh	‰-ʿA cfj Yb	

7ci fgY 8YHJ] g

7 fYX]hDc]bhg**

Gi a a UfmcZh\Y'7ci fgY

Gi VYWi5fYU. '7 f]a]bc`c[mi+blfcXi Wyg'h\Y'_YmWcbWydhg'UbX'WyffYbhXYVUhyg']b'Wf]a]bc`c[mi'7 cj Yfg'VUg]W]ggi Yg'gi W'Ug'h\Y'XYZ]b]h]cbz'a YUgi fYa YbhUbX'Yl d`UbUh]cbg'cZWf]a Yz'gcWJYhU`'fYUWf]cbg'hc'Wf]a Yz'Wf]a]bc`c[]WU`'h\Ycf]Ygz'h\Y'fc`Y'cZfYgYUfW\'UbX'h\Y']bZi YbW''cZWf]a]bc`c[mcb'di V`]Wdc`]Wh'

7 ci fgY @YUfb]b[Ci hWca Yg

- %" Cih]bY:h\Y:gWcdYž:U]a g:UbX:dfUWfWyg:cZ7f]a]bc:c[mUg:U:X]gWd:]bY/
- &" ⇒XYbhZm_Ymd`UmYfgžh\Ya Yg`UbX`XYVUhYg`UVci hWf]a Y
- ' " 8 Ya cbglfUlY 'Ub'i bXYfglUbX]b['cZ_YmWf]a]bc'c[]WJ`'l\Ycf]Yg'UbX'WcbWYdlg'l\fci [\ 'Wf]h]WJ` Yb[U[Ya Ybhk]h\ '`]hYfUli fYž'bYk g'UbX'ch\Yf'a YX]U
- ("8YgWf)VY'U'j Uf)YhmcZk Umg'hc'XYZ|bYža YUgi fY'UbX'YI d'U]b'Wf]a Y
-)" I bXYfgHJbX`JbX`i gY`VJg]WhYfa]bc`c[mWca a cb'hc'h\Y'Wf]a]bc`c[]WJ``Z]Y`X
- *" H\]b_'Wf]h]WU``m'UVci h'Wf]a Y'UbX']hg'WUi gYg
- +" 5bU`mgY`Wf]a Y`dfcV`Ya g`i g]b[`VUg]WWf]a]bc`c[]WU``dYfgdYWfj Yg

HYUWX]b[GhfUhY[]Yg

H\]g`Wci fgY`fYei]fYg`bc`df]cf`_bck `YX[Y`]b`7 f]a]bc`c[m" & `UVWcfXUbW' k]h\ I BGK `@YUfb]b[`UbX HYUW\]b[; i]XY`]bYg`k Y`YI dYWhc Yb[U[Y`mci `]b``YUfb]b[`h\fci [\`U`Wca V]bUh]cb`cZ`YWh fYgž'h hcf]U`gž]bX]j]Xi U``fYUX]b[`UbX`gh Xmž[i]XYX`h]h]cb`Zca `[i Ygh`YWh fYfg`UbX`UWUXYa]Wg`k \c`UfY`UWhj Y fYgYUfW\Yfg`]b`h\Y`Z]Y`Xž'a YUb]b[Z``ZYYXVUW_`cb`k f]hhYb`k cf_`UbX`h hcf]U``dUfh]W]dUh]cbž`UbX`ghi Wh fYX UWhj]h]Yg`h\UhYbWci fU[Y`]bXYdYbXYbhh\]b_]b[`UbX`h\Y`XYj Y`cda YbhcZX]gW]d`]bUfm_bck`YX[Y`UbX UWUXYa]Wg_]``g"

K Y'gYY'I BGK 'ghi XYbh`YUfbYfg'Ug'UWfj Y'dUffjWjdUbfg']b'h\Y'dfcXi Wfjcb'cZ_bck `YX[Y"'H\]g'Wci fgY df]cf]hJgYg'`YUfb]b[!Vm\Xc]b['UbX'U]a g'hc'ZcghYf'U'gd]f]hcZWf]hJW\`h\ci [\h'UbX'UWfj Y'Ybei]fm]b'U``ghi XYbh `YUfbYfg"'#i]g'YggYbhJU``h\Uh'mci 'HU_Y'ck bYfg\]d'cZmci f'ghi X]Yg'UbX'k cf_'cb'XYj Y`cd]b['mci f'g_]``g'Ug'Ub]bXYdYbXYbh`YUfbYf.

%" +b 'fh]g 'Wci fgY ']h]g 'Yl dYWYX 'fh Uhmci 'k] `` 'UhnYbX 'Uh `YUgh, \$i 'cZh\Y'hi hcf]U`g" 'Mci 'bYYX 'hc dUfh]W]dUfY ']b 'Vch\ ``YWi fYg 'UbX'hi hcf]U`g" '5 `` 'ci f``YWi fYg 'UbX'hi hcf]U`g 'UfY ']bhYfUW]j Y" 'DfYdUfUh]cbž `]ghYb]b['UbX'Wf]h]WU` 'Yb[U[Ya Ybhk]h\ 'Wci fgY'a UhYf]U`ž`YUfb]b['Zfca 'mci f'hYUW\Yfg'Vi h'U`gc'mci f dYYfg'UfY 'YggYbh]U` ']b[fYX]Ybhg'Zcf'U'gi WWfggZ ``Wca d'Yh]cb'cZh\]g 'Wci fgY"

&" Mci 'bYYX'hc'd'Ub'WUfYZ ``m'UbX'i gY'mci f'h]a Y'dfcXi Wh] Y`m']Zmci 'k]g\'hc'UW\]Yj Y'[ccX'fYgi `hg']b h\]g'Wci fgY"'5```UggYgga Ybh'hUg_g'g\ci `X'VY'fYgYUfW\YX'UbX'XfUZhYX'k Y```]b'UXj UbWY'cZ qi Va]qq]cb"

' "Mci 'UfY'fYgdcbg]V'Y 'Zcf'mci f'ck b'`YUfb]b[/k cf_'hc'XYj Y`cd'g_]``g'h\Uhk]``'YbUV'Y'mci 'hc'Yb[U[Y Wf]h]WU``mUbX'UbU`mh]WU``mk]h\ 'UWUXYa]W']hYfUhi fYž'bYk g'fYdcfh]b['UbX'dc`]WhXcW a Ybhg"'H\Y'[cU` cZh\]g'Wci fgY']g'bchhc'VY'UV'Y'hc'fYdfcXi WY'h\Y'WcbhYbh]b'U'XYgWf]dh]j Y'a UbbYf/k Y'k]``'Ugg]gh mci 'hc'VYVca Y'`]hYfUhY]b'UWUXYa]WfYgYUfW\'g_]`g'k]h\ 'h\]g'Wci fgY'Ug'h\Y'Z[fghghYdd]b[!ghcbY']b

h\UhdfcWfgg" ("H\fci[\cihmcifh]a Y`Uhil BGK ž'mci 'g\ci`X`VY'gYY_]b['hc'Yj U`i UhYž'gmbh\Yg]gY`UbX`Yb[U[Y

5ggYgga Ybh

 $\label{thm:condition} $$H^{g}_5ggYgga\ YbhYl\ d`]WhinhYghg`Zcf`Ub`i\ bXYfghUbX]b[`cZa\ UhYf]U``UbX`UddfcUWXYg`Wcj\ YfYX`]b``YWhi\ fYg'/hi\ fc]U`g`gc`Yb[U[]b[`]b`h\ YgY`UWhj]]h]Yg`]g`Wcbg]XYfYX`]bhY[fU``hc`UggYgga\ Ybhgi\ WWgg"`G]a\]`Uf`mž'k\]`Y`bch\ Wca\ di\ `gcfmž'h\ Y`GY`Z8\]fYWhYX`@YUfb]b[`HUg_g`fWca\ d`YhYX`cb`]bYE`WUb`VY`k\ cf_YX!h\ fci\ [\cj\Yf'h\ Y`Wci\ fgY\ cZh\ Y`HYfa\ ž`UbX`\Uj\ Y`VYYb`gdYWJZJWU``mXYg][\ bYX`hc`\Y`d`XYj\ Y`cd`h\ Y`g_]``g`bYWYggUfm\Zcf`h\ Y`F\ YgYUfWX\ 6f]Y\Z|b["$

A Uf_]b['7f]hYf]U

H\YfY`UfY`Z|jY`WcadcbYbhg`cZh\Y`6f]YZ|b[`UbX`YUW\UhffUWg`aUf_g`fgYY`VY`ck Ł

- % 6 WY [f[a`S`V gef[XUSf[a`aXfZW[eegW`H\]g`]g`gcaYhJaYg`hYfaYX`'dfcV`YaUhJgUhJcb'`]b`h\Y \i aUb]hJYg'/ 'gcWJU`gWJYbWYg`fgYY`\YfY`Zcf`Ub`YI WY``YbhUbX`Vf]YZX]gWYgg]cb`VmDfcZ`DUh H\ca qcbl`cb`k\UhdfcV`YaUhJqUhJcb`UWhU``maYUbqE''f%\$`aUf qE
- &" FZWbSc6_ wfwde, 'Di hh\Y'Wf]a Y']b'WcbhYl hVmUWW fUhY`mgWcd]b['h\Y']ggi Y']bWi X]b[']bWjXYbWYž dfYj UYbWYž'dUhYfbg'UWfcgg'h]a Y'UbX']a dUWf''7 ca a Ybh\YfY'cb'h\Y'j YfUWJmcZh\YgY'dUfUa YhYfg f\ck 'WcbZjXYbhmci 'UfY']b'h\Y'UWW fUWmcZh\]g']bZcfa Uhjcb3'7 cbg]XYf'Wca a cb']ggi Yg'k]h\'Wf]a Y ghUhjghjWg'Ug'Wcj YfYX']b'K YY_'&cZ'YWh fYg/5fY'a cgh']bWjXYbhg'fYdcfhYX'UbX'fYWcfXYX3'\deltabh'k\mbch3'\deltag']hX]ZJW'hhc'UWWgg']bZcfa Uhjcb'cb'h\Y']ggi Y3'\deltagc'k\Uha U_Yg']h\\UfX3'K\Uhch\Yf'Zcfa g cZXUhU'X]X'mci 'XfUk 'cb'hc'i bXYfqhUbX'h\Y'hcd]W8'f1\\$'a Uf_g\!
- '"I ZSf [e UgddW f/k]`ai` STagf fZ[e fab[U1.'<ck 'Xc'Wf]a]bc`c[]ghg`a U_Y`gYbgY`cZh\Y`]ggi Y3 7 ca d`YhY`U`gYUfW\`cZh\Y`]hYfUhi fY"'I gY`h\Y`) 'Ufh]WYg`]XYbh]Z]YX`Zcf`h\Y`Z]fghUgg][ba YbhUg`U gHJfh]b['dc]bh]Zmci 'UfY`[c]b['cb'hc'i gY`h\Y`gUa Y`hcd]W`f(\$`a Uf_gŁ
- ("5a`U'ge[a`, 'GiaaUf]gY'YI]gh]b['Yj]XYbWY'fh\]g'kci`X'VY'XYgWf]dh]jY'kf]h]b[E'UbX'dfcj]XY'gcaY h\ci[\h]``WcbWig]cbg'UVcihh\Y'kUmZcfkUfX'fh\]g'kci`X'VY'UbU'mh]Wkf]h]b[E''fl%\$'aUf_gE
-) " D WWWW UWe, "±0 'HY I H < Ufj UfX 'ghm`YžF YZYfYbWY ``]gh`]b 'U`d\UVYh]WU``cfXYf" 'f1%\$ 'a Uf_gŁ

ł H\ca gcbžD" f&, "\$%"% łż'DfcV`Ya žDfcV`Ya UhlgUhlcb'—K\Uhlg'h\Y'8]ZYfYbWY3' DUhhYf'6`c[ž5WWyggYX cb`]bYž\hdq,#dUhh\ca gcb"bYh&\$% #\$\%, #dfcV`Ya UhlgUhlcb!k\Uhg!h\Y!X]ZYfYbWY#

 $\label{thm:limit} \begin{tabular}{ll} Hi fb]h]b gYh]b[. Hi]g Ugg][ba Ybh]g gi Va]hYX h fci [\ 'Hi fb]h]b UbX ghi XYbhg WUb gYY 'Hi fb]h]b g]a] Uf]hm fYdcfhg"$

5 hm/b XUbVW F Yei]fYa Ybhg

 $\label{thm:local-control} $$H\YfY^{\cdot}]g^{\cdot}Ub^{\cdot}, $$i^{-\cdot}UfffYbXYbWY^{\cdot}fYei^{\cdot}]fYa^{\cdot}Ybh^{\prime}Zcf^{\cdot}h^{\cdot}Y^{\cdot}YWh^{\prime}^{\cdot}fYg^{\cdot}UbX^{\cdot}h^{\cdot}h^{\cdot}f^{\prime}]U^{\cdot}g^{\cdot}Zcf^{\cdot}h^{\cdot}]g^{\cdot}Wc^{\cdot}i^{\cdot}fgY^{\prime}$

7c(bX 'UbQ Yh]V

FYgci fWyg

DfYgWf]VYX F Ygci fWYg

FYWca a YbXYX FYgci fW/g

 $DfYgWf]VYX`UbX`FYWca~a~YbXYX`FYUX]b[~g`UbX`FYgci~fWYg`UXX]h]cbU``hc``h\Y`hYI~hVcc_`k~]```VY`Uj~U]`UV`Y`cb~h\Y`A~ccX`Y`g]hYžk~]h\`fYgci~fWYg`Uj~U]`UV`Y`h\fci~[~\@Y[~Ubhc`UbX`h\Y`I~B~GK~``]VfUfm''`$

7 ci fgY 9j U'i Uhcb UbX 8Yj Y'cda Ybh

6ch Zcfa U``UbX`]bZcfa U``ZYYXVUW_cb'h\]g'Wci fgY`]g'k Y`Wca Y`Zfca 'ghi XYbhg'h\fci [\ci hh\Y'gYa YghYf'' Ghi XYbhZYXVUW_cb'h\Y'Wci fgY`WcbhYbhz'UggYgga Ybhg'UbX`Zcfa Uhid`Umg'Ub']a dcffUbhifc`Y`]b'h\Y XYj Y`cda YbhUbX'Yj c`i h]cb'cZci f'Wci fgYgz'hc'Ybgi fY'h\Uhk Y'a U_Y'h\Y'bYWYggUfmUXUdfUh]cbg'hc'h\Y Wci fgY`Zcf'h\Y'Z hi fY''H\]g'gYa YghYf'k Y`k]``VY'gYY_]b['ZYYXVUW_Zfca 'mci 'Uhj Uf]ci g'dc]bhg']b'h\Y Wci fgYz'UbX`UfY`]bhYfYghYX`]b'i bXYfghUbX]b[']ZUbX`\ck 'Wci fgY`UWhj]h]Yg'Ugg]ghi]b 'mci f'XYj Y`cda YbhUg'Ub]bXYdYbXYbh'YUfbYf''K Y`k]``U`gc'VY'i g]b['h\Y'I b]j Yfg]hmg'a m9I dYf]YbWi'gnghYa 'hc'Yj U`i UhY'h\Y'Wci fgYz Vi hmci 'UfY'k Y`Wca Y'hc'Wca a i b]\WhY'Ubmch\Yf'ZYYXVUW_hc'mci mci f'`YWhi fYfg'cf'hi hcf'UhUbmih]a Y'''F YWWbh ZYXVUW_fYWl]j YX'cb'h\]g'Wci fgY`\Ug'fYgi `hYX']b']a dfcj Ya Ybhg'hc'Wci fgY'WcbhYbhz'XY`]j YfmUbX UggYgga YbhHUg_g'Zcf'gh XYbhg''

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

Hi fb]h]b Gi Va]gg]cb

#mci YbWci bhYf'U'dfcV'Ya 'k \Yb'UthYa dr]b['rc'gi Va]hmci f'Ugg][ba Ybht\fci [\'Hi fb]r]bž'd'YUgY
hY'Yd\cbY'9I hYfbU''Gi ddcfhcb'-',) '''' %cf'Ya U]''h\Ya 'cb'YI hYfbU'hY'hgi ddcfh4 i bgk "YXi "Ui '"'Gi ddcfh
\ci fg'UfY', .\$\$Ua '-'%\$.\$\$da 'cb'k YY_XUmg'UbX'-.\$\$Ua '-').\$\$da 'cb'k YY_YbXg'fl *) 'XUmg'U'mYUft\"'=\maintention
UfY'i bUV'Y 'rc'gi Va]hmci f'Ugg][ba YbhXi Y 'rc'U'\ZUi 'hk]h\'Hi fb]r]b'mci 'a Um'Udd'm\Zcf'Ub'YI hYbg]cb\ZVi hmci
a i ghfYhU]b'mci f'r]\W_Yhbi a VYf\Zfca '9I hYfbU''Gi ddcfhfU'cb['k]h\'Ubmch\Yf'fY'Yj UbhXcW a Ybfg\L'rc
]bWi XY'Ug'Yj]XYbWY 'rc'gi ddcfhmci f'YI hYbg]cb'Udd']\WUh]cb'''=\maintention
UfY'i bUV'Y'nc'gi Yj]XYbWY 'rc'gi ddcfhmci f'YI hYbg]cb'Udd']\WUh]cb'''\=\maintention
UfY'i bUV'Y'nc'gi Yj]XYbWY 'rc'gi ddcfhmci f'YI hYbg]cb'Udd']\Wuh]cb'''\=\maintention
UfY'i bUV'Y'nc'gi Yj JXYbWY 'rc'gi ddcfhmci f'YI hYbg]cb'Udd']\Wuh]cb'''\=\maintention
UfY'i bUV'Y'nc'gi Yj JXYbWY 'rc'gi ddcfhmci f'YI hYbg]cb'Udd']\Wh\fcbY''\text{mci 'Ya U]''\text{y'}UfY\W\'\mu\g''
Ui hca Uh\WU'\mfY\W']j Y'U'\h\W_Yhbi a VYf\Z'\text{y' h']Zmci 'hY'Yd\cbY'mci 'k]\''\text{bYYX'hc'gdYW}\Z\WU\mu\mu\g''\text{bY''\mu\g''}
Hi fb]h\b'\U'gc'dfcj]\XYg'i dXUhYg'cb'h\Y]f'gmghYa 'ghUh' g'cb'H\Y]f''

; YbYfU``mž'UggYgga YbhiHug_g'a i ghVY'gi Va]hhYX'Y`YVWfcb]\W)``mj]U'Y]h\Yf'Hi fb]hjb'cf'U'A ccX`Y Ugg][ba Ybh'' =b']bgHJb\W'g'k \YfY'h\]g']g'bchdcgg]V`Yž']hk]``'VY'gHJhYX'cb'mci f'\\circ i fgY'g'A ccX`Y'g]hY'k]h\ U`hYfbUhj Y'gi Va]gg]cb'XYHJ]`g''

cfi]bZcfa Uh]cbicbi\ckihcigi Va]hUgg][ba Ybhgicbi]bYij]UiA ccXiY.i\hdg.#gh XYbh'i bgk "YXi "Ui #\ck! qi Va]hUgq][ba Ybha ccXiY

$5\,WUXYa\,W< cbYghmUbXDU[\,Uf]ga$

D`U[]Uf]ga i]gii g]b[ih\Yik cfXgicfi]XYUgicZch\YfgiUbXidfYgYbh]b[ih\Ya iUgimci fick b"i=iWUbiHU_Yia Ubm Zcfa gžZfca iXYi]VYfUhYiWXYUh]b[ihciUWW]XYbhU`mWcdm]b[iZfca iUigci fWYik]h\ci hiUW_bck iYX[Ya Ybh'i

- i bXYfgHUbX'mci f'f][\hg'UbX'fYgdcbg]V]`]h]Yg'Ug'U'gh XYbhUhI BGK
 VY'Uk UfY'cZd`U[]Uf]ga ž'Wcdmf][\hz'I BGK 'Gh XYbh7cXY'cZ7cbXi WhUbX'5VWWdhUV`Y'I gY'cZ IBGK =7 HF Ygci fWrg Dc`]Wh

5 WUXYa]W±bZcfa Uhjcb

: cf`YggYbhJU``gh XYbh]bZcfa UhJcb`fY`UhJb['hc.

- fYei YghgʻZcfʻYl hYbg]cb/`UhYʻgi Va]gg]cbgʻ[i]XY`]bYg/
- fYj]Yk 'cZa Uf_g/
- I BGK < YU`h\ UbX GUZYmdc`]W]Yg/
- YI Ua]bUh]cb dfcWXi fYg/